

Configuration Management

Theory, Practice, and Application

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Jon M. Quigley and Kim L. Robertson



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This book is dedicated to professionals working in all aspects of product development and product life cycle management regardless of discipline and to those practicing configuration management in any of its forms worldwide. The world as we know it today would not exist had it not been for your efforts and the efforts of those who preceded you.

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Preface

To truly grasp configuration management (CM) first requires an understanding of the market sector and business environmental elements, as well as the back story to the pieces that play a role in effectively using this powerful management tool. Things such as the product life cycle, the supporting enterprise infrastructure, functional resources, product management, CM elements, data types, and control requirements are addressed before meatier issues pertaining to CM specifics are discussed.

Here then is the roadmap to this book.

- Section I—Define the basis of terms and their context
Chapters 1 through 7
- Section II—Define the interrelationship of CM to functional resources
Chapter 8 states the interrelationship of CM to the resources defined in Chapter 3
- Section III—Defining current practice
Chapters 9 and 10
- Section IV—When things go wrong
Chapter 11
- Section V—TIEMPO, related CM standards, and reference data
Chapter 12, CM standards and references, appendix, acronyms, bibliography, and index

These five sections meet the goal of providing a contextual understanding of the theory, practice, and application of CM. To make the text more readable, only BCE dates are noted unless associated with a figure title or quotation from source data.

The chapter organization was not determined haphazardly but is based on a research unique to this book, which indicated a general lack of understanding of how CM fits into all aspects of the business environment from the first discussion that an item is required to its eventual disposal at end of life. Our research in the areas of CM has also opened the door to redefining exactly what items CM applies to. The term “configuration item” or “configured item” (CI) is expanding from those of hardware and software items originally documented in the U.S. government standards. It must be remembered that the U.S. government attempted to document not only what had to be done, but how it was to be done. CIs started at the total system level and flowed down to contractors providing goods to the government. This also necessitates a broad systems-level view of CM as an enterprise-level activity, be that enterprise a government agency or a private sector product.

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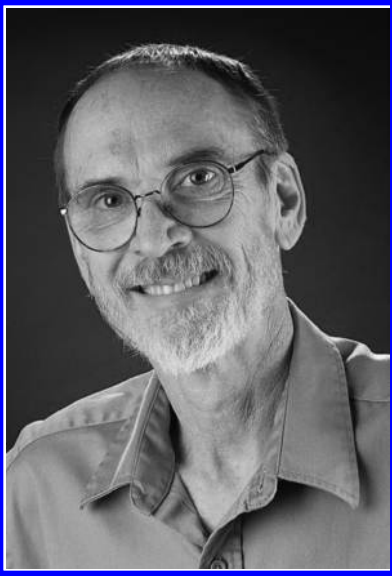
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- *All Business* (online)
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- *Tech Online India* (online)
- *Embedded Design India* (online)
- *CM Trends*



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DEFINE THE BASIS OF TERMS AND THEIR CONTEXT

I

Chapter 1

Overview of the Product Life Cycle

1.1 Questions to Ponder

- What are the five phases of product development? What are the key elements of product development? What are concerns associated with these areas?
- What are the input–output constraints and facilitators of the configuration management process?
- What are the input–output key elements?
- What are the differences between product market adaptation and product performance adaptation?
- How are the seven deadly sins used in marketing?
- How do cost and the influence of critical design decisions change over time?
- What are configuration market adaptations?
- What examples of product adaptive ration exist?
- What is the difference between design reuse and common design?
- What are the design reuse and common design key elements?
- What criteria are involved in defining a numbering schema?
- What is meant by a cost objective?

1.2 Introduction

Many separate pieces of information contained in specifications and handbooks from multiple nations, industries, and groups exist with a focus on one market sector or another that can be referenced for the specifics of the profession called “configuration management.” The current guidance documentation describing configuration management (CM) generally consists of the following seven elements. (This is based on what we have found across all market segments and is not consistent with guidance put forth by the International Standards Organization [ISO] or Electronic Industries Alliance [EIA], who only list five elements. Seven elements are listed for

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clarity. Generally, CM planning and management are lumped together and so are verification and audit by ISO and EIA.)

1. CM planning
2. Management of configurations
3. Configuration identification
4. Configuration change management
5. Configuration status accounting
6. Configuration verification
7. Configuration audit

CM could not exist without its subelement data management (DM). Although CM is most often associated with product, DM is associated with every record in the company regardless of form or format.

Practitioners of CM have been so well trained and the definitions for the terms used in their art have such specific meanings that they lose focus at times of the management theory that resulted in the documentation they know so well and cite chapter and verse. CM and its subelement DM are not something that sprung fully formed from the military minds of the post-World War II era ca. 1960. Part interchangeability existed as early as 210 BCE.

At other times, the definitions so methodically drafted, vetted, and released to the public over the last 40–60 years do not fit with the issues faced today. Words and concepts become muddled in the current context. They were originally created to define, not the how or why something is done or defined but what had to be done in a primarily paper-based engineering environment. Companies have been creative about leveraging the words in the specifications to have a broader, albeit still limited, scope but still interoperable under the original text of the associated standard.

The CM documentation suite has been revised as a matter of necessity. It has been accomplished with delays due to the internal checks and balances required to administer specifications and standards that have applicability over multiple branches of a country's military, space, nuclear regulatory or other government *influenced* infrastructure.

The practitioners of CM were found to be dedicated, productive, and competent performing CM activities to the best of their abilities. They can cite chapter and verse the definition of every acronym, word, and form specified for their management specialty.

Unfortunately, a few CM practitioners interviewed have made the leap from a market sector specific implementation in either the customer or the contractor capacity to a total life cycle view of all market sectors, which is inclusive of all phases of a product's life cycle from the end user, contractor, and subcontractor perspectives. Although specialists in their particular niche, this focused view of CM has led to a myopic understanding of the implications of poor CM as well as a lack of understanding of how it applies to the world marketplace. It has also led to a tendency for practitioners of CM in industries specializing in sales to government to discount CM, as it applies to all other market sectors. This despite the fact that companies in the nongovernment sales market sector have developed tools and processes that are decades ahead of those used in the government sales market sector.

Few people alive today were involved with the committees of experts gathered together to generate the requirements or their thinking at the time. It is time to look back to where the elements of CM came from, where we are today, and find how this contextual history can help us to plot the course forward.

Extensive research resulted in the observation that neither author could find any existing text that answered these basic questions pertaining to the CM.

- What is the history?
- Why are we where we are now?
- Where are we going?
- Why is the standardization and the global use of standardized items an outcome of CM?

We started on a quest to find out the answers to these questions. It has led us down through the ages to answers rooted in antiquity very different from those we anticipated. There were unexpected sources, twists, and turns that made the gathering of source data more of an archeology expedition leading to a degree of self-discovery along the journey. Our research was aided by many who were involved in CM communities on LinkedIn,* friends, colleagues, subject matter experts, deep introspection, discussions, visits to foreign countries, and reading of related materials.

We have attempted to sift through the material and present it in phases to make it easier to digest. Some may be eager to delve directly into what they see as the meat of CM and find that our presentation of the subject based on its evolution misses the point of having a book with CM in its title. Our intent is to first ground the reader in management theory from a configuration-centric perspective before discussing the specifics of CM practices within any unique product, sector, or discipline.

One of the principal roles of CM is to protect us from ourselves. In so doing, we also protect our suppliers and our customers. When high school or college students first encounter bills of materials, they experience shock and awe. An automotive wire harness with 368 leads must have a bill of materials with at least 368 components (some will be common, but we must still account for their presence), associated connectors, solder, anti-fretting compound, and so on. Every possible component falls under CM. One of the outcomes of CM is standardization such as the acceptance of video home system (VHS) over Betamax for home video in the 1980s. Standardization through CM has been going on for centuries. Screw threads are a prime example. Starting with intracompany standardization by pioneers such as Henry Maudslay in the early 1800s, it eventually spread to industry worldwide.

CM is mandated in every business improvement process at a low level before going higher levels such as Capability Maturity Model® Integration®, Information Technology Infrastructure Library, ISO series (i.e., ISO 20000), systems engineering, Six Sigma, and total quality management.

When we do not practice good CM, we end up in situations where we ship products to a customer without knowing the configuration of what we are shipping. At every given slice in time, we have a configuration, parts of which we decide to control. Some items that are truly CM are as follows:

- Raw material inventory
- Material released to the floor
- Production equipment
- Development equipment
- Support equipment
- Utility pipes, wires, etc.
- Work products
- Labels
- Colors
- Process documentation
- Paint

* Over 40 LinkedIn groups have participated in or monitored for applicable discussions relating to the subject contained in this book. Inputs received to topic discussions represented over 1700 years of combined configuration management experience ranging from 3 to 45 years per individual.

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- Plastic
- Packaging
- Drawings
- Records of decisions

What is difficult is to try and develop items that are not ultimately part of CM. Perhaps the ephemera we call *thoughts*, *feelings*, and *emotions* fall into this category. Of course, we do not necessarily track everything, because not everything has equal importance. A readily replaceable item such printer paper is probably very low priority (the receipt for making the paper would be under DM); however, any item that is part of a product must fall under CM.

We have seen companies deliver products with unknown software, unknown hardware, and unknown features to customers for evaluation. Every time when we see such rushed events occur, it has resulted in a marketing fiasco. So what is the moral of the story? It is the necessity to determine those things that are important and establish realistic controls, so that we always know what we are working with can reliably and consistently build or make the product—the key point is repeatability.

There are other items beyond material to which CM extend. Our processes should be under comparable configuration control, allowing us to review and trace our product quality associated with changes in the process.

We begin the odyssey with the product life cycle. It is critical to understanding how CM activities change over time. Contractual documentation under DM and change control, as well as each of the seven elements that make up CM of a product, are directly influenced by the product life cycle phases.

1.3 Phases

The five product phases are:

- Development
- Introduction
- Growth
- Maturity
- Decline

Each of these areas has an associated range of activities and risks. Each of the areas requires an organization to accomplish objectives or supply a variety of inputs to ensure the success of that phase and maximize the benefits to the organization. Our subsequent texts will break down each of these areas and discuss what happens, the types of activities the organization will perform to maximize the potential and mitigate risk.

1.3.1 Development

In the development phase of the product development life cycle, we are generating ideas for the product. We see opportunities in the market place and wish to explore if we can capitalize (not a vulgar word) upon these opportunities. Perhaps a new technology has become available to us. Our organization will want to investigate the application of that technology toward existing businesses. Maybe it is a new market. Perhaps the organization is looking from an entirely new application perspective. At any rate, this phase starts off by idea generation and rigorous critique of those ideas to guide the development to the product (or eliminate the idea of the product).

This critique is facilitated via prototyping and reviews of designs. Concurrently with the development of the product, we will develop our manufacturing capabilities and critique that development work as well. All of which will guide our design or final product instantiation and manufacturing processes.

We will also need to get some information on the product from our would-be customers. These are the people who will make it possible to generate a business case that is beyond mythical and more tangible. The business case will help us understand the design scope and specific incarnations to achieve our desired profitability margin. This profit calculation will be based on the following:

- The volume of customers testing we can expect.
- The cost to make and deliver the product (includes manufacturing and delivery).
- The selling price of the product.

The selling price is also derived from the volume calculation as there will be some volume implication due to the customer sale price (higher price can reduce number of customers). We will garner as much data as we can via market testing to arrive at this optimum selling price. Ultimately, at the end of development, we have a product that we will move on to the next step—introducing the product to the market place in earnest (as opposed to learning the desired particulars of the end product from prospective customers).

In the development phase, we will learn the variety of product adaptations permutations that will be required to meet the objective. We will begin to understand the scope of this variation, which will drive our design configuration demands through to our production and manufacturing configuration needs. Some examples of the things we may want to control through our CM activities during the development phase are as follows:

- Concepts that are under consideration for the product
- Product hardware variation needs as defined by market (customer)
- Product software variation as defined by market (customer)
 - Parameters
- Design failure modes effects analysis
- Design documentation (including changes to)
 - Software
 - Hardware
 - Test cases
- Prototype material throughout the development process
- Prototype software throughout the development process

Neglecting to control the CM during the development process will cause a litany of problems. We may not know exactly what we have built up until the production launch. We may find it difficult to learn and make certain statements with conviction without a chain of controlling events to assure the truth of those statements.

1.3.2 Introduction

We have developed a product that was based on market research and perceived opportunity. We have tested that product both from the market perspective and the quality expectations from the customer and our own business case requirements. Now it is time to make the product available to our clientele.

We are concerned with the marketing and distribution channels of our product line. How do we get the product to the right people? Because we now have a product to move, our plans for introduction will now be executed. If this product has some similarities to the rest of the products in our product line, then we will likely rely on those existing distribution mechanisms.

We may discover product uses that we did not envision in our development work. In this case, we are not talking about new markets but more errant uses of the product that we may have to remediate. As an extreme and a bit flippant example, we were not aware that the customer will use the product while in the water. We then decided that we should seal the enclosure.

We have not finished learning about the product even in this phase of the life cycle. Our product development process may have called for such manufacturing development activities such as (each of which can and should be under CM control)

- Process studies
- Measurement system assessment
- Process failure mode effects analysis
- Control plans

However, these are experientially based theoretical exercises. We have not likely produced a product at the rate we can expect in our expected production volumes. Even if we have ran a volume we believe to represent our expected volume, we have not done it for days or weeks on end as we may expect when we are at full production volumes. The stress of full production will likely illuminate process improvement areas as we ramp up to the production volumes. The improvements can come from any part of the chain to deliver the product to the customer. However, experience suggests, as our manufacturing line was likely not stressed through the prototype product development we may find things to improve.

1.3.3 Growth

If we have developed a product that is useful to our clients, our production volumes will grow allowing us to improve our product cost and pricing structures. Besides the volume purchase of material cost improvements, we will work with our manufacturing line, improving those processes and subsequent first pass yields, thereby reducing the associated rework costs. We may choose to steadily drive our price down also to increase the number of consumers benefiting (as well as our company). It is possible to both reduce the sale price of the product and improve the profit. This situation is unlikely to last for long as other potential suppliers see our success and want to follow our lead with their own offering.

We will see further coverage or refinements in our product delivery methods. We can see securing other contracts for the product with more customers over time, adding to those we have already acquired, so that we see the amount of the product we produce steadily grow.

Moreover, during the growth phase of the product, we may find other adaptation for the product and CM will once again take the stage. If we designed the product with extensibility in mind, we may elect to reinvest some of the profits into the product to meet more consumer demands that price cannot alone achieve. In doing so, we improve our sales volumes yet more (or again). Small adaptations to the product may allow us to penetrate entirely different and prior untapped market segments.

Requirements and even product concept of operations should begin with the documentation process so that product development and refinement meets it. One of the biggest issues in industry and government is uncontrolled changes to requirements leading to loss of any tie between the

functional baseline and allocation of those requirements. Product development and refinement must be planned. Configuration planning is perhaps the most important aspect of a successful CM implementation.

CM planning should describe what data is to be recorded and controlled, what roles are in play, who makes up the configuration control board, change management, how decisions are made, CM roles and responsibilities for each product and the enterprise level, how data is stored, the CM standards used, how interface control decisions are accomplished, disaster recovery, and much more. Without a proper CM planning, the CM processes may never succeed.

We will control how these are differentiated and brought to the market place via our CM techniques. If the product has software components, we may be able to radically alter the performance or the features facilitating access to these other areas. We can assign new parameters to alter the performance instead of incurring hardware costs. For example, we can have a platform that operates at one speed, and then through software parameters increase the speed of performance making this incarnation of the product the premium version.

Eventually, our rate of growth will start to decline. Though the slope is still positive, we will have a lower rate of slope (less steep) as we move to the maturity phase in our product life cycle.

1.3.4 Maturity

We have seen our product and our sales volume grow, and we begin to see that rate of growth slow. We are entering the maturity phase of our product life cycle. In the maturity phase, we are no longer acquiring customers at our previous rate. The market is becoming saturated; perhaps there are newer versions or competing products from other suppliers. No matter the reason, we can see that our product is nearing the end of the useful cycle. We should be planning some other product to replace this incoming revenue, as we steadily watch the rate of growth reduce. We can extend this maturity phase, perhaps, with cost-improvement techniques. Though our production and distribution processes can be quite mature, there is always the possibility of stemming the rate of decline via cost-improvement techniques—a few of which are as follows (more can be read in the book titled *Reducing Process Costs with Lean, Six Sigma, and Value Engineering Techniques**):

- Brainstorming
- Lean manufacturing
- Total quality management
- Six Sigma
- Product tear downs

All of these activities can help us understand where our costs can be better controlled, thus retaining our profit in the face of sales volume reductions. These techniques have a range of sophistication or complexity meaning any organization can use to ascertain and improve their cost structure.

Nevertheless, we will eventually see the product steadily decline until we reach the point where there is no growth or zero slope—the harbinger of the next phase decline. Beyond this point, we will see a loss of customers and sales volumes that are hallmark of the product decline.

* Reprinted with permission from the publisher: Pries, K.H., and Quigley, J.M. (2012). *Reducing Process Costs with Lean, Six Sigma, and Value Engineering Techniques*. Boca Raton, FL: CRC Press/Taylor & Francis Group.

1.3.5 Decline

In the decline phase, our rate of growth is now negative sloping. We no longer are garnering more customers and market share, but are losing both. We still may be able to eke out a profit, but we will have to work especially hard doing so. If we were forward thinking, we would likely have as a replacement a new and better *widget*, which will restart the entire process all over again. We will likely maintain some replacement parts for the product already sold but our manufacturing processes will be ramping down. If we did not believe we could produce a new widget that meets the customer demands or needs, we may ultimately discontinue this sort of product.

1.3.6 After the Decline

If we have been developing a replacement product to be introduced in parallel prior to our present product's demise, we may find opportunities for improving the development costs associated based on our aged product. For example, perhaps our replacement product will have the same envelop and enclosure geometry. Perhaps we will make a new iteration of the product that will fall in the adaptive radiation category (discussed in Section 1.5.2.1). In that case, perhaps we can effectively employ some of our existing tools for the next generation of the product.

1.4 CM and the Dynamics of Change

CM, as practiced in different enterprises, may concentrate on a single aspect of the product life cycle or the product life cycle as viewed from the perspective of one piece of the total market segment. This results in narrowing down the understanding of how configurations are managed as well as why they are managed. The enterprise may be the end user or it may play the role of a vendor under a supplier to the end user. The focus of CM at each lower level becomes more removed from the total configuration of the item. It is critical that the configuration manager understands the entire scope of the life cycle, as well as the scope of the portion their enterprise supports, and the dynamics that are inherently involved throughout a product life cycle. In many cases, the larger picture is lost due to how CM is viewed and implemented in any single enterprise. Providers of components, mechanisms, assemblies, and other items delivered to the end user all play a critical part in the overall system.

The more each provider of CM services understands about the process and product planning, designing and manufacture, or configuration architecture of the whole, the better the end product or system becomes. To truly understand CM in the broader context, it must be viewed in relationship to the business as a whole, and at least a rudimentary grasp of the functional resources within an organization and their role as well as basic concepts regarding each roles primary function. The following discussions as well as those in the next two sections pertain to CM as applied to the entire enterprise infrastructure rather than to DM, records management, and release management. Unfortunately, the "Configuration Management Department" in many enterprises performs only these important but subtler aspects of the entirety of CM. Many who make their careers in CM also define it along this same line.

The CM process, as seen by the U.S. Department of Defense (DOD), starts with the identification of a new need followed by mission analysis. This flow, shown in [Figure 1.1](#), is typical of services provided by the government. It is, however, only part of the story as defined by the U.S. DOD and written as guidance for government personnel. It is a minimalistic view of what the government must do and what the government expects the contractor to do. Viewed another way,

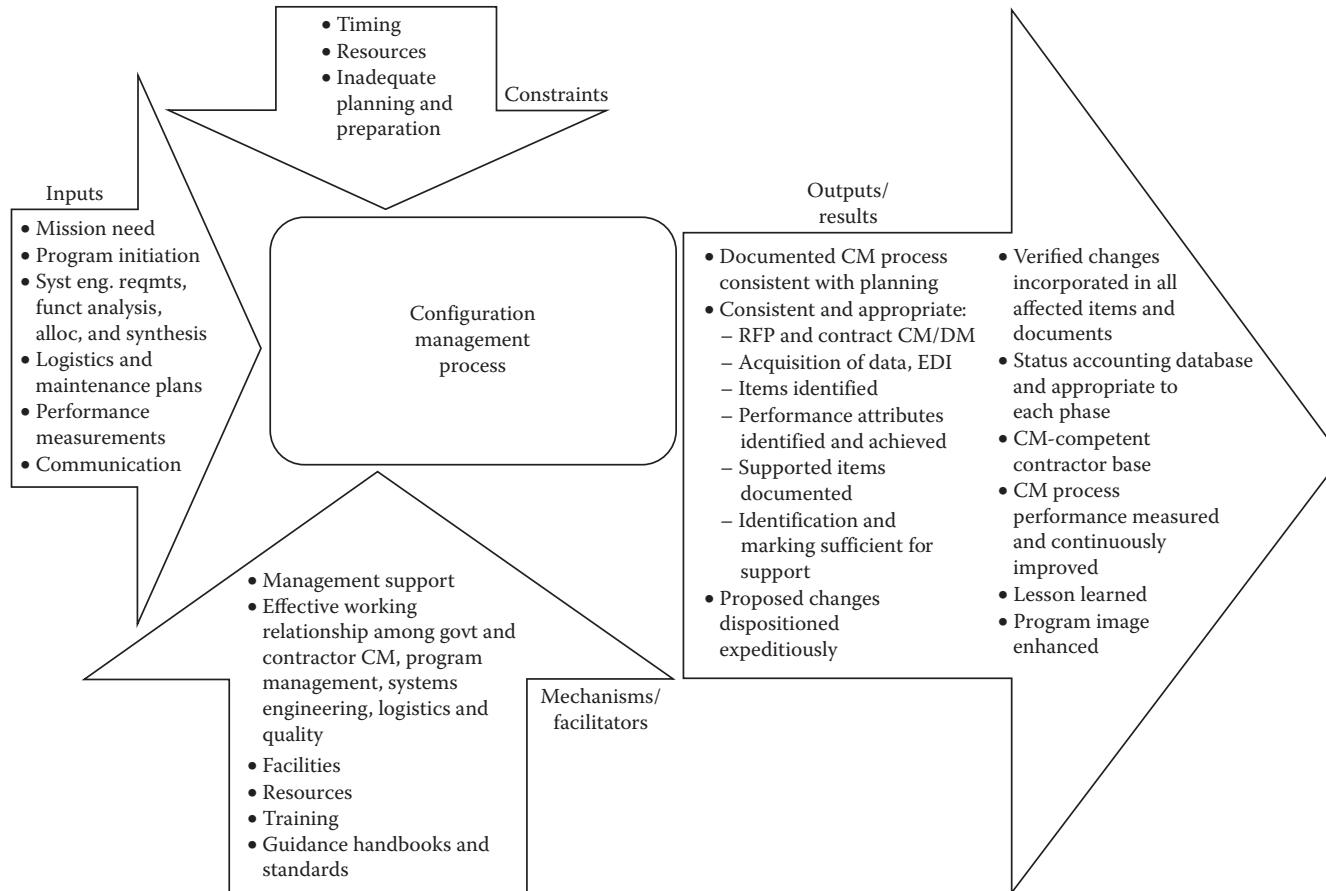


Figure 1.1 U.S. DOD configuration management process. (Data from DOD, U.S., *MIL-HDBK-61a, Military Handbook: Configuration Management Guidance*, Federal Government, U.S. [Figure 1.2](#), 2013.)

$$\begin{aligned}\frac{dN}{dt} &= r_1 N \left(1 - \frac{N}{K_1} + \beta_{12} \frac{M}{K_1} \right) \\ \frac{dM}{dt} &= r_2 M \left(1 - \frac{M}{K_2} + \beta_{21} \frac{N}{K_2} \right)\end{aligned}$$

N and M = population density
 r = intrinsic growth rate of the population
 K = carrying capacity of the local environment
 β = coefficient converting encounters of one species with new members of another

Figure 1.2 The Lotka–Volterra equation for species dependency.

it is nothing more than a choreographed script for buyers and sellers in a specific market segment, where the government controls the environment the sellers exist in. This artificial environment rarely exists in the nongovernment sales market sectors.

The commercial world is governed by market change dynamics that greatly influence CM considerations, but also the viability and sustainability of products and the infrastructure required to market and support them. This is a much broader application than strictly government considerations for systems and goods often driven by logistical necessity or by response to international considerations. It is critical that the CM practitioner has a firm grasp of this process, what drives it, and how it relates to the product life cycles.

Some may find it easier to grasp many aspects of change dynamics from an ecological viewpoint. In many cases, there is a direct corollary between business and the predator–prey relationships that exist in every ecosystem. Ecological interactions occur between organisms and their environment. They also occur between species trying to exist in the same environmental niche. Allelopathic trees such as the black walnut and eucalyptus release chemicals that inhibit the growth of other species. Predator–prey relationships can also develop that are beneficial to both species. The weaker species members of the prey are not allowed to reproduce or forage and the weaker predators starve. Both are symbiotic within the ecological area they reside. Unique defensive and offensive strategies develop with each species. Symbiotic relationships develop as well where both species benefit. This creates a case of logistics growth plus an increase in population growth of one species as a result of the presence of greater numbers of another species. The Lotka–Volterra* equations (Figure 1.2) form a simple framework for modeling this kind of species relationship.

Richard Goodwin utilized similar equations in 1965 to model the dynamics of various industries.†

Sayings like, *We’re going to eat their lunch with this one!* and *They’re eating us alive!* have existed in boardrooms for a long time. Both pay tribute to the ecological similarities of predator–prey and survivability conditions. Wherever possible, the ecological as well as the systematic view will be discussed to reinforce learning.

Each phase of the product life cycle brings different dynamics into play as it interacts with the marketplace. Each will influence the management of the product’s configuration. A sound grasp of CM theory, practice, and application is required to minimize the product to market churn to reflect better earnings before interest and taxes (EBIT).

CM activities shift as a product matures from guiding decisions relative to design and ease of logistics activities to assuring production repeatability. Thirty years of experience over 25 different programs ranging in value from \$20 million to \$1.2 billion and 270 projects ranging in size from \$5,000 to \$90,000 has shown that 80% of the decisions driving cost are made in the product

* Lotka, A.J. (1925). *Elements of Physical Biology*. Baltimore, MD: Lippincott Williams & Wilkins.

† Goodwin, R.M. (1967). *A Growth Cycle: Socialism, Capitalism and Economic Growth*, Feinstein, C.H. (ed.). Cambridge: Cambridge University Press.

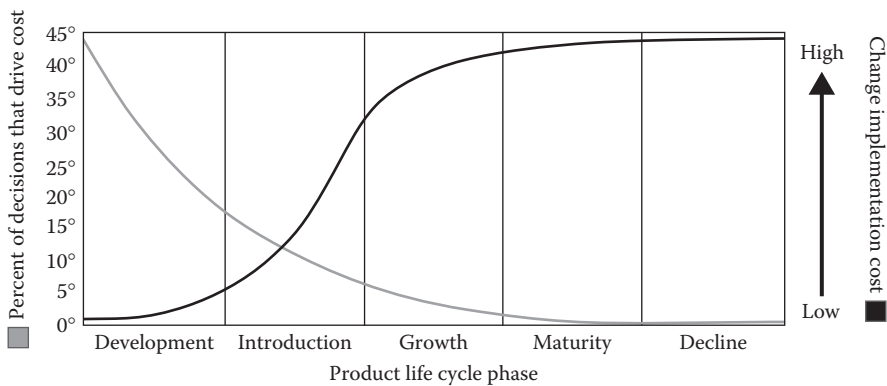


Figure 1.3 Cost and influence of critical design decisions plotted over time.

development phase of the product life cycle. It has also shown that the further along a product is in the life cycle, the more costly design changes become. There was less than a 1.5% variance over the sample size. Figure 1.3 graphically depicts these findings.

The environment in which an organism or a product finds itself changes over time. Most think of the Sahara as a dry foreboding expanse with life crowded along the Nile River. This has not always been the case. Stefan Kröpelin of the University of Cologne in Germany observed, “The climate change at (10,500 years ago) which turned most of the (8.4 million square meter) large Sahara into a savannah-type environment happened within a few hundred years only, certainly within less than 500 years.” Organisms suited for the savannah-type Sahara were not as successful in the dry periods that bracketed it.

Environmental climate change is not the only factor that influences the types and density of organisms within the environment. A single organism may thrive in a relatively unchanging environment only to be displaced by another that is better suited to thrive in its ecological niche.

Manufactured items also are viable and become nonviable in a very similar way and are just as dependent on the economic climate change and competition for the same market niche. To remain viable, an enterprise must be able to adapt and modify its marketing strategy and management of its approach to CM of its product and production infrastructure, as new technologies emerge and older ones cease to be supported in much the same way wolves survive in the tundra. Although the expenditure of energy for the nutrition gained is greater during the migration of Caribou as a teaming effort with other wolves, the wolf is content in summer months to be a solitary hunter relying on a diet, in some cases, comprised predominately of voles and other rodents.

Cyclic demand for products and product features also ebb and flow with economic changes. Business plans that relied heavily on one external dependency such as transportation of goods from a single location may find the model less viable than one relying on regional distribution or in some cases co-location with the end user or user community.

1.4.1 Survivability Conditions

An organism can survive only if several conditions exist.

* Bjorn Carey, 2006. *Sahara Desert Was Once Lush and Populated*. July 20. <http://www.livescience.com/4180-sahara-desert-lush-populated.html> (Accessed September 20, 2014).

14 ■ Configuration Management

1.4.1.1 Nature

- The physical environment is suitable (food, climate, and predators)
- The competitive environment is suitable (few or no competitors)
- Reproduction rate exceeds lifespan (its reproduction and survival rate exceeds its mortality rate)
- High dispersal rate (its dispersal rate allows it to exploit the entire niche)
- Adaptability (it has an ability to adapt to changing conditions giving it advantages over the current niche holder)

1.4.1.2 Products

There is a product corollary.

- The physical environment is suitable (raw materials, technology, fabrication capability, and competitors)
- The competitive environment is suitable (few or no competitors and it is meeting a perceived or real need)
- Reproduction rate exceeds lifespan (supply meets or exceeds demand)
- High dispersal rate (marketing and distribution channels are sound)
- Adaptability (it has an ability to adapt to changing conditions giving it advantages over the current niche holder)

Two main strategies come into play when making a decision to enter a market with a product. They are known as “product market adaptation” and “product performance adaptation.” Both require an understanding and synergy of regional, national, international, and cultural norms that influences how and where product will be used with the net result of increased market share in that segment.

Marketing can often make or break a product. In its simplest form, it relies on captivating the customer’s attention using appeals to one or more of the seven deadly sins mentioned by Dante Alighieri.*

1. Luxuria (lechery/lust)
 - a. If you use this product you’ll get the guy/girl!
2. Gula (gluttony)
 - a. This sale is for a limited time only!
3. Avaritia (avarice/greed)
 - a. Buy one get one free!
4. Acedia (sloth/discouragement)
 - a. You can earn a six figure income in as little as six weeks and as little as three hours a day!
5. Ira (wrath)
 - a. Hate weeds? Buy our weed beater now!
6. Invidia (envy)
 - a. The beauty secrets known only by the stars are now yours!
7. Superbia (pride)
 - a. You deserve it!

* Alighieri, D. (d. 1321). *The Divine Comedy: Complete the Vision of Paradise, Purgatory and Hell*, Translated by Rev. H.F. Cary. Salt Lake City, UT: Project Gutenberg eBook. November 30, 2012. <http://www.gutenberg.org/files/8800/8800-h/8800-h.htm>.

Each decision made regarding the products configuration allows it to be marketed in one of these seven ways. Each decision made regarding the products configuration allows your competitors to develop a counter marketing strategy to combat against it. There is an additional marketing sin not considered by Dante that must be added.

8. Metus (Fear)

- a. Do you know who is in your house right now?

The following case study concerns the opening up of a new market segment known as the “horseless carriage.” Here, you will find every aspect of survivability conditions required for creation of a market sector.

1.4.2 Evolution of the Horseless Carriage

Traditionally new market segments open due to the need to solve a problem. Such problems may be real as in the case of the environmental crisis solved by the automobile or the need may be concocted. New markets and products are rarely developed through the inspiration of a single individual. The automotive market came about through a synergy of the existing body of knowledge and other *environmental* conditions both in the marketplace and in the nature.

One topic of discussion at the world’s first international urban planning conference in 1898 was the growing health concerns due to horse excretions and the creatures that accompanied them. As the primary means of locomotion for wagons and other forms of transport, horse populations exceeded human population in cities.*

Manufacturers of “horseless carriages” using steam, electric, and internal combustion engines as the motive force attempted to meet the challenge. Gasoline was found unsuitable at first as a fuel for combustion engines so Henry Ford’s Model T was designed to use ethanol. Steam- and electric-powered vehicles held an early advantage but were eclipsed in the market by the combustion engine. Nicolas Joseph Cugnot built the first steam tractor in 1769. By 1881, Amédée-Ernest Bollée’s *La Rapide* achieves the impressive speed of 62 km/h. Electric cars improved to the point that in 1899 Camille Jénatzy’s electric automobile “La Jamais Contenté” set a world record for land speed of 100 km/h.

The success of the combustion-powered vehicle is no different than three species competing for the same ecosystem, where one develops an advantage over the other two. Eventually, the species with the greatest advantage gains a dominant position in the ecological environment. A similar struggle in the automotive *environment* is going on today. Due to the changes in the current environment, ethanol and electric are again in competition or being combined with the internal combustion engine as viable competitors in the automotive market segment.

1.4.2.1 A Look at the Converging Technologies

The synergy of converging technologies processes and components leading up to Henry Ford’s moving production line leading to the combustion engine automobile’s dominance has a long and often surprising history. Metalwork and metallurgy were critical components of the success of the horseless carriage. Forging of metals requires heating the metal to a malleable temperature, placing it on a solid object and striking it with another. Finding a way to do this rapidly while allowing the smith to move the metal being forged was critical to rapid production of tools and weapons. Animal and water power were harnessed to do this and lead to the development of the hammer mill.

* Morris, E. (2007). *From Horse Power to Horsepower*. Berkeley, CA: University of California Transportation Center—ACCESS number 30.

The helve hammer mill may have existed in China as early as 1050 BCE. If proven, this predates the Roman use by 1600 years or more. Hammer mills of this kind are thought to have been used to manufacture the weaponry for the estimated 8000 Terracotta Warriors in 210 BCE found at the burial site of Qin Shi Huang, the first Emperor of China.

Yang Fuxi, a 10th-generation maker of ancient crossbow, states that a crossbow trigger found at the site when compared to one found 3218.69 km apart contained interchangeable parts. This supports the statement by archeologist Liu Zhangcheng, where 30,000 arrowheads in the pits were tested with the difference in their sizes to be less than 1 cm. Some evidenced a difference of 0.22 mm. We know from this that weapon manufacturing was standardized.* A select sample of these arrowheads is shown in Figure 1.4.

Strict management of the configuration, manufacturing process, and quality management were required to achieve such a high degree of uniformity. It is unknown if production methods included checking the arrowheads against a gauge, perhaps ceramic as a half-mold from a master arrowhead, for uniformity. Evidence also exists that metallurgy was known and practiced using copper, tin nickel, magnesium, and cobalt.† Bronze swords found at the site were also found to be coated with a layer of chromium oxide that had kept the swords rust-free for 2000 years.‡

Moving forward in time to Rome we find specifications for iron spearheads (see Figure 1.5).

Consistency in spearhead size, weight, and material would have been deemed invaluable in Roman times. Without them, it would have been very hard to have had the efficient fighting force that Rome required to manage its provinces. Each legionnaire was generally equipped with *gladius* (a short sword about 46 cm long), *pugio* (dagger for 18–28 cm long), and one or more *pila* (a 2 m long javelin). Of these three items, the gladius-like swords may have varied in weight and perhaps balance depending on the reach of arm strength versus age and personal preference of the

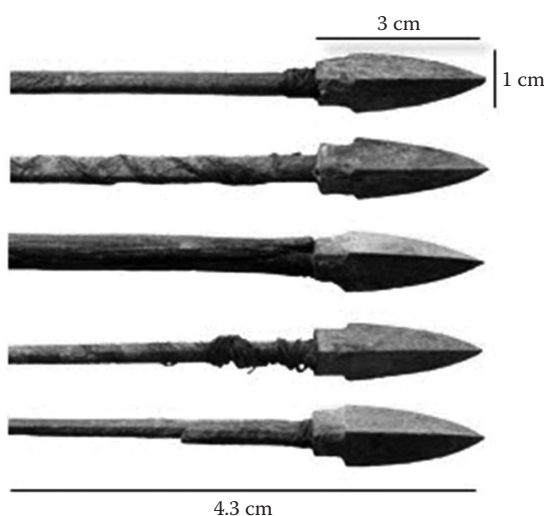


Figure 1.4 Bronze arrowheads 210 BCE, China.

* Talley, S. (Director). (2011). *Secrets of the Dead: China's Terracotta Warriors*. [Motion Picture]. PBS.org.

† *New Terra-Cotta Warriors Dig Begins in China*. (2009). National Geographic (AP). <http://news.nationalgeographic.com/news/2009/06/090615-terracotta-excavate-video-ap.html>

‡ Zhewen, L. (1993). *China's Imperial Tombs and Mausoleums*. Beijing, China: Foreign Languages Press. p. 216.

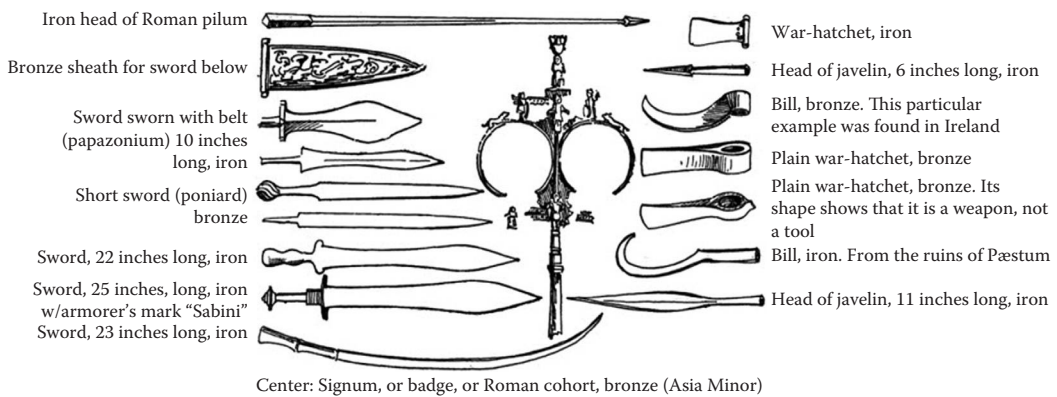


Figure 1.5 Roman weapons and descriptions. (From Demmin, A., *An Illustrated History of Arms and Armour: From the Earliest Period to the Present Time*, translated by C.C. Black. M.A.G. Bell and Sons, London, 1911. The Figure is a composite with each of the illustrations taken from a different page of the book. <https://archive.org/details/illustratedhisto00demmrch>. The Book was accessed on June 22, 2014. With permission.)

legionnaire. The pugio may have varied in length and configuration also based on the preference and perhaps birth origin of the legionnaire. It is conceivable that the pilum was controlled to very strict standards for efficiency in battle if nothing else.

The pilum was designed to be thrown and stick into an enemy's shield making the shield too unwieldy to use for defense. As a weapon used by every legionnaire standardizing length and weight would have held distinct advantages. Standardization would have allowed the pilum of a fallen comrade in arms to be picked up by anyone and thrown. Imagine the difficulties involved if today's gladiatorial sport of American football used balls of differing size and weight each play. The quarterback would never be able to properly train or stay in the zone. Conceivably similar considerations were given with this weapon for the same reasons. The mass of the light pilum of *Augustan era* was about 2.2 kg.* The weight and center of gravity of the pilum is assumed to have remained constant enough to allow it to meet the objective of effectively engaging the opponent at a range of 10–15 m.

The forging of metal is but one aspect of the journey to Henry Ford's production line. Development of fuels was another. In the period for 1800–1900, the United States relied on coal, natural gas, camphene and white naphtha also known as fuel oil for heating. White naphtha was also used as fuel for lamps as a less expensive alternative to whale oil. Distillation of naphtha from oil was documented in the *Book of Secrets* in the ninth century.† By-products of distillation included gasoline (see Figure 1.6). Gasoline and others went unused until the 1900s. Product entries into an existing market segment at times are based on utilization of by-products no one else has found a use for. Often by-products that had no known use were disposed of in local rivers and lakes. At times, people would see if the pollutants would burn and were taken by surprise when the lake caught fire, in his youth Earl Ray "E. R." Miller was one such experimenter.‡

* Walbank, F.W. (1957). *A Historical Commentary on Polybius*, 3 vols. Oxford: 1999 Special Edition Clarendon Press.

† Taylor, G.B. (2008). Al-Razi's "*Book of Secrets*": *The Practical Laboratory in the Medieval Islamic World*. California State University, Fullerton, CA.

‡ Earl Ray "E.R." Miller Sr., test driver for Ford and Hupmobile, who helped lay the brick track use in the first Indianapolis 500, mechanic for Cadillac on the first U.S. transcontinental race, Hollywood stuntman, and entrepreneur in mechanical innovations and an early Portland Cement franchisee.

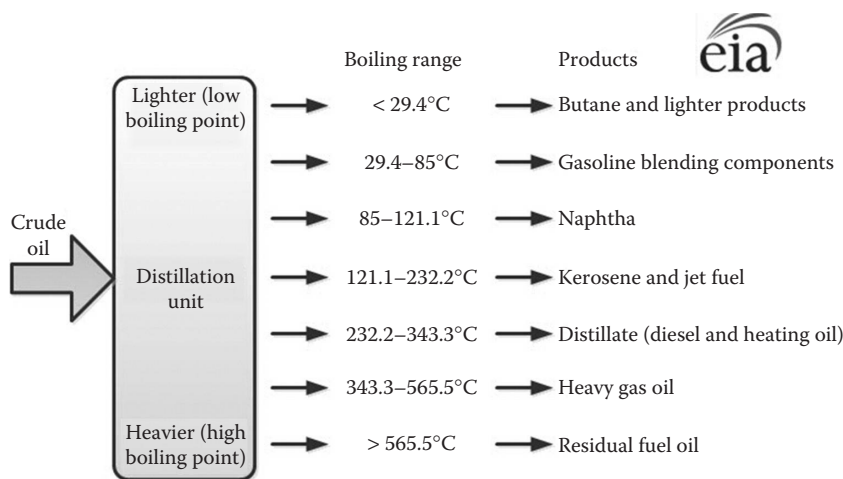


Figure 1.6 Crude oil by-products and distillation temperatures. (Data from U.S. Energy Information Administration—redrawn to convert degrees F to degrees C.)

Each of the other components that were utilized in the final vehicle has a similar evolutionary history. Henry Ford built on a long history of innovation. His 1913 moving production line reduced the time to manufacture an automobile from 12 hours to two hours and 30 minutes and the associated labor costs by 95.2%. A photo of the Ford production line is provided in Figure 1.7.

It was predated by Michael Joseph Owens by Owens Bottle Machine Company in 1903, where glass bottles were produced at a rate of 240 per minute at a reduced labor cost of 80% (see Figure 1.8). Henry Ford and Michael Joseph Owens used different CM approaches to achieve their production needs. Michael Joseph Owens automated the entire set of manufacturing operations into one machine. Henry Ford broke the manufacturing operations into manageable steps and placed them sequentially improving unit manufacturability.

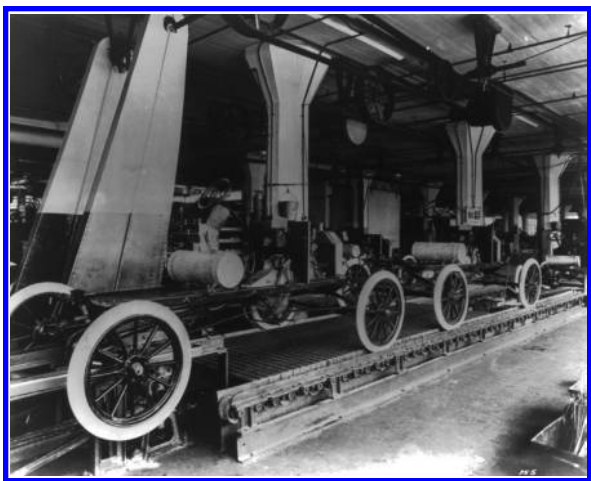


Figure 1.7 Assembly line at the Ford Motor Company's Highland Park plant. (Reproduction Number: LC-USZ62-19261 [b&w film copy neg.], 1913. Library of Congress Prints and Photographs Division Washington, DC, <http://www.loc.gov/pictures/item/2011661021/>.)

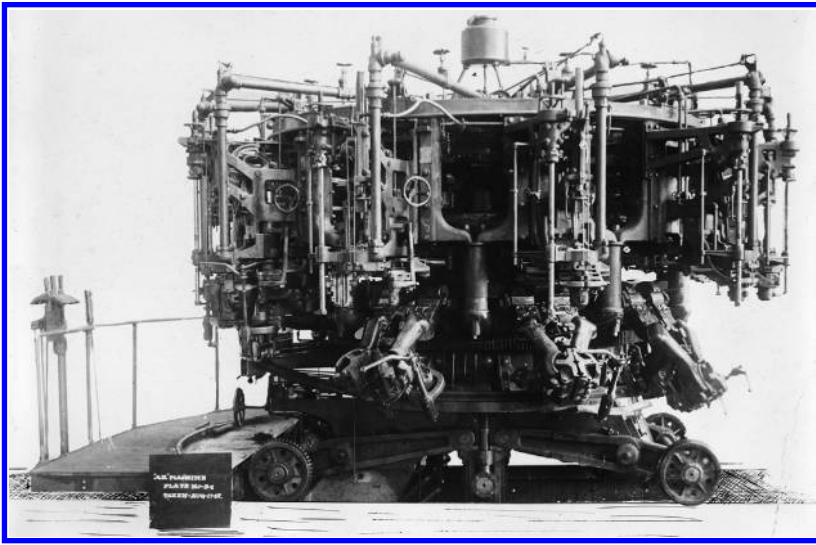


Figure 1.8 Ten-arm Owens automatic bottle machine. (Hine, L.W., 1874–1940 photographer, Reproduction Number: LC-DIG-nclc-05512 [b&w digital file from original glass negative] Library of Congress Prints and Photographs Division, Washington, DC, <http://www.loc.gov/pictures/collection/nclc/item/ncl2004001184/PP/>.)

CM decisions relative to the ease of production, assembly, repair, accessibility to the item to be repaired or replaced, transport, product options, parts sparing, tooling, components, materials, and unit life were critical to the success or failure of each competitor.

Sometimes configuration changes due to adaptive radiation are so significant that they impact an entire market segment. The first automobile with a control system like those used today was the Cadillac Type 53. The instrument cluster, gas pedal, clutch pedal, and brake pedal arrangement were much different than Ford's Model T. Austin copied the layout and employed it in its Austin 7. It then licensed the Austin 7 design to BMW and Datsun. It was not long before the configuration change was utilized worldwide. Similar adaptive radiation of configuration changes are being made today from standardization of map symbols in North Atlantic Treaty Organization (NATO) to refined hardware interfaces for computing devices.

Market performance is based on the two strategies of product market adaptation and product performance adaptation. It is graphically shown in Figure 1.9.

The market performance construct identified earlier is sound and forms the basis of the discussions that follow.

1.4.3 Product Market Adaptation

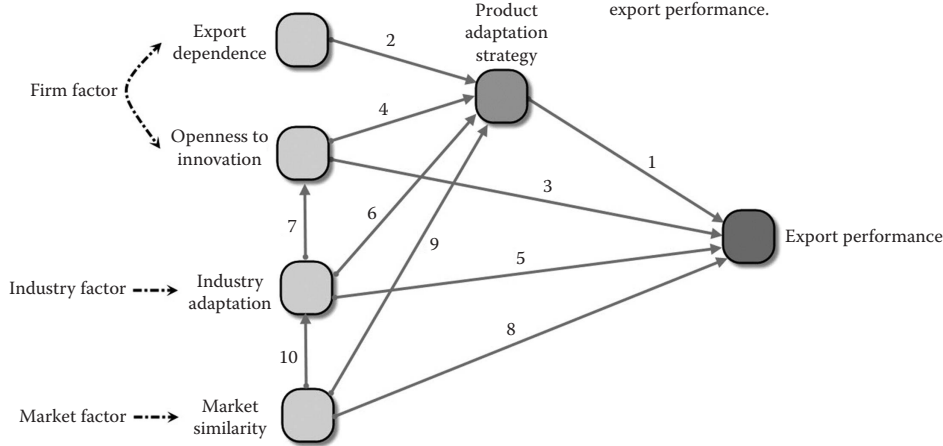
Product market adaptation is the strategy of introducing new products into an existing market based on either a modification of competitors existing product or an improvement of that product. It is not based on an enterprise investment in research and development to pioneer innovations or to open up a new market segment. It is rather an attempt to enter a market segment previously established by someone else in an attempt to acquire a portion of that market segment.

Product market adaptation is illustrated in the history of the rental car business. A gentleman named Joe Saunders in Nebraska affixed a mileage meter to the left front wheel of his Model T

1. The more active the product adaptation of the firm, the greater is its export performance.

2. The greater the export dependence of a firm, the more active is the firm with product adaptation.

3. The more open the firm to innovation, the greater is its export performance.



4. The more open the firm is to innovation, the more active is its product adaptation.

5. The more active the product adaptation in an industry, the lower is the export performance of a firm in the industry.

6. The more active the product adaptation in an industry, the more likely is a product adaptation strategy by a firm in that industry.

7. The more active the product adaptation in an industry, the more open is a firm to innovation.

8. The more similar the export and home market, the better is the export performance of a firm.

9. The more similar the export and home market, the less active is the firm in product adaptation.

10. The more similar the export and home market, the less active is the industry in product adaptation.

Figure 1.9 Market performance. (Adapted from Calantonea, R.J. et al., *J. Bus. Res.*, 59, 2, 176–185, 2006.)

Ford in 1916 and rented it out at 10 cents a mile. By 1925, he had opened up this new market segment and was operating in 21 states. Others saw the profitability of entering the market segment and went into direct competition. One of these was Walter L. Jacobs, who entered the market segment in 1918. In 1923, he sold his company to John Hertz, president of Yellow Cab and Yellow Truck and Coach Manufacturing Company. By 1925, Hertz had established the first coast-to-coast rental network using franchises and advertised heavily (see Figure 1.10).

The Hertz® Drive-Ur-Self System was acquired in 1926 by the General Motors Corporation when it bought Yellow Truck from John Hertz. Hertz rental cars dominated the market until Warren Avis entered the market segment in 1946 concentration on airport rentals. Avis concentrated specifically on car rentals at airports. When Avis entered the market, the majority of Hertz rentals took place in cities.

Historical forms of product market adaptation took the form of acquisition of or merger with an enterprise that is in the market sector and agreements between competitors to sell for the same price. This was taken to extremes during the 1800s with the forming of trusts (monopolies) in the oil (standard oil), sugar, steel (U.S. Steel), and railroad industries. The result was control of quantity, quality, and price. Passing of the Sherman Act in 1890 against price fixing and illegal activities and the Clinton Act in 1914 to limit mergers leveled the playing field, allowing more companies to truly compete. The playing field was overseen by the Federal Trade Commission (FTC) established in 1914.

Mergers are closely monitored in the United States by the FTC. Many mergers are simply to acquire technologies the enterprise does not currently possess, so that they can build rather than buy components in a product. In other cases, mergers are used to diversify so that an enterprise is able to survive a broader set of market-specific fluctuations. Glenn L. Martin Company (aerospace



Figure 1.10 Hertz® Drive-Ur-Self System. (Advertisement circa 1925 provided courtesy of the Hertz® Corporation. With permission.)

and launch/missile systems) did this when it merged with American-Marietta Corporation (paints, dyes, metallurgical products, and construction materials) to form Martin Marietta Corporation in 1961.

Market adaptation can be observed in the ebb and flow firms manufacturing *smart* devices (phones, tablets, etc.) and the integration of their capabilities across many aspects of daily life, including seeing what the nanny is doing real time, personal finances, locating a vehicle in a parking lot, turning it on, and prewarming the seats. They are also manifesting themselves in reaching a balance of standardization and market adaptation.

While all international products are not designed with this objective, the proportion of international products that balance standardization and adaptation appears to be growing and anecdotes justifying the merits of balancing standardization and adaptation come from a spectrum of industries. These include food and cosmetics (where adaptation would appear to be important) along with copiers and televisions (where standardization would appear to be critical). The logic being that, by balancing standardization and adaptation, MNCs (Multinational Corporations) can not only simultaneously harness the benefits of efficiency and responsiveness, but also coalesce into their products, inputs of both headquarters and foreign subsidiaries for greater competitive advantage.*

1.4.4 Product Performance Adaptation

Product performance adaptation differs from product market adaptation. It is not a strategy for entering a new market by copying and perhaps improving on a competitor's product, though both

* Subramaniam, M., and Hewett, K. (2004). Balancing standardization and adaptation for product performance in international markets: Testing the influence of headquarters-subsidiary contact and cooperation. *Management International Review*, Vol. 44, No. 2, 171–194. Reprinted with permission of Springer Science + Business Media, Heidelberg, Germany. pp. 171–194.



Figure 1.11 Subaru 360.

may be in the same market segment in their respective countries. It is rather the process of understanding the needs and norms of a market area and adapting your introduction of a product or the product itself to it to increase the sales performance in that market.

Consider the case of adapting a vehicle for the world market. The percentage of countries that drive vehicles on the right hand side of the road is almost double the number of countries that drive on the right hand side of the road. This identification of a cultural norm could be considered one of the keys to product performance adaptation. Documentation indicates that both right- and left-hand drive Model T Fords were manufactured and marketed in Australia and elsewhere. The Model T was built for a market with few paved roads and was a boon to those in rural communities. Product performance adaptations through consideration for cultural norms by some manufacturers were not initially successful.

An example of this was the first introduction of the Fuji Heavy Industries Subaru in 1968 by Malcolm Bricklin. It was named the 360 (Figure 1.11) due to its 356 cm³ two-stroke engine size that produced 25 hp. It was diminutive in size measuring a scant 2990 cm long × 1380 cm high × 1300 cm wide and was affectionately nicknamed the “Ladybug,” and it weighed in at 419.573 kg. It was 26% smaller than the 1969 VW Beetle, which measured 4070 cm long × 1500 cm high × 1540 cm wide.

Although the 360 was technically sophisticated at the time with unibody construction and torsion bar trailing arm suspension it was rated *Not Acceptable* by *Consumer Reports* in 1969 after a crash test against an American automobile. By 2010, Subaru had resolved such issues and held a 2.1% of the U.S. automotive market share.*

Subhash C. Jain makes the point that different markets for a product may be in different stages of product life cycle development. If a product’s foreign market is in a different stage of market development than its native market, some changes in the design may be required to make an adequate product/market match.† When viewed in this context, the Subaru 360 product was entering a market that was not a good product/market match.

Subhash C. Jain goes on to state, “Culture influences every aspect of marketing. The products people buy, the attributes they value, and the principals whose opinions they accept are all culture-based choices.” This aspect of product performance adaptation was not taken into account and made the *Consumer Reports* rating worse than it would have been for a more familiar product.

* Gopwani, J. (2010, March 11). Subaru builds on loyal customer base. *USA Today*.

† Jain, S.C. (1989). Standardization of international marketing strategy: Some research hypotheses. *Journal of Marketing*, Vol. 53, No. 1 (American Marketing Association), 70–79.

Henry Ford was forced to discontinue the production of the Model T in order for his company to remain viable. Other manufacturers were modifying body styles and vehicle capability with innovations that made the Model T outdated. In 1926, there were fewer than 500,000 Fords sold compared to about 100,000 for Chevrolet. On May 26, 1927, the last Model T was produced. Approximately 60,000 workers were laid off and Ford dealers were forced to purchase all Model T remaining inventory and parts if they wished to remain dealers as Ford factories retooled for the Model A. The Model A was released in December of 1927.*

1.5 CM and Market Adaptations

Although firms modify their market strategies to include both product market adaptation and product performance adaptation, it is important to consider the effect of the consumer being able to have an affinity for the product itself. This is accomplished not only through such things as brand loyalty or the need the product meets, but by how the culture it is marketed to values both strategies.

1.5.1 Mass Customization

In his autobiography *My Life and Work* published in 1922, Henry Ford stated, “Any customer can have a car painted any color that he wants so long as it is black.”† Earl Ray “E. R.” Miller‡ of Ely, Nevada, worked for Henry Ford during the Model T era. He states,

Henry Ford was a master in the art of common design. He attempted to standardize everything he could to make his production of the Model T more profitable. The crates that parts were shipped to the factory in were made to his specifications and after being unpacked we took them apart and used the parts in the assembly line. Not a board, screw, nut or bolt on those crates was thrown away. They all ended up in one of the cars.

He preferred to paint the Model T black simply because it dried faster and he could put more vehicles out the door. The only production year that black was the only color option was 1914. From 1908 through 1914 black wasn’t even an option. I remember grey, green, blue, and red ones. He called me and Louie Chevrolet up to his office one day and he was late so we were sitting on his desk smoking cigarettes. I never found out what he wanted because he fired us on the spot. He didn’t like anyone smoking.

Well Louie started his own company and I went to work for Hupmobile as a test driver. My job was to take the cars out on the road and try to break them. Every night they would take the body off my automobile and put it on a new chassis and off I’d go the next day while they looked at what I’d done to the automobile the day before and figure out how to fix it. Lots of folks think that engineers know what they are doing all along in the design process. They don’t. They design, build, test and if it breaks go back to design. You remember that.

* Earl Ray “E.R.” Miller Sr. former Ford employee.

† Ford, H., and Crowther, S. (2005). *My Life and Work*. Salt Lake City, UT: Project Gutenberg eBook. p. 72, Chapter IV.

‡ Earl Ray “E.R.” Miller Sr. describing design and supply chain innovations he assisted with at Ford during Model T production cost reduction.



Figure 1.12 Components of the Nike Free Trainer 5.0 ID.

Today, mass customization surrounds us and drives not only the product offerings but also product marketing, manufacturing, and sales. A recent visit to the Nike website provides an excellent example. The Nike Free Trainer 5.0 identification (ID) (see Figure 1.12) gives the customer multiple color options (Figure 1.13) for each shoe component that are selected by the consumer before placing an order.

Based on the numbers of colors available and assuming the use of the Nike logo for this product alone Nike is offering the consumer $9 \times 8 \times 15 \times 15 \times 13 \times 15 \times 4 \times 6 \times 10 = 758,160,000$ unique color variants of the product. The consumer's customization choices are logged, manufactured, and delivered within four weeks. This ability plays a substantial part in the firm's market share, brand loyalty, and customer satisfaction.

For another online version of mass customization one needs only to look into LEGO®. LEGO has built the company around reuse of stock components to produce a variety of *new* products. To facilitate or showcase this capability, it introduced a tool called "LEGO Digital Designer" (Figure 1.14).

The tool is essentially a self-contained computer-aided design package that makes it possible to develop a product without the use of actual materials. Once the product is designed, the bill of materials, assembly instructions as well as packaging for the product is generated giving each package a custom appearance. With LEGO's expanding component base, robotic creations are commonplace and limited to an individual's creativity. The company has online sharing of designs to facilitate growth in this customized sector.

Volkswagenwerk GmbH took a simpler approach to configuration and market adaptation. Detroit in the 1950's was experiencing excessive parts inventory costs to maintain the wide option offerings for any given model and passing the costs on to the consumer. In 1956, the air-cooled vehicle was featured by *Popular Mechanics* in its article "Owning a VW Is Like Being in Love." This article set the stage for not only the unconventional mechanical configuration, but equally for unconventional marketing approach. That year General Motors had a \$162,499,248 advertising budget.* Volkswagen limited exterior colors for the standard sedan to seven, with a small choice

* Rieger, B. (2013). *The People's Car: A Global History of the Volkswagen Beetle*. Cambridge, MA: Harvard University Press.

Shoe Part								Outside			Tongue Top ID	
Subchoices	Upper	Toe	Swoosh	Lace	Lining	Midsole Topline	Midsole	Solid	Translucent	XDR Outdoor	Nike Logo	ID Max of Five Characters
Black												
Wolf Gray												
White												
Flash Lime												
Atomic Teal												
Volt												
Electric Green												
George Green												
Vivid Sulfur												
Midnight Navy												
Blue Glow												
Game Royal												
Solar Red												
University Red												
Team Red												
Team Orange												
Total # choices	9	8	15	15	13	15	4	6	NA	NA	10	NA

ID, Identification; NA, Not Applicable.

Figure 1.13 Nike Free Trainer 5.0 ID customization options. XDR, Xtra Durable Rubber.

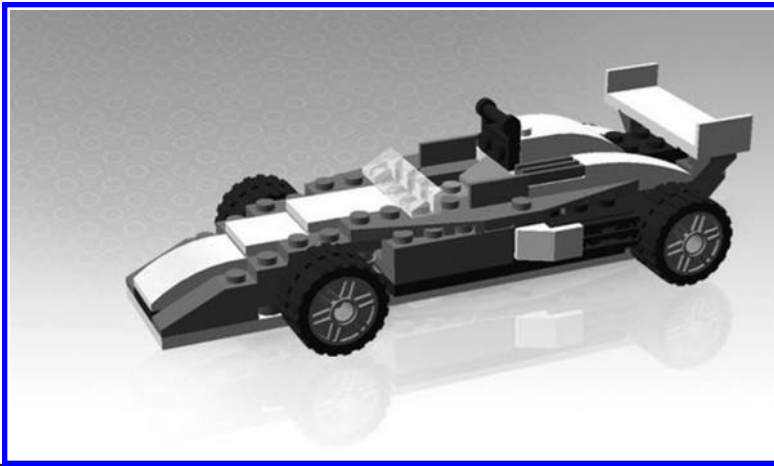


Figure 1.14 LEGO Digital Designer.

of pre-matched interior colors, and 16 accessories. This kept dealer and production inventories low. A keen attention to CM also enabled dealers to easily stock options and vehicles separately facilitating dealer stock turnover. Options could be added at any time and were not necessarily part of the fabrication process of the vehicle. 209,747 Volkswagen 1200 Sedans (Beetle) were exported to the United States in 1963.

Walt Disney Productions' release of *The Love Bug* in 1968 provided an unlooked for marketing plus for Volkswagenwerk GmbH. It was based on the 1961 book *Car, Boy, Girl* by Gordon Buford. Buddy Hackett who played Tennessee Steinmetz in the film states the pearl white Volkswagen was named "Herbie" after one of his skits about a ski instructor.

The Beetle was chosen due to the fact that of all the cars Walt Disney lined up in his casting call it was the only one people at the Disney studio who passed by petted.* Use of the vehicle in the movie was not sponsored by the manufacturer yet release of the movie and its sequels played a part in Volkswagenwerk GmbH's ability to maintain a sound market share despite an aging technology. The movie also facilitated expansion of movie-related product markets by other manufacturers. In February 1972, Volkswagen celebrated the sales of over 15 million Beetles by February 1970, surpassing the Ford Model T. Today, it holds the record of the most popular vehicle ever produced.†

1.5.2 Performance Adaptations

Adaptations of the product itself to either increase or adapt its performance can also be seen to have what appears to be a counterpart in the natural world. CM again plays a key role in not only determining how a product is designed, but all aspects of its producibility and maintenance. Charles Darwin published his journals of the December 27, 1831, to October 2, 1836, second voyage of HMS *Beagle*. He spent 39 months of the voyage on land as the expedition's gentleman geologist. This experience led to his theory of evolution. He postulated that the diversity of

* Stevenson, R. (Director). (1968). *The Love Bug Special Edition DVD (2003)*. [Motion Picture]. Walt Disney Productions, Burbank, CA.

† VOLKSWAGEN Brand History. (n.d.). Retrieved July 23, 2014, from *Autoevolution*: <http://www.autoevolution.com/volkswagen/history/>.

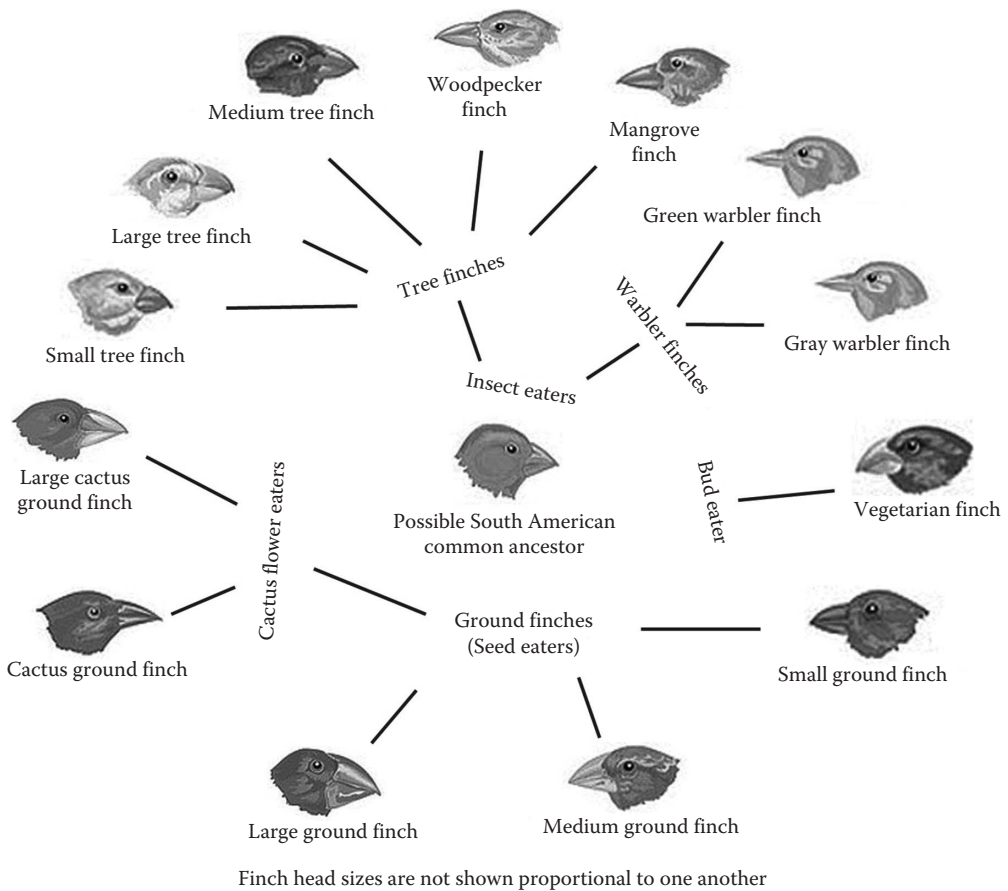


Figure 1.15 Galápagos finch species.

finch species he observed on the Archipiélago de Galápagos were possibly due to a diversification, later termed “evolution,” from a common South American ancestor (see Figure 1.15).

1.5.2.1 Adaptive Radiation

The debate over evolution and the view expressed in 1881 by William Paley* that such adaptations are God acting through the laws of nature has continued since his death in 1882. Much of what was observed by Darwin can also be seen in industry. The implications in the nature have formed the basis for much that has transpired since the theory was postulated. If the same observations are made with respect to the evolution of the Model A from the Ford Quadracycle, adaptive radiation moves from theory to the practical in the automotive world (see Figure 1.16). Ford’s approach to maximizing common platforms for the Model A variants was not unique. It has remained in practice in many industries until the present.

* Paley, W. (1743–1805). *Natural Theology*. New York: American Tract Society. <https://archive.org/details/naturaltheology00pale>.

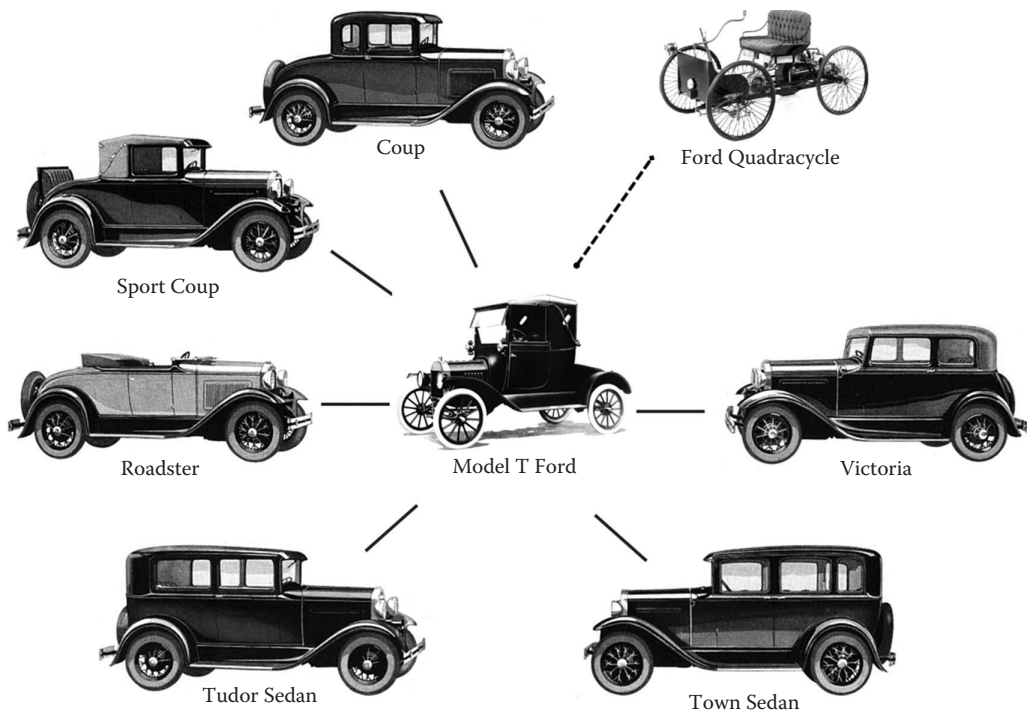


Figure 1.16 Adaptive radiation in engineering.

Hardware, software, and firmware development can be traced in much the same way experienced breeders of botanicals and animals trace the influence of the parents to the offspring. This is evident in the world of space launch systems and the competition to capture market share now that governments can no longer afford the great development expense due to changes in world politics. Although some contenders are funded in whole or in part by their respective governments, a number of launch vehicles are being developed independently. Space Exploration Technologies (SpaceX) is one such entry and has effectively used the concept of leveraged innovation in the development of the Falcon 9 launch booster. SpaceX has an aggressive and managed configuration approach for developing its market share (Figure 1.17).

One advantage of planned radiation is the ability to design in contingency profiles with pre-determined and managed configuration capabilities. On May 19, 2012, the launch of the SpaceX Falcon 9 carrying the Dragon spacecraft to the International Space Station experienced an event where the engine 5 pressure started trending high. The engine 5 check valve was replaced and the launch was successfully completed on May 22, 2012. Issues of this kind under the government-developed launch systems would normally have caused a six- to ten-week launch delay and a possible de-stack of the launch vehicle and re-manifesting of other vehicles in the launch queue until root cause investigations were completed.

Adaptive radiation of software can best be explained by relating it to a simpler case study than that of Darwin's finches. Manufacturing and design changes in hardware take time simply due to the manufacturing process. It requires sourcing of materials through supply chain management, receiving and inspection of the materials, performing forming or machining operations,

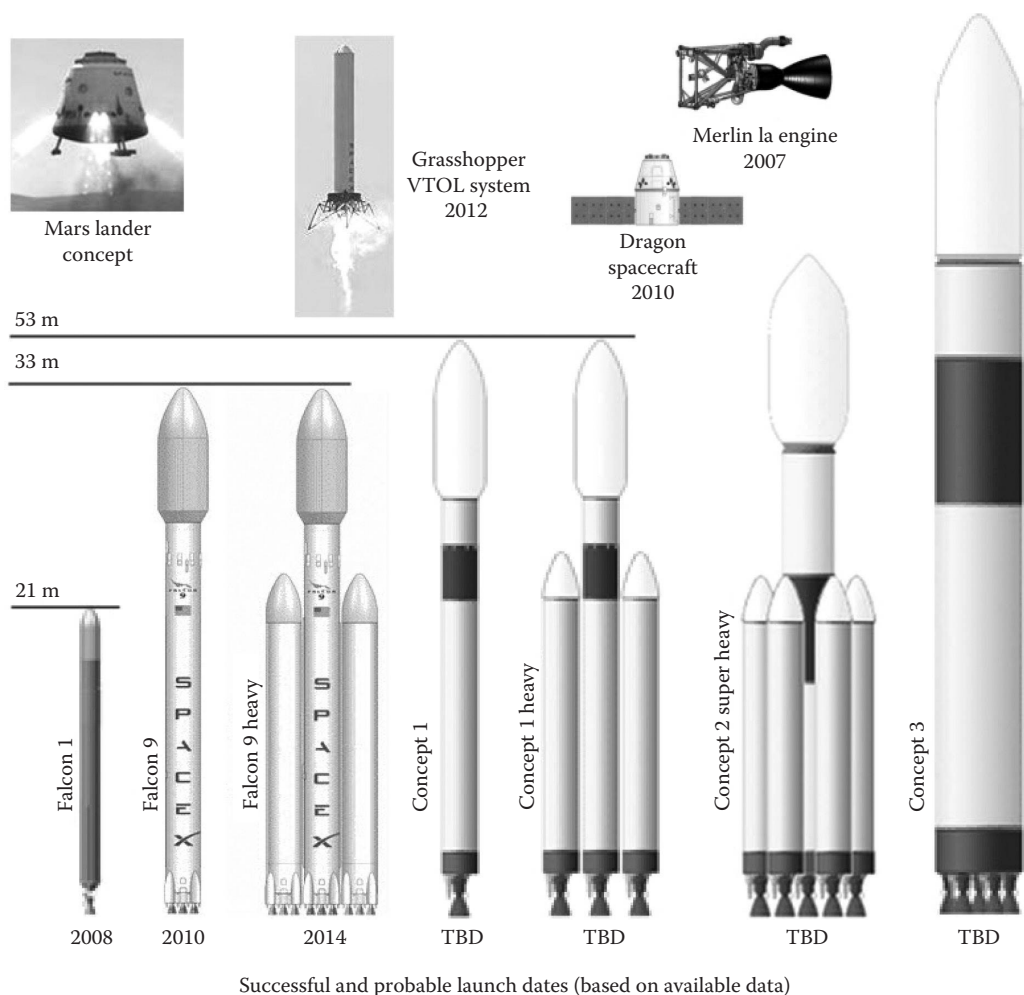


Figure 1.17 Planned radiation SpaceX.

inspection of the end product for defects, and conformance to the engineering and test. Hardware and software similarities and differences are depicted in [Figure 1.18](#).

Hardware and software differences cause them to radiate along slightly different paths though the CM principles are the same. Adaptive radiation in software is depicted in [Figure 1.19](#).

For some, it may be easier to understand how software radiates using a different example from nature.

In the laboratory, *Escherichia coli* (*E. coli*) bacteria is often the organism of choice due to its rapid reproduction rate. In one case, scientists at the Georgia Institute of Technology have inserted 500 million-year-old Paleozoic-era bacteria genes into *E. coli* in an attempt to determine if it will evolve the same way it did the first time around or whether it will evolve into a different, new organism. As of July 2012, 1000 generations had been observed. The new bacteria grew about two times slower than its modern-day counterpart at first and have since mutated rapidly to become stronger and healthier than today's bacteria. The ancient gene has not yet mutated to become more similar to its modern form, but rather, the bacteria found a new

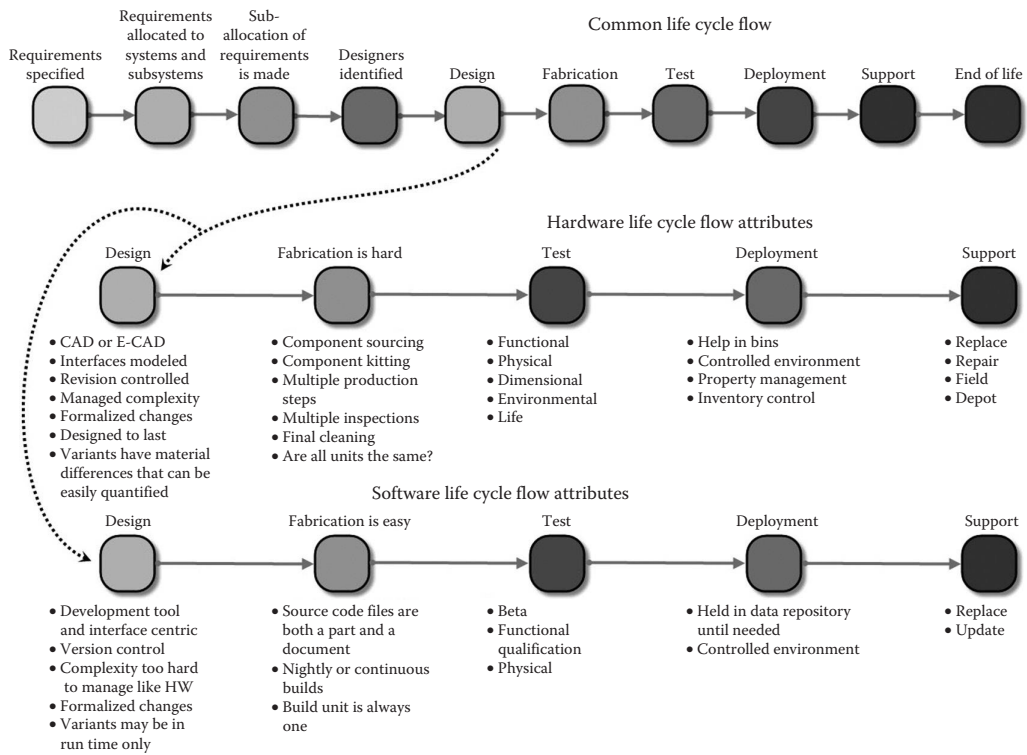


Figure 1.18 Hardware and software similarities and differences.

evolutionary trajectory.* Software follows a similar *evolutionary* path to that described by Betul Kacar, Eric Gaucher for the modified *E. coli* bacteria.

When an enterprise capitalizes on the capabilities of its infrastructure to create production tooling and shop aids and includes the users and fabricators of the tools and aids in the process it results in items better designed, more easily produced and rapidly tested. Leveraging design collaboration across the entire enterprise results in better designs, but designs that are less expensive to make. This aspect of management of the item's configuration is often overlooked. Designers create items that may cause expenditure of fabrication times that could be cut drastically if production is involved up front with configuration decisions.

When it is done with suppliers as equal partners in the design and profitability, it has been dubbed as “leveraged innovation.”† This brings the talents of all involved to fill a market niche they have not been in before or to capitalize on a market they are already a player in. It is an approach to the supplier–client relationship that is becoming more necessary to support a more stable form of market share based on the principle of one firm knowing what it does best partnering with another firm with different capabilities to leverage a synergy of knowledge and expertise to the benefit of

* Cristoph Adami, David M. Bryson, Charles Ofria, and Robert T. Pennock. (eds.) (2012). *Artificial Life XIII: Proceedings of the 13th International Conference on the Synthesis and Simulation of Living Systems*. July. MIT Press. pp. 11–18. http://mitpress.mit.edu/sites/default/files/titles/free_download/9780262310505_Artificial_Life_13.pdf.

† Francis Bidault, C.D. (1998). *Leveraged Innovation: Unlocking the Innovation Potential of Strategic Supply*. Houndmills: Macmillan Press Ltd.

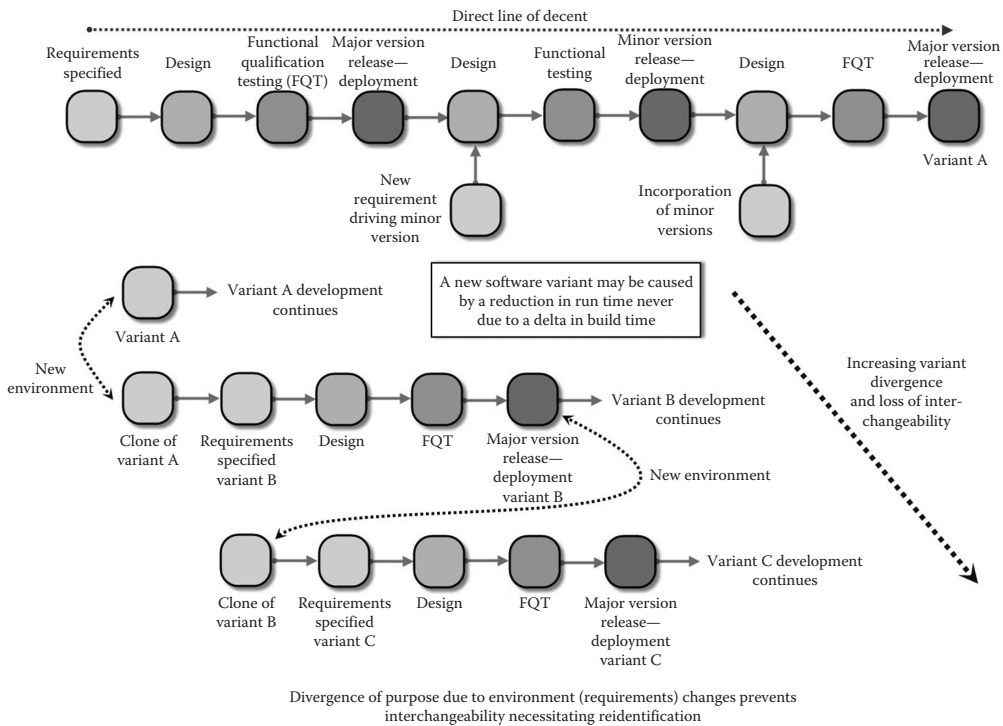


Figure 1.19 Adaptive radiation in software.

both manifesting in a greater market share and profit distribution. Leveraged innovation can also take place between different subsidiaries under a single enterprise.

1.5.2.2 New Drawing versus New Dash Number

The idea of product elements changing over time or in response to a new need is of importance to many aspects of CM, the market, and infrastructure support. The elements of form, fit, and function are often discussed in CM circles as reason to reidentify one item from another. Unfortunately form, fit, and function are often not clearly understood. Just as the Galápagos finches filled the unique environmental niches, the configuration of a single item such as a screw is purposefully designed to fill a specific need (Figure 1.20).

Screw heads take on different forms depending on their use. Other elements of the screw design also contribute to form, fit, and function.

- Head diameter
- Drive type (hex, phillips, flat, etc.)
- Head undercut
- Shoulder diameter
- Shoulder length
- Shoulder chamfer
- Thread form (square, triangular, trapezoidal, etc.)
- Lead, pitch, and start

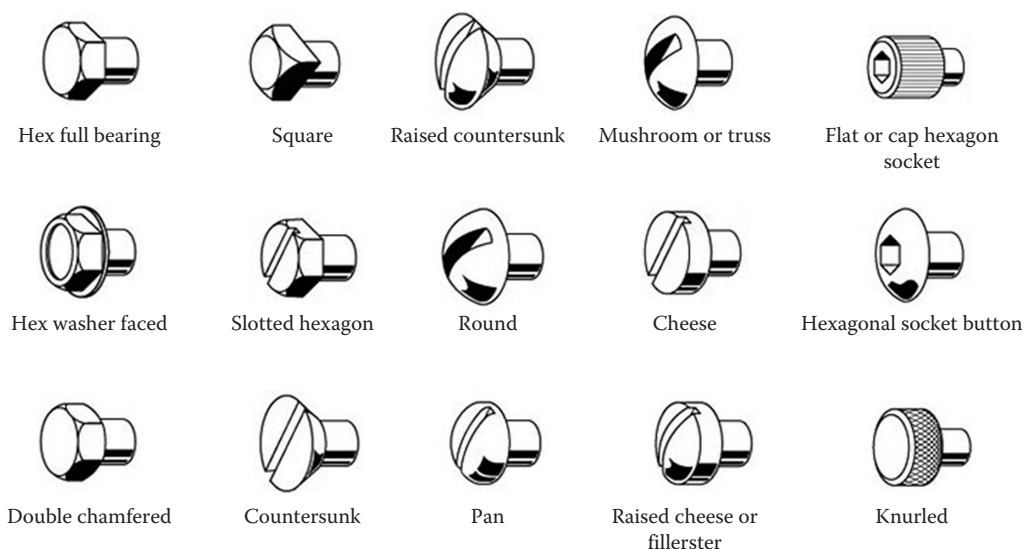


Figure 1.20 Screw heads forms.

- Tolerance
- Thread length
- Thread and thread standard (there are over 30 thread standards)
- Material and material pedigree
- Strength (hardness level)
- Right or left handedness
- Surface coatings and finish

Yet, form, fit, and function are more than this. Three seemingly identical machine screws may have to be marked differently. They may have been cleaned to different cleanliness levels. Two screws cleaned to the same cleanliness level may be different because one was lubricated after cleaning. Two screws cleaned to the same cleanliness level and lubricated after cleaning may have to be marked differently due to the lubrication used.

Taking the surface form, fit, and function criteria down to the particulate level is critical in many applications. It is even more critical if the item is lubricated or made of specific materials that outgas (also known as off-gas). Car dashboards outgas causing car windows to become smoky after time due to the outgassed substances.

Outgassing is a concern for any electronic equipment intended for use in high-vacuum environments. It refers to the release of gas trapped within a solid, such as a high-frequency circuit-board material. The effects of outgassing can impact a wide range of application areas in electronics, from satellites and space-based equipment to medical systems and equipment. In space-based equipment, released gas can condense on such materials as camera lenses, rendering them inoperative. Hospitals and medical facilities must eliminate materials that can suffer outgassing to maintain a sterile environment.*

* Coonrod, J. (2010, November 19). *What Is Outgassing and When Does It Matter?* Retrieved July 22, 2014, from Rog Blog: http://mwexpert.typepad.com/rog_blog/2010/11/19/, reprinted with permission of Rogers Corporation.

ISO cleanliness level 1 assemblies can only contain ISO cleanliness level 1 parts but can be used on any other ISO level assembly. This is referred to as one way part substitution. Again, there is a biological similarity in human blood types. Blood typing is concerned with antigens, antibodies, and rhesus (Rh) factors. Blood type AB Rh+ recipients can only receive blood from other AB Rh+ donors, but they can donate blood to any other blood group. This concept is depicted in Figure 1.21.

CM application is tailored to the product and reidentification is one aspect of CM. Part reidentification due to form, fit, and function criteria in a medical, aerospace, or other market segment,

<i>Blood Compatibility</i>			
<i>Type</i>	<i>Rh Factor</i>	<i>Can Donate Blood to</i>	<i>Can Receive Blood from</i>
A	+	A Rh+, AB Rh+	A Rh+, A Rh-, 0 Rh+, 0 Rh-
A	-	A Rh+, A Rh-, AB Rh+, AB Rh-	A Rh-, 0 Rh-
B	+	B Rh+, AB Rh+	B Rh+, B Rh-, 0 Rh+, 0 Rh-
B	-	A Rh+, A Rh-, AB Rh+, AB Rh-	B Rh-, 0 Rh-
AB	+	AB Rh+	A Rh+, A Rh-, B Rh+, B Rh-, AB Rh+, AB Rh-, 0 Rh-, 0 Rh-
AB	-	AB Rh+, AB Rh-	A Rh-, B Rh-, 0 Rh-, AB Rh-
0	+	A Rh+, B Rh+, AB Rh+, 0 Rh+	0 Rh+, 0 Rh-
0	-	A Rh+, A Rh-, B Rh+, B Rh-, AB Rh+, AB Rh-, 0 Rh+, 0 Rh-	0 Rh-

<i>ISO Cleanliness Levels</i>		
<i>ISO</i>	<i>Can be Used on ISO Level</i>	<i>Can Receive Parts from ISO Level</i>
1	1	1
2	2	1, 2
3	3	1, 2, 3
4	4	1, 2, 3, 4
5	5	1, 2, 3, 4, 5
6	6	1, 2, 3, 4, 5, 6
7	7	1, 2, 3, 4, 5, 6, 7
8	8	1, 2, 3, 4, 5, 6, 7, 8
9	9	1, 2, 3, 4, 5, 6, 7, 8, 9

ISO, International Standards Organization.

Figure 1.21 Comparison type and Rh versus ISO cleanliness levels.

ISO	Certification Particle Size (µm)						FS209
Class	0.1	0.2	0.3	0.5	1	5	Class
1	10	2	–	–	–	–	–
2	100	24	10	4	–	–	–
3	1,000	237	102	35	8	–	1
4	10,000	2,370	1,020	352	83	–	10
5	100,000	23,700	10,200	3,520	832	29	100
6	1,000,000	237,000	102,000	35,200	8,320	293	1,000
7	–	–	–	352,000	83,200	2,930	10,000
8	–	–	–	3,520,000	832,000	29,300	100,000
9	–	–	–	35,200,000	8,320,000	293,000	–

Figure 1.21 (Continued)

where cleanliness levels and outgassing are a concern, needs to be more rigorously applied than in other industries. All aspects of the product and the components that make up the item's product structure are taken into consideration. U.S. government DOD-STD-100* provides a sound definition of an interchangeable item.

When two or more items possess such functional and physical characteristic as to be equivalent in performance and durability and capable of being exchanged one for the other without alteration of the items themselves or of adjoining items except for adjustment, and without selection for fit or performance, the items are interchangeable.

Often the determination regarding how part reidentification is managed is based on the item remaining in family or if it starts a new family (out of family). The notion of something being in family or out of family can be interpreted in different ways depending on the product line and markets of the enterprise. One way to look at families is to look at the managed configuration of the product line segment from Eppinger®, a manufacturer of fishing lures in its Original Dardevle® Spoons. The spoons come in a set number of standardized sizes based on a lure profile originally established in 1906 by the firm's founder Lou Eppinger. Lures are marketed in a variety of finishes, patterns, and pattern color combinations, including the option for consumers to customize some aspects of the design (Figure 1.22).

Each pattern could be considered as a distinct family with color variants being configuration controlled as subfamilies. In the image, 15 patterns have been shown. This is a small subset of the entire Eppinger® offerings for this lure's line. Another approach could be to consider the Dardevle as a family in its own right rather than a product type with individual families.

Decisions regarding individual family members often will depend on how the design is viewed within the enterprise. If designs are created from the designer's viewpoint, they take one form. If designs are produced from a manufacturing viewpoint, they may appear another way. Both

* DOD, U.S. (1987). *DOD-STD-100, Engineering Drawing Practices, Revision D*. U.S. Government, Pentagon, Washington, DC. pp. 700–5.

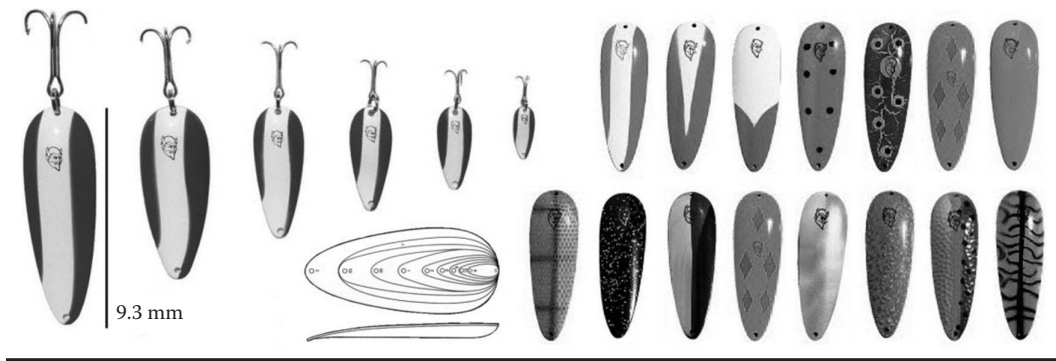


Figure 1.22 Eppinger® Original Dardevle® Spoons.

views rely on what is known as a “product structure.” Each object manufactured consists of parts, subassemblies, assemblies, and so on; each of these has a unique part identifier to distinguish it from something else. Identifiers may be numeric (111, 222, 333, 444, etc.), alphanumeric (A12bc6, A12cd6, etc.) or alpha (aaa, bbb, ccc, etc.) depending on the approach taken by the enterprise itself. In some cases, family relationships are tied back to the identifier established for the drawing itself as a prefix to the root drawing number in a relational scheme.

A practical part numbering system design should account for the limits of short-term memory. The *magic limit* is typically considered to be 7^1 . Many years of academic study, verified by real-world experience, proves that data entry errors increase as the number of characters increase. After a certain length, errors increase at an increasing rate: at 15 characters, the error probability is close to 100%.* Several numbering schemes are shown in Figure 1.23.

Relational drawing number schemes are common across some manufacturing organizations. The suffix is often referred to as a “dash number.” Under this kind of a system creation of a new addition to in-family parts would require a new dash number. Creation of a new out-of-family part would require a new drawing. The concept of new dash number versus new drawing is meaningless in firms that assign random numbers to their drawings and to the items the drawing denotes. In such cases, the relationship between drawing and part is tracked in the system used for records and release. These are mistakenly called “configuration management systems.” CM is much broader than change release, tracking, and management of data.

Use of numbering schema is also important for revision and version control. Numbering schema and hierarchal relationships differ between parts and software. Branching is described in an excellent post *Introducing Branching by Abstraction*.† A trunk may look as follows.

```
<root>
trunk/
foo-components/
foo-api/
foo-beans/
foo-impl/
```

* Miller, G.A. (1956, March). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *The Psychological Review*, Vol. 63, 81–97.

† Hammant, P. (2007, April 27). *Introducing Branching by Abstraction*. Retrieved July 23, 2014, from Paul Hammant’s Blog: http://paulhammant.com/blog/branch_by_abstraction.html#!

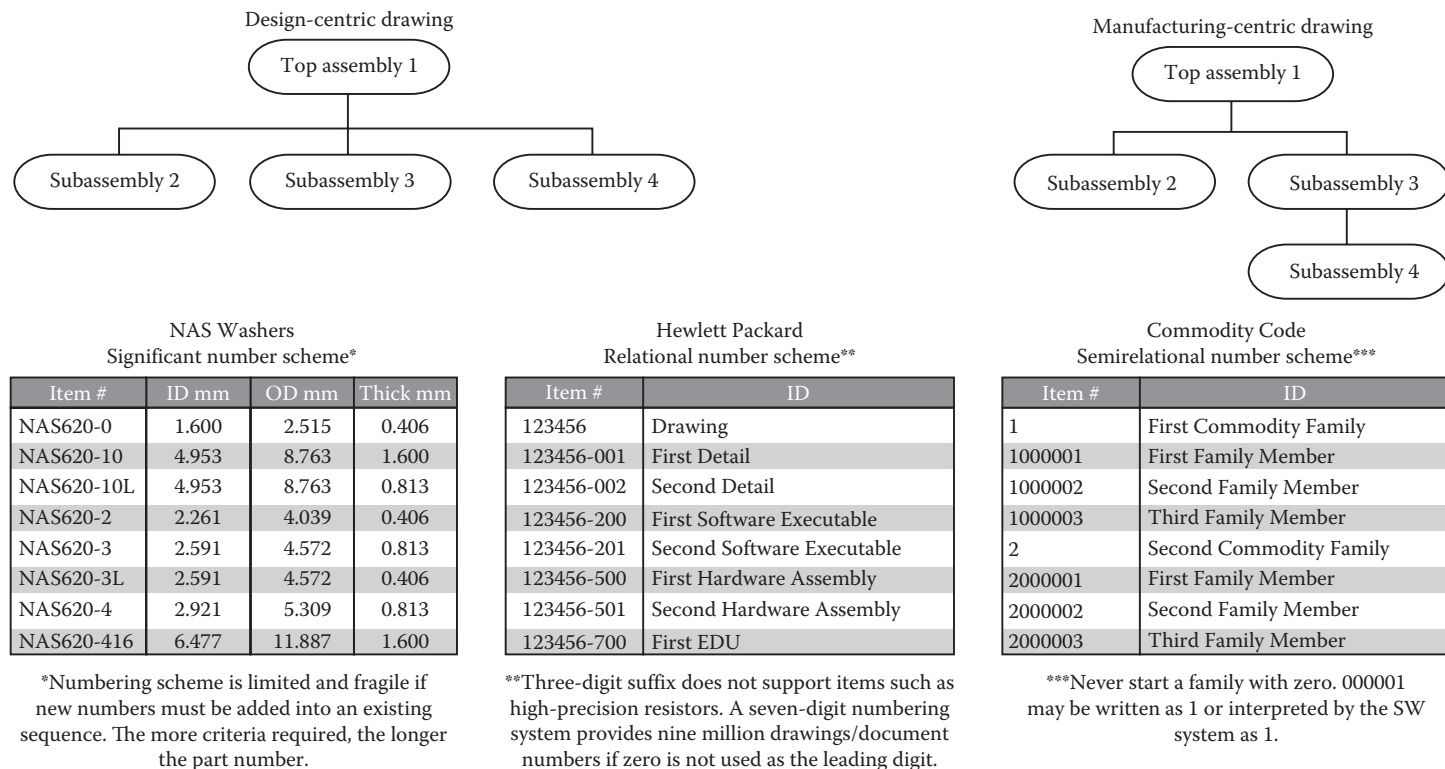


Figure 1.23 Drawing design and part numbering scheme.

```

    build.xml
    src/
    java/
    test/
    cruisecontrol-config-snippet.xml
remote-foo/
bar-services/
bar/
    build.xml
    src/
    java/
    test/
    cruisecontrol-config-snippet.xml
bar-web-service/

```

It is not a new concept and promotes branching from releases only.

```

<root>
trunk/
releases/
rel-1.0/
rel-1.1/
rel-1.2.x/

```

A software versioning system is <Unique Asset Name> <Major_Version_#>.<Medium_Version_#>.<Minor_Version_#>, where Major, Medium, and Minor could be used to communicate the complexity of the changes.* The one outgrowth of form, fit, and function considerations is the belief in some industry sectors relying on DOD-STD-100 or the American Society of Mechanical Engineers root documents that parts have revisions. This is at odds with not only standard industry practice but also with the U.S. government requirements as defined in DOD-STD-100,[†] where the practice is often found. The standard states:

The term revision refers to any change after that drawing has been released for use.
(pp. 700–707)

Part numbers shall not include the drawing revision, (See paragraph 402.5. e). (pp. 400–404)

It may be due to carrying forward misconceptions from paper-drafting systems, where parts defined on the drawing were perceived to have a revision. This arose due to the fact that they were identified on the drawing. This misconception is also seen in the U.S. government End Item Data Package requirements defined by government agencies.

If a part is not form, fit, and function interchangeable with any previous design iteration, it must be given a new identifier. In a production environment, parts in one bin must always be interchangeable. As a result, the concept of part number revisions is meaningless. Interchangeability of parts must also apply to part alternate parts from a second source of supply. As discussed

* Guerino, F. Chairman for The International Foundation for Information Technology (IF4IT) from a reply to a post on release naming conventions downloaded November 14, 2013.

[†] DOD, U.S., *DOD-STD-100, Engineering Drawing Practices, Revision D*.

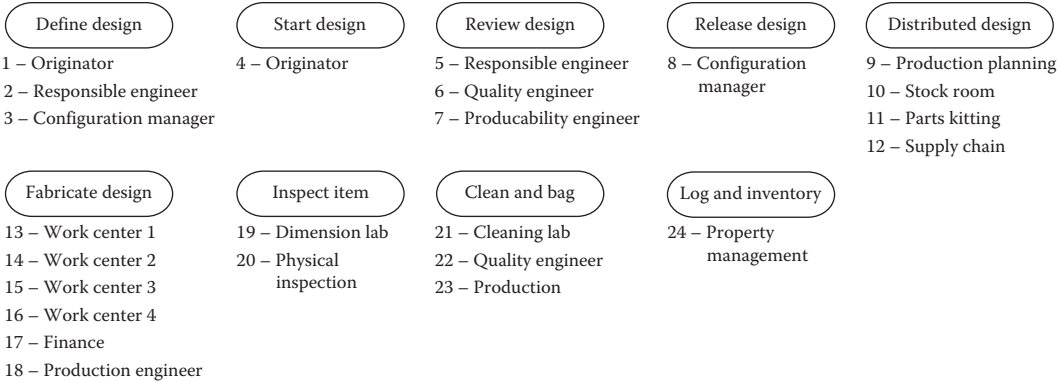


Figure 1.24 Simplified design/production flow with eight steps and 25 functions.

previously, it does not apply to parts of a higher quality level as higher grade parts are often substituted for lower grade parts despite a difference in part numbers. Tracking and reporting mandatory, latest, and as-built revision levels of parts spends valuable resources and is not required if the CM change implementation process is properly followed.

As parts go through steps toward design maturity, decisions are made regarding disposition of previously manufactured parts. Such dispositions are to scrap all existing inventory as the design is unsound or to rework the inventory to the new design iteration. Either decision equates to the rule that only one part type is contained in a single parts bin. Dispositions of *use as is* are irrelevant. If the old iteration and new iteration are form, fit, and function interchangeable and there is no disposition of these parts associated with the change (e.g., the disposition is “Not Applicable”). The cost of maintaining any relationship between a part and its revision is not trivial. It impacts all phases of design and production. A simplified design/production flow is provided in Figure 1.24.

From the early 1900s to today in many sectors a single drawing specified the configuration of 40 or distinct assemblies and details. In one case, such a drawing was revised 37 times with most revisions adding new configurations. Within the product data/life cycle management (PD/LM) system each distinct revision levels had been traced throughout all the revisions. Dispositions of not applicable had been duly entered and tracked by quality assurance, checked by production engineering, monitored by the property management system, and cross-verified when parts to make the items were consumed on fabrication orders. Assuming that there are 25 people identified in the simplified design/production flow involved in the process and each person involved in the process spent no more than 20 minutes for each drawing revision, this equates to over 308 hours.

$$20 \text{ minutes} \times 37 \text{ revisions} \times 25 \text{ people} = 18,500 \text{ minutes or } 308.3 \text{ hours}$$

The number of people and the time spent was purposely kept low. Assuming a different set of initial parameters to gauge cost impact on a medium-sized product with 500 parts manufactured by the firm and three revisions per drawing (initial release, revision 1, and revision 2) gives us a feel for total project cost impact.

$$500 \text{ parts} \times 20 \text{ minutes} \times 3 \text{ revisions} \times 25 \text{ people} = 750,000 \text{ minutes or } 12,500 \text{ hours}$$

Extrapolate this across the entire enterprise to all products after scaling the assumptions to the market segment and the impact of a poor CM decision regarding parts with revision control influences negative EBIT as well as market share in this market segment.

1.5.2.3 Design Reuse versus Common Design

As a product type matures standardization generally follows if the item is utilized across a broad enough market. One result of standardization is a benefit to the consumer. Another result is the loss of market segment for one or more providers as they adapt from one standard to the other. The war between Sony's Betamax format introduced in 1975 and VHS introduced by Japan Vector Corporation in 1976 is a classic case study. Betamax fell behind the VHS format in 1978 and Sony ceased production in the 1980s. The standardization was not a result of agreement on one standard by the producers but by the marketplace. The market segment measured hundreds of million units for a product that was dependent on the production of a complimentary product, the video tape cassette.*

Similar dynamics in all market segments are still being played out in other areas of standardization. Screw thread standards have been alluded to earlier. Standardization in a market segment can occur for a variety of reasons. It can be driven by economies of scale, scarcity of raw material, health and safety concerns as well as market preference. Economic reasons can also drive standardization of CM decisions within a single enterprise. Such internal standardization takes two forms known as "design reuse" and "common design." Each has advantages and disadvantages that must be carefully weighed by CM and the design team. Both capitalize on the premise that it is more cost effective to design an item once than to have it redesigned each time an item or similar item is required due to savings in recurring costs (costs to produce) and nonrecurring costs (costs to design plus tooling and fixtures). Returning to a portion of E.R. Miller's statement about Henry Ford's production methods will set the stage for the examining this area of CM.

Henry Ford was a master in the art of common design. He attempted to standardize everything he could to make his production of the Model T more profitable. The crates that parts were shipped to the factory in were made to his specifications and after being unpacked we took them apart and used the parts in the assembly line. Not a board, screw, nut or bolt on those crates was thrown away. They all ended up in one of the cars.

Mr. Miller refers to common design. He does not refer to design reuse. In the case of the Model T some elements of the product line were used on all of the Model T variants.

1.5.2.3.1 Design Reuse

Design reuse is a concept founded in antiquity. The apprentice learned how to make certain items pertaining to the trade from the master and in turn became a journeyman, master, and perhaps grand master with apprentices in turn. Shoes for horses could be scaled up or down in size depending on the animal being shod. Wagons, waterwheels, harnesses, and other products followed the same general pattern with the necessary modifications to size and shape to accommodate the end need. As production methods for making mechanical movements became refined, allowing greater tolerance control, they were documented. Designs were gathered and published in books such as *Five Hundred and Seven Mechanical Movements*.†

* Cusumano, M.A., Mylonadis, Y., and Rosenbloom, R.S. (Draft March 25, 1991). *Strategic Maneuvering and Mass-Market Dynamics: The Triumph of VHS over Beta*, WP# BPS-3266-91. <http://dspace.mit.edu/bitstream/handle/1721.1/2343/SWP-3266-23735195.pdf>.

† Brown, H.T. (2010). *Five Hundred and Seven Mechanical Movements*, 18th ed. Mendham, NJ: Brown and Seward republished the Astragal Press.

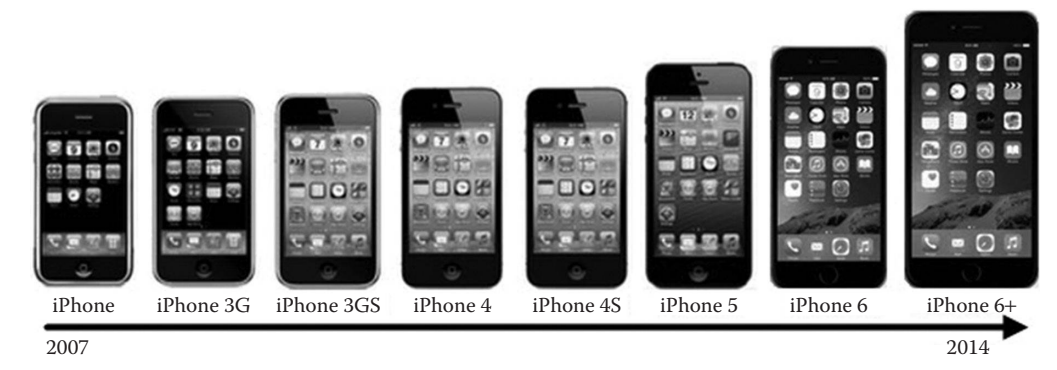


Figure 1.25 Apple® iPhone® models.

Design reuse is a different concept than common design. Design reuse is the leveraging forward of technologies to create the next level of technological advancement. Figure 1.25 is an example of this concept as manifested in the Apple iPhone. Design reuse can be traced back to design inception regardless of iteration. The benefit of this is to establish the provenance of the design and clearly establish the original ownership of the technological evolution. It is an example of CM principles and application assisting in defending against copyright, patent, and other infringements.

In the *Red Dwarf Series IV*, “Meltdown” episode,* Pythagoras is insistent that the solution to the war somehow involves triangles. Einstein tells him that not all problems in life can be solved by triangles.

This is not unlike the modern design-decision process, where engineering talent has become so ingrained into a single way of perceiving solutions to engineering challenges that a single methodology is always applied. It is also directly applicable to the determination of part and assembly candidates to be produced as design reuse in a production environment as well as the manufacturing infrastructure necessary to produce them. Standard manufacturing processes generally involve shaping of materials in a distinct variety of ways. It can be milled, formed on a lathe, cast (includes injection molding and roto-molding), forged, and, in certain instances, three-dimensionally printed. If an item has traditionally always been milled for a bell housing, and it is not on the critical path as far as lead time, then consideration may not be made to making it a forging due to what is known as “economies of scale,” despite historical data indicating if 10 units are produced the cost for milling and up-front investment to create a housing reach the breakeven point.

In a limited-need scenario, such aerospace applications determining what can and what should be considered as a candidate for a shared design can be a key factor in not only keeping a competitive edge but also to a program-by-program profitability. This is a one-sigma or, at best, a two-sigma solution set despite Six Sigma approaches elsewhere in the actual manufacturing process. In addition to the normal quality, cost and schedule constraints baselining the product design prior to evaluating options and impacts can drastically impact any exploration of anticipated performance and market development.

Discussions of *what sigma something is* are meaningless at this point and become an over-used catchphrase from everything from process errors to manufacturing yield. Concentrating of

* Bye, E. (Director). (1991). *Red Dwarf Series IV*, “Meltdown”. [Motion Picture].

potential future application of a static design element and maximized efficiency of production as well as growing application of the design element should outweigh sigma discussions.

Premature lock-in of a design or artificially imposing design constraints to force shared design is abandoning the idea that form follows function. Returning to relating this section to the natural world having a strong skeletal framework is the first necessity. Just as some natural designs occur in many different species good design stems from a sound construct. Put in another way do not put a skin on the animal before you know what the bones look like and how they are articulated. Then add the muscle, organs, and once you know if it is a dog, cow, bird, or fish, decide how to package it. The ceratopsians, *Pachycephalosaurus* and Rhinocerotidae, in all their variations shared a similar construct for supporting the head but were decidedly different in form.

In the day-to-day design-manufacturing cycle, design gives way to production, which in turn gives way to test. As tasks are completed, design staff move on to the next project and the eventual designs move through the product life cycle. Over a period of 20 years the cumulative knowledge of sound and less sound design decisions are not held in the memory of the design staff, but in the memory of CM in their role as a member of the program management team.

1.5.2.3.2 Common Design

Common design is a single design element (part or assembly) that is used across multiple applications, where the design is owned by and the evolution of the design is controlled by a single product group. A product line family may have multiple common design parts in it. A single model in a product line subfamily may also have common design parts that are common to that model only. These items (e.g., software, firmware, parts, subassemblies, and assemblies) include the collective intellectual property (IP) of the enterprise.

In an environment where the design is used on domestic as well as government programs, common design is treated much as commercial off-the-shelf parts are treated from an IP standpoint. The design was not produced or modified using government funds so the government has no rights to the data. Individual programs also have no control over the design and cannot modify it for their use if it is not suitable as is. Modifications to the design to add a new *in-family* or *out-of-family* variant are controlled by the product group that developed it. Common design is a single design element either (1) developed at private expense or sold to the commercial sector or (2) if developed using government funds, the contractor retains unrestricted rights and the government receives information only in copies with no rights. Under the U.S. Federal Acquisition Regulations (FAR) Part 12, Acquisition of Commercial Items, FAR 12.211, Technical Data:

Except as provided by agency-specific statutes, the Government shall acquire only the technical data and the rights in that data customarily provided to the public with a commercial item or process. The contracting officer shall presume that data delivered under a contract for commercial items was developed exclusively at private expense. When a contract for commercial items requires the delivery of technical data, the contracting officer shall include appropriate provisions and clauses delineating the rights in the technical data in addenda to the solicitation and contract (see Part 27 or agency FAR supplements).

Experience on multiple FAR Part 12 procurements has shown that provisions and clauses are rarely included in either the solicitation or the resulting contract. This leaves the data unencumbered on FAR Part 12 firm fixed price (FFP) contracts.

Shared design is a precursor to common design parts in instances where the design development is shared by two or more cost objectives. Multiple cost objectives are of great concern when an enterprise sells the same items to commercial as well as government markets. The shared design utilizes one set of engineering drawings and may be required to provide copies to each funding source. Shared design can be converted to a common design item if all cost objectives have been met and enterprise funds are used to make the conversion. Particular care must be made to assure that recurring and nonrecurring costs are properly allocated to all cost objectives. Do not assume that parts can be ordered in sufficient quantities and then purchased by a second cost objective. In the case of the U.S. government programs, a FFP program under FAR Part 15, “Contracting by Negotiation,” may include 52.232-32 “Performance-Based Payments.”

(f) Title.

(1) Title to the property described in this paragraph (f) shall vest in the Government. Vestiture shall be immediately upon the date of the first performance-based payment under this contract, for property acquired or produced before that date. Otherwise, vestiture shall occur when the property is or should have been allocable or properly chargeable to this contract

Title constraints can be avoided through proper planning of cost allocations to cost objectives. Under this arrangement CM considerations include treating shared design as a separate project not tied to any single cost objective. As it is utilized across multiple programs, each shared design item would have a distinct configuration identifier. In some cases, the configuration identifier could be a standard number for a family of items with subdifferentiation by part number. Individual part numbers are incorporated into the using of the product’s structure. Typical allocations for recurring and nonrecurring costs for multiple programs with shared design are shown in [Figure 1.26](#).

In all shared design scenarios, the data markings are applied after release instead of being embedded in the document. This may be accomplished by modifying metadata fields in the PD/LM system, which are not subject to engineering (e.g., contract number, charge number, program name, configuration item identifier, etc.). Proper CM of the PD/LM system would include a metadata field that allows the document to be coded as legends may be chosen or legends shall always be a predetermined choice. Modification of the metadata fields necessitate that the capability to modify the fields reside with a finite number of properly trained individuals performing the records and release function who are closely connected to the product area functional management. Typical shared design for a U.S.-based firm and four different cost objectives are shown in [Figure 1.27](#).

In the case of a firm doing business with a domestic commercial, international and U.S. government customers cost accounting as well as IP and International Traffic in Arms Technical Assistance Agreement considerations must be addressed prior to data being distributed outside the enterprise. CM implementations include document format, when data markings can be applied, charging of recurring and nonrecurring cost elements, and data delivery constraints.

Maximum effectiveness of CM application is achieved through the use of a single drawing in both cases. This requires document formats configured to support the application of all document markings after release. PD/LM systems should be configured to apply such markings when documents are output from the system and must be able to export single, multiple, or all documents associated with any individual product with a single request in an uneditable format such as portable data file (.pdf). Documents may include drawings, analysis, or supporting documentation such as reports, minutes, action items, specifications, and vendor statements of work.

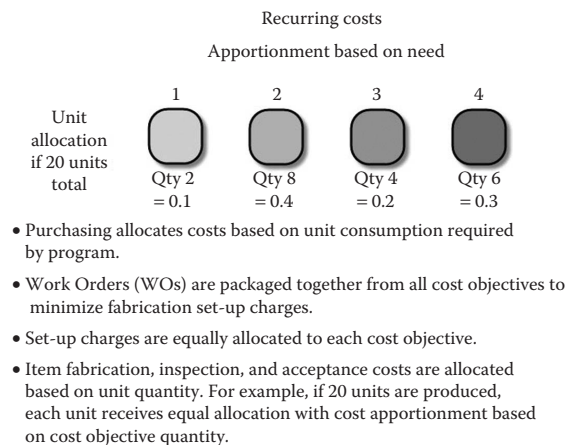
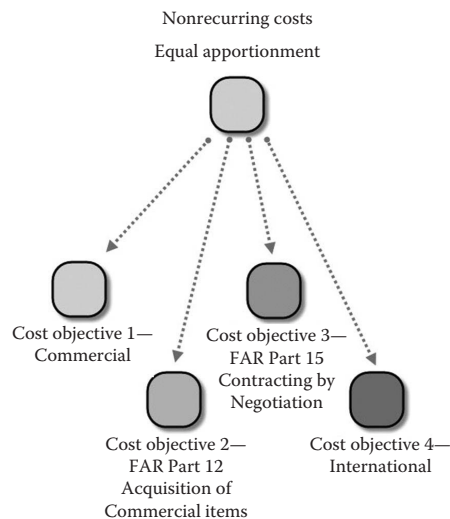


Figure 1.26 Shared design nonrecurring and recurring cost allocation.

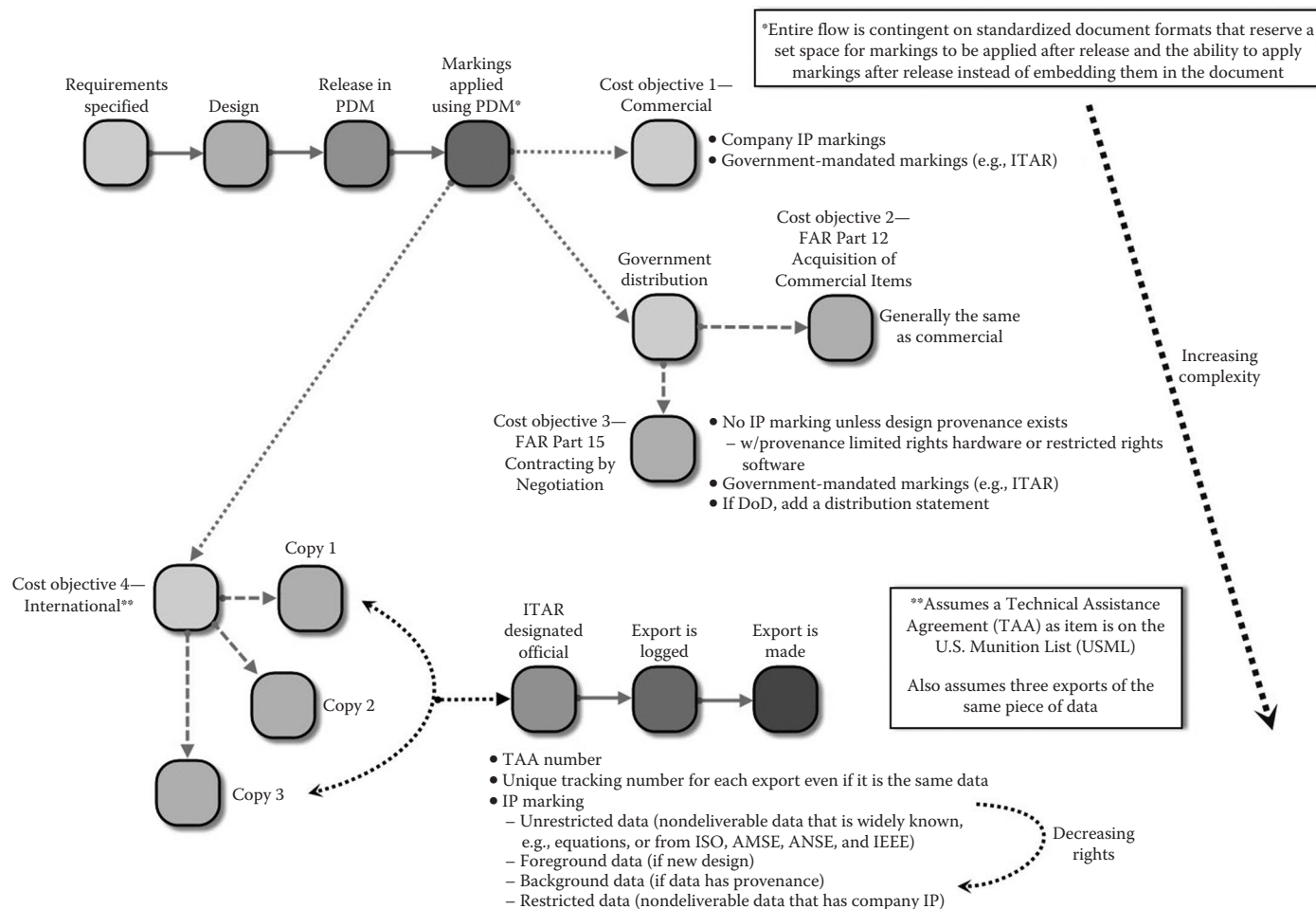


Figure 1.27 Typical shared design for a U.S.-based firm and four different cost objectives.

1.6 Case Studies

1.6.1 Case 1—Product Market Adaptation versus Performance Adaptation

Look at the timeline in [Figure 1.28](#) and determine which stages involved product market adaptation, product performance adaptation, and mass customization in the development of the automobile. Evaluate CM application in the products you purchase and the examples provided for SpaceX and iPhone to determine obvious and missed design reuse and common design elements and opportunities.

1.6.2 Case 2—Share Design Decision

Evaluate the following which is based on a real case to determine which elements of a design should be considered for a shared design and if the decisions made regarding the configuration of the manufacturing flow were the correct ones.

During visit to the Proton expendable rocket-manufacturing facilities in the former U.S.S.R., it was discovered by a U.S. provider of launch boosters that manufacturing tolerances for mechanical parts were only held to 1/10,000 in. (0.000254 cm) if the part interfaced with another part (a critical interface.) After a de-brief of the market segment, the president and several vice presidents (VPs) were tasked with evaluating the firm's design to determine how much could be saved by relaxing manufacturing tolerances and for which items the greatest savings could be made due to the shared design relationship existing between its U.S. government and commercial launch booster business. At the time, the company was also designing a new heavy booster. It was estimated that total customer need would not exceed 50 boosters (old and new design) when the decision was made.

As a result of the internal evaluation the following recommendations were made (All dollars are in 1985 dollars).

1. Configuration manager recommended that all new design and any change to existing designs should include relaxed tolerances as well as any shared design elements between the commercial and government booster lines as long as weight and center of gravity were not diminished below the advertised booster load lift limits. CM estimated that all drawings for the existing design shared design items could be converted in less than one month due to the amount of design activity at the time with a unit savings on every part manufactured.
 - a. Mission assurance concurred with the CM recommendation.
2. The VP for the launch booster product line discovered that one fabrication process took 200 hours to complete for a part that was critical to each launch vehicle. She/he recommended the company to invest \$1.8 million to automate the production process. At the time the fully burdened rate for production engineers was \$100/hour, resulting in a net savings of \$20,000 per unit.
3. The VP of production was concerned about part quality if all machining was not held to the same standard due to the re-training involved and recommended against relaxing any tolerances. Instead he recommended investment of \$1.2 million in an automated welding fixture that would reduce the cost to weld launch booster segment skins from \$8000 per seam to \$1000 per weld seam. There were five seams on each stage and three stages for a net savings of \$15,000 per launch booster.
 - a. Systems engineering was also against relaxing tolerances on manufactured parts due to the time it would take to retrain the engineering design staff and marketing considerations regarding the firm's stringent manufacturing processes.

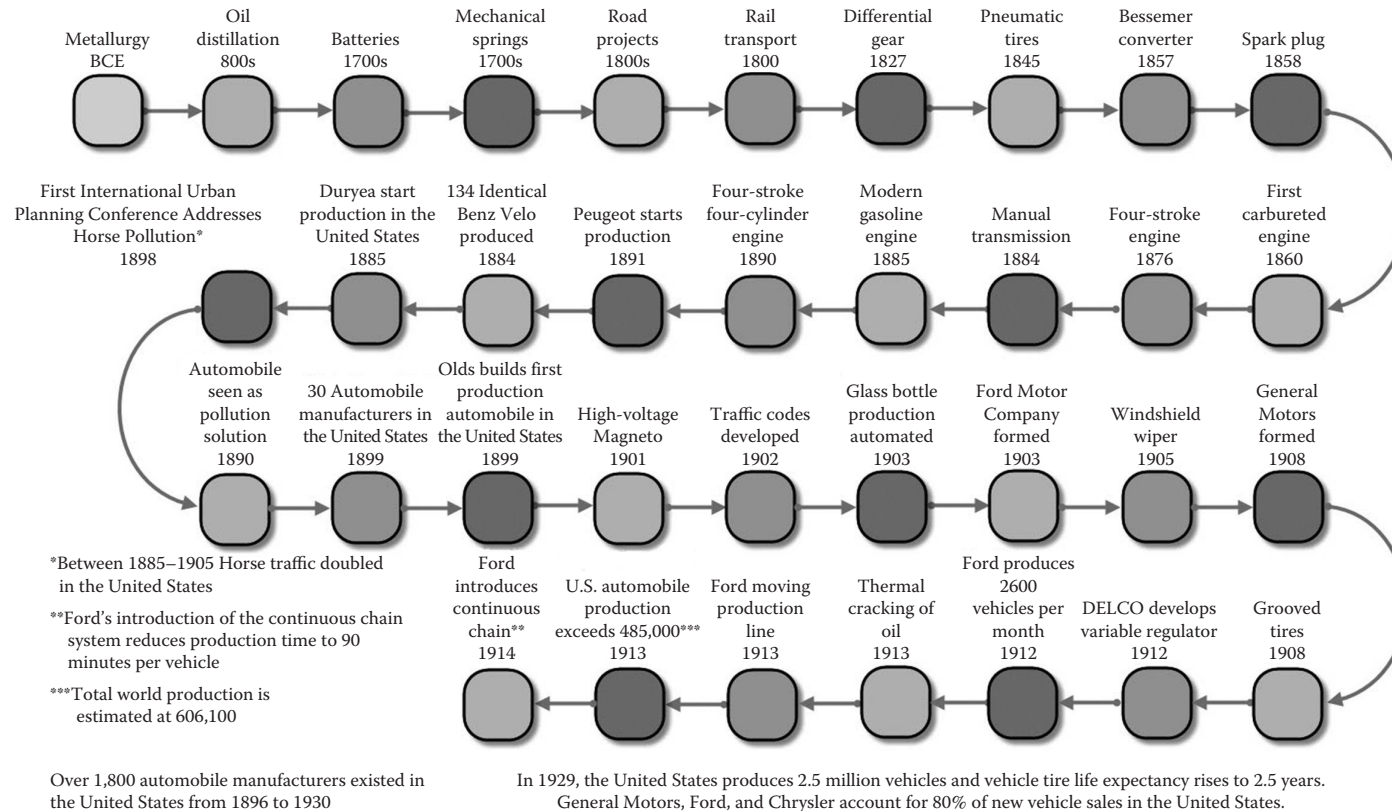


Figure 1.28 Timeline of critical automotive technologies and influencers from 1800s to 1930s.

The firm decided to proceed with recommendation 2 due to the total cost savings per unit. Here are some additional pieces of information that may help regarding the breakeven point for each recommendation. Only 30 more boosters were ever produced before moving to another booster design.

1. Not quantifiable as the implementation would be phased in to existing design and implemented on all new design. Estimated but not verifiable savings were 10% of the total manufacturing hours and a reduction in rejected parts of 90%. Design impact for existing designs was estimated at \$5000 total. 1400 drawings were estimated for the new design of the heavy booster. Drawing design time averaged 20 hours/drawing.
2. Breakeven point was unit 90 as each rocket required only one part (\$1.8 million/\$20,000).
3. Breakeven point was unit 80 (\$1.2 million/\$15,000).

The net result was a misguided effort that expended valuable resources with no payback.

Chapter 2

Overview of the Supporting Enterprise Infrastructure

2.1 Questions to Ponder

- What enterprise elements does configuration management (CM) directly interface with?
- Is there a clean process interface with release and change management?
- What is the process to handoff to operations in a clean and consistent manner?
- How is profitability associated with CM?
- Theorize the connection between innovation and CM.
- Describe an incremental and iterative development model and the role of CM in that method.
- What are their key elements?
- What concerns are associated with the key elements?
- What is the information technology (IT) backbone and how does it affect CM?
- Is there a sane way to manage applications and tool upgrades?
- What are the challenges faced in the implementation of IT systems security?
- How are platform transitions managed from a configuration perspective?
- What is the importance of CM with modular systems?
- What elements of cost comprise general and administrative (G&A) activities?
- What elements of cost comprise overhead (OH) activities?
- What internal and external forces drive intellectual property (IP) decisions?
- How do decisions regarding shared design, design reuse, common design, and leveraged innovation impact IP?
- What is the International Traffic in Arms Regulation (ITAR) and how does it impact CM domestically and internationally?

2.2 Introduction

CM activities influence and are influenced by many elements and organizations within the enterprise. Each speaks in a language that is often unique to a particular profession yet all are working toward the same goals of survivability, market share, profitability, environmental sustainability, and cultural diversity, while remaining compliant with local, national, and international laws. The CM professional must become multilingual within the enterprise understanding not only the language and purpose of each element, but how decisions regarding managing a configuration influence and are influenced by each element. It is very important to understand the responsibilities of each of these elements and organizations and the CM activities needed to support them. At the very least, data management and change management are involved in every case. See how many others you can identify.

Without an understanding of each element, it is difficult to gage the effectiveness of CM implementation or to know if the proposed improvement of the associated processes result in real cost savings and an increase in earnings before interest and taxes (EBIT). EBIT calculations are made using the formula below.

$$\text{EBIT} = \text{Revenues} - \text{Expenses}$$

$$\text{Expenses} = [\text{operating expenses} + \text{cost of goods sold (COGS)} + \text{depreciation} + \text{amortization}]$$

$$\text{Operating expenses} = \text{overhead and general and administrative expenses}$$

$$\text{COGS} = \text{inventory} + \text{nonrecurring design labor} + \text{recurring production labor}$$

EBIT is used rather than its successor earnings before interest, taxes, depreciation, and amortization, as the focus of this book addresses CM within a single enterprise rather than analysis or comparison of profitability between companies and industries. Similarly, the definitions provided above suffice to provide a basic understanding of EBIT elements. Operating expenses, COGS, depreciation, and amortization needs if evaluated from a product line perspective will change over the product life cycle as well as by market segment. CM decisions impact each of the cost elements at both the product and the enterprise levels.

This chapter focuses on operating expenses with IT and the U.S. ITAR, 22 Code of Federal Regulations 120–130 expanded upon due to the large EBIT increases that can be made in these areas through minor improvements. A discussion of Export Administration Regulations (EAR) is also provided in the ITAR section. ITAR and EAR directly influence configuration and market adaptations for both the buyer and seller in any international setting.

If we step back and look at all markets as an ecological system inhabited by companies behaving in predator–prey and symbiotic relationships, then a market segment is similar to an ecological zone uniting interrelated manufacturing and user communities within a specialized social formation with variable environmental conditions as part of a loosely integrated system. Communication is one factor in this technocenosis. As it evolves, it both adds and reduces complexity to the overall ecological zone.

In boicenosis, humidity, altitude, temperature, and territorial configurations play a part in the particular ecological zone. In a technocenosis-based ecology, financial gain, environmental impact (both internal infrastructure and biological overall ecological impact), perceived need, legal, ITAR, and other imposed regulations as well as profitability and growth potential form a similar stressor set relative to survival in the ecological zone. Under technocenosis, the need

for reduction of information to a portable form requires a specialized data solution. It is only comparatively recent that IT has come to mean electronic IT and that computer has supplanted electronic computing.

Cave painting, quipus, word pictures, cuneiform, tokens in clay envelopes, tattooing messages on shaved heads, quills and ink, block printing, movable type, teletype, strike-based bar, wheel and ball, and dot matrix printers were supplanted in turn by inkjet, laser, and portable data format files. Intranet, Internet, and the cloud interrelate and follow in much the same way. Elements of the cloud exist internal to many companies today. These take in the form of distributive virtual servers that are easily scaled to need. Aspects of the cloud are also being implemented externally to the many technology companies as well. As with any product reaching a tipping point due to complexity, most of the revenue stream both expended and acquired is not subject to the initial design, development, test, evaluation, and asset initial sale but rather to the maintenance and data reduction of the item and the subcomponents over its operational life cycle. In a spacecraft, this secondary aspect is often as high as 90% of total cost. With aircraft it is more.

How we view *security*, IP, ITAR, and other imposed requirements are being challenged and at some point in the near future will reach a point of change simply due to the formula pain plus desire equals change. The cloud, 3D printing, distributed manufacturing, integrated design/development are gaining a foothold in every technology-based ecological zone. They are supplanting existing technologies and evolving. Our current definitions of *secure* will change. Data in the cloud is no safer or less safe than any other enterprise IT solution. It is simply different and each has its place. The only difference is the capability to break security protocols protecting the data. Those who do not will lose market share. The technological landscape is in constant flux. As the ecological landscape changes so must those companies that live in it. It is a simple case of recognize, accept, adapt, integrate (where it makes sense), and survive. Those who do will survive longer.

2.3 Information Technology

IT relies on a highly sophisticated level of CM activities. This is contrary to the trend of many companies that have moved IT out from under CM in its organizational structure. Of all the firms evaluated as part of the research done for this book, only three were found to have a released CM plan for IT.

The growth of the importance of IT follows a natural progression when its history is examined. Jeremy Butler* highlighted four developmental periods for solving the communications, input, processing, and output cornerstones of IT.

Since 2003, Jeremy Butler's vision has to be expanded to add the information age

1. Pre-mechanical age: 3000 BCE–1450
2. Mechanical age: 1450–1840
3. Electromechanical age: 1840–1940
4. Electronic age: 1940–1990
5. Information age: 1990 to present

The recording of verbal communication in symbolic form so that data could be recorded, transferred or stored, retrieved, and re-communicated was critical to the development of IT as we understand it today.

* Butler, J.G. (1997). *Concepts in New Media*. University of Arizona, Tucson, AZ.

2.3.1 A Brief History of Information and Information Security

Clay tokens bearing wedge-shaped markings known as “cuneiform” have been found in early as 8000 BCE in Turkey, Syria, Israel, Jordan, Iraq, and Iran were used for record keeping. Any form of writing that is composed of wedge-shaped marks is known as cuneiform. Hollow clay envelopes, known as “bullae,” marked to correspond with the clay tokens inside have been found in Sumer around 3500 BCE (Figure 2.1). If the envelope had three marks on the outside, then three tokens were contained inside it. Denise Schmandt-Besserat, who researched the nature of information management, has made a strong case that the tokens continued within the clay envelopes recorded grain, livestock, oil, and perhaps manufactured goods, as a precursor to the accounting spreadsheet combined with a security system. Once a bullae is broken, the contents were traded for the goods they represented. The tokens inside the bullae were then used to make a new bullae or combined with other tokens to make new bullae. Eventually, clay tokens were replaced by clay tablets with wedge-shaped (cuneiform) symbols imprinted in the wet clay as an early pictographic writing system.

Other forms of information security were utilized until it could be retrieved by the intended recipient. The fictional accounts contained in “The Gold Bug and The Purloined Letter,”* “The Adventure of the Dancing Men,”† and the lanterns in the Old North Church during “Paul Revere’s Ride”‡ were ingenious but history documents other even more ingenious methods as early as 49 BCE§ during the Persian wars, where the Greek Histiaeus is said to have sent a message to Aristagoras tattooed on the scalp of a slave who had allowed his hair to grow back. Aristagoras shaved the slave’s head and retrieved the message and due to this intelligence attacked and burned Sardis with help from the Athenians and Eretrians. Other example of steganography included

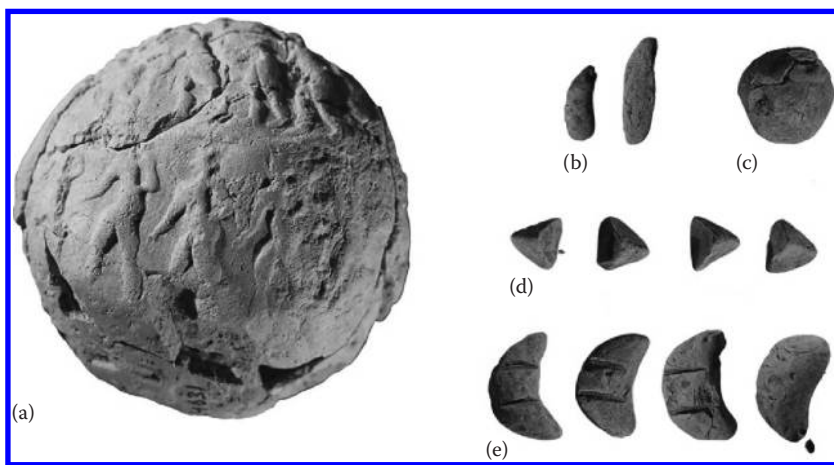


Figure 2.1 Bullae envelope with 11 plain and complex token inside from Near East, ca. 3700–3200 BCE: (a) 6.5 cm bullae with row of men walking and a predator attacking a deer representing wages for four day’s work; (b) two small measures of an unknown community; (c) one large measure of barley; (d) four days; and (e) four measures in metal.

* Poe, E.A. (1904). *The Purloined Letter* (from *The Works of Edgar Allan Poe—Cameo Edition*). Funk & Wagnalls Company.

† Doyle, A.C. (1903, December). The adventure of the dancing men. *The Strand Magazine*.

‡ Longfellow, H.W. (2013, September 28). *Paul Revere’s Ride*. Retrieved September 6, 2014, from <http://poetry.eserver.org/paul-revere.html>.

§ Herodotus. (2003). *The Histories, Book 5*, Translated by A.D. Selincourt. London: Penguin Group.

etched messages in wooden tablets covered with wax. One area of IT that has already derived some benefit from steganography is digital rights management.* Cryptography also has important connections to steganography. Since its inception, digital aspects of IT have impacted the ethics surrounding both steganography and cryptography. Today, steganography can hide data redundant pixels characters or sounds as computers treat sound, image, and text files as equal parts of the bit stream.

Jeremy Butler† traces its beginnings to the development of the Sumerian cuneiform script by 3000 BCE. Thousands of clay tablets have been found and translated. Most of them document business transactions. Sumerian cuneiform script was superseded by the Phoenician alphabet in the Neo-Assyrian Empire between 934 and 609 BCE. Yet this may be an over simplification as the precursor of the quipus existed as early as 3000 BCE in Andean South America. Quipus of up to 2000 individual cords made from dyed llama or alpaca hair strings recorded numeric and other values in a base 10 positional system.

Quipus (Figure 2.2) as a communication and information storage medium offered several advantages over cuneiform script incised into clay tablets for storing large quantities of data. Utilizing the textile-making technologies of the time strings could be made with a right-to-left spin or a left-to-right spin. Three types of knots were typically used (single—simple overhand or Flemish knot, long cord wrapped around itself two or more times—double, treble, fourfold, Fivefold ... etc., and figure-eight or e-knot—the cord forms the shape of the number 8, and the ends of the string exiting through the holes of the 8). Knots could be made in two different orientations resulting in different slant to the knot axis. Information (pendant) cords could be attached to the main cord in two ways and cords were also made in differing colors and color combinations with the overall result of multiple data parameter choices that could be reconfigured as needs changed over time.

* Frances S. Grodzinsky. (n.d.). *The Ethical Implications of the Messenger's Haircut: Steganography in the Digital*

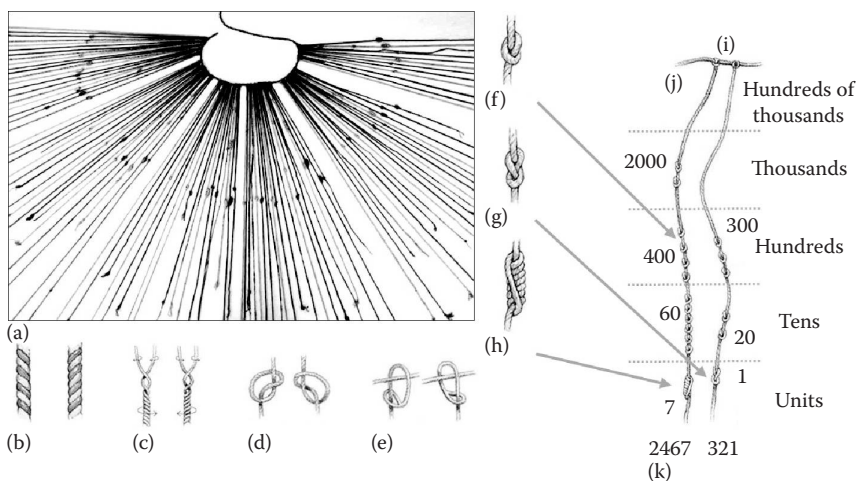


Figure 2.2 Quipus: (a) typical completed quipus; (b) cord color; (c) twist—right or left; (d) knot direction; (e) method of attachment; (f) single knot; (g) figure 8 knot; (h) long knot; (i) main cord; (j) two hanging cords; and (k) cord totals.

Age. Retrieved September 20, 2013, from http://bibliotecavirtual.clacso.org.ar/ar/libros/raec/ethicomp5/docs/hm_papers/25Grodzinsky_percent20Frances_percent20S.htm.

† Butler, J.G. (1998). *A History of Information Technology and Systems*. University of Arizona, Tucson, AZ.

Yet the capturing and sharing of technical information predates even this. The first writing system was believed to have been invented around 4000 BCE in the late Neolithic. Petroglyphs have been found from as early as 10,000 BCE.* Evidence exists that may prove to be a calendar in 15,000 BCE† and a symbol-based communication has been found from as far back as 30,000 BCE in Chauvet-Pont-d'Arc Cave in the Ardèche department of southern France. A simplified timeline of the development of information history is provided in Figure 2.3.

The evolution of related technologies in the pre-mechanical age concerned the recording in decipherable way information that was critical for survival. Invocation of deities for a good hunt or good harvest, calendars for marking the seasons based on astronomical observations, tracking elements of business, and contracts for goods and services. Basic design parameters for engineering purposes and other exigencies of the moment were the primary concern. City-state infrastructures grew and merged new forms of capturing information in a recognizable form evolved to support gathering of data to be recorded. James Burke‡ traces the evolution and connections between technologies that gave rise to the information age.

Although not specifically addressed by James Burke, the evolution of the software programming-capability based on the I Ching or Zhouyi traces to 3 BCE. Within it, 64 hexagrams are described that formed the base for the binary number system.§ That led to George Boole's creation of the Boolean algebra¶ and its application to digital logic and computer science. Until the advent of electromechanical devices capable of operating in a strictly yes/no, on/off mode associated with computers, there is a rich history of analog devices reaching back to the Antikythera mechanism in 100 BCE. Some of these included cryptography machines with IT counterparts existing in binary form today. A brief analog device history is provided in Figure 2.4.

The term “computer” was originally created to describe someone who does computation. From 1920 onward, computing machine was applied to machines that could make the same calculations as the human computers. During the electronic age with the advent of the digital computing machine the term was shortened to computer. For the human computer IT entailed detailed calculations and recordkeeping. Inventions such as the ACCO fastener,** three-ring binder, vertical and horizontal file, high-density compact mobile-shelving file systems, ledger sheets, and numerical filing systems using Rolodex-rotating file devices were considered the highest form of IT. Into the late 1980s, paper products required to document the configuration of a complicated deliverable item often weighed the same or more than the item itself. This was certainly true for the delivery of the first commercial Titan launch vehicle by Martin Marietta 1990. A major component of IT at this time included short- and long-term data repositories. Short-term data repositories were managed locally using filing systems, whereas long-term data storage for data that was not accessed on a regular basis was managed using a warehouse solution. This gave rise to a new industry market sector dedicated to data storage and retrieval of paper records. Then as now the

* Diring, D., and Minns, E. (2010). *The Alphabet: A Key to the History of Mankind*. Kessinger Publishing.

† Jones, D. (2013). *The Mystery of Göbekli Tepe and Its Message to Us*. Retrieved April 15, 2014, from <http://www.newdawnmagazine.com/articles/the-mystery-of-gobekli-tepe-and-its-message-to-us>.

‡ Burke, James (born 22 December 1936 CE) is a British broadcaster, science historian, author, and television producer.

§ Leibniz, G.W. (1703). *Explication de l'Arithmétique Binaire VII.223*. Retrieved August 22, 2014, from www.leibniz-translations.com.

¶ Boole, G. (1854). *An Investigation of the Laws of Thought*. Palm Springs, CA: Wexford College Press, Accessed from Gutenberg Project online on 2010.

** A kind of 2 prong fastener manufactured by ACCO company see <http://www.buynowonline.com/search.asp?l=1&keywords=PRONG+FASTENER&subcat=ULAA&manufact=1700005>.

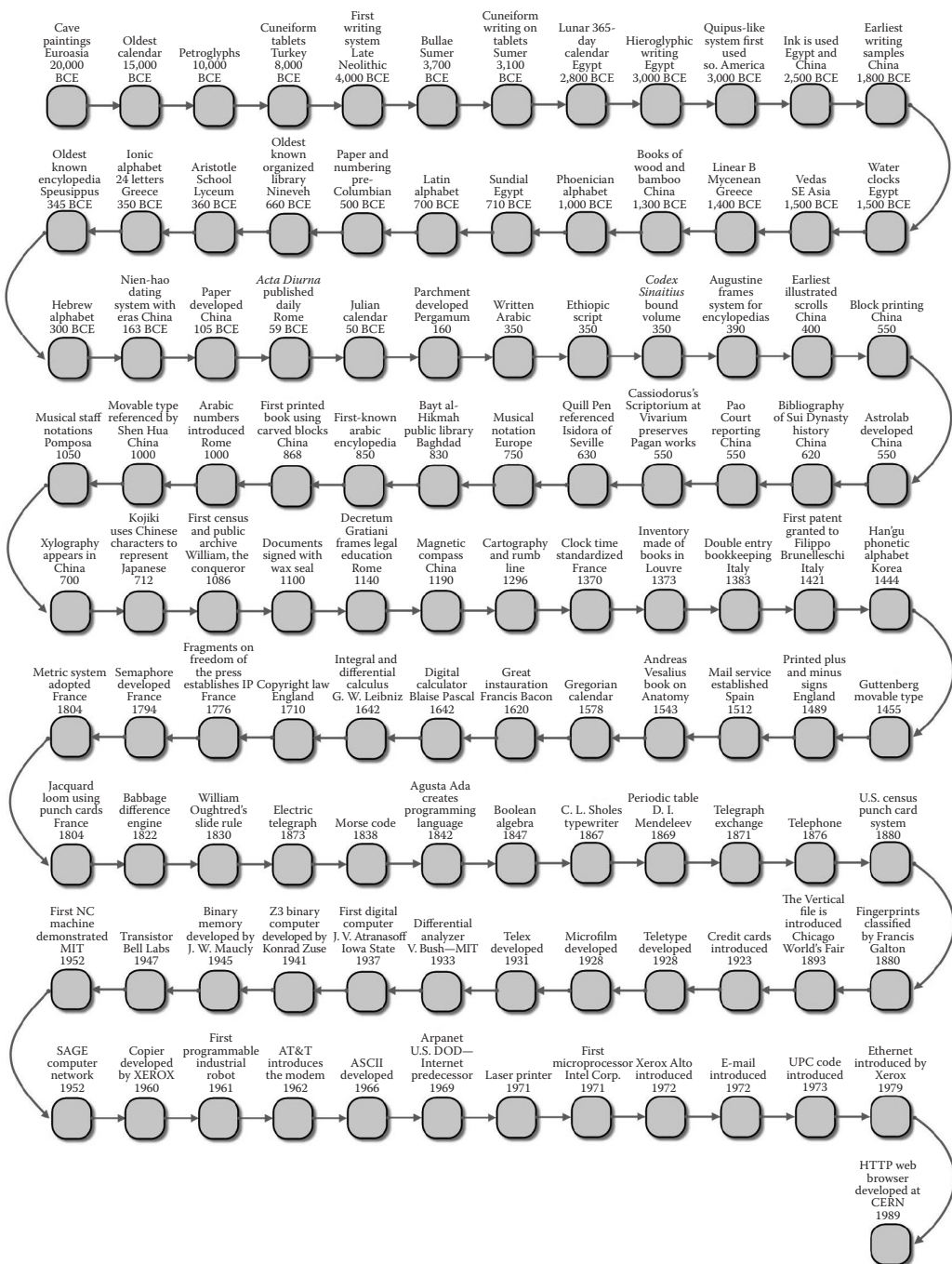


Figure 2.3 History information timeline depicting a subset of the history of information compiled by Geoffrey Nunberg for the *Encyclopedia Britannica* in 2002 in association with Daniel Brownstein. (The complete timeline is available at <http://people.ischool.berkeley.edu/~nunberg/timeline.html>.)

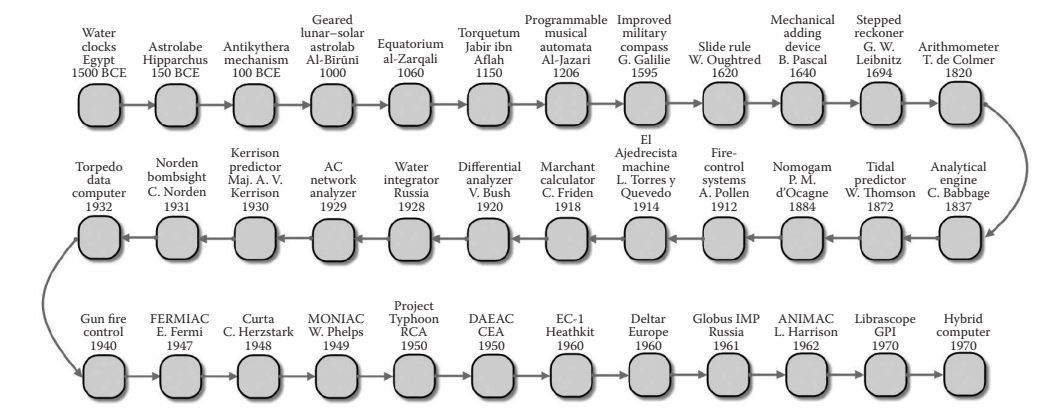


Figure 2.4 Analog device history.

long-term data warehouse ran the risk of not having a backup for the data map and occasionally of data corruption.

Loss of the index of warehouse container content at any time made it a daunting task to retrieve and inventory every container to create a new data map. This happens more often that industry would like to admit due to a lack of centralized indexed records. Occasionally warehouses were damaged by natural and man-made causes. Historical Titan launch vehicle records were lost at the Lockheed-Martin Waterton facility due to a leaking roof in the bunker the data was stored in. Over the years, the carefully indexed documents were reduced to a three-foot-deep pool of paper pulp that was only discovered when the water tight doors to the bunker were opened to retrieve Titan I archives pertaining to the U.S. government property.

With the ability to create and store records electronically, IT has taken on a new vibrancy. Not only is it possible to record and store data with metadata fields providing data mining capabilities only dreamed of a scant decade ago, but the influence of modern trends in how IT is viewed from the corporate level is redefining what is acknowledged as IT. In many cases, it was found that maintenance of hard copy files is no longer seen as part of IT but relegated to a subfunction of records management associated with governmental regulatory compliance. In some cases, it is performed by the data management function under CM and in others by a G&A function due to the regulatory aspect of many of the records so maintained.

Instead IT is redefining itself as the study, design, development, application, implementation, and support or management of computer-based information systems. In some cases, communications and video systems have been included in the definition, but these are being delegated to document operations and telecommunications in many market segments. Inherent in the definition provided above is maintaining security for those information systems and the content inside of them. Terms such as “big data” are entering into the vocabulary referring to data collections so large that they must be managed on parallel servers instead of using single server and standard database management tools. According to International Business Machines, every day, 2.5 billion GB of high-velocity data are created in a variety of forms, such as social media posts, information gathered in sensors and medical devices, videos, and transaction records.* Enterprise-driven

* IBM. (2013, September 22). *What Is Big Data?—Bringing Big Data to the Enterprise*. <http://www-01.ibm.com/software/au/data/bigdata/> retrieved 2014-08-12.

data associated with any market segment is a subset of this dataset. The IDC Digital Universe Study* sponsored by EMC, December 2012, goes on to project that the digital universe in the United States alone will see growth from 898 exabytes to 6.6 ZB of data between 2012 and 2020. This is more than a 25% increase per year. Yet this when combined with Western Europe will account for a scant 49% of the total data universe. Of the purely U.S. generated data, 25% is projected as requiring security with 60% of that data, or 15% of the total, having no protection at all. Additionally 18% of the total U.S. dataset would be useful if properly tagged and analyzed with an estimate that less than one half a percent is currently analyzed.

Conceivably enterprise related data although not evaluated would show a higher percentage of tagging and analysis due to its association with market segment dynamics and profitability. Yet there is much information that is critical to other business aspects such as IP provenance that remains only in paper world or pre-1990 record systems such as microfilm reels and microfiche sheets. A 30-year analysis of firms in the aerospace sector when projected across industries supporting the firms used in the study leads to the conclusion that data contained on drafting vellum sheets, microfilm, microfiche, 0.5 in. wide reels of 9-track magnetic tape, hard diskette platters, 8, 5.25, and 3.5 in. floppy disks and Iomega zip diskettes in archived data may account for 30% of an enterprise IP. Migration of this data to usable formats is difficult and expensive and rarely lends itself to automation.

Toward the end of the Space Transportation System (STS), the launch facilities at NASA's Kennedy Space Center in Florida were still using 086-based computers that had seen few computer upgrades since April 12, 1981, launch of STS-1 (Columbia). Replacement parts were being sourced on eBay.

New Horizons, a flyby mission to the Pluto/Charon system and the Kuiper belt, is the first in NASA's New Frontiers line of moderate-scale planetary missions and is the first mission to explore Pluto and its moons Charon, Nix, and Hydra. Launched on January 19, 2006, it is scheduled for a closest approach of about 10,000 km on July 14, 2015.† To avoid possible issues due to IT upgrades and obsolete hardware, the entire flight operations system computers and software systems for the multispectral visible imaging camera and the linear etalon imaging spectral array were mothballed by the instrument provider shortly after launch.

Evaluating IT storage needs is not an easy task. Often CM is asked to make projections of the data generated on a program by program basis. Although Moore's law provides some insight to data storage and retrieval solutions and needs by predicting a doubling in the number of transistors on integrated circuits (ICs) every 18 months, it does not take into account rising sophistication in engineering software tools and the potential impact of emerging nanotechnologies and heat dissipation improvements.

Moore's law as a predictor of the number of transistors in ICs over time is questionable. It is based on single-layer IC chips. Samsung introduced a 128G V-NAND SSD 24-layer 3D flash memory chip in 2013 stepping around the 30 nm spacing issue required to eliminate transistor cross talk. According to Moore's equation, this should not have happened until 2025 (Figure 2.5).

Eventually, Moore's law will be readjusted to account for the layered memory chip design. This may take the form of a simple step function, where the trend line simply ends for single-layer chip designs and continues at the same slope starting with the 128G V-NAND SSD 24-layer 3D flash

* EMC Corporation. (2012). *IDC Digital Universe Study: Big Data, Bigger Digital Shadows and Biggest Growth in the Far East*. EMC Corporation.

† Reuter, D. (2008). Ralph: A visible/infrared imager for the New Horizons Pluto/Kuiper belt mission. *Space Science Review*, Vol. 140, No. 1–4, 129–154.

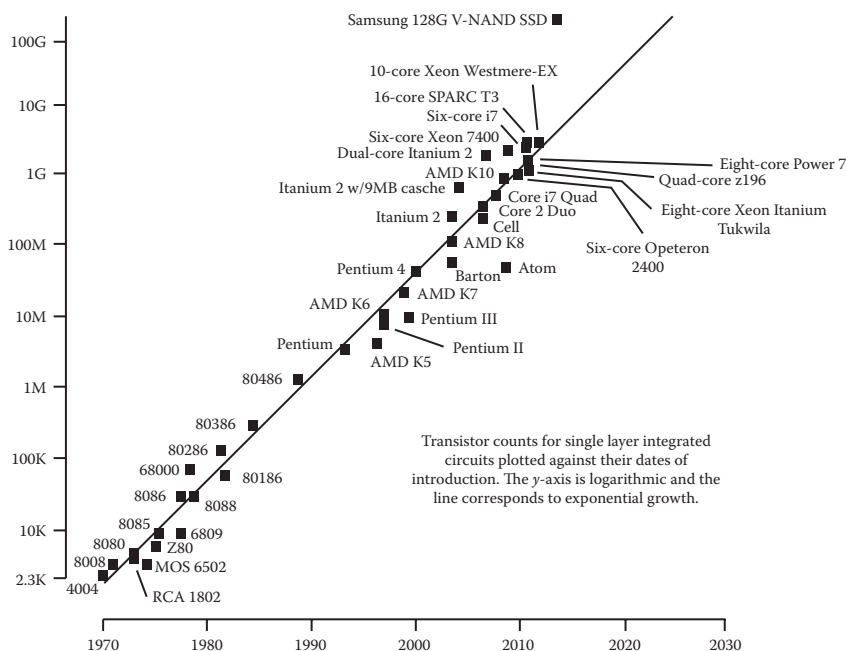


Figure 2.5 Moore's law.

memory chip or it could change slope and Moore's law many be valid only for the single-layer chip density progression.

The scaling of storage needs must be evaluated based on adding additional capability due to demand. In this, it is much like evaluating manufacturing capability on the factory floor and adding additional production lines based on demand. In the case of storage, the needs evaluation is increasing in a nonlinear way over time due to the rapid evolution in software used in product development as well as technological leaps forward. Åse Dragland states that a full 90% of all the data in the world has been generated over the last two years.* A similar increase in data received and tracked by most IT organizations has also been observed. This is due in no small part to how standard enterprise security information is gathered and processed. The similarities between infrastructure expansion between manufacturing and IT are shown in Figure 2.6.

Prior to 1997, few firms implemented IT solutions for monitoring employee movement between facilities, employee Internet and e-mail traffic, routine facility security checks or e-mail attachment data content for political correctness, or other contents. Enterprise IT solutions now include the collection and processing of such information. This adds to the nonlinear growth of data storage and evaluation and complicates the process of determining how to classify data needed for daily transaction functions from that required in case of a physical security breach or audit. In many respects, IT of digital data lends itself to project management with strong CM elements rather than to its early beginnings as a way to manage the computing and server resources. In an

* Dragland, Å. (n.d.). *Big Data—For Better or Worse*. Retrieved September 28, 2013, from <http://www.sintef.no/home/Press-Room/Research-News/Big-Data--for-better-or-worse/>.

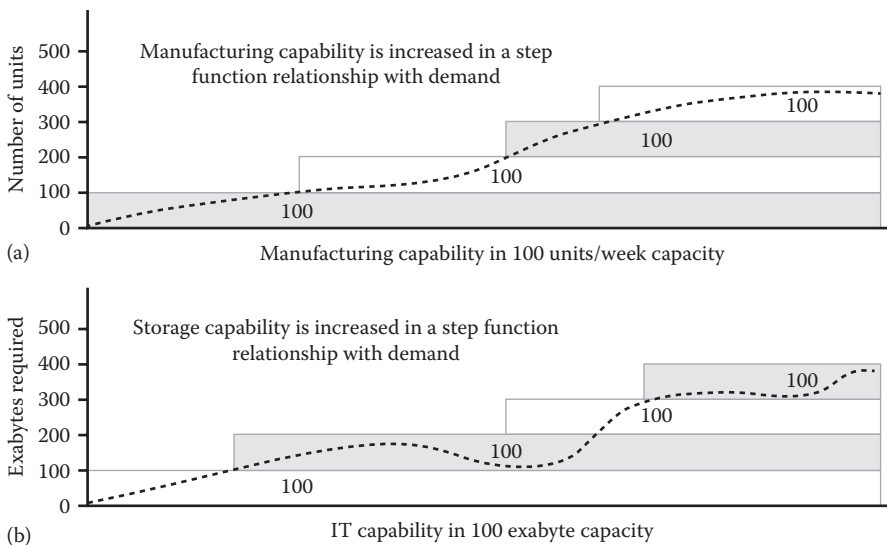


Figure 2.6 Manufacturing and IT infrastructure block updates (a) production needs increase based upon factory capabilities and (b) IT storage needs increase based upon server capabilities.

attempt to do this, many enterprises are moving to a form of cloud-based infrastructure similar to the Amazon Web Services platform introduced in 2002.

At this point, it is best if a few definitions are introduced.

- **Cloud computing:** Standardized elastic/scalable IT-enabled services, software, and infrastructure components delivered through an Internet or intranet interface with built-in redundancy and failover.
 - In many respects, portions of the cloud are active and growing in every business model since the early 1950s. The 1950s were a time of large mainframe computers with dedicated terminals that were not only a large financial investment for firms and institutions, but one that, when needed, used all its capabilities but, when not needed, sat idle for long periods of time.
 - Recent introduction of IaaS/PaaS technologies to enable internal cloud computing.
- **IT resources:** The associated human resources, systems maintenance and upgrades, utilities, facilities, capital expenditures, physical and electronic security, disaster preparedness, and administration infrastructure.
- **Lead strategy:** Adding capacity to an IT resource in anticipation of demand.*
- **Lag strategy:** Adding capacity when IT resource reaches its full capacity.
- **Match strategy:** Adding IT resource capacity in small increments, as demand increases.
- **Cluster:** Independent IT resources working as a single system based on reasonably similar hardware and operating systems (OSs).
- **Grids:** Organization of computational resources into logical pools that are loosely but collectively coordinated to constitute a virtual computer deployed on a middleware layer of resources.

* Erl, T., Puttini, R., and Mahmood, Z. (2013). *Cloud Computing: Concepts, Technology & Architecture*. Prentice Hall.

2.3.1.1 Examples of Capability Demand

- Modification of product data management or product life cycle management (PLM) meta-data fields that do not contain information constituting engineering data modifiable only by an engineering change order (ECO).
- Modification of established automated workflow to facilitate changes in policies, procedures, and practices (3P).
- Software updates across the infrastructure (e.g., Adobe Acrobat v11.0 replacing v10.0, so that Word documents can be generated from a nonbitmap/scanned PDF).
- A server file with restricted access.
- Rolling off of one ITS backbone* infrastructure or server software suite to another to facilitate new software tools.

2.3.1.2 Examples of Capacity Demand

- A request to accommodate 3 EB of data generated from test data streaming via a frame capture utility or program.
- Increased computing or storage infrastructure due to a capability demand.

Capability and capacity demand are interlinked with one often driving the other. Both are tied to the entirety of digital IT (Figure 2.7). In any organization, CM of hardware and software will require both a physical IT component and a digital IT component. The digital IT component is an element of OH. It continues to evolve as a profession, and in many companies, it has been allowed

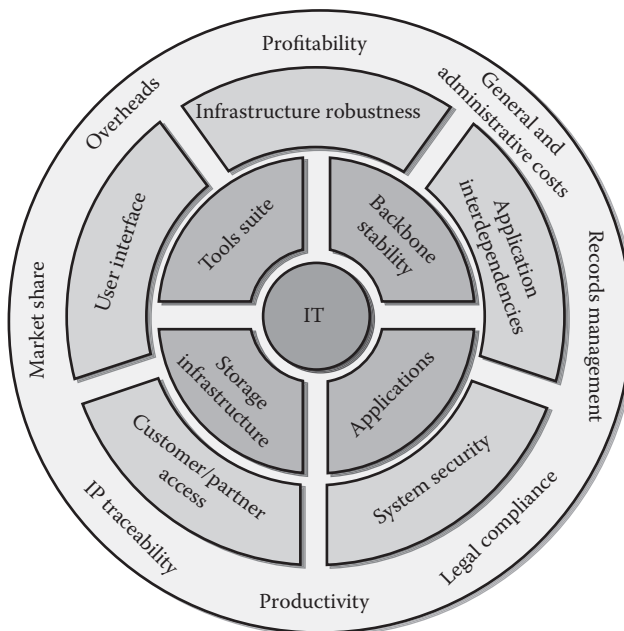


Figure 2.7 Scope of digital IT.

* ITS backbone is the internally networked server structure that form the backbone of the Information Technology Services deployment within a company.

to set itself aside from EBIT considerations with a self-defined charter and mission statement. Although a level of independent self-determination is necessary in any organization, occasionally it can be to the detriment of the revenue-generating function of an enterprise if not done responsibly.

This is where CM comes into play. Just as the survival of any species or product is dependent on its environment, survival of the enterprise is dependent on a digital IT contingent, which enhances survivability. The IT first line of support is the service desk or helpline. Other user interfaces may exist depending on the size of the organization supported. There are several basic IT service desk infrastructure approaches first in first out (FIFO), single-string approach based on criticality (SSC), and functional service request disposition (FSRD). This is shown in [Figure 2.8](#).

A FIFO approach does not take into account the criticality of the request and requests are processed in the order received. In a biological survival situation, the following survival guidelines generally apply. You can survive three minutes without air, three hours without shelter (except in extreme cold), three days without water, and three weeks without food. Consider what would happen if these were called into the service desk in the opposite order of shelter, food, water, and air in a FIFO scenario. The internal customer requiring air would expire if that request was not moved to the top of the list and acted on immediately. Considering the implications, FIFO is unacceptable from a system IT CM perspective as it ignores the relative importance of other items in the IT queue. We will discuss this further as it relates to the timing of implementation during the configuration control board (CCB) evaluations of changes.

SSC resolves some of the FIFO issues and may be a tenable approach in smaller enterprises. It has been observed to become increasingly ineffective in organizations with an IT infrastructure supporting over 80 users due to the link between capability and capacity demand. An IT infrastructure supporting 120 users soon finds itself adapting to the elements of the FSRD model.

Moving from an existing IT architecture to another requires the expenditure of enterprise profits, which in turn may impact the stability of the IT backbone, application suites, IT system security, G&A costs, IP considerations, and productivity, which again impacts profitability. Utilization of a *best-of-breed* approach to implement applications tied to the specific needs of proposal management, program management, contracts management, systems engineering, finance, CM of hardware and software (includes firmware), supply chain management, talent acquisition data management, and quality assurance requires a larger support staff to manage the interfaces between the applications and may not provide an optimal solution. Choice of a single application solution that encompasses all of the needs of the enterprise functional resources may not provide an optimal solution either.

The interdependencies between IT, G&A, OH, IP, and ITAR necessitate a strategic view of the IT system configuration but focused management of IT solution and planned phasing of updates to the technology involved to determine when block updates to the infrastructure will have the least impact and greatest payback.

2.3.2 Stability of Internal Infrastructure

Looking simply at the scope of IT, as presented in [Figure 2.7](#), it is hard to grasp the importance of the physical infrastructure required to support an intranet (internal network vs. Internet/external network or the impact failure in that infrastructure represents to the users of IT services). The stability of end-to-end Internet paths is dependent both on the underlying telecommunication switching system and the higher level software and hardware components specific to the Internet's

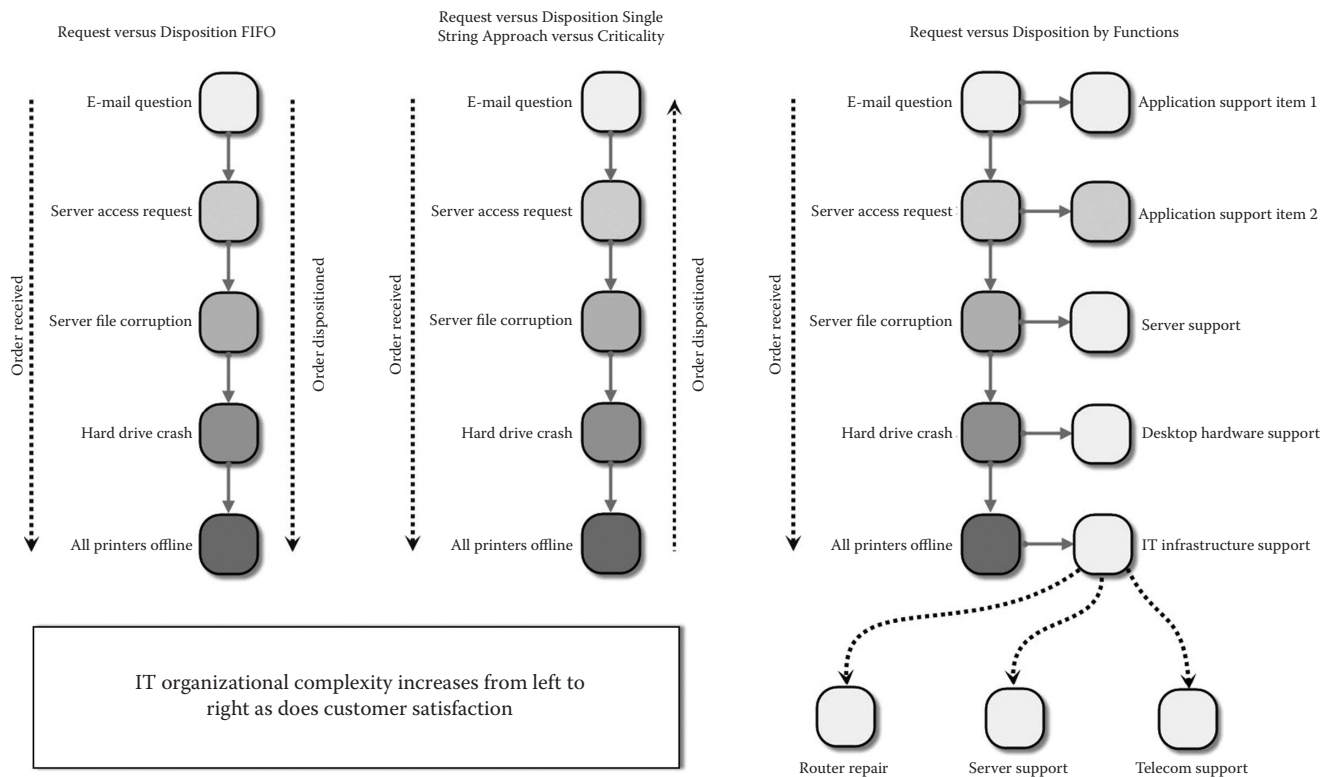


Figure 2.8 FIFO, SSC, and FSRD.

packet-switched forwarding and routing architecture.* This applies to an intranet setting as well as it is built on the same platform and utilizes transmission control protocol/Internet protocol, hypertext markup language, simple mail transfer protocol, and file transfer protocol and IT infrastructure library (ITIL) methodologies.

2.3.2.1 IT Backbone

Intranet stability is dependent on several factors that will be addressed briefly to provide a feel for the issues involved. It is not the intent to make the reader an expert in these areas but to provide an introduction to the subject to familiarize them with the subject and context. This familiarization is necessary to facilitate a clearer understanding of the information provided in the chapters that follow.

2.3.2.1.1 Telecommunication Stability

Peter Racskó in his article “Information Technology, Telecommunication and Economic Stability”† points out that the increase of effectiveness of a system performance might lead to instability of operation. The question whether the development of information and communication technologies can lead to instability of economic systems was examined. The final conclusion is yes, we cannot exclude that unlimited development of IT and telecommunication might induce structural instability.

Management of stability requires an understanding of what instability looks like as well as the transitory states leading from a system’s equilibrium toward the instability of the physical structure of the system itself. Stability concepts used in dynamic systems may require discrete iterative models or differential equations to demonstrate all stability phenomena in question.

Structural stability is a property of the system and not its equilibrium points. Dynamic similarity in this case means that the topological congruency is maintained between all systems and that fix points in one system match fixed points in another system. Put simply, small perturbations do not change the quality of systems performance and are often not noticeable to the end user.

2.3.2.1.2 Autonomous System Routing Protocols

The oldest routing protocol still in use today is the routing information protocol (RIP) with a technology link to as early as 1957. RIP has lost popularity and is generally supplanted by the open shortest path first (OSPF) and the intermediate system-to-intermediate system (IS-IS) routing protocols. These *interior routing protocols* are distinguished from *exterior routing protocols* connections between networks. Reactive protocols broadcast path request packets to find a route; proactive protocols maintain tables of possible routes and give them rankings. RIP, OSPF, and IS-IS are all types of proactive routing protocols. RIP is a *distance vector* protocol; counting the number of links to a destination and choosing the shortest. OSPF and IS-IS are *link state* protocols; monitoring performance of links in their libraries and adjust their rankings accordingly.‡

* Labovitz, C., Ahuja, A., and Jahanian, F. (1998). *Experimental Study of Internet Stability and Wide-Area Backbone Failures*. University of Michigan, Ann Arbor, MI.

† Racskó, P. (2010). Information technology, telecommunication and economic stability, cybernetics and information technologies. *Bulgarian Academy of Sciences*, Vol. 10, No 4 (Sofia). p. 5.

‡ Stein, A. (n.d.), *What Is the Purpose of a Routing Protocol?* http://www.chow.com/facts_7260499_autonomous-system-routing-protocol.html#ixzz2iAnG97ad.

2.3.2.1.3 Router/Routing Stability

2.3.2.1.3.1 Router Configuration Errors — April 25, 1997—A misconfigured router maintained by a small Virginia-based service provider injected an incorrect routing map into the global Internet. This map indicated that the Virginia company's network provided optimal connectivity to all Internet destinations. Internet providers that accepted this map automatically diverted all of their traffic to the Virginia provider. The resulting network congestion, instability, and overload of Internet router table memory effectively shut down most of the major Internet backbones for up to two hours. Incorrect published contact information for operations staff, and lack of procedures for inter-provider coordination exacerbated the problem.*

2.3.2.1.3.2 Transient Physical[†] — Problems with leased lines, router failures, or high levels of congestion lead to transient physical issues in intranet and Internet stability. Single-event faults, coupling faults, line degradation, and unconfirmed faults must also be expected and planned. In some instances, hardware may enter what is deemed a petulant mode due to packet sequencing or other factors causing a reset simply as an undocumented feature of the hardware.

2.3.2.1.3.3 Data Link Problems — August 14, 1998—A misconfigured critical Internet database server incorrectly referred all queries for Internet machine names ending in \.net “to the wrong secondary database server. As a result, a majority of connections to \.net” Internet web servers and other end stations failed for a period of several hours.‡

2.3.2.1.3.4 Software Issues — November 8, 1998—A malformed routing control message stemming from a software fault triggered an interoperability problem between core Internet backbone routers manufactured by different vendors. This problem led to persistent, pathological oscillation and failure in the communication between most Internet core backbone routers resulting in a widespread loss of network connectivity, and increased packet loss and latency. The majority of backbone providers resolved the outage within several hours after adding filters, which removed the malformed control message.§

2.3.2.1.3.5 Human Error — Misconfigurations caused by human error are often the reason of router instabilities that occur due to the intricacies of routing protocols. Studies show that almost 6% of bridging control protocol (BCP) updates is inconsistent and unable to show topological changes in the network. 70% of the miss-advertised prefixes occur due to BCP misconfigurations causing routing anomalies such as invalid routes, persistent oscillations, routing loops, and link state advertisements (LSA) penalties.¶

* Barrett, R., S. Haar, R., and Whitestone, R. (1997, April 25). Routing Snafu causes internet outage. *Interactive Week*.

† Smith, M. A Internet Routing Instability. www.cs.fsu.edu/~xyuan/.../michael_instability.ppt no date is on the power point presentation.

‡ North American Network Operators Group (NANOG) mailing list, <http://www.merit.edu/mail.archives/html/nanog/msg03039.html>.

§ NANOG mailing list, Retrieved on September 10, 2014, from <http://www.merit.edu/mail.archives/html/nanog/msg00569.html>.

¶ Routing Anomalies – Their Origins and How Do They Affect end Users. Retrieved on September 20, 2013, from http://www.noction.com/blog/how_routing_anomalies_occur.

2.3.2.1.4 Internet Protocol Packets and Congestion

A large network running OSPF protocol may occasionally experience the simultaneous or near-simultaneous update of a large number of LSAs. This is particularly true if OSPF traffic engineering extension is used, which may significantly increase the number of LSAs in the network. We call this event an LSA storm and it may be initiated by an unscheduled failure or a scheduled maintenance event. The failure may be hardware, software, or procedural in nature.

The LSA storm causes high central processing unit (CPU) and memory utilization at the router causing incoming packets to be delayed or dropped. Acknowledgments beyond the retransmission timer value result in retransmissions, and delayed Hello packets (beyond the router-dead interval) result in neighbor adjacencies being declared down. The retransmissions and additional LSA originations result in further CPU and memory usage, essentially causing a positive feedback loop, which, in the extreme case, may drive the network to an unstable state.

The default value of the retransmission timer is five seconds and that of the router-dead interval is 40 seconds. However, recently there has been a lot of interest in significantly reducing OSPF convergence time. As part of that plan, much shorter (subsecond) Hello and router-dead intervals have been proposed. In such a scenario, it will be more likely for Hello packets to be delayed beyond the router-dead interval during network congestion caused by an LSA storm.*

The network-working group recommends methods that can be used to improve the scalability and stability of large networks and should be adopted by smaller networks as a preferred practice. They are summarized below.

1. *Classify all OSPF packets in two classes:* A *high-priority* class comprising OSPF Hello packets and LSA packets, and a *low-priority* class comprising all other packets. The classification is accomplished by examining the OSPF packet header. While receiving a packet from a neighbor and while transmitting a packet to a neighbor, try to process a *high-priority* packet ahead of a *low-priority* packet.
2. *Inactivity timer:* Reset the inactivity timer for an adjacency whenever any OSPF unicast packet or any OSPF packet sent to AllSPFRouters over a point-to-point link is received over that adjacency instead of resetting the inactivity timer only on receipt of the Hello packet. Therefore, OSPF would declare the adjacency to be down only if no OSPF unicast packets or no OSPF packets sent to AllSPFRouters over a point-to-point link are received over that adjacency for a period equaling or exceeding the `outerDeadInterval`. The reason for not recommending this proposal in conjunction with the one above is to avoid potential undesirable side effects. One such effect is the delay in discovering the down status of an adjacency in a case where no high-priority Hello packets are being received, but the inactivity timer is being reset by other stale packets in the low-priority queue.
3. *Algorithms:* Use an exponential back off algorithm for determining the value of the LSA retransmission interval (`RxmtInterval`). Let $R(i)$ represent the `RxmtInterval` value used during the i th retransmission of an LSA. Use the following algorithm to compute $R(i)$.

$$R(1) = R_{min}$$

* Choudhury, G. (2005). *Prioritized Treatment of Specific OSPF Version 2 Packets and Congestion Avoidance*, Network Working Group, The Internet Society. Retrieved July 24, 2014, from <http://www.rfc-base.org/rfc-4222.html>.

$$R(i+1) = \text{Min}[KR(i), R_{\text{max}}] \quad \text{for } i \geq 1$$

where:

K, Rmin, and Rmax are constants

the function Min(.,.) represents the minimum value of its two arguments

Example values for K, Rmin, and Rmax may be 2, 5, and 40 seconds, respectively.

4. *Implicit congestion detection and action based on that:* If there is control message congestion at a router, its neighbors do not know about that explicitly. However, they can implicitly detect it based on the number of unacknowledged LSAs to this router. If this number exceeds a predetermined *high-water mark*, then the rate at which LSAs are sent to this router should be reduced progressively using an exponential back off mechanism but not below a certain minimum rate. At a future time, if the number of unacknowledged LSAs to this router falls below a predetermined *low-water mark*, then the rate of sending LSAs to this router should be increased progressively, again using an exponential back-off mechanism but not above a certain maximum rate.
5. *Throttling adjacencies to be brought up simultaneously:* If a router tries to bring up a large number of adjacencies to its neighbors simultaneously, then that may cause severe congestion due to database synchronization and LSA-flooding activities. It is recommended that during such a situation no more than n adjacencies should be brought up simultaneously. Once a subset of adjacencies has been brought up successfully, newer adjacencies may be brought up as long as the number of simultaneous adjacencies being brought up does not exceed n . The appropriate value of n would depend on the router processing power, total bandwidth available for control plane traffic, and propagation delay. The value of n should be configurable.

2.3.2.1.5 System Topology

Topology is a mathematical study pertaining to the connectedness, continuity, and boundary of shapes and spaces that began with geometric questions.* IT system topology is designed to support the needs of the enterprise and may be single tier or multitier dependent on needs. Some of the considerations that must be addressed to provide enterprise event management are identified below.

Historical data: Provides the ability to capture and analyze event data from a set period or specific data span, thus facilitating spot long-term trending.

Immediate alerting: Ensures that real-time changes and code updates are identified and impacts are tracked.

Integration flexibility: Provides the ability to utilize a library of adapters from vendor sources or developed in-house.

SaaS delivery: Removes the necessity for the added hardware and software upgrades, allowing a rapid response to get things up and running.

Scalability: Provides the capability to manage greater numbers of events per second and per day.

Real-time views: Allows real-time application chatter analysis to provide place in time understanding of the current application topology

The prototypical IT topology is shown in [Figure 2.9](#).

* Euler, L. (1735). *Seven Bridges of Königsberg*. St. Petersburg, Russia: Imperial Russian Academy of Sciences.

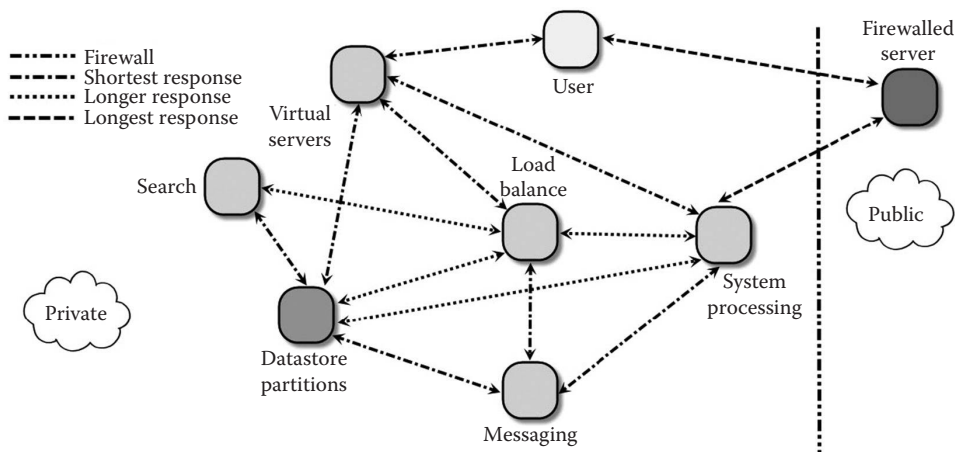


Figure 2.9 Prototypical IT topology.

2.3.2.1.6 Border Gateway Protocol for Internet Connection

Border gateway protocol (BGP) is involved with making critical core-routing decisions originally designed for transitioning to a decentralized system backbone and its associated networks. At the enterprise level, it uses a number of OSPF networks that are beyond the capability of OSPF to scale to the needed size. BGP also assists in assuring better redundancy to single Internet service provider (ISP) or multiple ISPs for multihoming (e.g., for computers and devices connected to more than one computer network.) BGP makes routing decisions based on path, or configured network policies and rule sets. In some cases, BGP design will not allow delivery while routes are being updated. Intranet routing table growth may impact less capable routers unable to cope with the memory requirements. Routing table growth is often tied to load balancing or multihomed networks. This can be mitigated using locator/identifier separation protocol gateways within the exchange points to avoid increases in the number of routes seen on the global BGP table.

There are several variants of the multihoming approach generally used to eliminate network potential single point of failure.

Single link, multiple IP address: The host has multiple IP addresses but a single physical upstream link. When the single link fails, all connectivity is down.

Multiple interfaces, single IP address: The host has multiple network interface controllers and each interface has one or more IP addresses. When one link fails, the others may still be available.

Multiple links, single IP address: This is the accepted definition of multihoming. With the use of a routing protocol such as BGP, the site the address space to all upstream links. When one link fails, the protocol stops traffic over the failing link. It is not generally used for single hosts.

Multiple interfaces, multiple IP address: Utilization of a specialized link load balancer or wide area network (WAN) load balancer between the firewall and the link router providing the advantage of using all available links to increase network bandwidth.

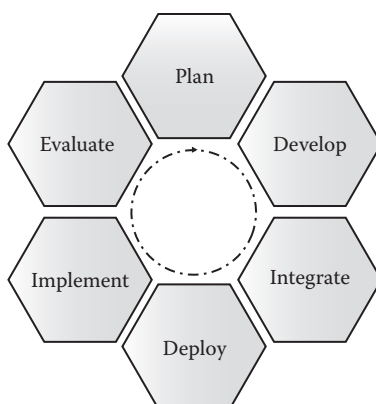


Figure 2.10 Business improvement cycle.

2.3.2.2 Application Deployment

Application deployment is done using what is known as a “circular strategy” with six key elements: plan, develop, integrate, deploy, monitor, and analyze. These are leveraged forward from the quality business process improvement cycle discussed in International Standards Organization (ISO) and elsewhere. Damon Edwards,* in an interview posted in an HP Blog by Jim Gardner,† had an interesting observation directly applicable to both the IT business improvement cycle and application deployment (Figure 2.10). Mr. Edwards implies that technology developers tend to view innovation as invention, whereas business management sees it as application of ideas to capture new customers and value for those customers. When both definitions exist in a single company, friction will occur. It is the challenge of every company to make it clear what innovation is and how it is to be used and measured.

In any form of communication, it is critical that all parties first agree on the terms to be used and those terms are strictly enforced during conversations that pertain to all steps involved. Terms with precise meanings will do much to eliminate errors in interpretation and as a result in a reduction in the overall timeframe that is involved.

Change is constant and change is not easy. Roger Hebden stated it in a simple formula in 1995.‡

$$\text{Pain} + \text{Desire} = \text{Change}$$

When the pain of using an existing application becomes so great that it impacts market survivability, the desire increases. When that desire is stronger than the perceived pain, change is the result.

For the deployment of a new application, planning is the first step in the cycle. For the deployment of an application upgrade or application replacement, this is the first step in the continuing cycle. Planning in this case is much more than the scheduling of events. It includes a complete blueprint of everything that is impacted by the rollout, starting with the nature of the problem and a validation of need, resolving incomplete, ambiguous, and contradictory requirements, trade

* Damon Edwards, co-founder of IT consultancy DTO Solutions, has spent more than a dozen years working on web operations from both the IT and business angles.

† Gardner, J. (2012, December 19). *IT Stability and Business Innovation Are Not Enemies*. Retrieved December 20, 2012, from <http://www.enterprisecioforum.com>.

‡ Hebden, R. (1995). *Affecting Organizational Change*. New York: IBM.

studies to evaluate best value solutions for meeting the need, in-house development or commercial off-the-shelf components (COTS) sourcing should be evaluated, implementation strategies, stakeholder identification, user identification, cross functional impacts, known–unknown and unknown–unknown evaluation and mitigation, roll-out scenario evaluation, training plans, material, timeline, new-user checkout and certification (if required), success metrics/business intelligence (BI) metrics, beta testing of the application in a sandbox/test bed area, as described in Section 2.1.1.4, data integration, and possible platform upgrades or changes.

Once the planning is in place software development takes one of two roads. Deployment of specialized software will involve development activities that take into account the unique characteristics of the end user. In a PLM system, COTS development interface workflows, existing policies, procedures, practices, and handbooks are taken into consideration and terms unique to the deployment are identified and instantiated into the software prior to loading into the sandbox/test bed area for a test to break period. In this case the resultant contract defines the scope and many COTS providers will entertain a demonstration phase where some of the requirements are shown. Once the requirements are clearly defined a contractual agreement is signed that define cost, schedule, disputes resolution and other terms and conditions required under the governing laws.

In an in-house development, a standardized version of the software development life cycle is generally followed. Several development models exist. Developers need to mix and match based on the scope of the project to meet end objectives and documentation requirements. Some are best suited for lab purposes whereas others meet the full intent of and context of ISO 12207, quality management systems—guidelines for CM. The intent of what is presented below is to convey a sense of what is involved in each rather than an in-depth explanation of software development and software CM implications.

In 2011, over 55 named software development methodologies were in use as well as multiple hybrids.* Six of these models will be discussed.

2.3.2.2.1 Similarities and differences between hardware and software

Let us look at the similarities and differences between hardware and software before proceeding with the software development types. What follows is a paraphrase of information contained in “Product Data Management and Software Configuration Management—Similarities and Differences.”†

2.3.2.2.1.1 Differences

■ Hardware

- Geared for part-centric production
- Production is expensive
- Designed to last
- Managed complexity
- Designed to make multiple copies
- Deliverables stored on pallets or in bins

* Jones, C. (2011). *Evaluating Ten Software Development Methodologies*. Namcook Analytics LLC. <http://namcookanalytics.com/evaluating-ten-software-development-methodologies/>. Accessed on June 14, 2014.

† Dahlqvist, A.P. (2001). *CM i ett produktperspektiv—ställer hårdare krav på integration av SCM och PDM*. The Association of Swedish Engineering Industries.

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■ Software

- Geared to function
- Production is cheap
- Designed to change
- Too much complexity to manage to the same level as hardware
- Quantity is always 1
- Deliverables are stored in a repository

2.3.2.2.1.2 Similarities Outweigh the Differences

■ Both manage and track

- Engineering change requests
- Requirements
- Problem reports
- Customer requests
- Documents
- Projects/activities/tasks
- Test cases
- Built Products
- Test results

■ Traceability is still king

2.3.2.2.1.3 Do Not Structure Software Like Hardware

■ If you try to structure software like hardware, you'll get weak structure.

- There's a clear functional mapping (allocation) between product function and design.
- Both need to be mapped and present.

■ Full traceability yields negative OH

- Good traceability and good traceability tools = lots of benefits.

2.3.2.2.1.4 Software and Hardware CM Differences

■ Everything is built from within the repository.

- Branching/merging is far more prevalent than in hardware CM.
- Delta/difference reports and peer reviews are essential.
- Nightly builds (or even continuous builds) are important.
 - Way too costly for most hardware—especially if re-tooling is required.
- Product variants are easier to manage.
 - But only if they are handled correctly—wherever possible as run-time variants, not build-time!
- Both functional and design product architectures.
- Software repository should be all that is necessary for technology transfer to a new owner, or back to the original contractor.
 - There is so much more needed for hardware.

2.3.2.2.2 Waterfall

The waterfall model ([Figure 2.11](#)) requires that strict application reviews take place at each stage prior to moving to the next. Revisiting prior decisions is discouraged and may be forbidden depending on how the software development plan is written.

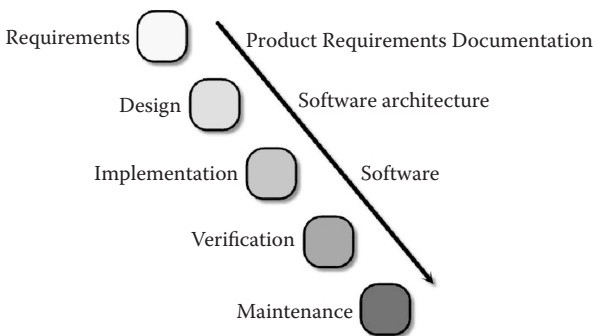


Figure 2.11 Waterfall model.

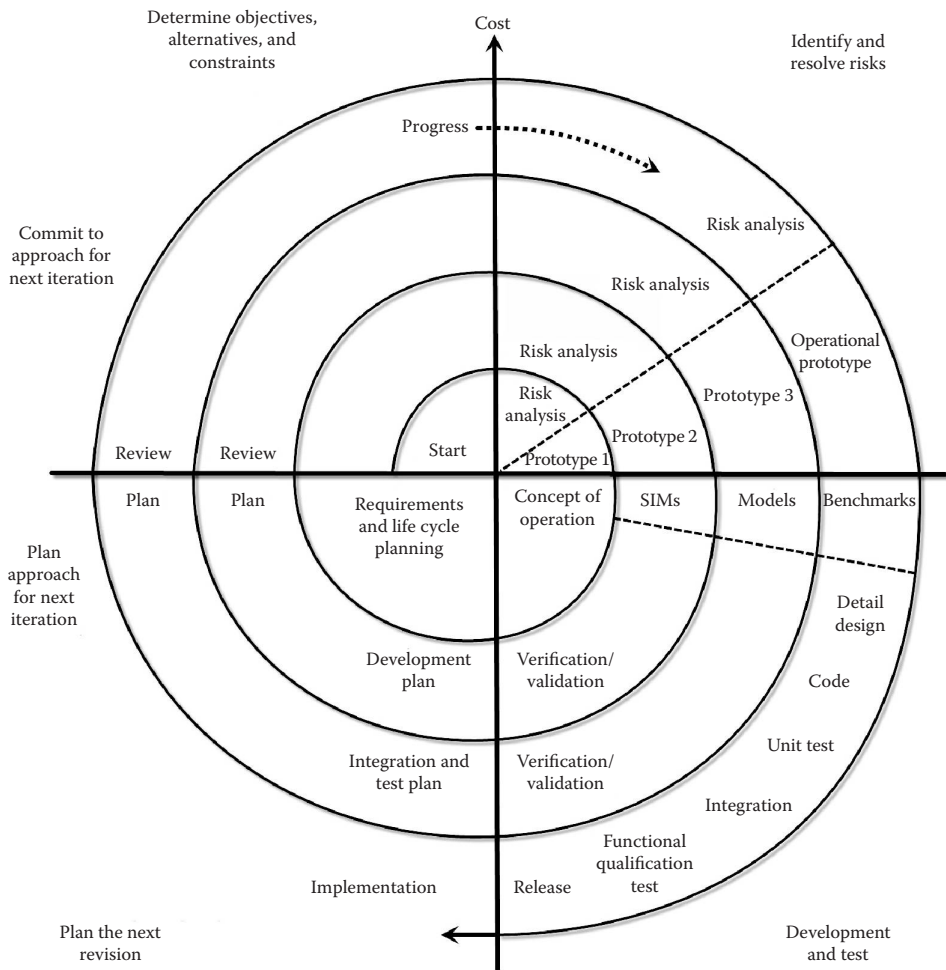


Figure 2.12 Spiral model.

The steps can be remembered using the mnemonic “A Dance in the Dark Every Monday” for *Analysis, Design, Implementation, Test, Documentation, and Execution*.

2.3.2.2.3 Spiral

The spiral model (Figure 2.12) builds in staged risk management during the development cycle mitigating shortcomings in other models and is well suited to complex systems.

In some cases, the cost versus risk avoidance posture of a project precludes using this model due to the impact on profitability.

2.3.2.2.4 Iterative and Incremental

Iterative and incremental generally refer to any combination of iterative design or iterative method (Figure 2.13) with the incremental build model.

Larger developmental efforts find it extremely useful as the number and nature of incremental builds and scalable to the particular design effort. Elements of iterative and incremental methods are found in other methodologies.

2.3.2.2.5 Agile Development

The Agile development (Figure 2.14) is derived from the Agile Manifesto which is based on twelve principles* that are used during the developmental cycle.

Extreme Programming[†] is a type of Agile development which can be visualized as 12 distinct steps, as given below:

* Kent Beck, et al. (2001). *Principles behind the Agile Manifesto*. Agile Alliance.

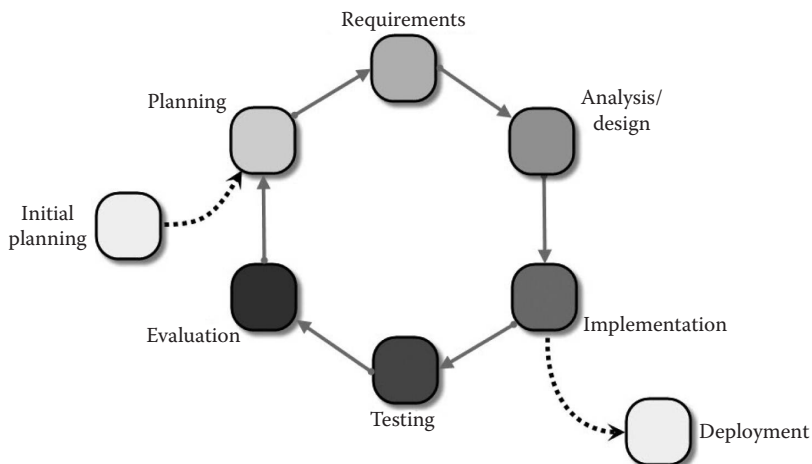


Figure 2.13 Iterative development model.

[†] Copeland, L. (2001, December 3). *Extreme Programming*. Retrieved July 12, 2013, from http://www.computerworld.com/s/article/66192/Extreme_Programming.

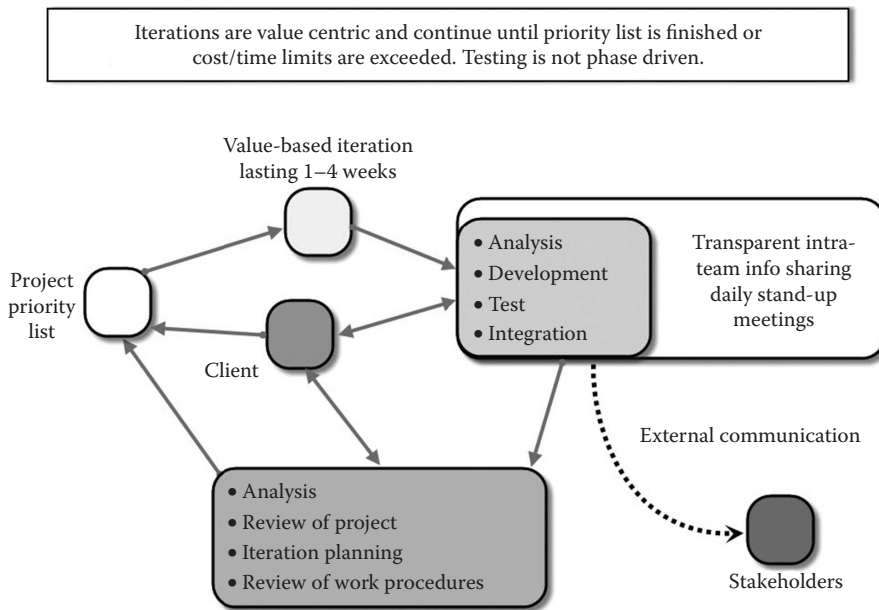


Figure 2.14 Agile development model.

1. Customer satisfaction by rapid delivery of useful software
2. Welcome changing requirements, even late in development
3. Working software is delivered frequently (weeks rather than months)
4. Working software is the principal measure of progress
5. Sustainable development, able to maintain a constant pace
6. Close, daily cooperation between business people and developers
7. Face-to-face conversation is the best form of communication (co-location)
8. Projects are built around motivated individuals who should be trusted
9. Continuous attention to technical excellence and good design
10. Simplicity—the art of maximizing the amount of work not done—is essential
11. Self-organizing teams
12. Regular adaptation to changing circumstances

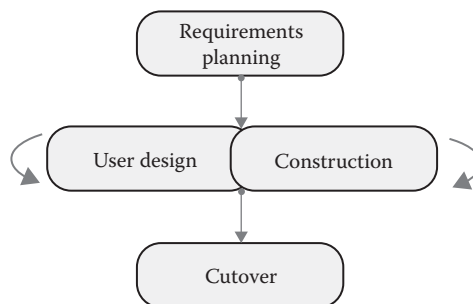


Figure 2.15 Rapid application development model.

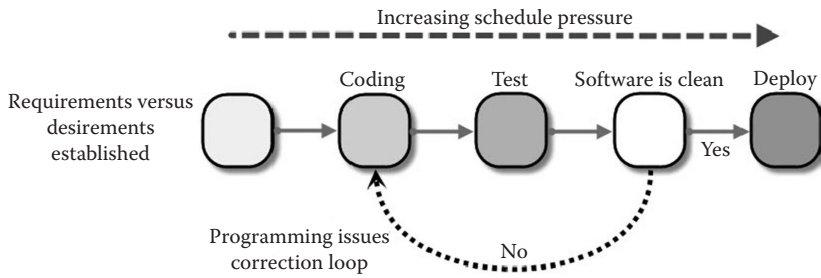


Figure 2.16 Code and fix methodology.

2.3.2.2.6 Rapid Application

The rapid application model (Figure 2.15) is based on minimal planning in favor of rapid prototyping with planning interleaved with software coding.

Structured techniques and prototyping are used to define requirements for end system design.

2.3.2.2.7 Code and Fix

Under code and fix (Figure 2.16), actual coding starts with little design planning due to schedule pressures. The developer has control over the use of tools, language algorithms, and coding style. Often documentation is minimal or nonexistent. During the test phase, programming issues surface and must be corrected prior to the deployment.

Testing and documenting the results is done with the goal of developing software that meets all of the requirements/must have items and as many of the desirements/would be nice to have as possibly. Once requirements have been met by the proposed software design, the desirements are incorporated using the concept of gathering the lowest hanging fruit first. This means that the easiest desirements are addressed first (low-hanging fruit) and the harder ones are evaluated using the formula $\text{pain} + \text{desire} = \text{change}$. The end result of the development activity is the generation of a scope document that clearly defines the cost and limitations of the development.

At the end of any development regardless of method used, success metrics/BI metrics are evaluated for positive or negative trending. Data gleaned from service-level automation and other sources are used to determine the level of acceptance and issues relating to the need for additional training or

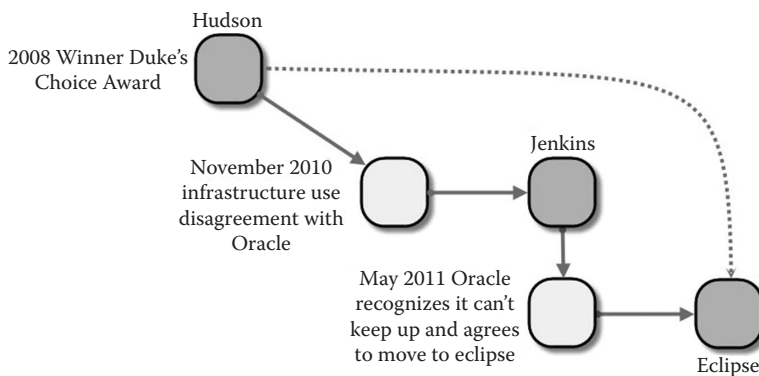


Figure 2.17 Software adaptation due to adversity.

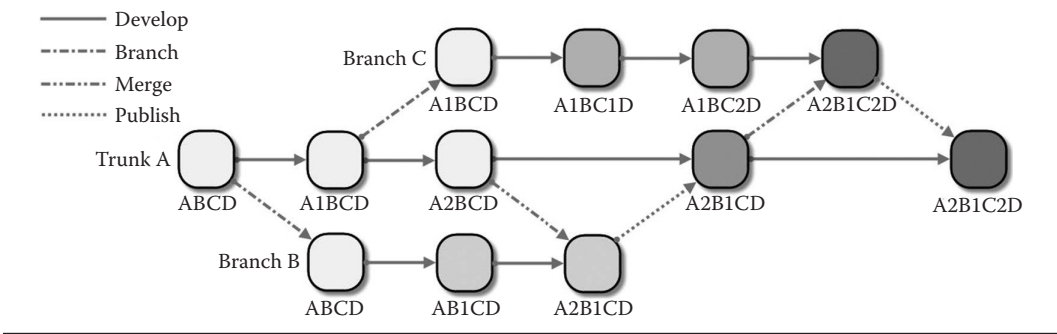


Figure 2.18 Branching and merging.

lack of a full understanding of the known and unknown-unknowns. During the evaluation period, everyone using the deployed application tests and provides evaluation and feedback. Some feedback is in the form of service orders others are in the form of recommended improvements. If the software deployment is for COTS software this evaluation is centric to the user base across industry.

2.3.2.2.8 Adaptation of Software Due to Adversity

Adaptive radiation, as discussed in Chapter 1, is driven by many environmental factors. The relatively recent generation of eclipse is a single example of adaptation of another kind. In most cases in nature as well as in any product sector adaptation of some kind is the rule. Revolution is the exception. Adaptation due to adversity, as shown in [Figure 2.17](#), is rather common in software.

2.3.2.2.9 Trunks and Branching

Parallel development of an item is not a new concept. It exists whenever an allocation of requirements exists. In the case of software, it has been come to be known under the general concept of branching and merging. Many believe it is centric to Agile development, but it has existed in multiple forms going back to programming using punch cards where subroutines were developed, tested, and then merged into the correct place in the card stack. Branching and merging are depicted in [Figure 2.18](#).

This method of development is frowned on by some who believe that maintaining multiple releases is a better method of managing the software configuration. They state with good reason that there is no 100% capability of merging with the current tool set until it is possible to merge at the semantic and syntax level. It is recommended that branching and merging is limited to merging blocks of text.

At present, the following issues exist even with merging of blocks of text:

- Failed publish
- Conflict clash and resolution (manual editing)
- Branch on conflict

An Agile Perspective on Branching and Merging is an excellent source of information.*

The authors point out that early and frequent feedback is critical in all Agile methods. This is aided by continuous or near continuous integration. This is supplemented by the practice of versioning everything and versioning often.

2.3.2.2.10 Tool Upgrades

Tool upgrades are a specialized case of application deployment with the following considerations.

- Check the IT system's configuration against the tools minimum criteria to assure system tool compatibility. In some cases, it may be necessary to update the IT infrastructure prior to IT tool upgrades to both enhance IT system performance and avoid instability issues caused by tool deployment.
- Evaluate the total IT system to detect stability issues and other problems and clean these up prior to the upgrade. These may include hardware and software issues, user account structures, sharing services, connections to peripheral devices and networks, firewalls, and other security measures and software configuration issues on the IT infrastructure. Once these issues are resolved issues with the IT infrastructure backbone, software will not migrate with the tool upgrade.
- Make sure that all required basic and specialized maintenance routines are completed resolving any server drive, partitioning, and other potential issues. Full general maintenance routines should also be run assuring that all cached data, temporary files, and any associated programmable random access memory data are reset throughout the system.
- Run updates on all COTS software and analyze the upgrades against the tool compatibility criteria. Install any required patches to assure compatibility prior to tool the upgrade.
- Run a full backup of the entire IT server structure just prior to the tool upgrade. Do not limit it to the server hosting the tool as it may reach out to other servers in the IT environment during and after the upgrade. Disconnect the backup from the IT backbone.

At this point, proceed with the tool upgrade and run a full spectrum systems check assessing the health of the IT infrastructure. If all is good proceed to the implementation phase.

2.3.2.3 IT System Security

IT security must be built in as one of the IT functionality elements. In many cases, IT breaches take place before tools are in place to protect valuable IP from theft or destruction. Following standard security protocols leveraged forward into the IT environment necessitates a highly defined degree of planning. Elements should draw from TL 9000, quality management system, ISO/Electronic Industries Alliance (EIA) 9003:2004, software engineering—guidelines for the application of ISO 9001:2000 to computer software, ISO/IEC 7064:2003, IT—security techniques—check character systems, ISO/EIA 9160:1998, information processing—data encipherment—physical layer interoperability requirements, as well as other guidance sources such as ISO/EIA 14888-1:2008 and ISO/EIA 14888-2:2008, IT—security techniques—digital signatures Parts 1 and 2.

* Berczuk, S., Appleton, B., and Cowham, R. (2005, November 30). *An Agile Perspective on Branching and Merging*. Retrieved November 22, 2013, from <http://www.cmcrossroads.com/article/agile-perspective-branching-and-merging>.

In the end, it really comes down to managing the configuration of the IT system as a whole through proper planning, physical security, disaster recovery (DR), and an underlying familiarization with IT infrastructure threats.

- DR planning for recovery from natural disasters and other unplanned events. Paul Kirvan, provides an excellent summary and plan template.*
 - IT DR plans (DRPs) provide step-by-step procedures for recovering disrupted systems and networks, and help them to resume normal operations. The goal of these processes is to minimize any negative impacts to company operations. The IT DR process identifies critical IT systems and networks; prioritizes their recovery time objective; and delineates the steps needed to restart, reconfigure, and recover them. A comprehensive IT DRP also includes all the relevant supplier contacts, sources of expertise for recovering disrupted systems, and a logical sequence of action steps to take for a smooth recovery.
 - Assuming you have completed a risk assessment and have identified potential threats to your IT infrastructure, the next step is to determine which infrastructure elements are most important to the performance of your company's business. Also assuming that all IT systems and networks are performing normally, your firm ought to be fully viable, competitive, and financially solid. When an incident—internal or external—negatively affects the IT infrastructure, the business could be compromised.
 - Plan table of contents from IT DRP Template v1.0
 - IT statement of intent
 - Policy statement
 - Objectives
 - Key personnel contact info
 - Notification calling tree
 - External contacts
 - External contacts calling tree
 - 1 Plan overview
 - 1.1 Plan updating
 - 1.2 Plan documentation storage
 - 1.3 Backup strategy
 - 1.4 Risk management
 - 2 Emergency response
 - 2.1 Alert, escalation, and plan invocation
 - 2.1.1 Plan triggering events
 - 2.1.2 Assembly points
 - 2.1.3 Activation of emergency response team
 - 2.2 DR team
 - 2.3 Emergency alert, escalation, and DRP activation
 - 2.3.1 Emergency alert
 - 2.3.2 DR procedures for management
 - 2.3.3 Contact with employees
 - 2.3.4 Backup staff

* Kirvan, P. (2009). *IT Disaster Recovery Plan Template v 1.0*. Retrieved October 27, 2013, from <http://searchdisasterrecovery.techtarget.com/Risk-assessments-in-disaster-recovery-planning-A-free-IT-risk-assessment-template-and-guide> reprinted with permission of TechTarget®.com®.

- 2.3.5 Recorded messages/updates
- 2.3.7 Alternate recovery facilities/hot site
- 2.3.8 Personnel and family notification
- 3 Media
 - 3.1 Media contact
 - 3.2 Media strategies
 - 3.3 Media team
 - 3.4 Rules for dealing with media
- 4 Insurance
- 5 Financial and legal issues
 - 5.1 Financial assessment
 - 5.2 Financial requirements
 - 5.3 Legal actions
- 6 DRP exercising
- Appendix A—Technology DRP templates
 - DRP for <system one>
 - DRP for <system two>
 - DRP for local area network (LAN)
 - DRP for wide area network (WAN)
 - DRP for remote connectivity
 - DRP for voice communications
- Appendix B—Suggested forms
 - Damage assessment form
 - Management of DR activities form
 - DR event recording form
- Physical security to prevent unauthorized access to servers and DR archives
 - Servers may be co-located for convenience or dispersed for added security
 - Duplicate data recovery backups should be located in several different locations
- IT infrastructure threats (leveraged from cloud computing protected*)
 - Abuse and unauthorized use
 - Spam
 - Malicious code
 - Insecure application programming interfaces
 - Provisioning
 - Orchestration
 - Monitoring
 - Layered complexity
 - Malicious insiders
 - Integrated IT management vulnerability
 - Shared technology vulnerabilities
 - Disk partitions, CPU caches, GPUs compartmentalization is weak
 - Isolation properties are vulnerable
 - Data loss and leakage
 - Sharing of resources and access media with external customers and partners

* Rhoton, J., Clercq, J.D., and Graves, D. (2013). *Cloud Computing Protected: Security Assessment Handbook*. Recursive Limited.

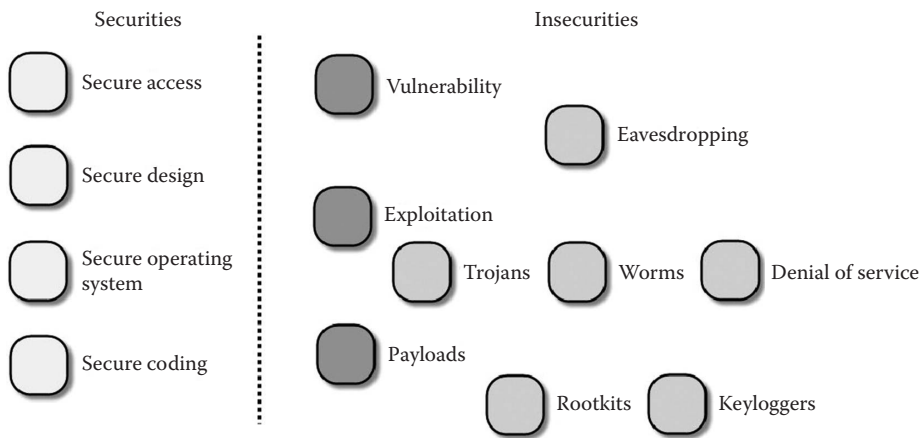


Figure 2.19 IT securities and insecurities.

- Service integration may be compromised
- Account, service, and traffic hijacking
 - Hijacking of user credentials results in
 - Communication interception
 - Wrongful transactions may be made
 - Authorized users may be blocked or simply monitored
 - Access can be a window for deeper penetration to controlled IT systems and data content

Most enterprise-level IT department provide some form of security architecture that describe how security countermeasures are positioned and how the interrelate with the overall IT architecture. The website SecurityArchitecture.org defines the systems attributes as confidentiality, integrity, availability, accountability, and assurance services.* IT insecurity consists of all threats such as vulnerability, exploitation, and payloads. IT securities and insecurities are shown in Figure 2.19.

Security can take the form of hardware, hardware based, and software solutions or a combination of all three. Once an IT system is compromised, it may be very difficult to remove the intruder without a complete system rebuild and sanitization of all data on the infrastructure.

Secured by design† computer security principles applied to the IT environment would include the following approaches:

Authentication: Ensuring the individual signed in is who they say they are. Authentication methods should consider preventions of replay; man in the middle or man in the browser-based attacks. It should also take into consideration loss prevention of tokens or code cards.

Least privilege: Provides lockout to portions of the IT substructure to those who need it to persons requiring access. This in effect compartmentalizes attacks to limited areas of the IT infrastructure. Every user may have access to the basic functionality and as security needs

* Open Security Architecture. (2006, January). *Definitions Overview*. Retrieved July 10, 2011, from <http://www.opensecurityarchitecture.org/cms/definitions>.

† *Secured by Design* is the official UK police initiative supporting “designing out crime” owned by Association of Chief Police Officers.

increase privileges in the system are successively locked down in a multitiered approach. In a server access setting, this may mean that only the system administrator has access to everything on the server and no one single user would.

Fail secure rather than fail insecure defaults: This is leveraged forward from safety engineering principles to prohibit making the systems insecure only in the case if a deliberate act made freely with knowledgeable forethought.

Unit testing and code reviews: Assuring that modules are secured when formal correctness proofs are not feasible or possible.

Automated theorem proving or automated deduction: Validating crucial software systems through the use of mathematical cross-check functions to prove the installed algorithms and code meet specification.

Chain of trust techniques: Ensuring loaded software is certified authentic by the system designers.

Microkernel implementation: Underlies the OS to apply labeling restrictions to the OS itself.

Cryptography: Defending interception of data between systems to reduce interception.

Firewalls: Providing protection from online intrusion.

Data integrity comparisons: Assuring data is the same between two sets of stored data and if different it was modified knowingly.

Endpoint security: To prevent data theft and infectious abuse and unauthorized use.

Critical to any form of DR mitigation is assuring that the backup media is validated as good before it is put into storage. Automated backup are great, but the plan must call for verifying the media. In addition, the plan must call for off-site storage of regular backups, not just storage in another room in the same or neighboring building. Natural disasters such as flood, fire, and wind can take out multiple buildings in close proximity to one another.

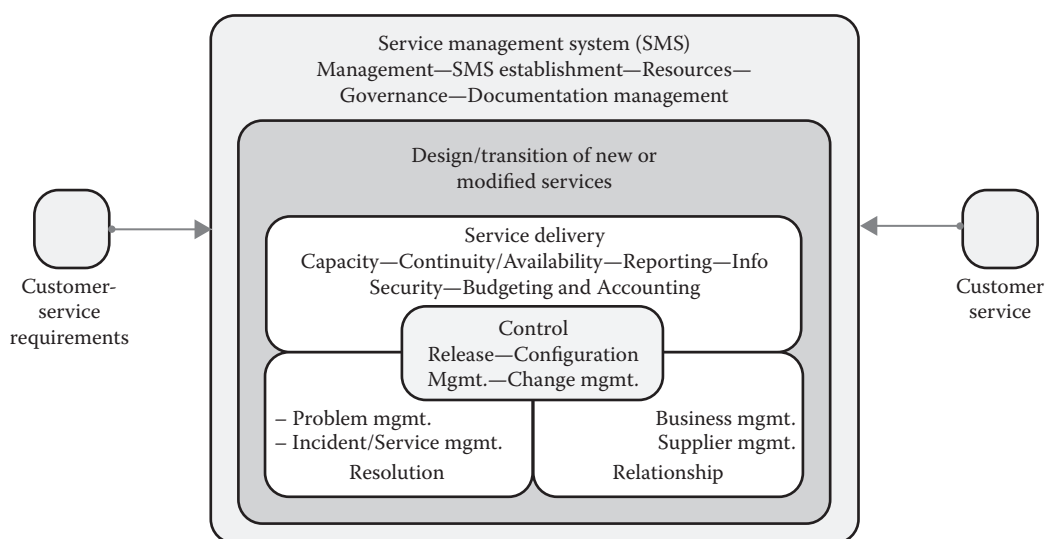


Figure 2.20 ISO 20000 and ITIL.

2.3.2.4 Platform Transitions

At times it may be necessary to transition from one IT backbone structure to another (Microsoft to Linux) or from one integrated database to another using the existing IT backbone. All transitions are difficult and the longer the transition time the more difficult it becomes.

An *everything at once* approach or a *piece-by-piece* (PBP) migration can be used. Both offer advantages and disadvantages depending on the migration type.

The focus of this book is CM so let us look at platform transitions and the related tool upgrades in light of data migration from a flat-file database structure used to record modifications to engineering artifacts to a multilayered database integrated PLM system. Such a transition must include management of all artifacts as discussed in ISO/EIA 10007:2003—Quality management systems—guidelines for CM, as it relates to ISO/EIA 20000-1:2011, IT—service management and *ITIL* (see [Figure 2.20](#)).

Perhaps the hardest aspect of all transitions is a lack of a systems engineering and CM perspective regarding the current state of the entire IT infrastructure. Software-to-software interface control drawings (ICDs), system-to-system ICDs, and giver–receiver lists as well as specifications describing the IT system as a whole and subsystem specifications describing each subelement have been nonexistent in the majority of companies reviewed prior to beginning this book.

2.3.2.4.1 Everything-at-Once Migration

Under the everything-at-once (EAO) migration concept the customer would continue to utilize the flat-file database structure as well as other standalone software tools and their related data structures. Maintenance of the tools and old codebase during such a migration is critical. This migration type is best managed with a fixed timeline, as the longer it takes to accomplish, the more expensive it becomes. Data maps will need to be validated between systems in a duplicate copy of the associated databases before they go live date of the PLM system. Conversion of nonelectronic historical data to electronic format such as a portable data format (PDF) needs to be scheduled and funded as part of the transition. Go-live activity will require IT services be made unavailable for a period of time, as the new PLM system is loaded to the active IT infrastructure instead of being housed in a sandbox/test environment, data migrations take place and system validation is done.

2.3.2.4.2 PBP Migration

The migration may be staged by function with an EAO migration plan for each. This concept allows for greater control over individual functional requirements as well as greater flexibility as the migration can be spread over several months with some savings in overall cost. The same degree of rigor is needed as with the EAO migration plus the added need to control data mapping to shared portions of the code and functionality. This will drive costs and will necessitate management of multiple deployments along with the associated server resources. Before each migration's go-live activity, all interfaces between the existing live dataset and the *to be migrated* dataset will need to be verified for cross-functional incompatibilities.

This migration by data module is not trivial and sound IT and CM methodologies and controls must be in place long before each submigration takes place. It is wise to prioritize migration of features on an elimination of effort duplication priority rather than a customer needs basis if cost is a consideration. In some cases, cost is not a player if one technology is no longer supported and the survival of the enterprise is at stake.

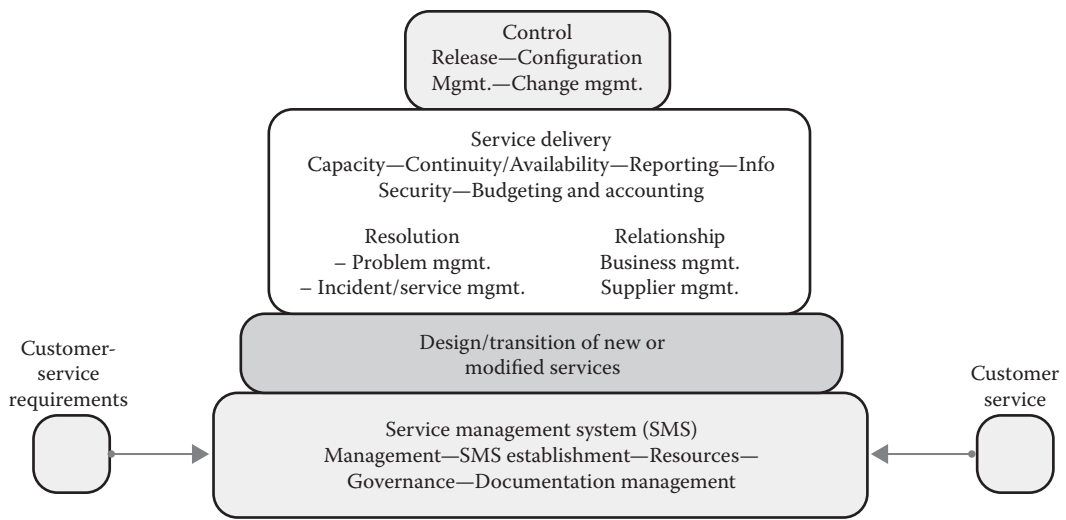


Figure 2.21 ISO 20000 and ITIL pyramid.

2.3.2.5 Importance of CM with Modular Systems

Central to the IT function is sound CM practices identified under the control function. Figure 2.21, ISO 20000 and ITIL, is a mahjong tile view of the interrelationships involved. Rotated in a 3D space, it forms a pyramid and provides us with a more visual representation of the specific hierarchy of functions involved.

CM in modular systems while different in specific context is no different than CM of any other system when viewed from the systems level. Figure 1.1, U.S. DOD CM process, can be viewed as a conceptual flow that can be scaled to meet specifics addressing the need at hand. Just like other systems, modular software systems merge multiple elements (software and devices) to make a complete software application. These components are integrated into a larger application. A typical home-based computer system consists of monitors, computer, printer, keyboard, mouse, wireless router, camera, speakers, scanner, and so on. Each of these items may be designed and fabricated by different companies yet each is critical to the overall performance of the system. Each item is a component or module of the modular system as a whole yet each is a system by itself.

Modular application development and integration into an enterprise application consists of COTS integrated together to form the entire system. Modular software development often made up from what is known as a “best-of-breed” COTS software components interfacing through software and hardware interfaces.

Logical boundaries, components, and applications are established. Applications communicate through established data protocols often set up by the OS developer for the software that is compatible with that OS. COTS manufacturers follow CM methodologies throughout the product life cycle. Similar application of CM methodologies should be followed for the IT landscapes evolving life cycle. The difference is that the IT system life cycle is easier to understand from an ecological viewpoint whereas the individual COTS components are viewed as a species viability viewpoint. Using printing as an example impact printers (type box, wheel, and ball) succumbed to dot matrix printers that in turn succumbed to line printers (drum, chain or track, bar, and comb)

again in turn succumbed to plotters, liquid ink (electrostatic), and laser. The IT modular framework ecology did not change. An ecological space still existed for a *printer* as part of the ecological mix. The specific COTS species occupying the ecological space was supplanted time after time by one that was better able to survive in that space.

Until recently modular system management was relatively straightforward in most enterprise settings. To facilitate security of the IT backbone, many companies have instituted strict policies regarding the installation of user-purchased specialized software or freeware despite the point in time increases in individual user productivity. A recent article by Victor Luckerson* discusses the move in many market segments of allowing employees to work using personal devices (laptops, tablets, phones, etc.) Bring your own technology policies facilitate less expenditure on the part of the company, eliminate associated depreciation, and generally faster upgrade of the interconnected modularity of the system. Drawbacks include some loss of control with respect to managing company data and other standard IT security issues. Depending on the industry, the costs savings versus risk posture is such that the convenience and cost aspects trump other concerns.

CM activities span the IT electromechanical age, electronic age, and information age. IT interfaces and mission needs statements often do not reflect this. Due to customer requirements many CM data, records, and release activities require the use of paper and automated systems. IT in the cleanest sense departs from the current definition. Today, many consider IT as the management of computer-based information systems and all that entails. This brings forth images of paperless workplaces with data flowing seamlessly into and out of all aspects of the enterprise through the wonders of bluetooth connectivity to cloud-based technologies. The paperless world has yet to become reality in many market sectors. It is not yet fully embraced by many IT organizations. Some still require certifications signed in ink and either scanned with e-mail or faxed

* Luckerson, V. (2013, November 11). Bring your own tech: Why personal devices are the future of work. *TIME* (U.S. Edition).

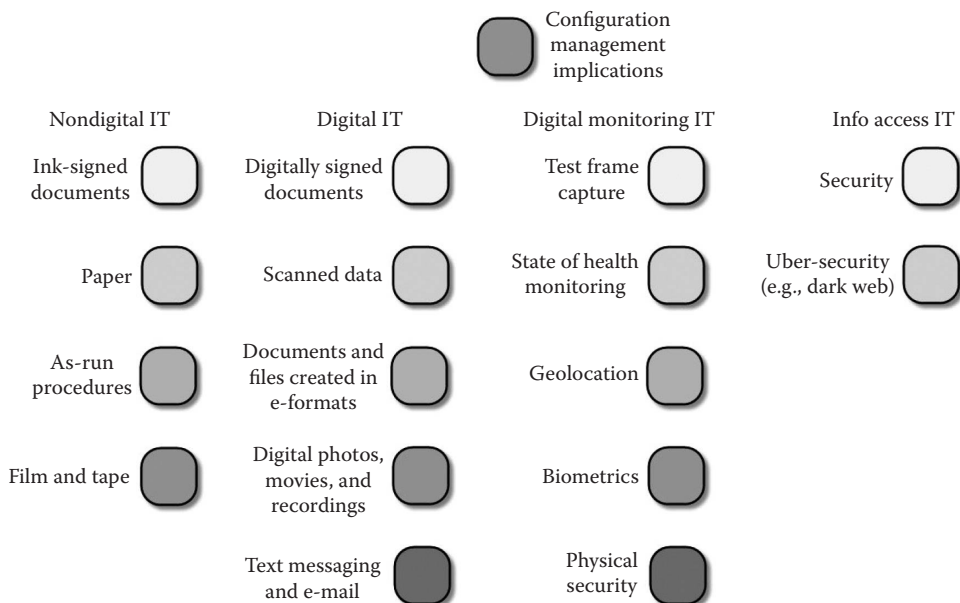


Figure 2.22 CM of the IT environment.

transmission and the original sent via postal or other carrier service prior to assigning access codes. This was observed as recently as 2013 as a common practice between two fortune 500 corporations. There are also CM implications presented by Deep Web technologies and successive encryption removal for uber-secure point in time transactions and information transmission. These will become increasingly important as we enter into the world of 3D technologies such as onsite growth of medical transplants keyed off the recipient's specific genetics rather than waiting for a donor and the potential of other human capability upgrades come online and merge many aspects of CM, security, and IT protection of critical to life organ models.

Management of the configuration and its documentation by a configuration manager necessitates that the practitioner work in both the old and new definitions of IT. In a supposedly digital environment there is a surprising resistance to utilize software tools for CM. This mix of hard copy signatures and recorded test results with signatures and stamps on paper, technological edge applications used for performance monitoring, and relatively standard digital IT is shown in [Figure 2.22](#). Although not all aspects are present at any single time, management and security implications are critical and should be addressed. The more decentralized the organization and the wider the modularity, the more critical this becomes.

2.3.2.6 IT Case Studies

Two case studies are presented to illustrate the complexities involved in management of configurations in IT.

2.3.2.6.1 Case Study 1—Software Suite Decision

A provider of products to the commercial and government sectors was under contract to deliver associated data to its government programs in specific file formats and application software versions. All contract data requirements list items were subject to government acceptance under the contract. Penalties for not doing so constituted a violation of the contract data deliverable requirements and contract termination that included the contractor paying all re-procurement costs to open competition and award the contract to another vendor.

The IT organization was not tied into the revenue-generating element of the enterprise and pushed out an upgraded software suite that allowed downward versions to be opened but did not provide for saving a file in the previous extension (e.g., opening mydoc.ext and only being able to save as mydoc.extc).

Because the extension and software version was contractual, this software suite upgrade resulted in issuance of a cure notice* associated with default. The IT action was reversed in time to avoid termination of the contract but not without financial penalty.

The IT professional responsible stated, "Software suite decision are the purview of IT and should not be mandated by our customers."

The root cause of this incident was a lack of a sound requirements definition and CM practices in the IT organization. Decisions to push out an upgraded software suite were based on a perceived cost savings if machine-based software were replaced with an intranet (internal network) solution with machine interfaces to the intranet (a precursor to cloud computing). Research into

* Federal Government, U.S. (2013). *U.S. Federal Acquisition Regulations 52.249.X, Termination for Default subpart (a)(1)ii and (a)(1)iii*. U.S. Government.

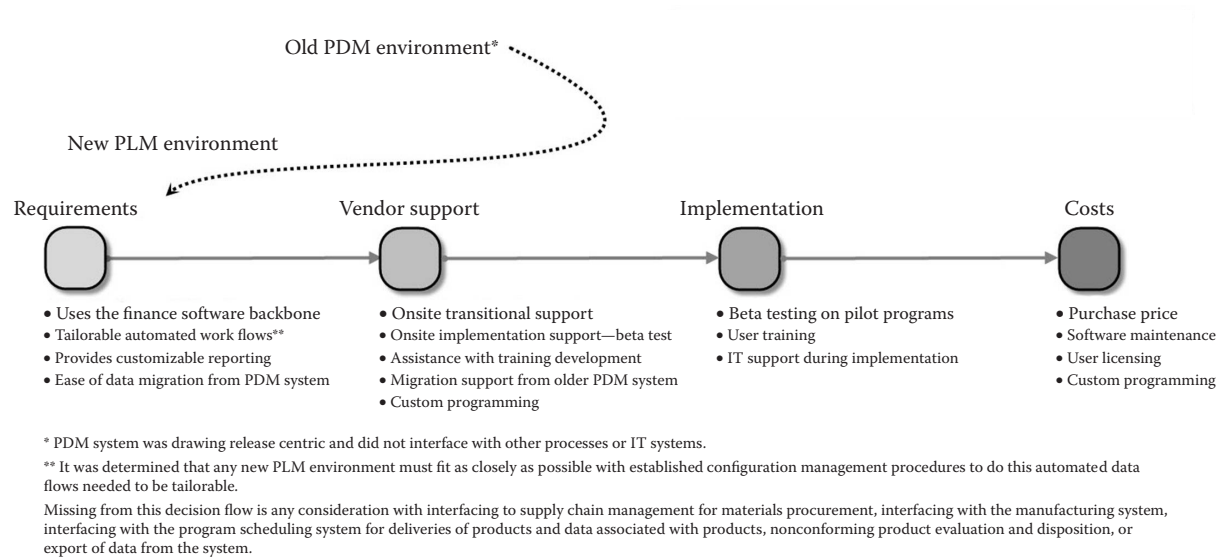


Figure 2.23 PLM procurement decision tree.

this case study shows no evidence that revenue-generating functions of the enterprise were consulted in the decision.

2.3.2.6.2 Case Study 2—PLM Decision

The IT decision for the acquisition of a PLM system to replace its aging PLM system was based on [Figure 2.23](#) decision tree.

The enterprise financial system software had recently been purchased. It used a different data backbone than the rest of the company and the chief financial officer (CFO) mandated that other systems infrastructure use the same backbone. This was seen as the driving consideration and the winning PLM system was compatible with the financial reporting systems backbone. It also provided management reports based on metadata fields that the CFO had determined would be beneficial to the program managers based on metrics (s)he had used at a previous employer.

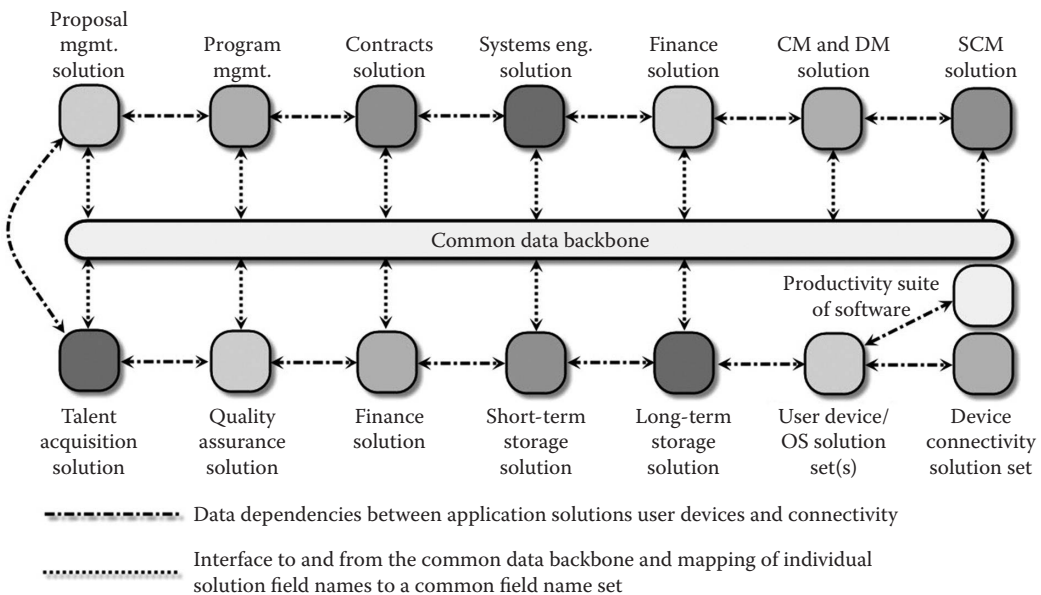
- Total number of drawings estimated
- Total number of drawings released to date versus the drawing releases planned
- Total number of drawings estimated versus total number of drawings used
- Average number of engineering changes per drawing

Several one-solution vendors were discussed and rejected without consideration, as the single solution included a finance module. The winning PLM system had no ability to schedule multiple deliverable data requirements, export documentation other than document by document manually entered requests (i.e., the top assembly item identification could not be entered and all drawings at their latest revision associated with the entire product structure be output in a single command. Each drawing had to be deduced from an indentured bill of material report and output individual user requests). Because the product data/life cycle management (PD/LM) system had been *drawing release* centric, other functionality was not considered. After implementation, this lack of broad reaching infrastructure functionality was addressed in what was deemed a best-of-breed approach versus a one-solution strategy ([Figure 2.24](#)).

As the enterprise matured, it found that the cost of best of breed was substantially greater than investing in a single solution. Costs to maintain best-of-breed interfaces with the common data backbone increased over time as individual solution providers updated their product necessitating constant update of the data field to backbone interface. Management of the entire IT infrastructure also required expenditure of resources as individual solution providers also moved from machine-based to web-based software interfaces at times reorganizing the software interfaces and workflows and interdependencies between the solution sets. A side effect of this was a noticeable increase in enterprise wide cross-functional procedure updates and a growing frustration in the user community. This frustration was referred to as “noise in the system.”

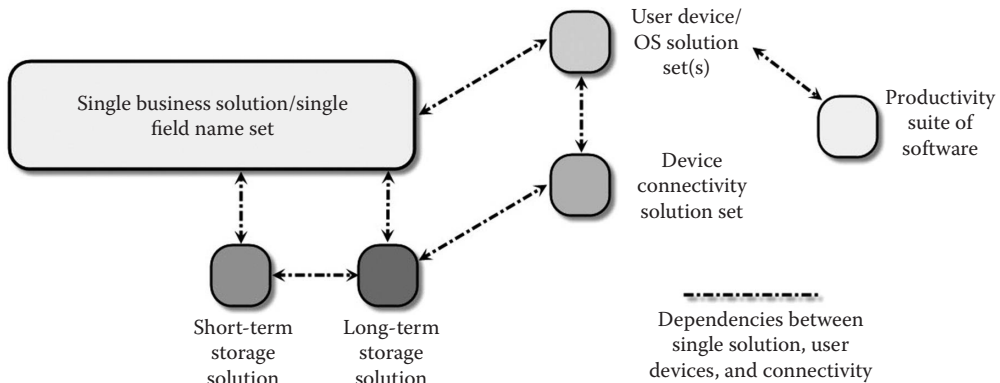
Throughout the implementation of the best-of-breed approach, IT saw no need to develop a plan to manage the configuration of the entire infrastructure. User needs were met, as users were often unaware of the needs of other organizations and worked at cross purposes. A CM plan and a best-of-breed CCB could have easily halved implementation costs. Had the investment in the initial financial system been declared a mistake, an integrated one solution software suite could have been implemented with an eventual savings of more than 30% savings long term just in software provider costs (savings = writing off the financial software + purchase and maintenance of the one solution suite).

The metrics determined by the CFO were not valid. The first was dependent on the computer-aided design (CAD) systems. The others could be easily manipulated by the design team.



IT Staff increases with the complexity of the best-of-breed infrastructure and the number of upgrades to each software solution. New solution sets must be mapped to the common data backbone.

(a)



IT staff decreases with the single business solution infrastructure but the solution submodules may not be optimal for the needs of each organization supported.

(b)

Figure 2.24 (a) Best-of-breed versus (b) single business application IT strategies.

- Total number of drawings was estimated.
 - Many firms use this metric despite increasing sophistication in design and modeling tools. It evolved out to the paper-drafting system.
 - Drafting boards allowed multiple details and assemblies to be shown on a single drawing. This facilitated the evaluation of the finished assembly on one set of drawings and associated lists.
 - As CAD systems evolved, CAD models became more sophisticated necessitating more drawings to reflect the same number of details and assemblies that could be shown on a single paper drawing set.

- At the firm under discussion.
 - Drafting Board—30 details and/or assemblies = one drawing
 - AutoCAD 12—30 details and/or assemblies = six drawings
 - AutoCAD Inventor—30 details and/or assemblies = nine drawings
 - Solid Works—30 details and/or assemblies = 21–30 drawings
- Over time the number of details and assemblies remained constant.
- Total number of drawings released to date versus the drawing releases planned.
 - Once engineers found out the metric was being used, drawings with minimal details were released (often with no content) to meet release schedules.
- Total number of drawings estimated versus total number of drawings used.
 - Once engineers found out the metric was being used, drawings with more details or assemblies than advisable were released to meet drawing count often with instable models.
- Average number of engineering changes per drawing
 - Once engineers found out the metric was being used changes were saved and packaged to show improvements often to the detriment of parts procurement and manufacturing needs.

CM could have played a key role in not only developing sound metrics, but by establishing requirements to be utilized in the PLM choice that actually met engineering and CM needs. They were excluded from much of the requirements development process and the resulting poor decisions proved to be expensive lessons learned. Chapter 10 will delve deeper into other examples of where CM was excluded and could have added value to the decision-making process.

These case studies reflect the limitations of a supporter mindset in the IT organizational structure as a close-knit organization that is secure from outside intervention and geared to respond to user needs based on their requests as described by Langer and York.* The disconnect between how IT sees itself and how it best serves the enterprise may be due in part to its developmental history.

Many software–user interfaces are moving to a cloud-based or cloud implementable-based user interface hosted on the enterprise IT backbone regardless of the sophistication of the IT infrastructure as a whole. Although grids may be deployed as part of an IT cloud or noncloud strategies for meeting IT needs. Where the struggle is most complicated is finding the right mix of IT resources to meet enterprise needs. No single resource strategy will meet all needs (lead strategy, lag strategy, or match strategy) unless a strong CM element is present. Demands for IT resources can be classified for our purposes in the two broad categories of capability demand and capacity demand.

2.4 Overhead, General and Administrative, and Other Cost Elements

The contents of this section are designed to present in an easily grasp format, an introduction to cost element, techniques, and examples to further the understanding of later content.

* Langer, A.M., and Yorks, L. (2013). *Strategic IT: Best Practices for Managers and Executives (CIO)*. John Wiley & Sons.

Its content draws on personal observations, from referenced materials and from managerial accounting.*

Reviews of multiple business segments have revealed a growing lack of business acumen by those involved in CM. This is not to be confused with the broader definition of managing the configuration. This has resulted in companies introducing changes in their policies, procedures, and practices that work at cross purpose to not only sound business practices, but to meeting financial responsibilities on contracted work and to company stockholders.

Specifying the addition of a single mandatory signature for the release of engineering drawing has far reaching profitability impacts. Time studies were performed in an industry segment building one-off machines of great complexity to determine the average length of time required to log into a PD/LM system, evaluate an ECO, the associated drawing and part objects and approve it electronically. It was found that for minor-to-medium-level complexity, such a review could not be done in less than 30 seconds. Next, the total number of such ECOs in the PD/LM for programs of various sizes was examined against total engineering objects at the same companies. The average number of ECOs per piece of engineering was found to be 6.5 with a range of 1.2–48. The average number of engineering objects (e.g., drawings, specifications, statements of work, test and other procedures, plans, etc.) per program was 2,600 with a range of between 300 and 29,000.

Using a sum of \$200.00 for each hour of direct hour worked (includes salary, benefits, and other associated indirect costs). One minute is valued at \$3.33 ($\$200/60 = \$3.33$) and one additional is valued at \$1.11. ($\$3.33/3 = \$1.11$). Leveraging this per signature cost over the number of ECOs multiplied by the average number of engineering object gives us the average impact to the average program.

$\$1.11 \text{ per signature} \times 6.5 \text{ ECOs per object} \times 2,600 \text{ objects per program} = \$18,759 \text{ per program}$

The companies involved had a total of 1,496 programs impacted

$\$18,759 \text{ per program} \times 1,496 \text{ programs} = \$28,063,464 \text{ (impact across all companies studied)}$

This \$28,063,464 could have been used for risk reduction, budget or schedule maintenance, and be booked as profit if on a firm-fixed price contract.

Leveraging the information from the study further, the average time to locate an object on a screen and click a mouse button was found to be an average of five seconds. Using the same \$200 for each hour of direct hour worked leads us to a cost per click of

$$\left(\frac{\$200 \text{ per hour}}{60 \text{ seconds}} \right) \times 5 \text{ seconds} = \$0.27 \text{ per click}$$

Keystroke data was reviewed over a five day period for a single individual performing CM activities. The average number of times the mouse was clicked was observed to be 753 eight hour day. This equates to \$208.95 or \$209 rounded per day just to move the mouse and click.

* Maher, M.W., Stickney, C.P., and Weil, R.L. (2011). *Managerial Accounting: An Introduction to Concepts, Methods, and Uses*. Cengage Learning.

We assumed the individual studied is the norm and that great savings and efficiencies can be realized through establishing file structures and data management flows that allow access to data with a minimum of file nesting.

The above are but two simple examples of why some business acumen is required by those performing CM functions. Accounting is part of the information system of any company and CM implementation contributes to EBIT or it detracts from it. CM practitioners should not only understand how their action or inaction impacts EBIT, but they should understand how to read a financial statement. What follows is designed to impart a rudimentary grasp of the subject as it applies to this book. It is not an attempt to present the subject in depth.

Costs can be divided into two categories generally as direct and indirect costs. As with the section on IT, some definitions for terms used in this book are required at this point to facilitate the discussion that follows.

Cost objective: Any revenue-generating activity such as a product, service, program, or other activity.

Direct cost: All costs directly associated with a single cost objective.

Variable cost: Fixed and variable costs not directly associated with a cost objective. Indirect costs include G&A, OH, bid and proposal (B&P), independent research and development (IR&D), and authorization for expenditure (AFE) are accounting terms. We will use AFE as authorization for expenditure and not average funds employed throughout this book.

B&P and IR&D* are presented from a basic perspective and may be explored in more depth through other resources.

Paul Bauman Jr. states:[†]

Overhead and G&A (General and Administrative) are two of the most loosely used terms in government contract accounting. Everyone uses them ... few really know what they are.

Let's start with what is the same. Both are indirect costs. That is, they are costs that you incur in the course of running your company that you cannot easily (directly) charge to a particular contract. For example, rent, office supplies, accounting, management, etc.

The difference is that G&A refers to that portion of your indirect costs that apply to your whole operation; whereas overhead applies to a portion of your operation. Examples of overhead are: engineering overhead, labor overhead or manufacturing overhead, material handling, sub contract management. All apply to a specific function or cost within the organization.

Overhead pools are selected based on the nature of the operation. Generally you select different overheads if the costs associated with different parts of your operation are different. For example, if your projects entail a combination of in house labor and sub contract labor you might notice that your in house labor entails indirect costs

* Leveraged from information contained in United Technologies Corporation. (1998, November). *Independent Research & Development and Bid & Proposal Costs*. Retrieved November 3, 2013, from www.utc.com/StaticFiles/UTC/StaticFiles/proposals_english.pdf.

[†] Baumann, P. (2007, April 24). *What's the Difference between Overhead and G&A?* Retrieved October 3, 2013, from <http://www.theasbc.org/news/15315/The-ASBC-Community-News-Whats-the-difference-between-Overhead-and-GA.htm>. Reprinted with the permission of the author.

(benefits, payroll taxes, leave, etc) that do not apply to your sub contracts. On the other hand, you might notice that there is a cost for management of the sub contracts that is not present for in house labor. In this case you might want to set up in house labor overhead and sub contract management overhead pools. Meanwhile you collect those costs that apply across the board (accounting, business development, etc) into a common G&A pool.

To get the cost of a job or a department in your company you take the sum of the direct costs (those you charge directly to the job) and a fair share allocation of indirect costs. Using our example above, your labor costs for a job would be the sum of direct labor (salaries you pay) plus a fair share of labor overhead plus a fair share of G&A. Meanwhile, your sub contract cost for a job would be the sum of the sub contract cost, plus a fair share of sub contract handling and G&A.

For our purposes

B&P: Part of the G&A rate. Those costs incurred in the preparation, submittal of solicited, and unsolicited proposals to government and commercial customers.

IR&D: Part of the G&A rate. Basic research toward increased knowledge of a science. Applied research exploiting the scientific potential or improvements in technologies, techniques, materials, and methodologies/processes; development of scientific and technical application in product design, development, and test and evaluation of new or improved products and services; and systems and concept formulation studies to identify new or modified systems, equipment, and components.

The definitions that follow for OH and G&A are specific to a particular company. They are simply an example but not rules that always apply. It depends on the mission and expenses of the company. There is no rule that says a given cost is always G&A or always OH.

OH: OHs are an ongoing expense required for any business to function. As noted earlier, OH costs do not generate revenue. They can be fixed or indirect. Fixed OHs are thought of as static and do not change substantially based on activity. Indirect OHs vary based on activity.

- Insurance
- Supplies and manufacturing expendables
- Taxes
- Company (corporate) travel unrelated to a specific contract. In some cases, travel may be part of the G&A rate if associated with a G&A function such as accounting or contracts rather than an OH item.
- Depreciation
- In some cases factory support labor
- Inventory management
 - Purchased materials and parts not worked on
 - Work in process
 - Finished goods inventory

It is a common practice to divide OHs into pools separating corporate from company and business unit. OH pools for department supervision, depreciation, training, and fringe benefits. These may be further subdivided based on organizational responsibilities under a business unit such as engineering, manufacturing, and material handling. OHs are allocated over the entire

revenue producing labor (labor charged direct to a cost objective) hour base. In the case of engineering, OH the allocation would be allocated over the total engineering direct labor hours.

G&A: Any expense incurred for managing and administering the whole business unit and allocated to final cost objectives. These expenses in the corporate ledger and financial report will generally appear under operating expenses. G&A may include the following:

- Rent
- Insurance
- Utilities
- Human resources
- Accounting
- Contracts
- Consulting expenses
- Public relations
- Legal
- Corporate management
- Equipment depreciation
- Outside audit fees
- Subscriptions
- IR&D
- B&P

Management of the configuration of a building or for the design, development, integration, test, and installation of a new item as a capital expenditure or updating manufacturing infrastructure will require the CM practitioner to size the strategic and tactical implementation to the management need.

Returning to the broader aspects of cost accounting several sound business practices need to be observed to make direct and indirect cost data usable. The following is leveraged from paragraph 8-400 of the U.S. Defense Contract Audit Agency (DCAA) Contract Audit Manual.* Portions of the definitions are taken in their entirety from the DCAA Contract Audit Manual others have been simplified to meet the scope of this text.

Consistency in estimating: Estimating, accumulating, and reporting of costs should be applied consistently.

Consistency in allocating: Costs incurred for the same purpose are allocated the same way to ensure that each type of cost is allocated only once and on only one basis to any contract or other cost objective. All costs incurred for the same purpose, in like circumstances, are either direct costs only or indirect costs only with respect to final cost objectives.

Allocating home-office expenses to segments: Expenses incurred for specific segments are to be allocated directly to those segments. Expenses not directly allocable, but possessing an objective measurable relationship to segments, should be grouped in logical and homogeneous expense pools and distributed on allocation bases reflecting the relationship of the expenses to the segments concerned.

* DCAA, U.S. (2013). *Cost Accounting Standards, Defense Contract Audit Agency (Chapter 8-400 Section 4)*. U.S. Government.

Capitalization of tangible assets: Capitalize the acquisition cost of tangible assets in accordance with a written policy that is reasonable and consistently applied.

Unallowable costs: An expressly unallowable cost is that which is specifically named and stated to be unallowable by law, regulation, or contract. It must be separately accounted for and not allocated to a contract.

Cost accounting period: The cost accounting period used by a contractor must be either its fiscal year or a fixed annual period other than its fiscal year (e.g., a calendar year) across its entire business base.

Standard costs for direct material and labor: Such practices must be written and the established labor-rate standards and variances against the standard recorded and adjusted yearly (e.g., fabrication, minor assembly, final assembly, and test may have a standard rate). The functions performed within each department are similar, the employees involved are interchangeable, and the inputs of direct material are homogeneous. Each variance account is distributed annually on the basis of the department's labor dollars. The practices are stated in writing, consistently followed, and the standard costs are entered into the books of account.

Cost accounting for compensated absence: Compensation paid by contractors to their employees for such benefits as vacation and other leave should be assigned to the cost accounting period or periods in which the entitlement was earned.

Depreciation of tangible assets: Estimated residual values must be determined for all tangible capital assets or groups of assets. The residual values must be deducted from the capitalized value.

Allocation of business unit G&A expenses to final cost objective: G&A expenses must be grouped in a separate indirect cost pool and allocated only to final cost objectives. For an expense to be classified as G&A, it must be incurred for managing and administering the whole business unit.

Accounting for acquisition cost of material: The cost of material and allocation to cost objectives must be done according to written statements of accounting policies and practices. If the material is procured for a single cost objective, it should be allocated as direct, and if it is considered shop supplies, it can be an indirect cost allocation across the work center.

Composition and measurement of pension costs: There are basically two kinds of pension plans: defined contribution plans and defined benefit plans. A defined contribution plan provides benefits to retirees according to the amount of the fixed contribution to be made by a contractor. In a defined benefit plan, contributions made by the contractor are calculated actuarially to provide preestablished benefits. The cost of benefits under a *pay as you go* plan must be measured in the same manner as the costs under a defined benefit plan.

Adjustment and allocation of pension costs: Actuarial gains and losses represent differences between actuarial assumptions and need to be properly accounted for with the result that pension obligations can be met and clear and concise criteria for determining the funding status for pension plans exists and can be tracked as a financial liability.

Cost of money: There is a cost associated with borrowing money for capital improvements. This cost of obtaining facilities capital is a contract cost and commonly referred to as the "cost of money." Criteria for measuring and allocating an appropriate share of the cost of facilities capital identifiable with the facilities employed in a business should be established.

Deferred compensation: Deferred earnings should be paid out at the same rate that they were earned (e.g., if banked overtime was earned in 2013 and paid in 2018 the payout should reflect the salary scale at the time the hours were banked).

Insurance: Records to substantiate the amounts of premiums, refunds, dividends, losses, and self-insurance charges. They should also show the frequency, amount, and location of actual losses by major type of risk.

Cost of money as an element of the cost of acquisition: The cost of money applicable to the investment in tangible and intangible capital assets being constructed, fabricated, or developed for a contractor's own use shall be included in the capitalized acquisition cost of such assets.

Allocation of direct and indirect costs: A written statement of accounting policies and practices should exist for classifying costs as direct or indirect, which shall be consistently applied; indirect costs shall be accumulated in indirect cost pools, which are homogeneous; and pooled costs shall be allocated to cost objectives in reasonable proportion to the beneficial or causal relationships of the pooled cost-to-cost objectives.

Accounting for IR&D and B&P costs: Costs for IR&D and B&P activities are part of G&A and should be accumulated by project and allocated using the same procedure as G&A.

Another concept that configuration managers need to understand is that of cost estimating relationships (CERs). CERs are a method used to estimate future costs based on past performance. A CER is also referred to as a factor or a factor applied to a base. Across the companies studied use of a CER that included for CM was found to be inconsistent. Those that used CERs accounted for every hour worked on a program regardless of the nature of the labor from an employee remuneration aspect (e.g., all hours, paid or unpaid were recorded in the timekeeping system against the cost objective worked on). Since all CM hours were accounted for a valid cost estimating relationship could be generated.

Generally, CERs for related aspects of a program, product, or service are formed using the largest labor element of cost, wherefrom the item factored costs are determined. The following example is provided as a means of explanation.

A contractor has been tracking all costs associated with its programs for a period of time. The total number of engineering hours per year was discovered to have a consistent relationship with the number of individual items (parts, assemblies) designed and produced. Nonengineering direct labor was then evaluated against the engineering labor and also found to have a consistently relationship over time. Based on this evaluation a CER was developed based on the number of individual items.

Each individual part = 280 hours direct engineering labor

280 hours direct engineering labor = 9 hours configuration management

5 hours of mission assurance

2 hour of reliability

0.5 hour of safety

1 hour of parts, materials, and processes

After validation the company used a CER of 297.5 hours per part that included engineering, configuration management, mission assurance, and reliability and parts, materials, and processes ($280 + 9 + 5 + 2 + 0.5 + 1 = 297.5$ hours). This was validated each year and adjustments made resulting from changes to business practices and efficiencies.

The largest drawback to developing any CER is not having the total cost basis of the item. One company studied was evaluating the implementation of a CER similar to the earlier example. Historical data was gathered for actuals with the result of a CER (adjusted to the earlier example)

of 196.35 hours per part that included engineering, CM, mission assurance, reliability and parts, materials, and processes. As the accounting system did not account for every hour spent and those working on the program were donating 20 hours a week for every 40 charged, the CER was 33% lower. Had it been implemented every program would be under estimated by one-third.

Occasionally, companies will attempt to estimate cost using parametric estimating methodologies to establish the cost of a new item. In its simple form, a parametric estimate is based on the premise that if it looks like a box $12'' \times 12'' \times 36''$ and we just built a box $12'' \times 24'' \times 36''$, then the new box should cost half as much as it is half the size. When applied to complicated and often cutting-edge technologies, it can cause significant cost issues. During the 1990s, bids were placed by major corporations to repurpose aging U.S. government resources for another purpose. In one instance, a proof of concept contract was awarded for conversion of two government assets to a company with a bid using parametric estimating. The bid was evaluated by both internal and external sources of the company for reasonableness prior to award. After the performance started, it was discovered that assumptions used to create and validate their parametric estimate were flawed. The company had underestimated the effort by over 70%.

2.5 Intellectual Property

IP is that broad category of tangible and intangible things that encompasses everything created as products of the human intellect. IP can be categorized as personal, familial, guild, tribal, religious, company, and, in some cases, national.

Personal: Inventions, arts, communications, photos, tweets, and anything posted on social media

Familial: Recipes, traditions, and unique to family ways of doing things

Guild: Inventions, trademarks, trade secrets, traditions, stories, and rituals

Tribal: Totems, beliefs, traditions, stories, and rituals

Religious: Icons, beliefs, books, codes, mysteries, and rituals

Company: Inventions, trademarks, and trade secrets

National: Identity and monopolies

Known as “traders in purple,” Phoenicians first produced Tyrian purple from the spiny dye-murex, the banded dye-murex, and the rock-shell murex. The process was Phoenicians’ IP. Despite all attempts, no evidence that Phoenician sails were ever dyed with Tyrian purple were found by the authors. It is believed that as it was so valuable in trade, it was not used for this purpose.

2.5.1 What Is IP?

IP brings up recollections of things such as copyright law, trademark law, patent law, trade secrets, *Sui generis*, and public domain. All these exist to protect the interests of one party from being encroached upon by another party. The understanding of each item and their application often involves a broad based cultural mindset. In some countries, the application of a thing to a new purpose not intended by the original patent holder may be given a new patent (e.g., the application of a thing and not the thing itself is patentable). A different technical approach may also allow different people to be granted copyright for seemingly identical works. The different types of IP are shown in [Figure 2.25](#).



Figure 2.25 Types of intellectual property.

In the United States, there are 45 categories or classes of trademark. Product (or goods) classes account for the first 34. Service classes account for the rest. Use of a trademark under license may be granted to one firm, whereas the true owner of the original trademark is another. Licensing of a trademark originally held for include Class 12: vehicles and products for locomotion on land, water, and air to others for; Class 14: jewelry products; Class 21: housewares and glass products; Class 25: clothing and apparel products; and Class 28: toys and sporting goods.

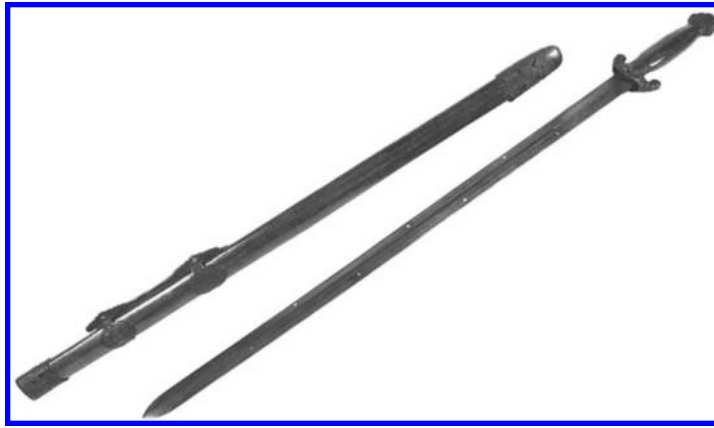


Figure 2.26 Jian sword.

2.5.2 What Drives IP?

Seeking and asserting IP rights provides the holder certain rights to these rather intangible assets and forms of legal remedies for encroachment on them in a court of law. The application of markings notifying others of the rights held by the owner is critical. Enforcement relies on the reader to respect those rights. Enforcement of rights under cases of infringement at times is difficult and costly.

2.5.2.1 Internal

IP rights are protected as they provide the company an edge because they compete within the ecological market niche they inhabit. In some cases, the edge is perceived and in others it is factual. Knowing internally that the copyright on the phrase “Now contains formula ZC241 to reduce your salt intake” on a food container is a perceived competitive edge by the consumer. Internally it is known that formula ZC241 is potassium chloride (also known as KCl).

Holding dear the trade secret of how to create carbon nanotubes from lint would be a factual edge. Such factual competitive edges may protect the company’s products in the marketplace for several years.

2.5.2.2 External

From a practical aspect form, IP have existed external to the personal, familial, guild, tribal, religious, company, and national consideration since recorded time. For the purposes of the remaining discussion in this chapter, these will be referred to as “entities.” It exists anytime one entity has some knowledge it wishes to keep from another. Personally, it may be ones true name rather than public name or other attribute that protects ones identity or possessions. Between siblings, it may be the location of an item that if found could do actual or perceived harm if found or related to a person of authority. Between guilds, it may be a particular process held

only by masters of the trade. Between tribes, it may be the location of a relic or “rites of passage” from child to adult. From a religious aspect, it may be the location of or the ability to translate sacred writings or concepts or the location of revered objects. Nationally, it may be the ability to defend or attack.

Those nations with advanced technology desired to keep it away from others who did not possess it and took steps to do so. Entities that could make weapons of copper had an advantage over weapons made of stone. Entities with bronze had an advantage over copper and so on until the present. This weapons technology history is evident in the sword types in some forms of martial arts today. Fighting with the single hand forged iron Jian sword (Figure 2.26) required precise movements so not to snap it along its length. Forged iron gave way to steel three layer blade providing greater strength and flexibility. This technology was not available to the west until the first century.

2.5.3 How It Applies to CM

CM and data management activities are central to the management of documentation. In many enterprises, the configuration manager is the last set of eyes to look at a document prior to formal release. Working in close association with contracts and legal (often IP legends are generated by and rules for their application fall to the legal department) the configuration manager assures the proper legend is on the document. Should the item being produced be subject to governmental marking requirements where certain rights are passed to the government company compliance with those marking requirements are also verified.

Typical items looked at prior to release include the following:

- Copyright marking relevant to unpublished works
- Proper use of trademarks
- Intellectual rights statements
- Citations pertaining to licensed technologies
- Technology transfer identifiers required by a Technology Transfer Control Plan (TTCP)

2.5.4 Why Is It Necessary?

The World Intellectual Property Organization Treaty* enacted by U.S. 17 U.S.C. §§ 512, 1201–1205, 1301–1332; 28 U.S.C. § 4001 defines IP generally as rights in relation to literary, artistic, and scientific works; the performance of performing artists, phonograms, and broadcasts; inventions in all fields of human endeavor; scientific discoveries; industrial designs; trademarks; geographical indication, service marks, and commercial names and designations; and all other rights resulting from intellectual activity in the industrial, scientific, literary, and artistic fields.

As *property* rights, IP rights are exclusionary—so that third parties are prohibited from their use and exploitation.

* World Intellectual Property Organization (WIPO). Retrieved September 4, 2014, from http://www.wipo.int/export/sites/www/freepublications/en/intproperty/450/wipo_pub_450.pdf.

With normal property rights then, the nature of the object in which property rights subsist gives it a monopolistic character. For example, if the property is a bicycle, only one person can own and use it. If one person is using the bicycle, no one else can do so.

However, IP rights are fundamentally different—concurrent use of inventions or copyright materials is possible. For example, one invention could be produced by a number of manufacturers and used by hundreds or thousands of people. A musical performance can be recorded and then broadcast and then replayed hundreds of times by hundreds of different people. Use and/or performance do not diminish value or cause the IP to perish, unlike the position with most normal property.

An easy way to distinguish the different categories of IP rights from each other is to recognize those that are *hard* and those that are *soft*.

The World Intellectual Property Organization goes on to define copyright, database rights, unregistered design rights, and unregistered trademarks, trade secrets, and confidential information as soft rights. These require no registration, no fee, and no formalities. They arise automatically—you get *something for nothing*.

It also defines hard rights as patents, registered designs, and registered trademarks.

In the United States, it is possible to register copyright to demonstrate ownership of that particular work. One way of showing that you own copyright at a particular point in time is to make a copy of the work in question and send it through the post in a sealed envelope. The envelope should be date marked and preferably recorded/signed for delivery then left unopened. If required, you could dramatically prove as a matter of evidence by opening the envelope in a court of law that copyright existed on the marked date.

The growing international aspects involved require the differences in how IP is defined and marked are understood and applied when products are marketed in the international setting. Current laws and practices regarding IP are evolving. 3D printing should it evolve into on-site growth of human tissue based on an individual's specific genetic makeup will challenge long-cherished IP laws and justification not to mention the management of the associated infrastructure and commodities used in the process.

2.5.5 IP and Legal Documentation (Incarnations or Permutations of the Design)

Most industries reserve first rights to the IP developed by an employee as one of the conditions of employment. First rights allow the employer to evaluate ideas and technologies based on their needs and those that do not fit well with the focus of the enterprise may be given to the individual who developed them.

The evolutionary aspects of products were explored. Like the provenance of a work of art must be impeccably established the provenance of a design must also be established before the intellectual rights of other designs leveraged from it can be claimed. In some cases, the concept of first reduced to practice may be all that can be relied on due to lack of formally controlled documentation.

U.S. government contracts generally are given unlimited rights to anything developed under a contract. Ownership resides with the contractor and the government is allowed to utilize the technology as it sees fit. Should the provenance of a design prove that it existed prior to the contract date, limited rights to the technology can be established that prohibit use except for the specific purpose the information is provided for under the contract. These limitations are also extended to software items, called “restricted rights.”

2.6 International Traffic in Arms Regulations

Restrictions in technology transfer have existed in one form or another as have sanctions by one entity against another since earliest times. The Arms Export Control Act (AECA), ITAR, and the U.S. Munitions List (USML) are a manifestation of this. The AECA was enacted in 1976 as a means to restrict data concerning items with military application for countries making up what was known as the Eastern Bloc (East Germany Soviet Union, Czechoslovakia, Bulgaria, Albania, Hungary, Romania, and Poland). These countries formed the Union of Soviet Socialist Republics* and were engaged in a sustained state of political and military tension with what was known as the Western Bloc [In 1949: Belgium, Canada, Denmark, France, Iceland, Italy, Luxembourg, the Netherlands, Norway, Portugal, the United Kingdom, and the United States. The other member countries were Greece and Turkey (1952) and Germany (1955)] known as the Cold War.

The AECA is described in Title 22, Chapter I, Subchapter M, of the U.S. CFR. The USML identifies items that are controlled and it is interpreted by the U.S. Department of State Directorate of Defense Trade and Controls (DDTC). Since its inception, items contained on the USML have changed. Information on the USML through the ITAR can only be shared with non-U.S. persons if authorized by the Department of State. Many items on the list are not intuitively arms related.

In 2013, the definition of a “U.S. Person” included U.S. citizens, persons granted political asylum, a part of the U.S. government, a business entity incorporated in the United States under the U.S. law and permanent residents granted a U.S. right to work permit who do not work for a foreign company, government, or governmental organizations. U.S. citizens who work for a foreign company, government, or governmental organizations are not considered U.S. persons but representatives of that company or government.

Exports can take the form of foreign military sales, export licenses, warehouse and distribution agreements, technical assistance agreements (TAA), and manufacturing license agreements. Technology control plans (TCP) are defined under the National Industrial Security Program Operating Manual 10-509 and by the ITAR 22CFR § 126.13 (c). In addition, TTCP may specifically identify file formats and other restriction of data transferred. A company needs to register with

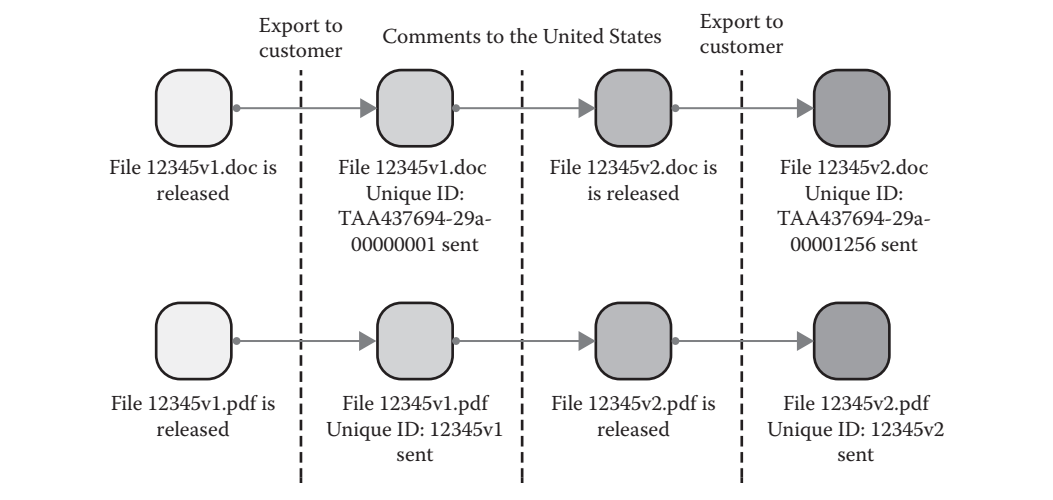


Figure 2.27 TAA unique identifiers.

* Союз Советских Социалистических Республик (СССР), also known as USSR.



True "+ULFBERHT+" blade, National Museum in Copenhagen, Denmark



Fake "+ULFBERHT+" blade, Germanisches Nationalmuseum, Nuremberg

Figure 2.28 Ancient sword forgery.

DDTC and know what is required of them to be in compliance with the ITAR, and self-certify that they possess this knowledge and will implement it.

One critical CM aspect of the TAA is the requirement that each piece of data transferred is uniquely identified and tracked. This means that each revision or version of the data is uniquely identified. Generally, CM is not consulted when TAAs and TTCPs are started. This may result in overcomplicated requirements. One example would be if the customer is performing part of the design activity and requires the native files to be delivered and the TAA specifies that data will be delivered as PDF format only with the document number and revision acting as the unique

Chapter 3

Functional Resources

3.1 Questions to Ponder

- What parts of project management should fall under revision and change control?
- What parts of engineering should fall under revision and change control?
- Is there a need for configuration management (CM) control and change management for the processes of an organization? Explain your answer.
- List and describe the documents used in your development work. Identify which ones should fall under revision and change control.
- Explain the implications of poor CM and change management on the manufacturing process.
- What are command and control media? Should this be controlled, if so how?
- What role does project management activities play in change management?
- Describe a change control board. What is their objective? Who should be a member of a change control board?
- Describe the connection between verification and product specification. Theorize how this is impacted by unknown product contents.
- Describe the connection between project scope and project closure. Theorize how this is impacted by uncontrolled product changes.

3.2 Introduction

This chapter explores some of the key functional elements that exist in many companies. It establishes the contextual background, so the configuration management (CM) interface with these functions can better be understood. Chapter 8 explores the CM interface and how CM supports each of these functions. CM from the enterprise perspective and its subelements of CM planning, CM management, configuration identification, configuration change management,

configuration status accounting, configuration verification, configuration audit, and data management all play a distinct role in how effective each of the key functional elements operate.

CM at the enterprise level has much broader in scope than CM of a particular configured item or CM of a particular program. Some may argue that managing the configuration of a contract, building, cleanroom, or test laboratory is not CM. Many say that elements of CM are involved, but it is not CM. Another viewpoint is that while a hand holding a piece of paper is not the paper itself, the hand is involved, and so if any element of CM is involved then CM is present. This second argument is gaining wide acceptance internationally and supported by current guidance and requirements documents. Each of the elements that make up CM must be tailored to the task at hand. In the case of financial records, although a receipt for petty cash may not require change control, it does require planning, management, status accounting, verification, audit, and data management.

3.3 Project Management

Project management has been part of the human life since the times of the pharaohs and pyramids (2700 BCE) and other large logistical endeavors of the ancient world. The result of these activities may seem more production oriented (the building of the pyramids, for example). There are a multitude of supporting activities tied to project management: concept selection, scope and change management, human resources, and support infrastructure.

The modern incarnation of project management is often associated with 1950. Project management is not a homogeneous discipline but a collection of knowledge areas. These areas are clearly defined by the Project Management Institute, Project Management Body of Knowledge,* and others as

1. Integration management
2. Scope management
3. Time management
4. Cost management
5. Quality management
6. Communication management
7. Risk management
8. Procurement management
9. Stakeholder management

3.3.1 Project Integration Management

According to the Project Management Institute, project integration management

includes the processes and activities needed to identify, define, combine, unify and coordinate the various processes and project management activities*

* Haughey, D. (2013, July 9). *Project Management Body of Knowledge*. Retrieved August 4, 2013, from <http://www.projectsmart.co.uk/>, <http://www.projectsmart.co.uk/pmbok.php>.

The specific areas of interest to CM are as follows:

- Develop project charter
- Develop project management plan
- Direct and manage project execution
- Monitor and control the project work
- Perform integrated change control
- Close project or phase

These processes and activities allow the project to be executed effectively through coordination of planning and executing to meet the defined scope while maximizing return on investment. The nature of these areas requires changes to be formally evaluated and dispositioned to assure proposed alterations are tied to scope or a change to project direction. Any changes that impact these areas will require review and a mechanism for articulating the changes through the project team—something akin to a release making the new revisions and direction changes to the project team.

3.3.2 Scope Management

In project management parlance, *scope* is the ultimate objective we wish to attain through our project activities. To reach this objective, it requires an expenditure of money and an investment in time, talent, and material. Tasks to achieve this objective are created and monitored. The sum of these activities will amount to the scope of the project. Changing the objective, often changes the scope of the work and, therefore, the activities the team should take. Failure to adequately manage the scope of a project or program happens so frequently that there is a specific name associated with it commonly called “scope creep,” if driven by the internal or external customer, and “gold plating,” if driven within the program team itself. Uncontrolled changes resulting from failure to control scope creep will have a significant impact on the probability of project success. In some circles, this is referred to as program “death by a thousand lashes.”

It is here the configuration management is heavily involved as this is the embryonic first phase of the product lifecycle. It is here that configurations are identified from a user, contractual and enterprise business framework.*

A number of tools are available to define the project scope. The most significant of these are as follows:

- Project charter
- Statement of work
- Schedule
- Work breakdown structure

Project management controls the scope definition documentation only updating with approved alterations and then communicating the changes through the project team. This traceability of scope to approved changes helps ensure that there is no *gold plating* or unaccounted for *scope creep*.

* Dirk Wessel, Chief CM Section NCI Agency input during text review.

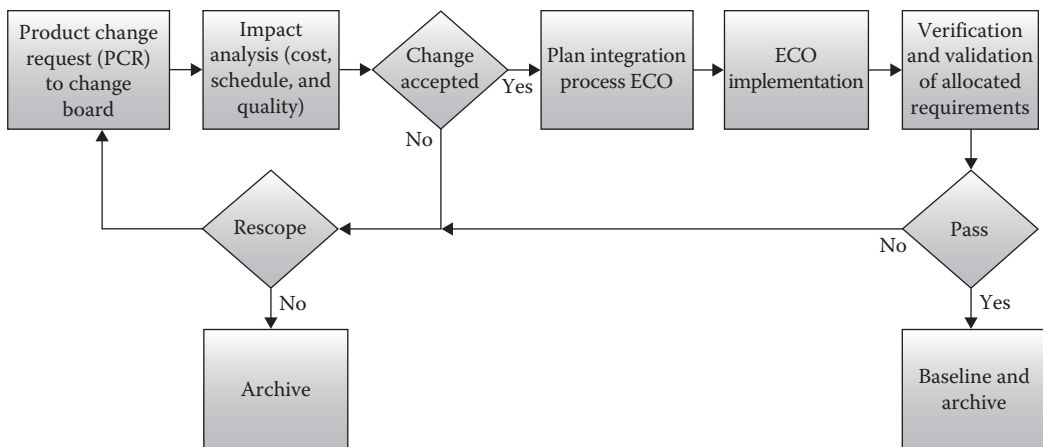


Figure 3.1 A typical change assessment ECO, engineering change order.

The scope documentation will be reviewed throughout the program/project life cycle and at the end of the project to compare the output of the project to the internal requirements or contractual obligations. Strict control over scope documentation as well as the changes generated in the course of the project and product development is essential. Experience suggests no project will go through its life cycle without incurring change. These changes move through a change management system, much like the one in Figure 3.1, before being approved and incorporated, resolving any associated risks during evaluation prior to implementation.

3.3.3 Time Management

Time management employs tools to understand the time and delivery aspects of the project. To do so, activities required to meet the project scope and ensure success are determined and scheduled including all dependencies. Dependencies are the interconnections between tasks and objectives. An example of a dependency is the interrelationship between software delivery and software testing. A finish-to-start dependency results as software must be complete before software testing can begin.

Once these items and dependencies are defined they are ingested into a project time tracking tool—perhaps in a Gantt* view—as shown in Figure 3.2. Planned performance is tracked against the actual performance via the schedule baseline. The schedule baseline allows the project manager, team, and executive management to understand the actual progress compared to the planned performance visually. If the dependencies are done correctly, most tools will predict the changed introduction date based on the present performance and the remaining depending tasks. Program management can use these tools to chart how the changes to the scope (change requests to the project) impact the final project delivery and project the associated costs. This is management of the configuration in a time-based environment.

Two objectives need to be met in keeping track of the impacts and subsequent project schedule. The most important is the ability to readily see the tangible implications on schedule and as an

* A kind of Bar chart developed by Gantt, H., in 1910.

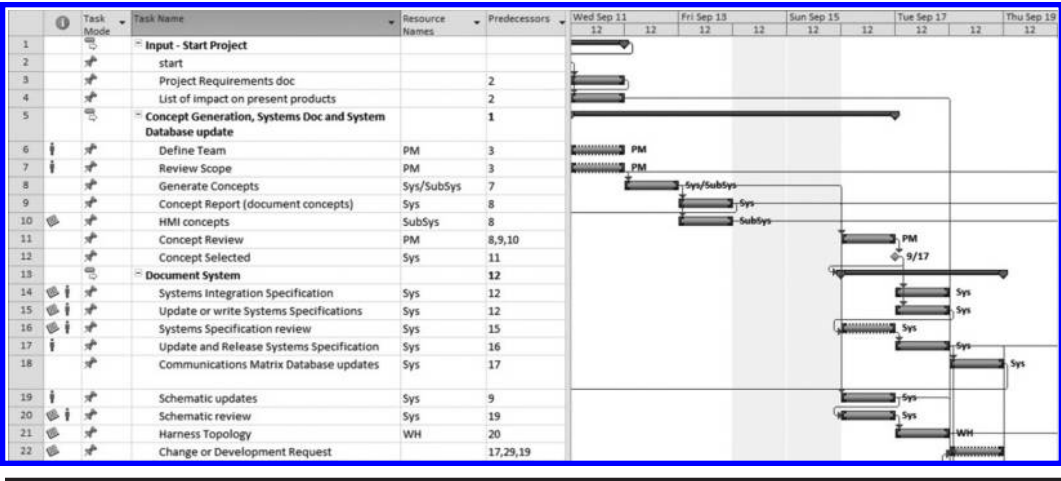


Figure 3.2 Gantt chart.

after action review performing a critique for subsequent project improvements. This is in essence a map of our project’s progress including the planned to actual durations for tasks as well as the impact of changes on the project.

3.3.4 Project Communications Management

All projects will be populated with team members and require input from a variety of stakeholders. A communication plan will help manage and maintain expectations.

The typical contents of the communication plan identified below are from *Project Management of Complex and Embedded System**:

3.3.4.1 Information Distribution

A description of the communication distribution method should be provided—often a chart detailing the communication responsibilities is created. International Organization for Standardization (ISO)/TS 16949 requires the inclusion of customer specific documents.

3.3.4.2 Information Description

This refers to a description regarding the type of information for distribution, format content, and level of detail.

3.3.4.3 Information Schedule

Information schedule reveals the method for assessing the rates of delivery of information.

* Pries, K.H., and Quigley, J.M. (2009). *Project Management of Complex and Embedded Systems*. Auerbach Publications/Tailor & Francis Group. p. 26. Reprinted with permission from the Publisher.

3.3.4.4 Progress Reporting

A description or reference of the process for collecting and reporting project status or progress reports.

3.3.4.5 Communications Plan Revision

The method for revising, updating, and otherwise refining the communication management plans as the project progresses.

3.3.4.6 Escalation Process

A significant part of the communication plan is defining the escalation process for the project. There will be times when we are struggling for decisions and a direction. Team members team may be divided on a particular subject and we will need to pre-plan how to break such *log jams* when they occur. The escalation process is just that, in the event we find we are unable to gain consensus on our strategy or actions.

3.3.4.7 Administrative Closure

Administrative closure refers to generating, gathering, and distributing information for phase formalization or project completion. It consists of documenting project results to formalize acceptance of the proposed or completed products by the sponsor or customer. It includes collecting project records, ensuring that they reflect the final specifications, analyzing project success, recording effectiveness and lessons learned, and archiving such information for future use.

Of particular noteworthy interest is the communication plan revision section, as this is the introduction of controlled changes to the document, and often listed in the front matter for the plan. The communication plan changes will be controlled throughout the project life cycle as more is learned during project execution. This plan may also require changes when the key stakeholders or project sponsors are changed. Ultimately, the changes in the project operating environment that influence the communication plan—who, what, when, why, and how—may require the plan to be updated via control mechanisms.

3.3.5 Project Cost Management (Earned Value Management)

Project management has its own way of measuring cost and schedule performance known as earned value (EV). This management tool from the U.S. Department of Defense influences industrial and commercial project management. Earned value management (EVM) is connected inextricably to the scope of the work undertaken and has other prerequisites as well. Basic elements of EVM center on planned value, also known as budgeted cost of work scheduled, (BCWS) and actual cost (AC), also known as actual cost of work performed, and EV, also known as budgeted cost of work performed (BCWP).

Successful implementation of an EVM system requires:

- Connection between specific work packages and cost accounting system.
- Appropriate and quick time-reporting mechanisms.
- Measurements of the present state of tasks with respect to completion.

Meeting these criteria enables measurements and comparison to the project scope to map both schedule and cost for the project. The specific measurements of interest are listed subsequently.

3.3.5.1 Schedule Performance Index

Schedule performance index refers to the ratio of work performed to the value of the work planned.

3.3.5.2 Cost Performance

The ratio of EV to AC

3.3.5.3 Schedule Variance

Schedule variance measures how much ahead or behind the project is compared to its schedule. It can be measured on a cost basis using the actual budgeted work against planned budgeted work. One way to calculate it is as follows:

$$\text{Schedule variance (SV)} = \text{BCWP} - \text{BCWS}$$

A positive SV indicates the project is ahead of schedule whereas a negative SV indicates the project is behind schedule.

3.3.5.4 Cost Variance

Cost variance measures how much ahead or behind the project is compared to its budget. It can be measured on a cost basis using the planned budgeted work against the actual planned work. One way to calculate it is shown below:

$$\text{Cost variance (CV)} = \text{BCWP} - \text{BCWP}$$

A positive CV indicates the project is under budget, whereas a negative CV indicates the project is over budget.

Each of these areas change control implications when the scope changes. Unaccounted for changes to the scope of a project as well as accounted for changes to the scope of a project will affect program cost monitoring and control actions. To make the most of these progress measurements, it requires that baseline is updated to reflect the expected performance with these additional activities. Changes to the scope can add tasks, change estimates of tasks, change material costs and duration, and create additional interdependencies that must be accounted.

Other elements associated with EVM include

- Budget at completion (BAC) = Baselined effort – (hours × hourly rate).
- Estimate to complete (ETC), to calculate EAC.
- Estimate at completion (EAC) = AC + ETC.
- Variance at completion = BAC – EAC.

3.3.6 Project Quality Management

Project quality management is concerned with the actions, processes, and activities performed to deliver the desired quality of output to the sponsor, stakeholders, and customers. Organizations may have quality handbooks and quality policies that are part of the entire organization's quality

system. In the context of this book, quality is defined as “The comparison of something to the idealized, and the ability of that something to meet those idealized target measurements.”

To provide this assessment and to adjust the project direction to achieve the ultimate quality targets requires measurements, analysis, and course corrections. The course corrections can come in the form of change requests as we change the

1. Product
2. Product development processes
3. Product manufacturing processes
4. Project management processes

Test and verification of models or prototype parts that represent the product are subject to changes to the design or how the design is produced. Both of them will require change notification and tracking.

Item identification hinges directly to the quality management activities in all form, fit, function, and quality disposition evaluations occurring during the review process of the initial design parameters as well as in evaluation of changes to existing designs and the materials associated with those designs. Figure 1.21 presented one aspect of such decisions based on differing levels of cleanliness. Other differences pertain to material choice, material testing and vendor certification activities, and monitoring.

3.3.7 Project Risk Management

Project risk management consists of the activities to avoid or relieve the impacts of the anomalies or anticipated eventualities on the project. This area of project management is recurring throughout the project as a project steadily learns more and monitors for symptoms of impending *unfortunate events* that may impede success. Items found are logged into a risk register for analysis and mitigation. The probability (likelihood) and impact (severity) of the item on the project success is categorized. Precursor symptom or metrics are established for each item. Mitigations (actions taken to alleviate the risk) are identified and assigned to individuals responsible for completing the actions. This living document is subject to change as the project moves through the design/development and production phases. It is prudent to revisit risk management activities when there are changes in scope. This is part of the configuration change review board activities associated with an assessment of the risk impact for any proposed change.

3.3.8 Action Item List

Work and progress and review actions are tracked via action item logs. Sometimes these are documents or spreadsheets and other times this logging and tracking is performed on a white board or in a database. These tools are used to keep track of the team performance against expectations. The tool articulates what needs to be done, when the task needs to be completed, and who is responsible for a specific item. The log will change as situations are encountered in the course of the execution or work performed on the project's behalf. Experience suggests the action item list needs to be managed by released revision or versions to assure adequate review and acceptance of tasks and task closure.

3.4 Engineering

“Engineering” is a general term that is applicable to multiple factors associated with design as well as to multiple disciplines that support those factors. The term comes from Latin *ingenium*, meaning “cleverness” and *ingeniare*, meaning “to contrive or devise.” In a general context, as it applies to management of configurations, engineering can be broken down into aerospace, automotive, chemical, civil, Earth systems, electrical, environmental, mechanical, nano, parts, production, software, and systems. Each of these has multiple subspecialties, including thermal, stress, and reliability.

Engineering is the mechanism by which an organization’s products come to realization. Marketing activities, at least in part, identify the opportunities to which a company can avail itself in a given market segment. A company’s marketing boundary spans activities and may find underserved segments or subsegments for which it can either adapt an existing product line or generate an entirely new product line. If the product is a software, then adaptation parameters can be used to configure the product to meet this new product segment demand. If it is believed that an area is susceptible to market variation, then that fact is accounted for in product development, thus making adaptation relatively easy. In other cases, engineers may be required to produce an entirely new product concept to fill the market void. Some organizations have process for performing product development work. Project management may likewise have a series of steps or gates to go through to produce the product.

Standards for system development include IEEE-1220-2005,^{*} EIA-632,[†] and ISO/IEC-15288.[‡] Standards organizations seem to have developed a penchant for further refining organization/process models into a new format called “maturity models.” These models define an aging/increase in wisdom approach to organization.

The development engineering requires a tightrope walk between structured and loose structure to allow enough creative room for engineers to explore the product possibilities—quick changes to learn about how the product could perform and where the product needs to be altered to make the most of the opportunity. This does not mean zero control, but relies more on the engineer to act in accordance with good development techniques. It can be likened to sterile transfer techniques. Prototype handling and alteration requires controls on the manipulation—for example, making many changes to parameters without understanding the implications of such changes.

In many engineering organizations, there are defined processes for the product development work, rather than leaving it entirely as an *ad hoc* creation and delivering the product to market. These organizations take measurements of key processes to ascertain capability and take actions to improve that metric or process capability. This results in a *closed-loop* system, in which the system is altered as the capabilities of the system are learned. In this case, the system is the set or subset of processes to which the organization works to design and develop the product. For evidence, consider organizations that are certified by ISO, Software Engineering Institute,[§] or Capability Maturity Model® Integration® and have recurring audits to confirm the organizations position on the continuum.

^{*} IEEE. (2005). *IEEE-1220-2005, IEEE Standard for Application and Management of the Systems Engineering Process*. IEEE, New York, NY.

[†] EIA. (2003). *EIA-632, Processes for Engineering a System*. EIA, Washington, DC.

[‡] ISO. (2008). *ISO/IEC-15288:2008, Systems Engineering: System Life Cycle Processes*. ISO, Geneva, Switzerland.

[§] Christel, M., and Kang, K.C. (1992). *Issues in Requirements Elicitation*, Technical Report CMU/SEI-92-TR-012, ESC-92-TR-012. Software Engineering Institute Carnegie Mellon® University, Pittsburgh, PA.

3.4.1 Design and Requirements

Requirements are the catalyst for the development process, the spark being the business case. A business case without requirements will not produce a product. The requirements without the business case for the product will not likely be profitable. An illustration for the disaggregation of the requirements is provided in Figure 3.3. Systems engineering allocates requirements from the functional requirements baseline to subsystems and other engineering departments to implement. This allocated baseline documentation sets the scope for the subsystems and components. Each requirement at the systems level is broken down into ever-increasing detail requirements at the subsystem and component levels.

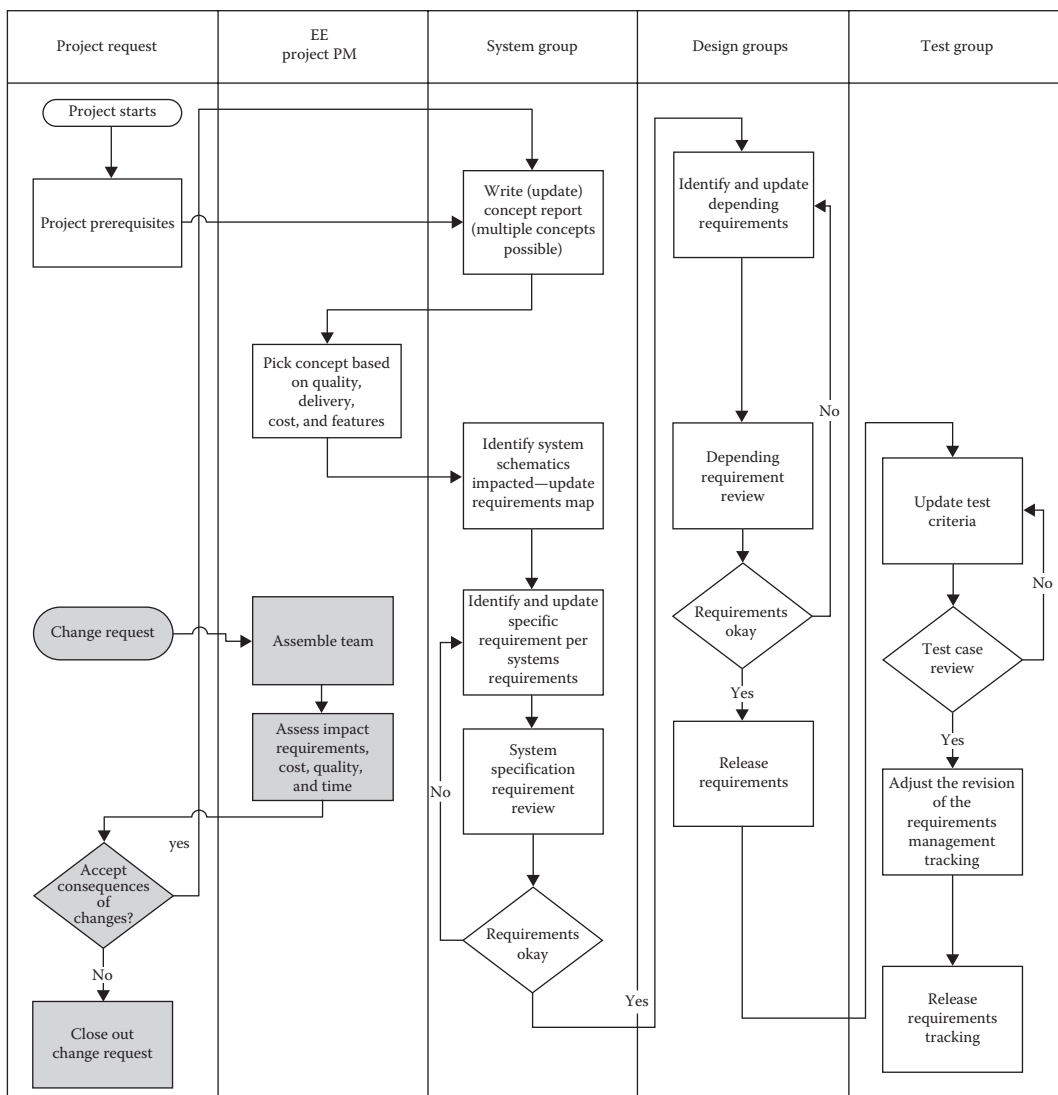


Figure 3.3 Requirements management system.

A list of the attributes of good requirements is presented as follows:

- *Clear, concise, and valid:* If it is not, it should not be a requirement.
- *Complete:* All information necessary for achieving the requirement.
- *Consistent:* No contradictions between requirements
- *Uniquely Identified:* One requirement ID per requirement.
- *Traceable:* Traceable all the way back to the scope of the project.
- *Verifiable:* Able to perform objective analysis/test to confirm objectives are met.
- *Prioritized:* Level of urgency associated with project objectives.

Each requirement is written with an individual identifier to facilitate both the traceability and the verifiable requirements attributes. Each requirement should pass configuration identification rules and is traced to a specific need in the configuration status and accounting system, allowing them to be linked to physical products. Only in this way can each requirement be traced throughout the entire product life cycle from user requirement to end product implementation. This is different than simply accounting for requirements in a requirements management tool to assist in product acceptance in a functional audit such as a functional configuration audit.

The lowest level requirements (the most detailed requirements) are traceable to the prior level, which is in turn traceable to the prior level in an indentured or child–parent relationship.

- Systems engineering requirements
 - Subsystem requirements
 - Component requirements
 - Hardware
 - Software
 - Firmware

Test cases for the requirements are also mapped to these requirements, ensuring the product gets adequate test and verification coverage to ascertain the quality and to tie out the requirement with an artifact proving that the requirement has been met.

Management of the configuration is an adjunct to requirements and requirements allocation. Project scope must be traceable to these requirements. In the following case, the project scope is a particular function or need that has to be met, for example, a new feature or a function for an automobile. This new feature needs to be integrated into an existing architecture. [Figure 3.4](#) shows how all of these are linked.

The top level scope is the left most column. We subsequently breakdown the product scope (our Work Breakdown Structure [WBS] will help us disaggregate) into systems requirements, and ultimately the individual component or subsystem requirements. In the following case, we see that for Product requirement 1.1, we have two systems requirements and three component requirements.

From here, we can define iterative and incremental deliveries based on priorities. This action results in defining the number of releases required to achieve the project objectives. Package content is defined and can be tested efficiently as the iterative and incremental packages are produced. This traceability makes it possible for the test cases to trace the scope and assess in detail the impact of a test failure. By showing the links to the scope, specifically from project scope, to systems level and supporting component-level requirements, efficient product development is possible. As artifacts are created proving that each requirement is met with product requirements, verification matrix can be completed or the artifacts can be ingested into a requirement tracking system such as the dynamic object oriented requirements system or similar systems.

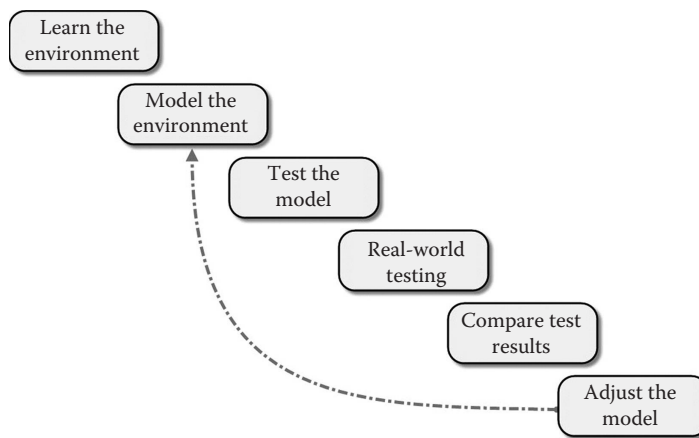


Figure 3.4 Scope, systems requirement, and component requirement.

Delivery of the elements are scheduled and performance measurement can begin only after allocation of the customer's requirements are made to the various systems, subsystems, and components comprising the following items:

- Technical need
- Customer need
- Regulatory requirements
- Complexity and risk

Technical needs are the dependencies to getting the product features working. An operating system must be developed before the expected features. *Customer needs* are the priority. These are tracked as a specific *feature* with some *measure of performance* associated with them. A feature-oriented tracking of the most desirable attributes (most saleable) of the product or the function with the highest profit margin or the most customer's needs met is recommended.

Deliveries of an end product that meets requirements or regulations or that allow the system to be exercised are necessary. A *regulatory requirement* may be the development of an instrument cluster. This results in prioritizing the speedometer and other required instrumentation to allow the systems integration or vehicle testing to be started.

Some features or functions may have considerable uncertainty involved. Perhaps as much field exposure or field feedback to suitably create or adjust the product performance is needed. Engineering may prioritize these more complicated or uncertain aspects to the start of the project, giving time to adjust the system or subsystem design. Perhaps uncertainty exists in models or other simulation activity we have performed and confirmation is needed. This too could be an item for prioritization.

Each project team will prioritize based on the constraints put upon the team. In any event, the requirements development and prioritization are part of the building of our release and test plans.

If specific material is required to fulfill a design aspect, the team should identify it clearly (e.g., chemical composition and other characteristics of interest). Specification at this level, however, means a predetermined cost and allows little or no room to achieve a given design requirement cost effectively. This situation is satisfactory if the material specified is the only way to

achieve the design objective. Due material handling considerations must be addressed through the production process (e.g., physical properties, radiation or electrostatic discharge vulnerability, fracture critical items, etc.)

3.4.2 Simulation and Verification

Test and verification activities to provide requirement artifacts of proof are a subset of engineering activities. Project verification activities provide the feedback loop for the product development work. Throughout the process, engineering is learning about the quality of the product and, to a lesser extent, the inaccuracies in specification generation work including undocumented product aspects. It is not possible to account for all of the unwanted behavior in the product specification until such time as it manifests itself.

Simulation may be used as a mechanism for the verification of the product. Simulation allows the exploration of the product possibilities without making the actual parts. This facilitates learning about the product without great investment in time, money, and opportunity cost. Risks in developing the product are reduced provided the models are accurate. To take advantage of simulation requires creating models. Models are the mechanisms through which the program learns about the product and the environment. To be effective, the model will need to accurately represent real life. To ensure this is the case, real-world conditions must be evaluated and understood prior to model creation. Simulations are run after the model is created to determine the model's alignment with the real-world environment. Ultimately, the model will converge upon the real world predicting what will happen. Once the model accurately represents the real world, it can be utilized to predict system behavior. Model development, as shown in Figure 3.5, is an iterative and multiple loop process of managed building, testing, learning, and model adjustment.

3.4.3 Bills of Materials and Bills of Documentation

Once engineers come to the point where the constituent parts of the product are known and the documentation associated with them, they are ingested into the product data/life cycle management (PD/LM) system. Generally, this is an iterative development methodology, altering the bill of materials (BOMs) and bills of documentation (BOD) as product testing and verification activities take place.

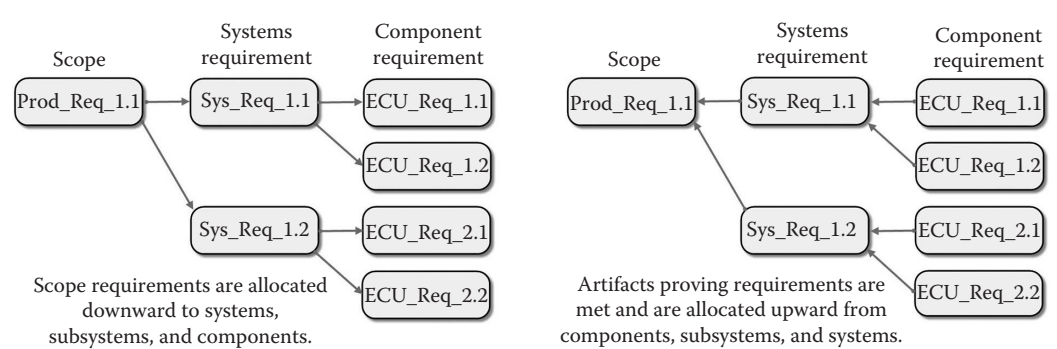


Figure 3.5 A typical simulation flow.

BOMs are typically from either a design-centric view or a manufacturing-centric view, as depicted in Figure 1.23. The BOM is generally the first collection of data that supply chain management utilizes to assess the probable cost of the product, and manufacturing engineers use to set up the work flow through the production centers. The preliminary engineering BOM is commonly constructed using a computer spreadsheet represented in a tree format. If the product is embedded, the BOMs may consist of a microcontroller/microprocessor and associated code, making a subassembly. If the product is a service, a bill of resources may be more appropriate. Service designers are more likely to concern themselves with bill of resources than BOMs. A bill of resources is a document that specifies the resources, often people, needed to achieve the consummation of the service.

Just as parts, be they code, model elements, hardware, or some other form, associated with the item make up the BOM. Documents associated with the item form the BOD. Just as engineering itself can be tied to the item it produces, associated test results and analysis can be tied directly to the item being tested in the PD/LM system.

3.5 Production

Eli Whitney's "uniformity system" is cited as the source of many engineering disciplines in the United States and abroad. CM is one of them. His part interchangeability also known as the "armory system" and "American system of manufacturing" was perfected by Captain John Hall and Simeon North. Their success predates Whitney's armory, which did not attain production of interchangeable parts until 1825, shortly after his death. Whitney's demonstration of part interchangeability in 1801 is generally believed to have been a hoax using carefully selected and meticulously crafted parts and not a demonstration of the production capable in Whitney's armory.

It is known that treasury secretary Oliver Wolcott, Jr., provided Whitney a copy of a pamphlet on arms manufacture 10 months after he was awarded a contract to manufacture 10,000 to 15,000 muskets. It is believed that the pamphlet may have been obtained by Thomas Jefferson while in France around 1785. Jean-Baptiste Vaquette de Gribeauval, Honoré Blanc, and Louis de Tousard are generally credited as being the true pioneers of parts interchangeability,* as we generally see it today. The pamphlet itself may have been authored by Blanc.†

Production has advanced considerably from the days of Eli Whitney. Now we can have a variety of subassemblies apply to more than one product. We may have contract manufacturing provide some of our constituent parts for a top-level product. This contract manufacturer may be in the business of making *subassemblies to print* for a variety of industries and companies. All of these necessitate managing changes to each product including BOMs and production processes.

Inherent in the generation of any product is the concept of enterprise wide CM. It is critical that CM of the end product be managed, and it is just as critical that all tools and processes used to produce a product be linked to those products. If this does not happen, it is not possible to assess the impact of any proposed change to a process, facility layout, cleanroom, or production equipment, too.

* Althin, T.K. (1948). *C.E. Johansson, 1864–1943: The Master of Measurement*. Stockholm, Sweden: Nordisk-Rotogravyr.

† Roe, J.W. (1916). *English and American Tool Builders*. New Haven, CT: Yale University Press.

3.5.1 Production Setup

As a product develops the tools, processes workflows, and the environment needed to produce, it also evolves. Manufacturing personnel need to be included in the design process to ensure that the design is something that can be economically made. Design needs to be consistent with present production methods, tools and techniques, or the future manufacturing strategies and upgrades planned to be on line when the design is completed. Such planned synergies reduce the time and money associated with getting the product to the production line and product throughput.

3.5.2 Production Test and Verification

Like testing and verification activities for the design process, similar activities also take place for the manufacturing process. Instead of being bound only by the product, companies are also bound by the ever-growing capability of their product systems. Early in the product development, manufacturing processes may not be aligned with the production need. An amalgam of the existing product processes along with temporary processes to produce the prototype parts may exist. Over the design development process, production will move toward all of the production intent processes. It is prudent to monitor the state of the manufacturing processes that deliver the prototype parts and know what processes are associated with what level of prototype parts, as this is the groundwork necessary prior to the *go live* production of the final product.

Companies may see revision after revision of their product equipment and processes including control plans and other manufacturing documentation as we move through the development process. Process verification testing is performed as the manufacturing process matures to ensure these are able to achieve the production targets for volume, first pass yield, and quality. First pass yield is the ratio of the amount of product that is able to be shipped to the total number of parts produced. The closer the product is to 100%, the lesser will be the rework required prior to final acceptance and shipping.

Various tools have been utilized over time in the journey toward attaining the manufacturing goal of 100% product acceptance, lowered component inventory, and increased component throughput. These have gone by zero defects, total quality management, just-in-time manufacturing, lean production, Kaizen, Six Sigma, and so on. *The Goal*, by physicist Eliyahu M. Goldratt,* explores these themes in an easily understood story narrative.

Finally, when all of the production processes and equipment are in place, a battery of tests is run on the product built from these processes. Many times, this battery of tests will resemble the design verification tests performed on the product. Processes and equipment from which we built our test products are documented, along with the test cases and results. If testing answers indicate a production-ready state, the company will move on to ramp up and start the production. Occasionally, if something from our testing of the production parts is not nominal, changes to the production process must be explored. Changing the production process will also require alterations in the process documentation to capture the change.

* Goldratt, E.M., and Cox, J. (1992). *The Goal*. North River Press, Great Barrington, MA.

3.6 Finance

Finance generally falls into two succinct areas. Program/project finance and company finance. The project management-centric aspect has been discussed in Section 3.2.5.

This discussion will address company finance. Finance in this context refers to

- Money and capital markets
- Investments
- Financial management

Company finance produces financial statement to the governing board and stockholders. These reports address

- Balance sheet, a statement of financial position
- Income statement, a statement of comprehensive income, and a statement of profit and loss or as a profit and loss report
- Statement detailing cash flow relative to operating, investing, and financing activities.

Larger corporations may require the inclusion of statement notes, executive analysis, and associated management decisions. The International Accounting Board* states:

The objective of general purpose external financial reporting is to provide financial information about the reporting entity that is useful to present and potential investors and creditors in making decisions in their capacity as capital providers.

Should anything in the ambient environment change, then the reports will need to be adjusted. Some of the areas of concern are as follows:

- Current ratio
- Acid ratio
- Inventory turnover ratio
- Days sales outstanding
- Fixed assets turnover ratio
- Operating capital ratio
- Debt ratio
- Profit margin on sales
- Return on assets
- Return on equity

Corporate finance is also responsible for payment of debt, allocation of costs to the proper cost pools and objectives, and, in conjunction with company, legal preparation and payment of taxes.

* IASB. (2010, September). *Conceptual Framework for Financial Reporting 2010*. Retrieved April 12, 2014, from <http://www.iasplus.com/>, <http://www.iasplus.com/en/standards/other/framework>.

3.7 Legal

No matter the size of the organization or the industry, there will be legal implications. The larger the organization, or more geographically dispersed, the larger those implications—in other words, the more rules that must be abided by. If the industry is a regulated industry such as automotive or food and drug industry, more legal constraints exist. To meet these demands, an organization may have an internal legal department. The legal department is responsible for ensuring an understanding of the laws that apply to or otherwise impact the organization. Those rules and regulations start at the local level (city) and progress outward. An organization whose product is built or consumed internationally will have to meet the applicable laws in the other regions as well. This includes those laws that apply to the talent base (some refer to these as human resources). The human resource department may be the interface between the legal department and the employee base in some situations and represent company position relative to employee concerns.

Legal department staff is trained to handle an ever-changing regulatory and contractual climate. New product development work will require analysis from a legal department perspective to assure regulatory compliance. Any new venture where the staff may not have much experience with the legal ramifications of the product and customer use will require input from the legal department. If the company final product design is unable to meet the claims made for that product, then customer dissatisfaction may involve customer remuneration or product replacement through legal action.

The legal department will also likely manage intellectual property marking, new technology reporting, and marking compliance. In the international setting, this also includes the implementation of trade restrictions pertaining to identified technologies such as the U.S. International Traffic in Arms Regulations.

The legal department will investigate the competing or existing intellectual property and patents to ascertain the uniqueness of any company-generated property. They will often bridge the gap from technical language to the legal technical language filing patent submissions as well as interim documentation, including provisional patents. This may include managing any incentive plan remuneration for our employees that cede the intellectual property.

Unless the enterprise is specifically engaged in providing goods and services to a government, they may not have a specific department managing contracts and contractual issues. Should a separate contracts function exist, they are generally involved with contract interpretation and compliance with the customer community and not with the company's contractual relationship with its employees.

3.8 Contracts Department

Many companies have a standalone contracts department. This department performs all functions relating to the bid and proposal contractual review as well as management of the contractual relationship between the company and its customers. The similar relationship between the contractor and its suppliers is managed in close coordination with the contracts department by the supply chain management element of the company. In some cases, this area may be referred to as “purchasing.” In other situations, the purchasing department is a subfunction under supply chain management specializing in buying commodities whereas subcontract administrators specialize in major procurements.

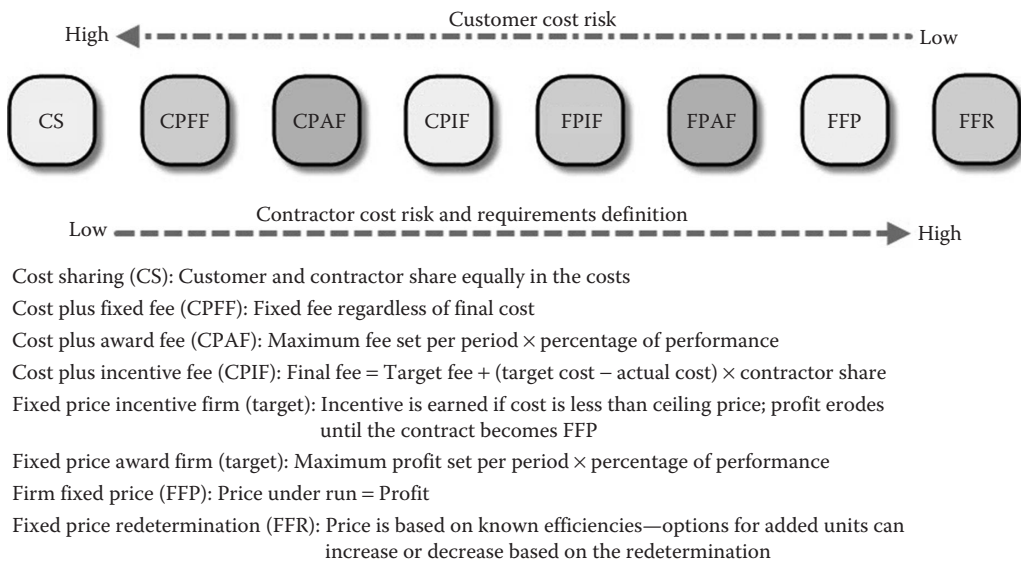


Figure 3.6 Customer versus contractor risk profile.

Each contract has associated risks. Depending on the contract type, the risk is weighted in favor of either the contractor or the customer. This is shown in Figure 3.6.

The discipline of contract management includes the following:

1. Providing scope
2. Negotiating terms and conditions
3. Agreeing and managing changes and amendments
4. Monitoring performance
5. Confirmation of closure

Contracts are binding agreements between identified parties with an agreement. Management of the contractual relationship seeks to minimize the risks and maximize profits through the efficient and effective management of the contractual obligations.

Nearly 65 percent of enterprises report that contract lifecycle management (CLM) has improved exposure to financial and legal risk.*

CLM is one aspect of program life cycle management. A contract is a written or oral legally binding agreement between competent parties for a legal purpose. It may be a promise on both sides to do something for something else of perceived value or it may be a promise not to do something in exchange for something of perceived value.

* Raj, A. (2014). *Best Practices in Contract Management: Strategies for Optimizing Business Relationships*. Retrieved April 14, 2014, from <http://www.academia.edu/>, http://www.academia.edu/5102810/HR_Assgt.

3.9 Supply Chain Management

Supply chain management involves all of the activities associated with the acquisition of materials, goods, and services from suppliers. The supply chain itself consists of raw material suppliers, subassembly suppliers, and extends out through the delivery of finished products, supplies, and services to the customer. The supply chain network is shown in Figure 3.7.

Supply chain activity for non-commodity items generally includes a statement of work, data deliverables and a flowdown of program mission assurance requirements. If the supplier is designing a new product, the requirements associated with that product result from allocations from the program system specification from a program subsystem or component specification. Should it be a factory offload, where the company issuing the subcontract is the design authority, one or more control drawings may also be included in the subcontract (e.g., interface control drawing, procurement control drawing, vendor item drawing, etc.)

As products and services become more complex, a single company rarely has the internal resources to adequately perform all the associated infrastructure needs. Outsourcing to acquire these services has become the new business norm for companies of all sizes. Value Transformation Limited Liability Corporation, a small company, makes use of companies around the world, including Brickwork of India for research and other services. In other cases, a firm like Price Waterhouse may provide independent audit of company finances and either assist or prepare calculations of taxes payable to local, state, and national governments.

3.10 Facilities

If the organization is of a *brick and mortar* type, they will need to manage those facilities. Facility management is the coordination and maintenance of the physical things that keep the organization running and working at peak performance. Facilities concerns include the utilization of space and layout, manufacturing, test equipment, and machinery; organizational infrastructure and equipment to keep our personnel safe and productive; management of property and metrology to assure

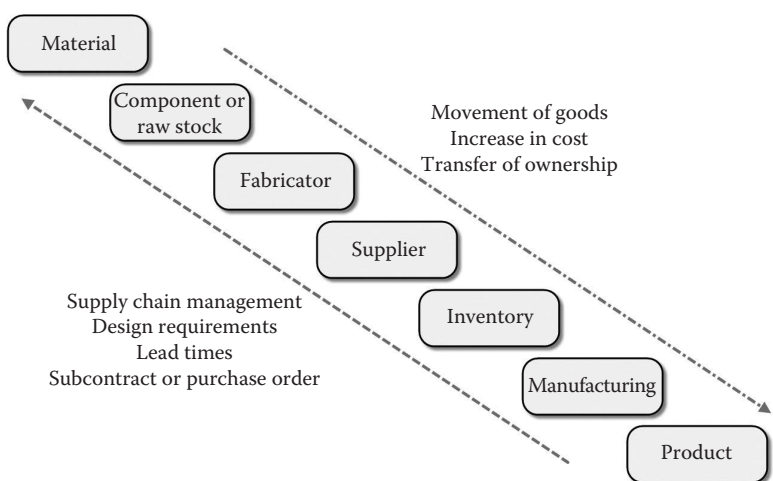


Figure 3.7 Supply chain network.

item certification for use is current; and compliance with regulations and assorted codes (e.g., health, safety, and fire codes). This department manages the maintenance of equipment including repair or replacement of capital assets such as buildings, vehicles, and equipment. Maintenance work includes preventive maintenance work as well as *repairs as fail* efforts. Activities to head off those untimely failure events such as inspecting the equipment also fall within this area.

3.10.1 Property Management

One critical facilities subfunction is that of property management. In the United States, to do business with the government, contractors are required to have an approved property management system that includes activities associated with receiving inspection, stock room control, proper allocation of materials, and segregation of customer property from company property or bonded storage of company stock to programs.

Chapter 4

Configuration Management and Product Management

4.1 Questions to Ponder

- How do changes in the market affect configuration management (CM) product development efforts?
- Describe how CM applies to marketing activities?
- Who performs the boundary spanning activity for the organization when it comes to the product definition and customer desires?
- What attributes of the software make identification much more difficult?
- What attributes of the embedded hardware make identification necessary?
- Is there, or should there be, a connection between marketing research and CM?
- How are marketing experiments influenced by CM?
- Theorize the connection between marketing message and the CM.

4.2 Introduction

Chapter 4 establishes the link between product and the commercial environment. Configuration management (CM) plays a critical role in each of the subsections discussed from management of market feedback, management of implementation strategies, to product development.

4.3 Marketing

It may be a bit of a surprise to find out that product management starts well before the product development aspects of delivering the product. An organization's marketing department surveys the markets and submarkets in which the organization can compete. They develop a strategic approach to the market based on the organization's strengths, aversion to risk, and desired

performance results over a long-term horizon. This strategy will be one of the attributes in the company product mix to achieve or develop market share and profit margins.

All of those disciplines, even the supporting mechanisms for the organization are implicated, so too with the associated change management. Recently, Jon Quigley had the occasion to purchase a car at a dealership. His General Motors Corporation (GMC) “Jimmy” had more than 250,000 miles on it and the cost of operation exceeded the rationale point of fixing. While in the showroom, he noticed a rather large flat-screen monitor promoting the company’s product line. It was touchscreen so he navigated through the material with his son. His son noticed a button and activated the function associated with it. To their surprise, they found the identification information for the information platform, as shown in Figure 4.1, and a direct link to the CM of the product.

The marketing organization performs boundary spanning activities for the company. This group is responsible for monitoring *would be* customer trends for opportunities. According to the American Marketing Association, the definition of marketing is:

Marketing is the activity, set of institutions, and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large. (Approved July 2013)*

Marketing refers to the department responsible for demonstrating the value proposition of the company in addition to determining the target markets and managing the marketing mix elements to achieve the organizational objectives, which will likely have some connection to profitability.

The eight Os provided below summarize the target market selection activities†:

1. Occupants
2. Objects
3. Occasions
4. Objectives
5. Outlets
6. Organization
7. Operations
8. Opposition

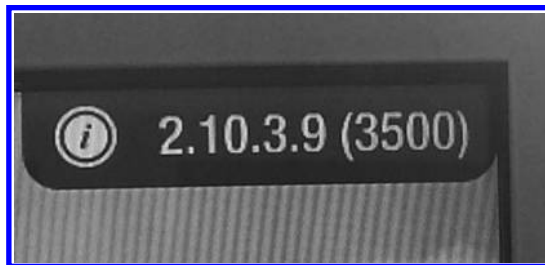


Figure 4.1 Touchscreen identification information.

* American Marketing Association. (2004, October). *Definition of Marketing*. Retrieved March 14, 2014, from <https://www.ama.org/AboutAMA/Pages/Definition-of-Marketing.aspx>.

† Czinkota, M.R., and Ronkainen, I.A. (2003). *International Marketing*. Cincinnati, OH: South-Western College. Cincinnati, OH, p. 17.

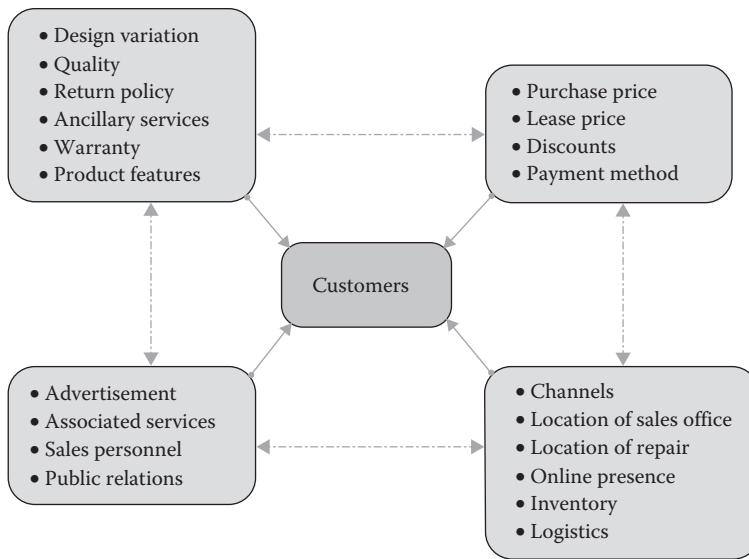


Figure 4.2 Marketing elements.

The elements of the marketing mix that must be managed are product, price, promotion, and place. Marketing experts will manipulate these variables in the effort to maximize the performance of the total product portfolio. Marketing elements are shown in Figure 4.2.

Often product, price, promotion, and place are referred to as the four Ps of marketing. Each of them will be discussed in turn in the sections that follow.

4.3.1 Product

In the parlance of marketing, product means all of the policies associated with the elements that make up the value proposition along with the actual product (which could also be a service). This also includes right from all of the physical and performance attributes of the product to the packaging and warranty. Even if the firm is selling a product, they likely have some services associated with the products that are also delivered to their customers. Consider the purchase of an automobile. Many companies offer a maintenance package with the vehicle purchase. Sometimes this package is included in a customer care arrangement and sometimes it is an additional item the customer may elect to purchase.

4.3.2 Price

The pricing policy dictates the price at which the company offers the product to the customer. This will be influenced by product demand, which is in turn influenced by the perception of the brand and competitive forces. In considering the price, logistics and distribution channels must be evaluated. If the company has affiliations with other organizations, they will also have to consider those needs to make profit on the transactions with the end customer. The company may run *experiments* to test the elasticity of their pricing. Price elasticity is the measurement of the impact of the product cost and the change in product demand by the company.

An increase in the sale price of our product by 10% may see a corresponding decrease in the purchase of the product. Simply put:

$$\text{Elasticity of demand} = \text{percent change in quantity} / \text{percent change in price}$$

Many factors influence the price elasticity of demand. Some of them are as follows:

Substitution: Market segments that are saturated are elastic, whereas market segments that are not are inelastic (e.g., personal hygiene items vs. joint replacement).

Luxury versus necessity: Luxury items are elastic whereas necessities are not (e.g., special medicines vs. jewelry).

Income percentage: Items that consume the greatest percentage of expendable income are elastic whereas items that do not are inelastic (e.g., transportation or housing vs. salt).

Reaction time: The longer the period the consumer has to react, the more elastic the demand (e.g., a three-hour sale generates less income than a two-week sale).

4.3.3 Promotion

Promotion is a method of communicating with customers the often intangible benefits of a product or service and is managed to provide information about the product or service, increase demand, and differentiate a product from the competition. Companies will use a combination of advertising, sales promotions, and publicity to draw attention to their brand in order to influence sales in the target markets.

Generally, promotions follow a strategic plan and are accomplished using a variety of media forms:

- Stationary (billboards)
- Print (newspapers and magazines)
- Video and radio
- Digital (Internet, through social media such as Facebook, YouTube, etc.)

Promotion is a way of spinning a product in such a way that the target audience accepts it. It is just as important to public relations as a world-class complaint resolution department.

4.3.4 Place

In reality *place* refers to the distribution policy or variables in it. The two elements are the logistics of getting the product to the desired destination and channel management. These elements physically connect the customer to the product.

Logistics are activities taken to ensure the product is available at the right place and at the appropriate time. The goal is to assure the product is *on the shelf* for purchase when potential customers are looking for it.

The channel management variable deals with the entire process of establishing and managing the intermediaries between creating the organization and the ultimate customer. From the identification of channels that can improve product acceptance by the market to contract are included in this portion of the marketing tool suite.

4.3.5 Marketing and Market Research

Understanding the market is critical to the continued life of a product in any market segment. As a strategic practice, it forms one of the cornerstones involved with the strategic evaluation of the competitive environment as well as a basis for understanding and managing perception. This necessitates not only an understanding of the needs and views of the consumer base, but of the input from strategic and leveraged innovation business partners. Key factors considered include the following:

- Need versus availability
- Market trending
- Price analysis
- Analysis of competition (domestic and international)
- Market segmentation (domestic and international)
- Brand strength (yours and your competitions)
- Risks (implied and actual)
- Media utilization based on targeted demographics
- Marketing media mix
- Test marketing
- Perception management

Market research and marketing research are closely related. The overlap is shown in Figure 4.3.

4.3.6 Customer Interface

The marketing department is typically the primary interface to the potential customer base. Marketing is generally responsible for understanding the demands of the clientele and bringing that information to product engineering personnel. Engineering personnel then convert the non-technical discussion to a technical discussion assigning specific attributes to the product, more on that later in this chapter. The marketing group sets about assessing areas of concern to prospective customers learning as much as can be learned about what the customer would define an acceptable or more acceptable product or service (e.g., what is required to meet their demands?).

The marketing department will do this via market studies, market surveys, and demonstrations of possible solutions to the customers to gather this information. They will also explore market segments to prioritize future developmental work. Market segmentation is the dividing up of the larger market into subsets. A company can then identify which of those market segments

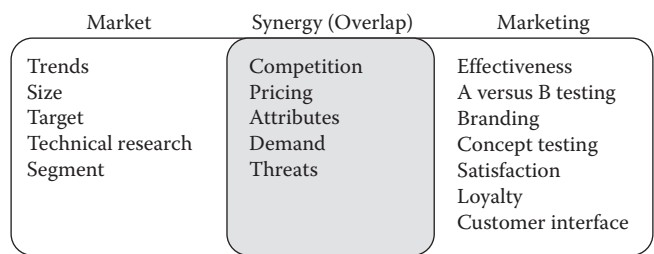


Figure 4.3 Market versus marketing.

best match them and their monetary goals and prioritize those segments by focusing their efforts on meeting those needs.

4.3.7 Market Segmentation

During the days of Henry Ford's Model T, you could easily get the vehicle in black. Black paint dried the quickest, which meant the output and profitability of his manufacturing facility would not be constrained by running multiple paint colors except as a necessity. As the automobile was a new commodity, the manufacturer could dictate the available features. As competition increased, paint color became a customer-driven need and companies adapted to meet the need or lost market share. Now the customer can choose the car type and color they want within a wide range of possibilities based on the following multiple market drivers:

- Geographic
- Demographic
- Psychographic
- Behavioral

Ultimately, the marketing message is tailored to match the uniqueness of each of these drivers within the specific market segment. They may also tailor the price for the product, alter some of the feature content, and use other tactics to maximize marketing opportunities.

4.4 Increasing the Complexity of the Product

The advancement of the electronic age and Moore's law has driven complexity in electrical aspects of products over the years. Moore's law is based on the observation that the transistor densities for microprocessors doubles every 18 months to 2 years. As these densities go up, the capabilities we can get from the product increase. We see more functions delivered in the product as our microcontroller now has many different interfaces and memory spaces.

In a similar way, increasing the regulatory pressure to achieve varying national or international priorities have driven how some products are made, what they can be made of, how they are packaged as well as multiple environmental and safety rules.

4.4.1 Embedded Software

Embedded software is more common than many may believe. It finds home in many products such as

- Microwaves
- Radios and stereos
- Automobiles
- Planes
- Medical equipment
- Consumer electronics

In embedded products, the development team has a significant portion of the software effort located in the product itself. An embedded development project consists of software development wedded

to a microcontroller or microprocessor-based hardware. The features of the product developed reside in the combination of hardware and software. The software provides the application and drives hardware function. The software can consist of an operating system for complex item along with application code. Product-specific features reside in the application code. Even if the hardware can support a feature, it does not mean the software is available for that feature to work. The hardware may have a universal asynchronous receiver/transmitter (UART) but that does not mean that the communication works on a product, as the feature may not be accessed or even enabled. These attributes are difficult to know by observation of physical properties (visually). Embedded software allows additional functionality to be added as a maintenance activity or as a purchased upgrade.

4.4.1.1 Embedded Firmware

Some parts of the software and the hardware differentiate poorly (hence the frequently used neologism “firmware”). Firmware weds hardware and software because on its own hardware such as a programmable read-only memory (PROM) has no function without the software burned into it. Engineers work the hardware and the software development simultaneously in order to achieve a form of inorganic symbiosis; that is, the final product results from a dialectic exchange, a back and forth adaptation of each component to the other.

4.4.1.2 Physical Attributes of Software Not Visible

In the case of UART, it becomes difficult to know the capability of the software after compilation. One can infer software contents from a variety of sources. The connection starts at the product requirements and extends past the actual coding to the compilation of the software. These connections are compelling whether the coding is traditional or via models (as in model-based development). Ultimately, the goal is to make this deduction as free from error as possible. To do so requires careful planning of the function growth and change management through the development cycle. The more distributed the product development (the longer the lines of logistics), the more complex this situation becomes. If one person is writing software, that person would need to remember all the functions they put into the software. Not the best situation to be in, however, with luck perhaps survivable. Software projects often do not have one person writing all of the code to eliminate a single-point failure.

Comments in the software work only prior to compilation, which is a good way to track the contents during the writing. This practice also makes extensibility a bit easier when the product grows or morph functions post product launch. It is incumbent on those writing the code to keep a close connection between the requirements, source code, and compiled version, the only real way to understand the software content.

4.4.1.3 Capabilities of Software Not Externally Obvious

Software despite its uniqueness often has capabilities not readily apparent or obvious. Commands in software often are reliant on the content of tables loaded with parameters not resident in the software itself but controlled and loaded into erasable PROM from a secondary data source. The program may generate these data sets itself in the case of systems with a built-in capability for learning based on previous inputs, or in other cases, due to external analysis that cause the program to behave in a certain way. An example of the latter would be the modification of table data to increase the performance of a vehicle rather than increasing its efficiency.

4.4.2 Embedded Hardware

Embedded hardware is the target system for the software. Compiled software is uploaded into the hardware. The hardware consists of the microcontroller or microprocessor core, along with the supporting circuitry to perform the functions specified. During development, our hardware will have increasing feature growth, as the company ramps the prototype iterations toward the final product learning from the prototypes along the way. The hardware will not only grow from the feedback loop (testing) but also from the perspective of building progressively more capable iterations to get the most amount of time with the product possible. For the UART example, the company may choose not to put the transceiver interface to the bus in the first iteration of the product if this functionality is not immediately required or at risk.

4.4.2.1 Embedded Hardware Attributes Not Readily Visible

Like the software, the hardware feature content or capability may not be readily discernible. Many parts are surface mounted and small. Some areas of circuit boards may be covered with conformal coating or other protectorate to meet environmental factors such as protection from moisture. Components such as microcontrollers may have functions specified in the data sheet but not utilized. Simple data communication applications leverage a pin that is typically used as an input–output device in a way often referred to as “bit-banging.”

4.4.2.2 Capabilities of Hardware Not Obvious through Implied

Purchase of a vehicle with a certain safety rating implies that the vehicle is safe even though the built-in safety capabilities may not be obvious during the fabrication of the vehicle itself. Structural panels embedded into the doors and other frame members may act to move the energy of a collision around the passenger compartment rather than through it. A spacecraft will endure vibration as well as acoustic shock on its way to orbit. It also may see erosion due to atomic oxygen and ionic charging during its mission life or excessive torques if it has a single solar array that must be mitigated. These are examples of some capabilities that while not obvious are implied.

4.4.3 System Complexity

At one time, there were no *computers* or *microcontrollers* on a motorized vehicle. In the mid-1980s, heavy commercial vehicles had a single device, and it was on the engine largely associated with emissions regulations. Modern vehicles have a multitude of these types of controllers, even the radio is more than a radio. Features and complexity are also increasing in household appliances, televisions, cable boxes, and microwaves. Complex communication schemes are commonplace in addition to basic product complexity.

System complexity is not limited to the products produced. The systems used to produce these products have likewise increased in complexity as we distribute the development and production internationally.

4.5 Distributed Product Development

It is common knowledge that the world is becoming ever more interconnected. This is true for almost everything, not just embedded products but also for mechanical parts. Organizations acquire not only expertise, but efficiencies by looking globally to assure the product cost as well as the quality. A design may be developed in one location, or through a global collaboration and so also for its manufacture. The subassemblies may originate from around the world in multiple factories in a variety of geographic regions producing the same product to save on logistics costs (shipping).

4.5.1 Outsourced Coordinated Development

With the ease of access to communication tools and labor and talent emerging around the world, product development is a global exercise. Coordinated development globally has some challenges despite of the ability to share data and interesting and ubiquitous communication tools. Managing the development direction and changes to the product under potentially long logistics channels can be a significant source of consternation. One organization studied has 10–12 week latency from the time of design change to the time the organization receives the first prototype parts for critique. During that time, considerable changes may be required in the design, as the rest of the organization learns about the product.

It is not just about prototype part logistics, but also the nature of change and projects in general. As the saying goes, “The only thing constant in life is change.”* Consider an entire system developed and assembled from parts that are sourced globally. This happens every day in automotive and in aerospace industries. Parts may be developed by one supplier and once completed will be sent to another supplier in another part of the world. The instrument cluster for an automobile developed in Germany ultimately contains heavy-tooled plastic parts from Asia and is manufactured and assembled in Mexico then shipped to the United States and put onto the vehicle.

This is achieved via coordinated outsourcing work packages. Control of this logistical chain is necessary to be successful on a recurring or routine basis.

* François de la Rochefoucauld, 1613–1680 CE.

Chapter 5

A Configuration Item and What It Implies

5.1 Questions to Ponder

- What is a configuration item (CI)?
- What criteria need to be considered before designating something as a CI?
- What is involved in the configuration identification process?
- Does CM apply if something is not designated a CI?
- What is serialization and why is it important?
- Is CM concerned with all phases of the product life cycle or only with management of the allocated and product baseline up to the point of sale?
- Does CM only apply to documentation?
- What CM implications are associated with 3D printing?
- What is meant by traceability and why is it important?
- What do the terms allocation, verification, and validation mean?
- What are the outputs, activities, inputs, constraints, and enablers associated with meeting functional requirements?
- What CM elements are associated with management of intellectual property (IP)?
- What is the CM life cycle process?
- How do the U.S. government missions stages relate to baseline management?
- Is the developmental configuration a baseline?
- What is an aligned product development model?
- What is a technical data package?
- What is involved with change control?
- What is the purpose of status and accounting and what does it imply?
- Why is audit necessary?

5.2 Introduction

We have discussed many factors that influence configuration management (CM) and how it relates to the market segment and enterprise resources over the product life cycle. Those who practice CM are often so close to the day-to-day implementation that they lose track of the philosophy behind why CM exists and the intent of some of the terms that have come into common usage that are related to it.

The documents CM personnel rely on have been leveraged forward from decade to decade, with little broadening of the applicability of the terms and the underlying concepts behind them (see Section 7.3.1). Methods, technologies, markets, viability of market solutions, and tools used are constantly evolving. The view point that the customer dictates the level of control required to manage the configuration of a product, while true in the case of contractual obligations, often falls short of the entire scope of management involved.

This chapter will focus on the concept of designating something a configuration item (CI) or stated another way a configured item and what that implies in the form of information and how that information is managed. Throughout the book, CI will be used as the acronym for both configuration item and configured item.

The remainder of this book will also introduce many discussions reflecting current thought on the implementation of CM in the twenty-first century and beyond. Jack Wasson* states,

At one time, Configuration Management was only about establishing proven configurations for delivered products and controlling the changes to them, now it has to accommodate changes and manage the outcome in the best possible way. It is about maintaining accurate and valid data to retain corporate knowledge and history (i.e. lessons learned) so we don't have to keep paying for it over and over.

During November 2013, the LinkedIn North Atlantic Treaty Organization (NATO) CM Symposium Group† came up with the following definition of a CI:

A configuration (configured) item is defined as any product that requires formal release and control of supporting information prior to acceptance by the user; where the supporting information is detailed with sufficient precision for all internal and external stakeholders to understand.

A configuration (configured) item shall be assigned a unique configuration (configured) item identifier (CII) that when associated with the place of origin assures the item's provenance and content are irrefutable.

Lower level elements of a product may themselves be designated as configuration (configured) items where that level of control is identified as being required; for example as a result of:

- Being produced by an entity external to the enterprise;
- Regulatory factors; or
- Other factors (e.g. safety, integral to product functionality, unique requirements, etc.)

* Wasson, J. (2008). *Configuration Management for the 21st Century*. Retrieved November 23, 2013, from <https://www.cmpic.com/whitepapers/whitepapercm21.pdf>. Reprinted with the permission of the author.

† Wessel, D., Pep, G., Sounanef, Pickering, C., Robertson, K., Watson, M., DeAleida, R., Hartley, D., and LinkedIn NATO CM Symposium Group. LinkedIn discussion "What is a configuration item and which consequences does the selection of CIs have to your organization," moderated by Dirk Wessel started on July 1, 2013. Reprinted with the permission of the author.

As designating a product as a configuration (configured) item imposes additional information constraints on the product that increase over the product lifecycle; it is advisable to perform a cost/risk vs. derived benefits analysis prior to designating a product as a configuration (configured) item.

Supporting information includes but is not limited to all enterprise and vendor level information regarding formulation, safety, handling, test, operation and installation, environmental and biological impacts due to use, other known hazards and similar data associated with the product, items it comprises and processes used during product creation.

This definition is much broader than the definition provided in the following sources despite its closeness to the aliases, related terms and examples in ANSI/EIA 640-B. Nevertheless, it has a major flaw. CM activities continue beyond product acceptance to product end of life.

- ISO 10007:2003, Quality management systems—Guidelines for configuration management

Configuration Item: entity within a configuration that satisfies an end use function.

- ANSI/EIA 649-B, TechAmerica standard: Configuration Management Standard, Table 2

An aggregation of hardware, software, firmware or any discrete portion thereof that satisfies an end use function, and is designated for separate configuration management (i.e., it has specified requirements, and is an item to which the effectivity of changes is addressed).

Aliases, Related Terms and Examples

- Computer software configuration item (CSCI)
 - Configuration object
 - Configured item
 - Configured product
 - Controlled item
 - Designated item
 - Product
- MIL-STD-490, Specification Practices
 - 1.4.2 Configuration item. Hardware or software, or an aggregation of both, which is designated by the contracting agency for configuration management.
 - 1.4.3 Hardware Configuration Item (HWCI). See Configuration item.
 - 1.4.4 Computer Software Configuration Item (CSCI). See Configuration item.
 - MIL-STD-973, Configuration Management
 - 3.13 Computer Software Configuration Item (CSCI). A configuration item that is computer software.
 - 3.23 Configuration Item (CI). A configuration item is an aggregation of hardware or software that satisfies an end function and is designated by the Government for separate configuration management.

- MIL-HDBK-61A, Military Handbook Configuration Management—Guidance, Section 1.3.

A configuration item (CI) may be an individual item, or may be a significant part of a system or of a higher-level CI. It is designated at an appropriate level for documenting performance attributes and managing changes to those attributes. The CI concept has confused some people into thinking that the level at which CIs are designated is the point where configuration management stops. In reality, the CI level is where configuration management really begins; the process encompasses, to some degree, every item of hardware and software down to the lowest bolt, nut and screw, or lowest software unit. This does not mean that the acquiring activity, the prime contractor, or even sub-contractors have visibility or configuration control authority over every part. Rather it means that some organization within either the supply chain or the standardization process has configuration documentation and change control responsibility for each part. The attributes of configuration items are defined in configuration documentation. Configuration baselines are established to identify the current approved documents. Configuration items are uniquely identified. They are verified to make sure they conform to, and perform as defined in, the configuration documentation.

- Wikipedia November 23, 2013, http://en.wikipedia.org/wiki/Configuration_item

The term **configuration item** or **CI** refers to the fundamental structural unit of a configuration management system. Examples of CIs include individual requirements documents, software, models, and plans.*

The NATO CM Symposium Group definition of a CI introduces the concepts of provenance and content to the definition of a CI. Provenance from the French word “provenir,” which means “to come from,” covers an object’s complete documented history. It was chosen for use in the definition as it includes documentation throughout the product’s life cycle and not simply to the point of creation. Content was similarly chosen as content may change over time.

MIL-HDBK-61A definition of a CI makes the proviso that the “CI level is where configuration management really begins.”

Configuration management actually begins at that point the decision is made to enter any market segment and continues throughout the product’s development, introduction, growth, maturity, and decline. It is not necessary to designate a product as CI for CM to take place. In many cases, when performing on a contract to produce items for a specific customer, it is inadvisable to designate something as a CI until decisions have been made regarding its use and maintenance. ISO 7001 identifies a set of items that should be considered when selecting a CI.

- ISO 10007:2003, Quality management systems—guidelines for configuration management, Selection criteria should consider:
 - Statutory and regulatory requirements
 - Criticality in terms of risks and safety
 - New or modified technology, design, or development
 - Interfaces with other configuration items

* From Wikipedia released under CC-BY-SA license at <http://creativecommons.org/licenses/by-sa/3.0/>.

- Procurement conditions
- Support and service

The standard goes on to caution:

The number of configuration items selected should optimize the ability to control the product. The selection of configuration items should be initiated as early as possible in the product life cycle. The configuration items should be reviewed as the product evolves.

The list of things to be considered in ISO 1007 is incomplete and to be meaningful should also consider the following:

- Cost versus benefits
- Quality
- Reliability
- Estimated life

Under the area of support and service, the following points should be added:

- Reparability
- Location of repair
- Difficulty of repair

CI should be designated at the highest level possible and too few CIs rather than too many CIs in the final product are advised. This is at odds with the view taken by many involved in providing items to governments. We will address that further in the Section 5.3.

Designation of a product as a CI implies that there is an identifier associated with it. This CII is often overcomplicated and in some cases misunderstood. A CII can be anything that specifically identifies a CI from the other CIs and when paired with its provenance (pedigree) is part of the product's identity.

Depending on how you view the issue in the *general context*, a person's national identity code [social security number (SSN, in the United States) or other] is their CII number. All of your medical records, employment history, education, and such are tracked against it. The country in which you reside derives benefit from it as they can, as the situation requires, generate revenue from that CII, trace its actions and medical history, access your credit history, current accounts, and any other information they wish about each CII in the system. A person's national identity code may be coupled to one's passport (if they are not the same) and movements abroad may be monitored as well for government use.

U.S. currency is another government use of the concept of what, in a very broad sense, is a CII. U.S. currency in use in 2013 had a series date, the Federal Reserve district number (also appears as the prefix of the serial number), note number position, plate serial number, and a serial number associated with its denomination. The provenance of a U.S. currency note can be established irrefutably to its place of origin and position on the sheet of notes printed ([Figure 5.1](#)).

While series numbers change with each new secretary of the Treasury and part number changes as the design of the note denomination changes, the serial number is unique to the note in that series and denomination and serve as a general representation of the relationship between a CII and serialization. A single dollar note has the same buying power against other currencies on the day it is spent. This would lead one to expect the one dollar note to be the same in form and

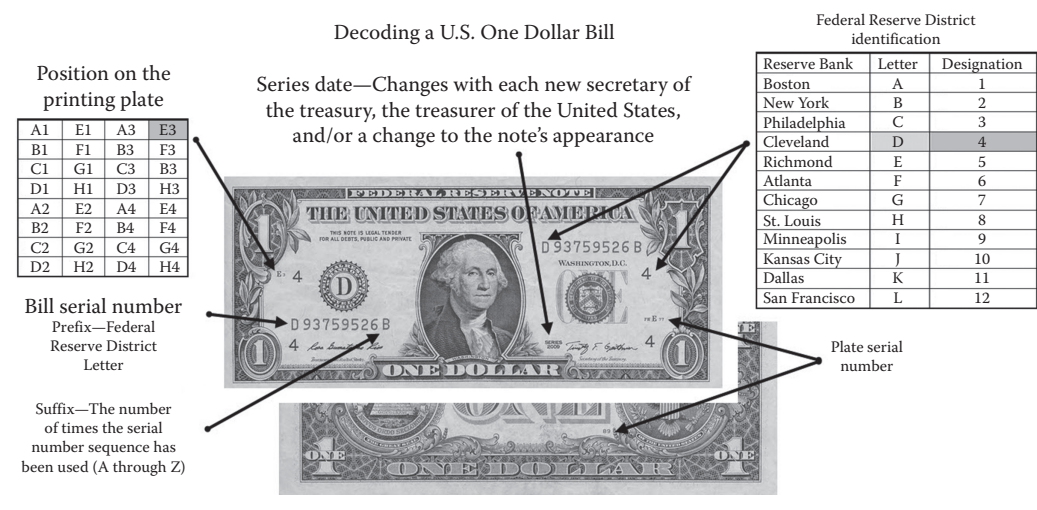


Figure 5.1 U.S. Dollar provenance.

format. This is far from the truth. The U.S. legal tender one dollar note from 1861 to 1864 featured the face of Salmon P. Chase, U.S. secretary of Treasury. The more familiar image of George Washington did not appear until 1869. At various times, the one dollar note has gone by many names that reflected its worth. Some one dollar silver certificates in 1891 featured the image of Martha Washington. Those issued during 1896 featured both George and Martha Washington. Those issued in 1899 featured the American Bald Eagle.

Every major form of currency has relatable information sets. In the case of the United States, one dollar note the case can easily be made that the series date plus the plate serial number constitute the CII for the note being printed. CII numbering scheme is as varied as the market segments they exist in. In the case of the United States one dollar note; the series date plus the plate serial number constitute the CII. A sample CII numbering schema is shown in [Figure 5.2](#).

5.3 Serialization

The decision to assign a serial number (also known as the manufacturer's serial number, product key, or other unique code) to identify a single unit from another unit in the same production run is not a trivial decision. Serial number is also a misleading description, as it can be composed of any string of alpha numeric or symbols applied to a unit in a sequence that can later be decoded. Some industrial sectors prefer to serialize and then add what are known as "nominal characters" after the serial number to denote changes in the item status during the product life cycle as a quickly recognizable item genealogy.

XZY2460001	Assigned serial number
XZY2460001T	Serial number after test
XZY2460001TV	Serial number after test and validation
XZY2460001TVA	Serial number after test, validation, and acceptance
XZY2460001TVAM1	Serial number after test, validation, acceptance, and mod kit 1
XZY2460001TVA1M1M2	Serial number after test, validation, acceptance, mod kit 1, and mod kit 2

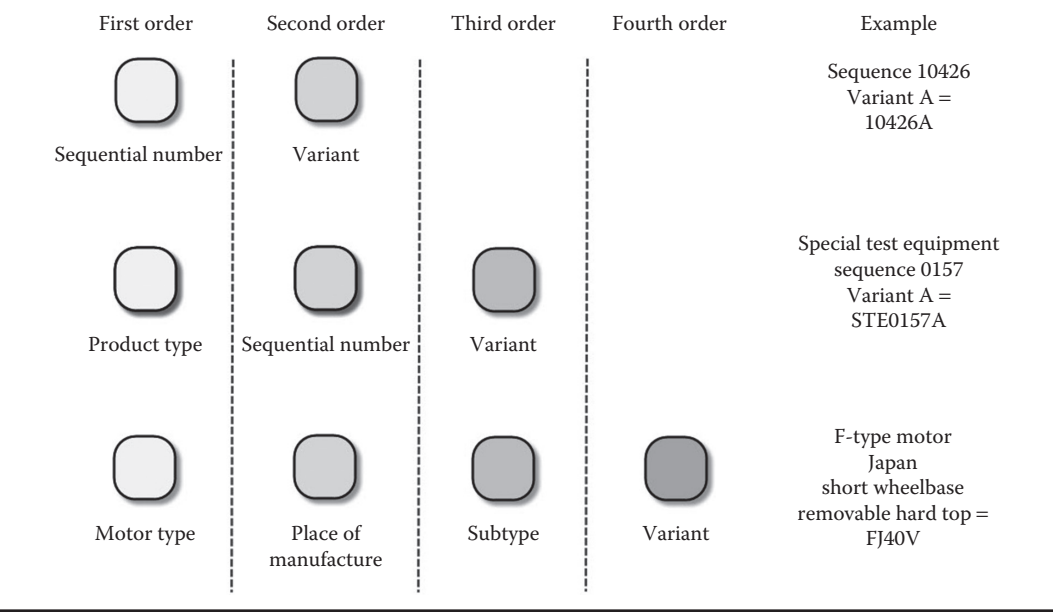


Figure 5.2 CII numbering schema.

This is not unlike the tradition of keeping family genealogy adding the mother’s maiden name to the middle name of each child in some cultures

Peter Merrill VahDonk
Sam Merrill Ensign VahDonk
Joshua Merrill Ensign Fitzroy VahDonk
Joshua Merrill Ensign Fitzroy Sharma VahDonk

Serialization exists on almost every item we use in our daily lives and offers many advantages to the producer as well as to the consumer and can be applied or associated with tangible as well as intangible goods. Serial numbers may also be necessary to validate certificates and certificate Authorities through the application of mathematically rigorous serial numbers and serial number arithmetic not identifying a single instance of the content being protected. In 2010, the U.S. Food and Drug Administration (FDA) published final guidance for pharmaceuticals serialization on prescription drug packages to assist in the prevention of counterfeit medicines in the marketplace.* It follows standard global trade item number protocols used worldwide by 23 industrial sectors, including healthcare, and adopted by 65 countries to uniquely identify pharmaceutical products. Serial numbers are also utilized in information technology (IT) network protocols and generally enforced using special rules, including sophisticated lollipop-shaped sequence number spaces proposed by Dr. Radia Perlman.†

* FDA, U.S. (2010). *Guidance for Industry Standards for Securing the Drug Supply Chain—Standardized Numerical Identification for Prescription Drug Packages: Final Guidance*, Silver Spring, MD: U.S. Department of Health and Human Services Food and Drug Administration. U.S. FDA.

† Perlman, R. (1983). Fault-tolerant broadcasting of routing information. *Computer Networks*, Vol. 7, 395–405.

If futurists are correct, the following from the movie *Blade Runner** may be only decades away in one form or another.

Cambodian Lady: “Finest quality. Superior workmanship. There is a maker’s serial number 9906947-XB71 Snake scale.”

It distinguishes multiple copies of any item *under configuration management* from one another as an aid to traceability. There is no set formula to serial number application or creation. It transcends market segments and market niche.

There is no distinct key that can be used as guidance for the creation of a serial number. Generally, guidance is that it is unique to each copy of the product. In some market sectors, there is an attempt to tie it to the drawing associated with the top assembly of the CII. This is not always the best approach to serialization of an item. How it will manifest itself as a best practice in the future is unknown. Once the capabilities of 3D printing evolve, it may result in identification coded into the product itself as portrayed in *Blade Runner*. Combined with the evolution in nanotechnologies this is entirely possible. Currently configuration data for hip and other biomechanical replacements are serialized and tracked to the patient. It is inconceivable that similar tracking of 3D-printed internal organs would not be implemented. Serialization approaches vary. Some of these approaches from different industries are shown in Figure 5.3.

The following general rules for serialization are used in many market segments.

- Once a serial number is assigned, it can never be changed.
- If a serialized product is installed into a higher level product, the higher level product is said to have consumed the lower level one.
- A single instance of a design item is typically used in association with repair and warranty repair/replacement traceability.
- Candidates for serialization include the following:
 - The product, if designated as a CI
 - Lower level products incorporated into the top-level product
 - Any item that can be replaced in any logistics activity
 - Spare lower level products available for sale as a standalone item

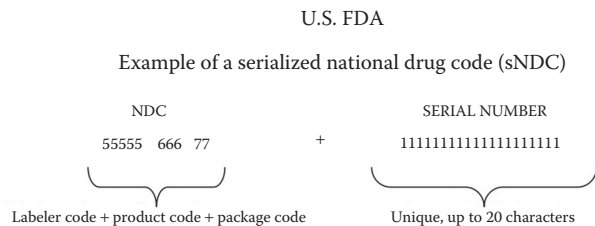
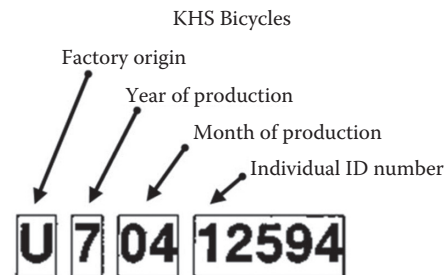
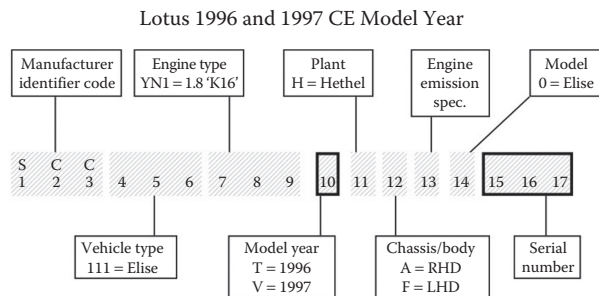
Going back to the earlier representation of a person as a CI, this might include any 3D organ grown inside or outside of the body and replacement parts such as knees and hip joint components. This is one possibility envisioned by Hod Lipson and Melba Jurman.[†] We will discuss 3D printing further in section 6.4.1.

5.4 Traceability

The concept of traceability may be the easiest to understand by referring to the website <http://www.trackdollarbills.com/>, which allows an individual to enter the denomination and serial numbers of the U.S. paper currency in their possession, and should another member of the community later enter the same denomination and serial number, it would make a connection of where the note has been. This is similar to the way international movement of individuals can be traced through their

* Scott, R. (Director). (1982). *Blade Runner*. [Motion Picture]. Warner Brothers Studios, Burbank, CA.

[†] Lipson, H., and Kurman, M. (2013). *Fabricated: The New World of 3D Printing*. Hoboken, NJ: John Wiley & Sons.



Case steam tractor

Case steam production data

Year	Starting serial no.	Ending serial no.	Total	HP sizes
1876	1	75	75	10, 8
1877	76	184	109	10, 8
1878	185	421	237	10, 8
1879	422	665	244	8, 10, 15
1880	666	975	310	8, 10, 12, 15, 20
1881	976	1386	411	8, 10, 12, 15, 16, 20
1882	1387	1892	506	8, 10, 12, 16, 20, 30
1883	1893	2484	592	8, 10, 12, 16, 20, 25, 30
1884	2485	2786	302	10, 12, 14, 16, 20, 25, 30
1885	2787	2981	195	8, 10, 12, 14
1886	2982	3163	182	8, 10, 12, 30
1887	3164	3399	236	8, 10, 12, 16, 30
1888	3400	3679	280	6, 8, 10, 12, 16, 20, 30
1889	3680	3976	297	6, 8, 10, 12, 14, 16, 20, 25, 30

Figure 5.3 Serialization approaches.

passport. As with many aspects of one's life the day-to-day exigencies of work at times hide aspects of CM from registering on the CM professional. Daily we see reasons why traceability is important in the news and social media. In 2012, we saw record numbers of automotive,* children's toys,† food products,‡ and other items due to inadequate management of product configurations and associated processes.

The U.S. FDA, suppliers, and consumers may soon have standard traceability mechanisms based on commonly collected data into a meaningful system to facilitate risk reduction, supplier control, traceability, and minimizing recall damage, which are all critical components of any food safety plan. Regardless of a company's position in the food supply chain, dependence on those companies one up and one down the ladder creates liability and exposure. In agriculture, traceability is critical through long processes and zones (farm, blend operations, distribution, picking operations, and retail). This issue was the subject of November 26, 2013, at 12:00 hours, Eastern Standard Time, Food Seminars International sponsored a seminar using WebEx "Using Traceability and Controls to Reduce Risk and Recall: Integrating Food Safety Systems."

Traceability goes both ways when applied to products. It is not simply the tracing of a requirement to the system or subsystem, but it is flowed down throughout the product life cycle, so that a requirements matrix verifying that the form, fit, function, and quality of the item is met and any associated validation and verification objectives are proved. Understanding the heritage of not only the design and how it applies to the whole but also the individual elements that make up the finished product is critical. This may be a new way of looking at traceability for many in CM. The following figures provide a pictorial look at three forms of traceability that are of particular concern to management of any product.

Functional requirements traceability (Figure 5.4) is what is generally thought of as traceability by most practitioners of CM. It is but one element of traceability.

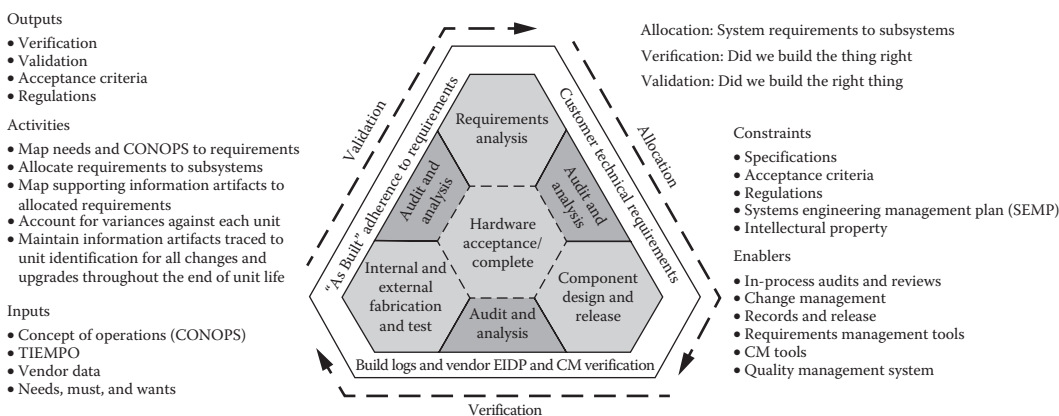


Figure 5.4 Functional requirements.

* Gorzelany, J. (2012, December 29). *Biggest Auto Recalls of 2012 (And Why They Haven't Affected New Car Sales)*. Retrieved November 26, 2013, from <http://www.forbes.com/sites/jimgorzelany/2012/12/29/biggest-auto-recalls-of-2012/>.

† Sole-Smith, V. (2013). *How to Protect Kids from Lead Toys*, <http://www.goodhousekeeping.com/health/womens-health/poisonous-lead-toys-0907>. Retrieved December 26, 2014.

‡ Bottemiller, H. (2012, October 8). *2.5 Million Pounds of Recalled Canadian Beef Entered U.S.* Retrieved November 26, 2013, from <http://www.foodsafetynews.com/2012/10/2-5-million-pounds-of-recalled-canadian-beef-entered-u-s/#.U9FDCPlidV8E>.

As soon as all allocations have been established, every supporting information artifact must be gathered and mapped (traced) to requirements. A single artifact may fill multiple requirements and cross traceability must be established. Lower level elements of a product may be produced within the company or they may be produced by another company. The make or buy analysis or trade study becomes part of the traceability of the requirements allocation, the basis for the generation of a vendor statement of work, specifications, interfaces, and negotiation of vendor intellectual property (IP) considerations. This supporting information includes, but is not limited to, all enterprise- and vendor-level information regarding formulation, safety, handling, test, operation and installation, environmental and biological impacts due to use, other known hazards and similar data associated with the product, items it comprises, and processes used during product creation.

Test, Inspection & Evaluation Master Plan Organized (TIEMPO) has been found as a very effective tool for the collection of the necessary artifacts and leverages forward aspects of the U.S. Department of Defense's Test and Evaluation Master Plan (TEMP) by adding in inspection as well analysis and demonstration. These align exactly with Section 3.6.3 (Verification requirements) of the U.S. Federal Highway Administration and California Department of Transportation systems engineering guidebook. So TEMP becomes TIEMPO, Spanish for "time" or "weather" depending on the context used. TIEMPO as a tool simply means if you do not take the time, you will hit some very bad weather on your project. The TIEMPO methodology shown in Figure 5.5 will be discussed further in Chapter 12.

The key aspect of TIEMPO is the mapping of the product delivery or product growth through the development process. In the document, the content in each individually developed iteration product incarnation is described. These *development baselines* are mapped to the critiquing methods of test, evaluation, and inspection giving a comprehensive view of the product growth and level of quality.

IP aspects of each product require a level of traceability that reaches far beyond the tracing of requirements for verification and validation of a product (Figure 5.6). IP may include implied and actual warranties as well as remedies for latent and patent defects.

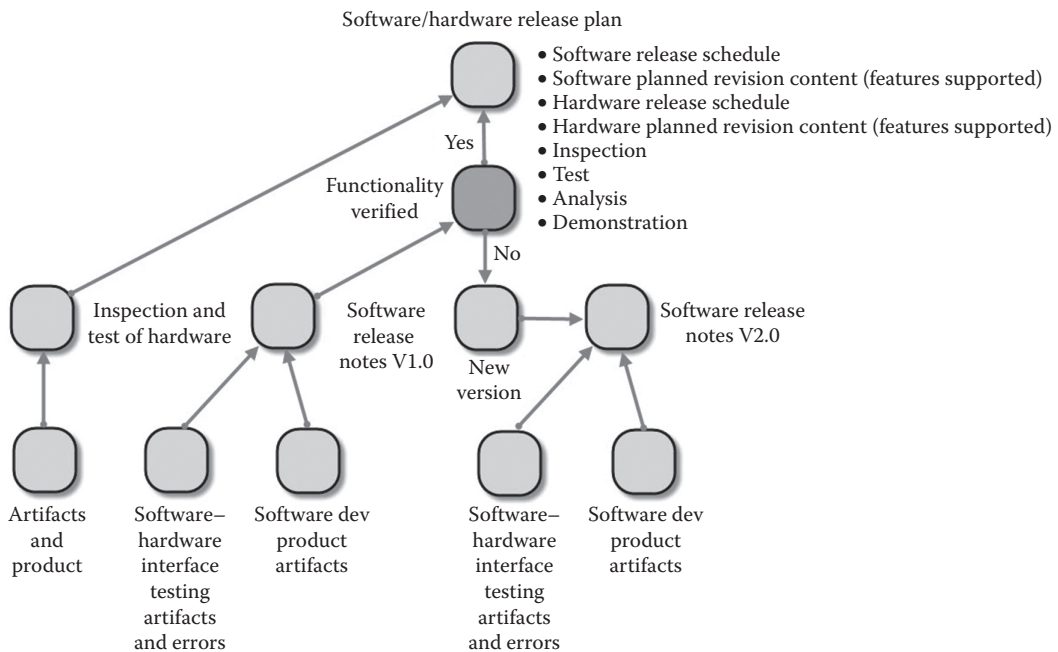


Figure 5.5 TIEMPO.

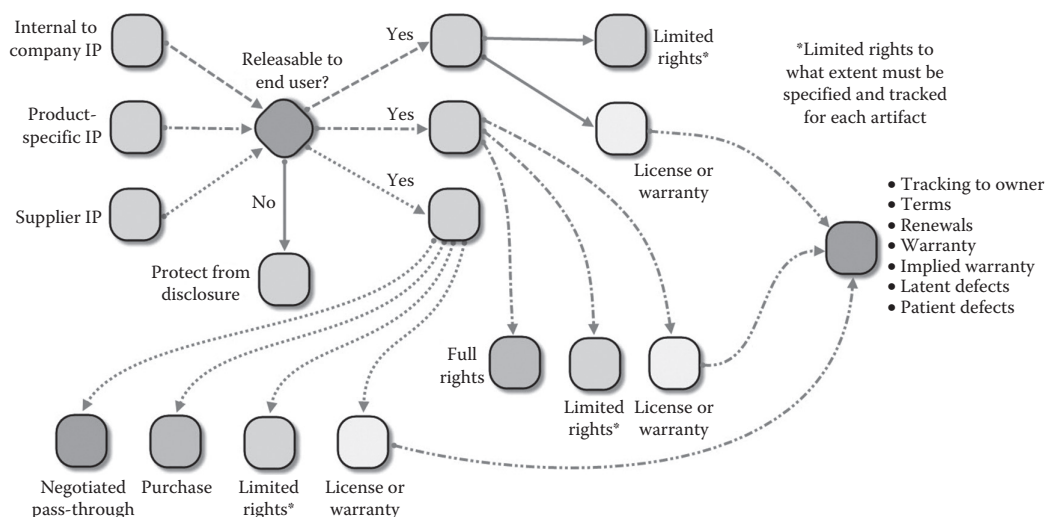


Figure 5.6 Intellectual property.

Other product-related supporting information may need to be gathered and traced to the product, elements within the product, or as required to meet the internal process improvement and other internal and regulatory needs. Traceability does not start with the designation of an item as a CI and may continue indefinitely if it pertains to manufacturing process, plant operations, geopolitical, or environmental standpoint.

5.5 Higher Level of Management Controls

IEEE Standard 828-2012* describes seven primary lower level processes and two special instances of applying the lower level processes.

- The primary lower level processes are
 - Planning
 - Management
 - Configuration identification
 - Configuration change control
 - Configuration status accounting
 - Configuration auditing
 - Configuration release management
- The special instances are
 - Interface control
 - Supplier CI control

CM life cycle processes are shown in [Figure 5.7](#).

* IEEE. (2012). *IEEE-828-2012—IEEE Standard for Configuration Management in Systems and Software Engineering*. New York, NY: IEEE.

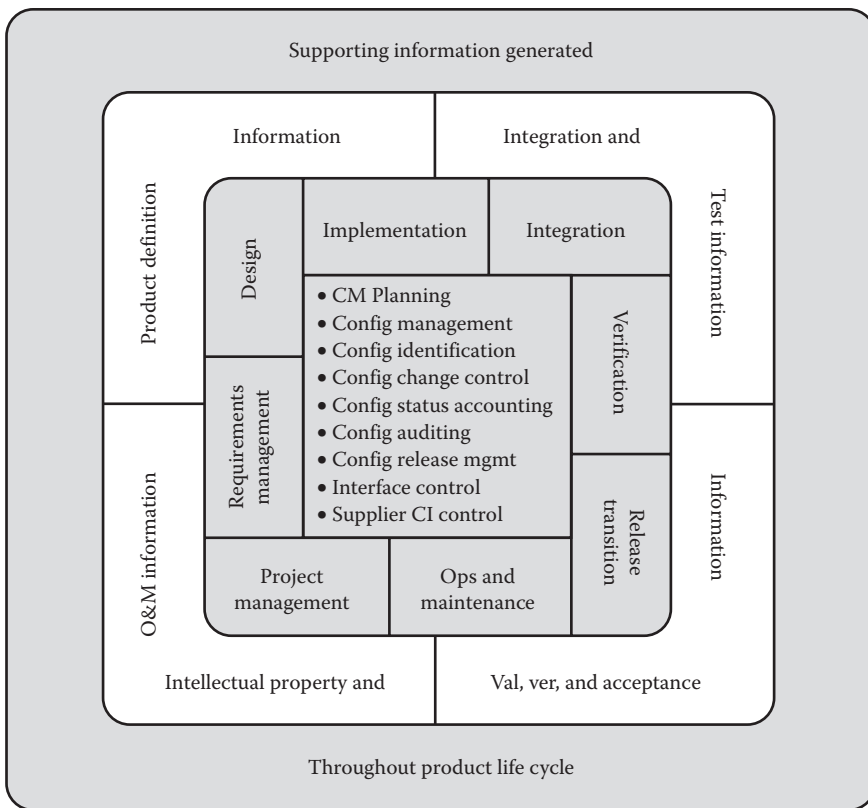


Figure 5.7 CM life cycle processes.

5.5.1 CM Planning

ANSI/EIA 649-B-2011* provides the following guidance in Section 5.1, “Configuration Management Planning and Management.”

CM planning and management over the life cycle of a product are essential to achieve an effective, predictable, and repeatable CM process. CM planning focuses on the product and on the customer(s) and shapes the application of solid, practical procedures that result in cost avoidance and enhanced product quality and stability.

Comprehensive CM planning and management includes:

- Applying the appropriate level of CM functions throughout the product’s life cycle
- Implementing policies and procedures, resulting in effective product configuration management
- Assigning CM functional responsibilities to various organizational elements

* TechAmerica. (2011). *ANSI/EIA 649-B-2011, TechAmerica Standard: Configuration Management Standard*. TechAmerica.

- Training of CM personnel and any others who have CM responsibilities
- Determining and applying adequate resources, including CM software tools, and facilities
- Establishing CM performance indicators to serve as a basis for continuous improvement
- Assuring performance of Configuration Management by suppliers
- Integrating the organization's product configuration information processes

Arrival at this definition was not a trivial process and it should not be taken lightly, nor should it be taken out of context with everything previously addressed in this book. Performing CM planning activities is more than completing a boilerplate CM plan based on a set of criteria established using customer, company or content suggested by IEEE Standard 828, "IEEE Standard for Configuration Management in Systems and Software Engineering"; ISO 10007-2003, "Quality Management Systems—Guidelines for Configuration Management"; or ANSI/EIA 649-B-2011, "TechAmerica Standard: Configuration Management Standard."

Figure 1.3 presented the cost and influence of critical design decisions plotted over time. One of those design decisions involves CM planning. Planning the management of the configuration not only requires a knowledge of CM principles but also requires the application of those principles to the specifics of the market sector the product is in, a knowledge of the product itself, company functional resources, consumer needs, and expectations as well as the IP and regulatory aspects involved.

Planning an excursion to a location you have never visited requires research as well as a deeper understanding of multiple parameters. Considerations for a visit to a hydrothermal vent in the abyssal zone on the Comfortless Cove Hydrothermal Field (4°48' South 12°22' West, elevation -2996 m) would be quite different than a visit to HaLong Bay or the Bay of Descending Dragons, Vietnam (20° 53' 60" North 107° 6' 60" East).

Each of the elements cited from ANSI/EIA 649-B above requires the same level of comprehension. There is no *one size fits all* solution for CM implementation. Similarities will exist in how you perform the planning function but the solution you arrive at will be unique to the product and its place in the product life cycle. This will become clearer as you progress through the rest of this book.

Larry Bowen in his presentation on *Advanced Configuration Management** observed that in the IT area, the following considerations should be made regarding the planning, CM, and cost assumptions for implementation.

WALK, THEN RUN!
THE PLAN IS NOTHING, PLANNING IS EVERYTHING!
CLAIM EARNED VALUE AS YOU IMPLEMENT!

- Work from a Plan
- Assume a Phased Implementation
 - Involve End Users in Developing the Technical Plan, Implementation Strategy and Training Plan
- Assume that Legacy Data, Systems and Procedures will be Incorporated
- Satisfy, don't Optimize

* Bowen, L.R. (2007). *Advanced Configuration Management*. Boulder, CO: Larry R. Bowen.

- Use Pilot Projects to Test Assumptions
- Gather User Feedback and Incorporate it
- Collect and Analyze Metrics to Measure Results
- Remain Flexible; Adjust or Abandon Unsuccessful Efforts Early
- Form a Customer/Contractor Team to:
 - Analyze Requirements
 - Maintain All Information Electronically
 - Manage Real-Time Upgrades and Installation of Enhancements
- Implement a Constrained System
- Plan Roll Out to Production
- Establish a Configuration Control Board (CCB) to Baseline the System and Control Enhancements/Upgrades
- System Engineering, Information Technology, Data Management, Engineering, Manufacturing, Procurement, Logistics and Configuration Management Must Work as a Team Controlling the Development to a Requirements Document that is Used to Implement User Requirements
- Select a Standard Set of Tools to Minimize as Much as Possible Customized Code/Applications to Make the PDM System Work
- *Hit the Long Poles in the Tent First*—Use Metrics to Drive the Implementation
- *Burden Fund the System*—Make its Use Free to Programs and Projects. Data Entry should be paid for by the Project/Program. The PD/LM System and its Maintenance are paid for by the company

A good rule of thumb after the initial implementation is approximately \$600,000 for maintenance and \$800,000 for continued development until the desired system functionality is achieved. These costs are based on approximately 400 users (approximately 150 concurrent) in an enterprise involving 8000 employees. Do not underestimate the cost of migrating legacy data into the system.

A user's group is mandatory to continue system upgrades that meet program and other user requirements.

5.5.2 Configuration Identification

The subject of configuration identification will be explored in depth in Chapter 10.

IEEE Standard 828 states,

The purpose of configuration identification is to determine naming schemes for configuration items (CIs), identify the items that require control as CIs, and to apply appropriate names to them.

The scope of configuration identification includes: determining the CIs that are to be managed and determining what documentation information is to be used for describing the physical and functional characteristics of each CI; planning for the collection, storage, retrieval, and change control of baselined versions of the items and their descriptive documentation information; establishing and maintaining associations between versions of each item and its descriptive information; establishing versioned assemblies or collections of CI versions that satisfy the totality of end use functions; establishing and maintaining associations between versions of

such assemblies or collections and the descriptive documentation information of the physical and functional characteristics of the assembly or collection, and describing the product structure through the selection of CIs and identification of their interrelationships.

The determining factor is whether an item or information will be needed if the project needs to reinstate a previous baselined position in the life cycle to once again move forward on the build cycle.

Configuration Management Data Base (CMDB):

- Attribution: Attribution shall be provided to the CCB that is accountable for the affected baseline.
- Impact analysis: A documented impact analysis reviewed by all the CCB members shall be recorded.
 - Impact analysis shall consider severity of any problem to be corrected by the change as well as how frequently or how widely such problem will affect the product's users. Impacts to the product development project shall also be considered.
- Rationale and approval: The CCB shall approve/reject the change using its established decision process and shall provide the reason for their decision.
- Notification: Notification to affected parties shall be part of the formal process.
- Reversibility: Baseline change control shall be supported by versioning systems that allow individual reversibility of constituent configuration items.
 - This, aided by the set of changes requirement, assures full reversibility.
- Set of Changes: The affected baseline and the impacted artifacts (from the impact analysis) form the set of changes to apply to the baseline and shall be documented.
- Audit trail: A record of the change request forms containing the process evidence shall be kept for auditability purposes.

MIL-HDBK-61A, Military Handbook Configuration Management Guidance gives what many believe is the typical definition of activities that take place during configuration identification.

5.1 Configuration Identification Activity—Configuration identification incrementally establishes and maintains the definitive current basis for control and status accounting of a system and its configuration items (CIs) throughout their life cycle (development, production, deployment and operational support, until demilitarization and disposal). The configuration identification process ensures that all acquisition and sustainment management disciplines have common sets of documentation as the basis for developing a new system, modifying an existing component; buying a product for operational use, and providing support for the system and its components. The configuration identification process also includes identifiers that are shorthand references to items and their documentation. Good configuration control procedures assure the continuous integrity of the configuration identification. The configuration identification process includes:

- Selecting configuration items at appropriate levels of the product structure to facilitate the documentation, control and support of the items and their documentation.

- Determining the types of configuration documentation required for each CI to define its performance, functional and physical attributes, including internal and external interfaces. Configuration documentation provides the basis to develop and procure software/parts/material, fabricate and assemble parts, inspect and test items, and maintain systems.
- Determining the appropriate configuration control authority for each configuration document consistent with logistic support planning for the associated CI.
- Issuing identifiers for the CIs and the configuration documentation.
- Maintaining the configuration identification of CIs to facilitate effective logistics support of items in service.
- Releasing configuration documentation; and
- Establishing configuration baselines for the configuration control of CIs.

Effective configuration identification is a pre-requisite for the other configuration management activities (configuration control, status accounting, audit), which all use the products of configuration identification. If CIs and their associated configuration documentation are not properly identified, it is impossible to control the changes to the items' configuration, to establish accurate records and reports, or to validate the configuration through audit. Inaccurate or incomplete configuration documentation may result in defective products, schedule delays, and higher maintenance costs after delivery.

Jack Wasson goes on to give the following definition of configuration identification:

This process involves identification of documents comprising the configuration baselines for the system and lower-level items (including logistics support elements) and identification of those items and documents. When an item is identified, it is known as a configuration item (CI). Configuration Identification determines the makeup of any and all products along with their associated documentation. It defines performance, interface, and other attributes for configuration items; provides unique identity (i.e. drawing, document or ID numbers) to products, components, and documentation; specifies identification markings (if required); modifies product and document identifiers to reflect major changes; maintains release control and baseline definition; provides reference for changes and corrective actions; and correlates document revision level to product configuration, which enables users to distinguish between product versions, allows people to correlate a product to the appropriate instructions, and correlates items to service life. What it boils down to is that configuration identification determines how document control numbers and version numbering are applied and used so that everything is labeled correctly and understandably as prescribed by the Configuration Item (CI) manager of that product.

The concept of baseline is mentioned in both the definitions. Many familiar with CM as something done after receipt of a contract will be familiar with the concept of milestone events and a baseline gate that is normally associated with them.

The mission stage timeline shown subsequently is roughly relatable to the product phases of development, introduction, growth, maturity, and decline discussed in Chapter 1. For many practitioners of CM, their exposure is limited to contracted work in a governmental setting and little consideration is given to the product phases, as they relate to the market segment the product is

being offered in. One misconception is that a CI can only be in a single baseline when in actual practice elements of the CI may be in any phase. Common design items incorporated into the CI may be in the product baseline. Some subcontracted items may be in the development configuration phase nearing the product baseline. Internal to the company, CIs may be in the developmental configuration phase just entering into the first of many major reviews. Figure 5.8 shows the relationship between baseline and mission stage.

The term “unified change control” may not be familiar to many CM professionals. It was chosen as it is better understood in some industries and equates to what some may identify as *integrated change control*. Unified implies a larger scope and requires that all aspects of a change be evaluated not only against a particular product procurement but also against every other product in the entire system prior to being authorized. A seemingly simple change to the focal plane in a remote sensing device that increases image quality across the visible spectrum while degrading it in the infrared and ultraviolet will impact the ability to use algorithms developed for the evaluation of a single dataset in the degraded frequencies and may result in the product not being suitable for its intended use. It is recommended that an aligned product development model be used

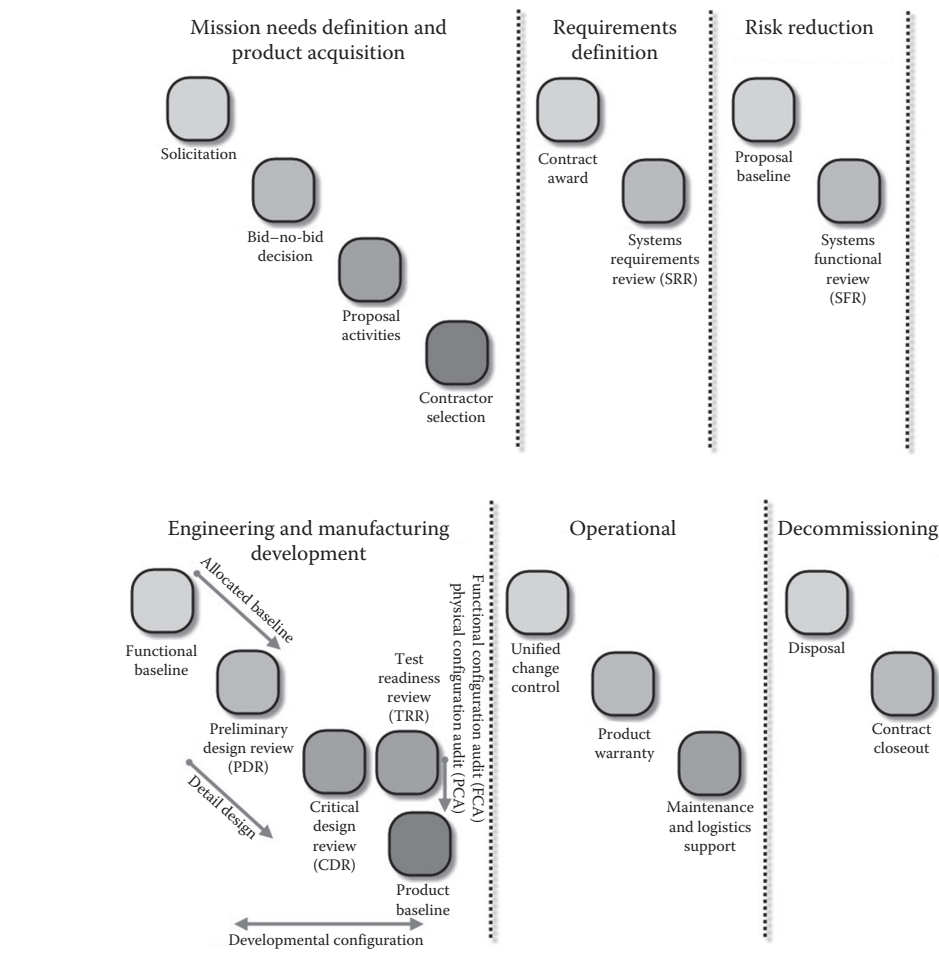


Figure 5.8 Baseline versus mission stage.

to assure a full understanding of the scope of the items whose configurations are being managed. Figure 5.9 illustrates the simple aligned hardware–software model with the generally recognizable milestones and baselines.

On a now decommissioned U.S. ballistic missile program, the missile stage contractors produced stage diameters that were not all the same. The lack of a controlled management of the configuration rippled throughout the launch system, impacting the thickness of pads used to support the stages in the launch tube, the ground support equipment, stage-to-stage interfaces, missile assembly procedures as well as logistics and launch system deployment.

This identification of incompatibilities across all systems through the proper evaluation of impacts prior to implementing a change is the realization of CM in its purest sense. The IEEE Standard 828 citation provided earlier identifies a key and often overlooked element of the baseline process. “Reversibility: Baseline change control shall be supported by versioning systems that allow individual reversibility of constituent configuration items.” Reversibility in this context means that the CM system is capable of identifying the release status of all elements for any CI on the date the baseline was established, as well as for each serial number of the CI on the date it was accepted for shipment or sale. Of the companies evaluated prior to the writing of this book, reversibility of any baseline in the software area was generally present. It was found that the greater the reversibility of the baseline in all other areas, the closer the product produced was to the commercial marketplace.

The closer the firm was to relying entirely on a government revenue stream the less likely it was to have baseline reversibility. This generalization needs to be qualified. Companies that were experienced in providing logistical support for their products understood baseline reversibility and managed it much better than companies producing very specialized products in a *one-off* environment, where a single item or fewer than 10 serial numbers are produced for government use, nonsystems integrators were likely to use a CM system that could provide the release status of all elements for any serial number of the CI. Generally, the CM system could only identify the latest of all information (drawings, specifications, models, analysis, etc.) on the date a query was made.

Although companies did often produce an *as built* versus *as designed* reconciliation report that included all major and minor variances and authorized part substitutions in many cases, it was not searchable and not associated in the CM system with the specific serial number. Part substitutions and variances were not tracked in the CM system due to incompatibilities between quality management, build, and design databases. In some cases, records associated with the products received for upgrade were not available. The lack of data availability in an automated system for each serial number is disastrous to the maintenance of anomaly resolution of complex systems. It makes recall of sold products due to latent defects or poor design nearly impossible. In one case, the design development proof of concept evaluation units using nonqualified parts included in the product structure of an operational satellite were not discovered until part way through final assembly.

No CM system or method of configuration identification is perfect. Errors will occur and some of these are documented in Chapter 12. The key to reducing critical issues is in the proper evaluation of the CM application to the product using standard methodologies from all functional resources and tying together metadata generated by each in such a way that configuration identification is adequately established and the provenance of each serial number is irrefutable.

Product provenance and logistical implications of a product’s maintenance, should it be maintainable, are critical to the life of each product. Four conditions normally exist during the after point of sales life of a product.

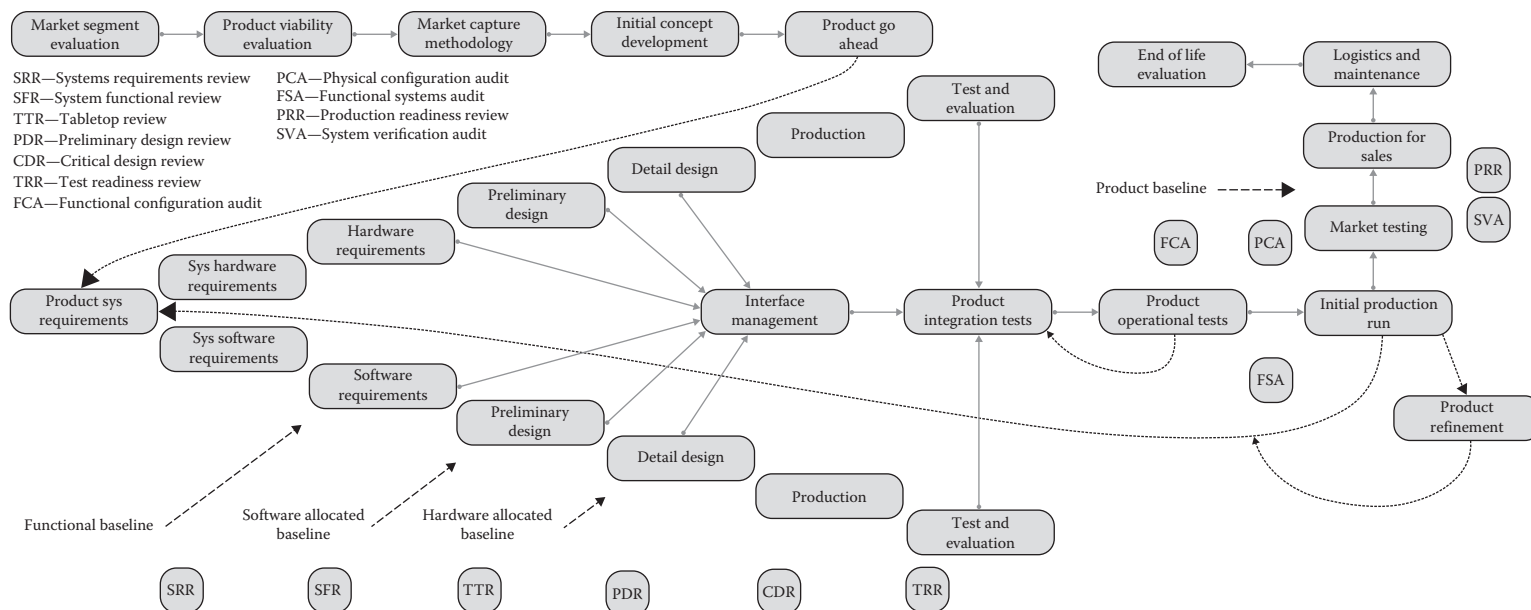


Figure 5.9 Aligned product development model.

1. The company is still producing the product and is providing repair/maintenance services.
2. The company is still producing the product and sells repair elements for third-party installation/repair/maintenance.
3. The company is still producing the product and is providing repair/maintenance services and other vendors are selling nonoriginal manufacturer elements.
4. The company is no longer producing the product and a third party is producing and selling repair elements for third-party repair/maintenance.

Put into an easier to grasp context:

1. You can purchase a vehicle for personal transportation and have the vehicle dealer repair/maintain it.
2. You can have repair/maintenance services done by a nondealer or do them yourself using original equipment manufacturer (OEM) parts.
3. You can have repair/maintenance services done by a nondealer or do them yourself using non-OEM parts.
4. Your vehicle is out of production and restoration/repair/maintenance services can only be done using non-OEM parts by a nondealer or by doing them yourself.

Often those providing products designed specifically for government use will be requested to provide a technical data package in accordance with a standard format and content structure (e.g., MIL-STD-31000*) to facilitate re-procurement of products or re-competition on a build to print basis. Offloading of production is an equivalent analogous activity in commercial markets after the completion of market testing. Data packages for both are similar in nature and contain all information required to produce the item by another party without reference to internal documents or company-protected IP. In some cases, production of dyes, jigs, and fixtures are provided along with other information (drawings, test procedures, inspection points and procedures, and final acceptance criteria).

5.5.3 Change Control

Change is a fundamental component of our universe. Change goes around us regardless of personal desires to hold elements in our lives, products, and businesses static. The best we can hope to accomplish is to manage change. So what is meant by change management as it applies to a company's products and internal operations? Figure 5.10 shows that it is not enough to react to change. It is also necessary to actively plan for change and that change control does not stop at change approval. The change process for a given change only ends when every aspect of its implementation has been verified as complete.

It is not enough to simply generate, review, and release a change. Change management is not complete until the total implementation of the change has been verified. This includes modifying units that may be in process or in stock waiting for delivery. It also includes all recall and rework activities associated with product delivered to a sales organization and rework of all sold items. The reality of change management includes much more than is typically included with many product data/life cycle management (PD/LM) systems. Change management is the process of utilizing

* DOD, U.S. (2009). *MIL-STD-31000A, U.S. Department of Defense Standard Practice: Technical Data Packages*. Washington, DC: U.S. Government, Pentagon.

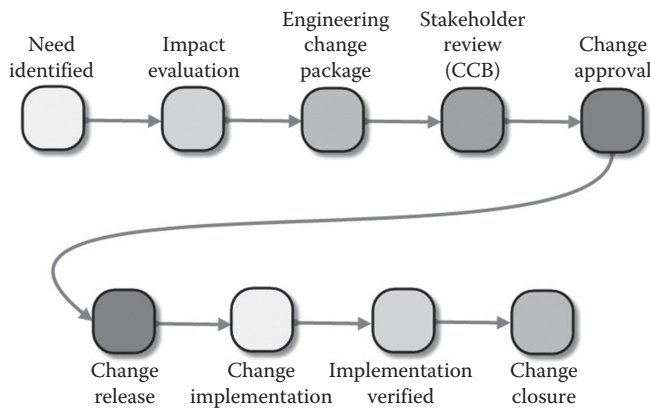


Figure 5.10 Change management.

change control capabilities from the identification of a need to change through implementation and verification of implementing the change.

The prerequisite to change control is understanding what is being developed, how subsystems interact, what information should be developed, how that information will be used, and what the product structure and data structure look like and how they are interrelated. Change control must be an end-to-end system that considers not only the what, why, where, and when of change implementation, but the impact to cost and schedule of the product. It also needs to account for test temporary configurations, major and minor variances, and what are known as “block updates” to the design that establish, upgrade, and repair liens against all delivered units. Block updates to the design are an everyday occurrence in consumer software and software-inclusive products such as Blu-ray players and telecommunication devices. In the automotive sector, they form the basis for recall of units sold and are rolled into product under production or available for sale from new vehicle sales locations. Noncritical block updates of automotive parts may be tied to changing manufacturing capabilities as well as the standardization of product component and are tracked against parts lists for vehicles sold on a component cross-reference basis.

A test of this capability was made prior to the writing this chapter that involved the purchase of a new ignition switch for a 1971 Ford 350 Econoline van. The existing switch was removed and the Ford dealer pulled a new unit from stock as well as an adapter ring to allow its use as a replacement for the original part. Form, fit, function, and quality of the new unit were superior to the old unit and CM had been maintained up to the point of interchangeability as a logistics support activity. This evidenced a clear understanding and implementation of configuration control throughout the product life cycle of the 1971 van as well as an impressive wide-reaching enterprise-level CM implementation that allowed for real-time IT searches for replacement and repair activities.

Engineering change request (ECR) is one element of change control and change management that is often misunderstood and misused. The ECR is often the precursor of a block update to the design of a CI and consists of a definition of what needs to be changed, the complete rationale for the change as well as known system, cost, and schedule impacts as well as recommended point of implementation (lot, serial number, date, etc.). Once the ECR is evaluated, it can be placed into the system as a lien against the engineering, and a change can be evaluated by all stakeholders prior to the implementation or it can be rejected. ECRs can be as simple as a lien against design due to subelement obsolesces and replacement or as complete as a product phase-out due to lack of sales or fabrication capability. A simplified change flow is shown in [Figure 5.11](#).

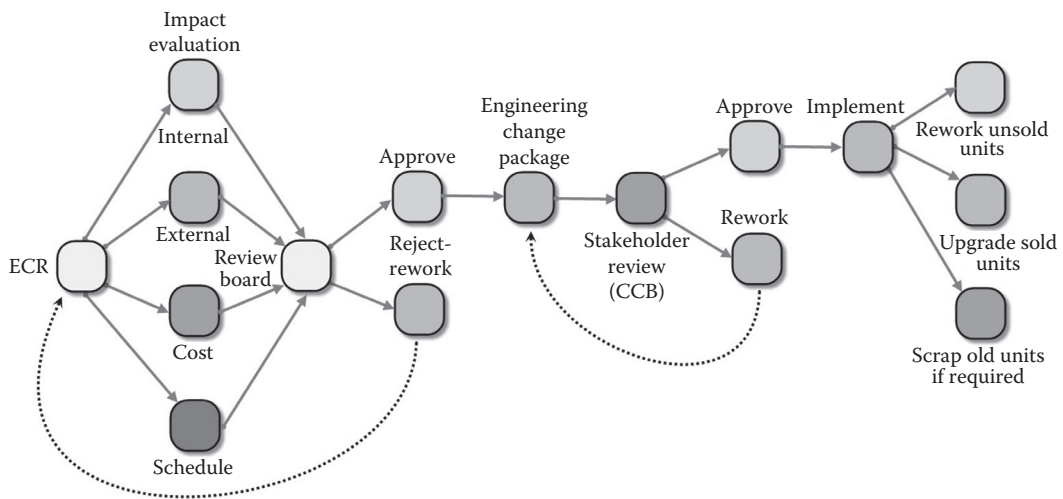


Figure 5.11 Simplified change flow.

Mentally merging the simplified change flow and the aligned product development model provides some idea of the complexities involved with managing a configuration in an understandable framework. This is essentially the same change flow that was used during development of the U.S. Saturn V rocket used to launch Skylab and Apollo astronauts. At the time Saturn V was the most complex electromechanical device conceived and fabricated. The entire program was managed using paper drawings with no computer-based PD/LM system. The single most important difference between CM on Saturn V and similar activities going on at companies such as Space-X today is the thousand fold increase in the amount of data that must be managed today.

5.5.4 Configuration Status Accounting

ANSI/EIA 649-B, TechAmerica Standard: Configuration Management Standard, Table 2 defines configuration status accounting as:

The CM function that formalizes the recording and reporting of the established product configuration information, the status of requested changes, and the implementation of approved changes including changes occurring to product units during operation and maintenance.

Aliases, Related Terms and Examples

- Configuration database
- Configuration records
- Status accounting

MIL-HDBK-61A, Military Handbook Configuration Management Guidance gives the configuration manager a slightly different perspective.

4.2.1 (d) **Configuration Status Accounting (CSA)**—All of the other CM activities provide information to the status accounting data base as a by-product of transactions

that take place as the functions are performed. Limited or constrained only by contractual provisions and aided or facilitated by the documented CM process and open communications, this activity provides the visibility into status and configuration information concerning the product and its documentation.

The CSA information is maintained in a CM database that may include such information as the as-designed, as-built, as-delivered, or as-modified configuration of any serial-numbered unit of the product as well as of any replaceable component within the product. Other information, such as the current status of any change, the history of any change, and the schedules for and status of configuration audits (including the status of resultant action items) can also be accessed in the database.

Metrics (performance measurements) on CM activities are generated from the information in the CSA data base and provided to the Management and Planning function for use in monitoring the process and in developing continuous improvements. To the extent that contractor and Government data bases and processes are integrated, the Government CM Manager may also be able to monitor contractor performance trends.

In general terms, status and accounting is the activity involved in the collection, management, accounting for, and reporting on all of the information that is generated relative to a product regardless of source as well as data mining of that information to be used to

- Identify where in the life cycle every element of a product is.
- Identify what design, production, test, and evaluation operations have been performed on it.
- The direct and indirect cost allocations associated with it.
- All pending and approved variances, ECRs, and changes associated with any established baseline.
- Transition gates between baselines and reversibility of all elements to any previous baseline.
- Metrics associated with the product and any or all of its elements.

Status and accounting is done as part of the management of a configuration by a single organization if all accounting and transactional systems are tightly integrated or it may be done by different functional elements. Configuration and data management is far reaching and in companies where CM is not responsible for all status and accounting activities, they can greatly influence the design and content of the collected data to meet the needs of the enterprise. This requires that all functional resources work collaboratively to implement preplanned data capture, integration, application of consistent metadata nomenclature and integrated intra-database functionality, so that information contained in separate databases can be utilized across all management functions.

5.5.5 Configuration Audit

The most common reviews and audits identified in [Figure 5.9](#) are the standard kinds of reviews that many CM practitioners are familiar with. They can either be considered to simply be snapshots in time that take place at predetermined intervals during the product life cycle mandated by government requirements or in process audits performed on each change against the functional baseline, as it moves from initiation, review, approval, implementation, and verification.

Some of these events are deemed reviews:

- System requirements review (SRR)
- System functional review (SFR)
- Tabletop review (TTR)
- Preliminary design review (PDR)
- Critical design review (CDR)
- Test readiness review (TRR)
- Production readiness review (PRR)

The rest can be deemed to be audits:

- Functional configuration audit (FCA)
- Physical configuration audit (PCA)
- Functional system audit (FSA), previously called formal qualification review (FQR)
- System verification audit (SVA)

Each review or audit answers specific questions.

- *SRR*: Have all system requirements been identified, known unknowns mitigated, and unknown unknowns identified.
- *SFR*: Have all interfaces between system elements been documented and intersystem dependencies allocated.
- *TTR*: Does the design approach meet the needs and have all trade studies been done against the design to assure it meets requirements and maximizes EBIT.
- *PDR*: Does the design approach satisfy the requirement.
- *CDR*: Does the design approach satisfy the requirement.
- *TRR*: Is the item ready for testing, have test parameters been defined, and any test temporary configuration departures been identified.
- *PRR*: Are all outstanding changes dispositioned, all other reviews and audits completed, and production able to start with no liens against the product or the production and test facility infrastructure.
- *FCA*: To ensure that all functional requirements specified in the baseline specifications have been demonstrated.
- *PCA*: To ensure that the hardware and software are built in conformity with the engineering documentation.
- *FSA*: To ensure that system functional requirements that were not evaluated at the CI level have been demonstrated.
- *SVA*: To ensure that the all systems associated with a product conform to total system requirements.

SVAs may not be performed if a single company is responsible for the production of all of the system components. This is generally not the case in multinational or systems developed and deployed by a government.

Although some kind of audits are applicable in all cases, conducting these reviews and audits to the levels specified by the U.S. government as a standard practice must be tempered by an

evaluation of not only the product being produced, but of the market segment the product is produced for. In a nongovernment sales environment, following the exact requirements may be an overkill.

They were established to give government customers assurance that the contractor was performing to the contract and that the end product met government needs. Although some form of physical and functional assessments are required prior to any product to be authorized for production, the FCA and PCA events were specifically created to establish a product (e.g., production) baseline to which all succeeding delivered products to that government would comply. Stringent and inflexible government procurement rules often require the same degree of adherence to FCA and PCA format and content regardless of product ordered or the government's intent to order more than a single unit. These reviews are often contractual and curtail the ability to take full advantage of Lean Methodologies. Six Sigma and Lean Methodologies were not created to be broadly applicable in a one-off manufacturing environment. Some manufacturing processes in a government–customer environment will benefit from Six Sigma and lean application; however, total production runs of in the tens, hundreds, and occasionally thousands significantly reduce the benefits possible in a commercial environment.

Refined review and audit methodologies exist in the commercial market and happen on a continuous basis rather than as set events due to the same survival criteria that allowed the product to enter and either maintain or increase its market share. Management of the configuration in the commercial environment is done in an empowered environment, where each person involved in new product development should be considered a member of the product element team and all teams are in synergy. Throughout the process, in-process reviews and audits happen on continual bases, allowing rapid realignment of all product parameters with significant cost savings.

5.5.6 Metrics

Inherent in any integrated process is the need to understand how well that process is working. Development of metrics and reporting against them is one management tool that has been found very helpful. So what constitutes a good metric? Of those firms studied in preparation for this book four fundamental elements were found to exist.

1. It has to be meaningful
2. It has to be measurable
3. It has to be something that cannot be manipulated
4. It has to be timely

5.5.6.1 The Number of Engineering Drawings Released over Time—Poor Metric

This metric fails each of the four fundamentals.

1. Work is constantly scheduled, rescheduled, and may even be done away with during the performance of a program due to changes, false starts, manufacturability, and test results. A program may believe that 1600 drawings may be required at the start of the program, but the true number may increase or decrease as the program moves along. Entire assemblies originally planned for an in-house design and build may be outsourced. These actions can reduce drawing count by as much as 15%.

2. In many cases, drawing numbers are not reserved until concept development is done in the development software (computer-aided design, software tools, etc). Data for the metric pulled from the PD/LM system the data is only accurate for the drawings that have been assigned numbers.
3. Once it is understood that the number of drawings is being measured as a metric, our studies show that engineering will increase or decrease the number of details, and assemblies defined by any single drawing or software version description document.
4. Data pulled from the PD/LM system may be required to support weekly or monthly reviews. As a result, the data is needed for the report much earlier than the meeting date.

5.5.6.2 The Engineering Orders Released against a Drawing—Poor Metric

This metric fails three of the four fundamentals.

1. Measuring the number of engineering orders against a drawing as an indicator of program performance actually increases program costs and does nothing to help manage program performance. Change is part of the design, build, test, and redesign process. As design matures over time, changes against any part of the design decline. Engineering change to design is driven by not only the stability of the functional baseline, but the complexity and stability of the development itself. As the technological boundaries are pushed from known solutions to state-of-the-art development, the percent of engineering orders rises steeply.
2. It is measurable.
3. Once it is understood that the number of engineering orders per drawings is being measured as a metric, our studies show that engineering will reduce the number of items addressed in any single engineering order to lower the number of engineering orders.
4. Changes to the engineering design approach need to be understood by the entire team and not just by the design team of a single element of the design. The faster engineering change is coordinated through the change review process the more efficient the entire team operates.

5.5.6.3 The Number of CM and Software CM Requirements in the Contract—Good Metric

This metric meets each of the four fundamentals.

1. An in-depth review of contract requirements is critical to CM planning and implementation.
2. As requirements are identified, they can be measured.
3. The contract at award established the functional baseline and each change to the contract reestablishes the functional baseline.
4. The review is performed at contract award and again each contractual change is implemented giving adequate time to make adjustments in how CM is managed on the program. It also allows incremental closeout of those requirements as the program progresses through the product life cycle.

5.5.6.4 The How Long Engineering Orders Take to Be Approved and Released—Good Metric

This metric meets each of the four fundamentals.

1. Critical to program success is the timely release and incorporation of engineering into a product. This metric pinpoints hotspots and is used as an indicator of lack of responsiveness. The information allows root cause analysis to be done to see if it is due to poor change requirements, lack of staffing, or other reason.
2. Most PD/LM systems allow for tracking of change approvals by individual or department. Such reports can be run on a prescheduled basis or *ad hoc*.
3. Standard review times should be established during the CM planning phase. A 48-hour rule was found to be the most common. Any approvals taking longer than 48 hours failed the metric.

5.5.6.4.1 Other Sound Metrics

- The number of audit and/or corrective action findings or observations.
 - The number is more than a pre-established “norm.”
- The number of days required to close audit and/or corrective action findings or observations.
- The number of months since a review of company Level I, II, III, and IV data for obsolete references to other documents has been made.
 - Eighteen months is a good standard to measure against.
 - This metric while a good one can be completely eliminated if referenced documents are removed from the document and put into a document bill of material in the PD/LM system.
- Length of e-mail strings on technical topics.
 - More than three generally indicates the need for a meeting.
- Percent of design restarts due to the original design solution being too costly, not adequate, or ill conceived.
- Percent of lessons learned analysis actually input into a relational database
 - Lessons learned not in a relational database are simply lessons documented.
- Percent of leveraged forward designs that have metadata with upward and downward cross-references in the PD/LM system.
 - Older design should cross-reference to newer leveraged design and newer design should cross reference to older design
 - This is the only way in a PD/LM system that you can track the design heritage.

Chapter 6

Data Definition, Data Types, and Control Requirements

6.1 Questions to Ponder

- Why are there different control requirements for each configuration level?
- Do the configuration levels facilitate mass customization? If so, how?
- What function does version control fulfill?
- Describe the connection between version control and product verification.
- What is the role of configuration management (CM) in managing enterprise-level data associated with the business but not the actual product designated configuration item or configured item (CI)?

6.2 Introduction

Data and management of data is the lifeblood of any organization. Key to management of data is an understanding of not only the level of control that is needed, but what that level of control means in the context of configuration management (CM). Data consists of all data not just data associated with a single item such as a configured item (CI). Unfortunately, most of the firms evaluated were found to have limited control over the interrelated enterprise data structure. Despite its criticality and the need for data identification and change control on all but the more insignificant forms of data in many firms, it is nonexistent.

6.3 Data Definition

The availability of information of all sorts has never been greater than it is at present. Tool refinements allow us to measure, analyze, report, discuss, form opinions about, and interconnect in a way that is beyond the conception of those who developed the original standards for CM. Attempts to sort through what information has meaning at any point-in-time are often clouded

by the rising information-generated noise simply due to the experience of the everyday life. For a book such as this to put data in perspective, it is necessary to discuss information in general and that piece of information related to CM in specific terms.

Configuration data: Information relative to the design, development, and delivery of a product (or service).

Business data: The subset of all information relative to the business itself. Although not data specifically related to acceptance of CI, business data is controlled data.

Metadata: Data fields that do not form part of either configuration data or business data are not controlled data and assist us to either sort the data or gather information about it for reporting purposes.

Controlled data: Data under configuration control using versions or revisions (letter, date, time stamp, etc.). Controlled data also includes event data such as part numbers, which do not require revision of version control.

Information: Anything that can be perceived, deduced, or formulated based on the intellectual curiosity of the species. This includes any written or unwritten information received through the senses as well as those things that can be conceived of based on personal knowledge or experience. All data is information.

Intelligence: Meaningfulness of the information, for example, the ability to derive intelligence pertinent to the information being examined at a point in time.

GEIA-859a* defines data as:

Data is information (e.g., concepts, thoughts, and opinions) that have been recorded in a form that is convenient to move or process. Data may represent tables of values of various types (numbers, characters, and so on). Data can also take more complex forms such as engineering drawings and other documents, software, pictures, maps, sound, and animation.

It defines data relative to three areas: product, business, and operational. MIL-HDBK-61† echo's this definition as follows:

In this age of rapidly developing information technology, data management and particularly the management of digital data is an essential prerequisite to the performance of configuration management. Digital data is information prepared by electronic means and made available to users by electronic data access, interchange, transfer, or on electronic/magnetic media. There is virtually no data today, short of handwritten notes that do not fall into this category. Configuration management of data is therefore part of data management activity; and management of the configuration of a product configuration cannot be accomplished without it.

Yet these definitions are insufficient from an enterprise CM perspective. Data comes in all forms. Graphical and photographic, sound recordings, receipts, letters, memos, internal web pages,

* TechAmerica. (2012). *GEIA-859a, TechAmerica Standard: Data Management*. Washington, DC: TechAmerica Standards & Technology Department.

† DOD, U.S. (2001). *MIL-HDBK-61a, Military Handbook: Configuration Management Guidance*. Washington, DC: U.S. Government Pentagon.

engineering notebooks, databases, and others are all important. A CM professional working on a single program or a part of a program often finds most of their activity artificially limited relative to the larger scope of the business. It does not negate the responsibility for them to think and act with the larger scope in mind. CM planning must account for this larger picture.

Consider the following case study:

One of the largest financial scandals in U.S. history, the Savings and Loan Crisis of the late 1970s came to a head in the 1980s and ended in the early 1990s. Savings and Loan deposits were insured by the U.S. Federal Savings and Loan Insurance Corporation (FSLIC) and depositors continued to put money into these institutions despite the indication that all was not well. Complex factors eventually resulted in the insolvency of the FSLIC. As a result the U.S. government bailed out of the thrifts spending some \$124 billion in taxpayer dollars. 747 insolvent Savings and Loans were liquidated by the U.S. government's Resolution Trust Corporation (RTC). Toward the end of the RTC's efforts the question was asked by government officials, "How much of the \$124 billion had been spent on contracts to women owned, small, or small and disadvantaged owned firms?"

The Denver RTC contracts area was not able to provide a complete answer simply because that information had not been deemed significant enough to track as part of its data management activities despite it being a requirement in every contract let by the Contractor Selection and Engagement Contract Branch of each RTC office.

One of the individual interviewed about the RTC case study stated, "No one told us until the last two months of the RTC charter that the information was going to be required so we didn't make any provisions for capturing it in our database."

This is often the case with many kinds of data at the product, business, and operational levels. Some guidance will be provided in Chapter 8 regarding the kinds of data that should be considered for management relative to each of the functional resources described in Chapter 3.

From the mid- to late 1990s, data management and data managers were in most cases directly tied to the CM department in most companies doing business with the U.S. Department of Defense and by association with other U.S. government agencies. The CM department controlled all incoming and outgoing communication between the contractor and the customer, all internal memos, assisted with a functional decomposition of all requirements documents, maintained *official* copies of those documents in annotated form (updated to reflect the latest contract changes), prepared proposed specification change notices and proposed engineering change notices, and in many cases maintained a conformed contract for the legal or contracts department as well as verifying the content of every piece of deliverable data and all programmatic information. In addition, it was the responsibility of the CM department to establish and maintain a program document library containing the official version of all of the requirements associated with a program. This was alternately known as the "contract technical baseline" and the "functional baseline."

By 2010, data management had morphed into the distinct subareas of knowledge management, information management, and data management. Much of what had been done manually started to involve data capture through sophisticated databases unique to each organization and product data/life cycle management (PD/LM) systems. Unfortunately, some of the quality assurance aspects performed under the older data management paradigm were mislaid. What we find in discussions in LinkedIn and other groups relative to "traditional" CM and the "new" CM is that some see them as a parallel to the movement from the Gothic to the Renaissance from the fourteenth through the seventeenth century.

From before the time of Charlemagne (768), art was used as the major form of communication to a lay public. Events from scripture including those centric to the life of the Christos were depicted in stained glass, sculpture, tapestries, frescos, and egg tempera. These visual narratives contained a biblical and an extra-biblical narration* of the events leading to the resurrection in a form understandable to the unlettered populous. After the Black Death, ca. 1348–1350, images of the Christos started to portray the figure as that of the law giver with graphic portrayals of penalties for not following the exactness of church law. Decades after the Black Plague saw a period of Renaissance or *re-birth* merging the traditions of the Roman Catholic Church in light of the reemerging belief and science of ancient Greece. Cosimo de' Medici, in the fourteenth century, purchased scrolls of Greek texts translated into Latin and paid Marsilio Ficino to translate the complete works of Plato and collected a vast library of other Greek and Roman works, which he paid to have copied and established two libraries with the copies influencing Renaissance intellectual life.

In a similar way, proponents of “traditional” CM are viewed as holding to old ways, based on paper, world definitions and methodologies as many “traditional” configuration data and status accounting roles are disbursed to other organizations and functions such as systems engineering, knowledge management, and information technology (IT). Those who believe in a parallel between traditional CM and whatever will emerge as the Renaissance of CM are often frustrated at what they see as clinging to the past in spite of the changing data-intensive world of the present. Yet proponents of the “new” CM appear to be just as reliant on International Standards Organization (ISO), American Society of Mechanical Engineers (ASME), and Electronic Industries Alliance (EIA) standards written by the same bodies that cling to the “old” CM structure and much is lost along the way.

The ASME Y14.35M standard also follows *traditional* methods by excluding the letters I, O, Q, S, X, and Z from the list of approved revisions due to their resemblance to the numbers 1, 0, 0, 5, 8, and 2. This prohibition was established in a time where drawing copies were stored in filing cabinets rather than in electronic form and runs contrary to similar numbering schema used elsewhere in U.S. contract documents themselves where contract line item numbers (CLINs), exhibit line item numbers (ELINs), and provisioning list line item numbers (PLINs) generally are alpha or alphanumeric in nature and exclude alphas I and O. Hopefully these restrictions will eventually be eliminated as the capabilities of automated databases are embraced by CM practitioners and customers alike. Figure 6.1 shows line item number formats currently in use by the U.S. government buying offices.

Part of what has been lost or misplaced by the configuration managers is a sense of the purpose behind data gathering and its importance in the life of the company and its products. The data CM needs to be aware of and makes provisions for goes beyond the informational base established to allow reproducibility of a vetted design. Thomas Redman's† analysis of data as the most important business asset within corporations points out what in most CM implementation has been forgotten. That data is a very valuable asset that needs to be as professionally and aggressively managed as other assets. Data must be put to productive use and must also be easily accessible and of high quality, so that sound business decisions can be made.

* Voragine, de J. (2013). *The Golden Legend*, Translated by W. Caxton. Seattle, WA: CreateSpace Independent Publishing Platform.

† Redman, T.C. (2008). *Data Driven: Profiting from Your Most Important Business Asset*. Boston, MA: Harvard Business Review Press.

Accounting Classification Reference Number (ACRN)	0001 through 9999
Contract Line Item Number (CLIN)	0001 through 9999
Sub-CLIN	0001AA, 0001AB, ... through 9999ZZ
Info CLIN	000101 through 000199
Exhibit Line Item Number (ELIN)	Generally 01 through 009, then 00A through 00Z 010 through 019, then 01A through 01Z ... 090 through 099, then 09A through 09Z ... 9Z0 through 9Z9, then 9ZA through 9ZZ
From PGI 204.71-Uniform Contract Line Item Numbering System and DFARS 204	
Provisioning List Line Item Number (PLIN)	AAAA through 9999
From DED 309, Provisioning List Line Item Number (PLIN)	

Note: Letters I and O are not used

Figure 6.1 Line item number formats.

His research indicates that the cost of poor data can result in a loss of 10%–20% of revenue. His other findings suggest:

- Knowledge workers spend 30% of each day looking for data with a 50% success rate.
- Data, if found, contains between 10% and 25% data inaccuracies.
- Lack of data cross-references and coordination.
- Inadequate data definition resulting in the data being misinterpreted.
- Inadequate data safeguards.
- Multiple sources of truth for the same data.
- Too much data and not enough intelligence.

We will explore the implications further in Chapter 8. Prior to that, let us delve deeper into each of the items listed above.

6.3.1 Knowledge Workers Spend 30% of Each Day Looking for Data with a 50% Success Rate

Going back to our \$200/hour billable rate for an average engineer, this 15% loss in productivity adds up over a year. In many U.S. firms, there are 2080 hours in a nonleap year. Adjusting this down for national holiday's (10 days) and personal holidays (21 days) and sick days (10 days) leaves gives us a total of $2080 - ([10 + 21 + 10] \times 8)$ or 1752 billable hours/year times 15% or a loss of 262.2 hours/year simply looking for and not finding data per person per year. This equates to \$52,560 at

the billable rate ($262.8 \times \$200$). Assuming a medium-size program utilizing 100 engineers equates to \$5,256,000 for a single year at the billable rate. Granted this number is inflated because you may wish to use a nonbillable rate or your billable rate may be lower but the loss is substantial. This accounts only for the engineering portion of the project. Additional losses occur across the entire company. This loss means that if a company hired 12.63 additional engineers at the \$200/hour billable rate to perform data management ($\$5,256,000 / [2080 \times \$200]$) it would cost the company no more than the loss they are seeing in just the engineering department on the program. This is approximately the number of data managers on a program pre-1990.

The 12.63 additional data managers today may be excessive simply due to advances in technologies. Adding two data managers per 100 engineers to a program properly trained in creating the infrastructure, data links, quality control, and data cross-linking would result in substantial benefits and a reduction in time wasted in fruitless searches. Simply adding cross-references in metadata fields between superseded and superseding documentation and for design heritage alone would result untold benefits in the areas of understanding not only the current design and technical baselines but also in tracing the evolutionary sources of intellectual property (IP) by establishing its provenance. In a governmental setting, such knowledge would preclude providing unlimited rights to data when limited or restricted rights were warranted.

6.3.2 Data, if Found, Contains between 10% and 25% Data Inaccuracies

Should it be the case that 10% of your data contains errors, how reliable are decisions being made from it? Gentry Lee describes a case where the statement was made, “The atmosphere follows a Gaussian (normal bell curve) distribution...”^{*} Mr. Lee corrected this individual and the scope of the scientific investigation was dramatically changed. They had not considered other distribution types such as normal, bimodal, or lognormal or if the curve distribution could be mesokurtic, leptokurtic, or platykurtic in nature. Most data errors observed in the research leading to the writing of this section were not of as critical a nature. The general observations fell into reliance on old data for a new analysis rather than using the latest data, minor typographical errors, the wrong image attached to the data object (e.g., document 1234567 Revision A had the image for 987654 Rev A attached to it), transposition of numbers in equations and results, and data used to test database functionality not being cleared out after the test.

These sound relatively harmless but they are costly. During the development of the handling equipment for a now decommissioned Intercontinental Ballistic Missile in the United States, the requirement was placed in a specification to filter the air used by the motors on trucks at the test site to remove particles such as blowing sand. Beach sand is approximately 100–2000 μm in size. The requirement was intended to be $1.00\text{E}0 + 2 \mu\text{m}$. The document copy used by the lead designer unfortunately read $1.00\text{E}0-2$ or $0.01 \mu\text{m}$, which is the size of tobacco smoke. Without questioning the typo, the engineer presented a design for a truck engine air filter that was larger than the Subaru 360, shown in Figure 1.11.

In another case IP markings were applied to portable data format (PDF) files contained in the PD/LM system when exported from the system by specifying the legend to be used in a metadata field. This allowed the company to utilize the same design and document files on multiple programs instead of cloning the data, assigning a new object identifier, and hard coding the IP information directly into the associated files attached to the object in the PD/LM

^{*} Lee, G. (2007). “So you want to be a Systems Engineer” video presentation. Pasadena, CA: Jet Propulsion Laboratory.

system. The improvement was beta tested, rolled out, and used for five years before anyone noticed that the test legends had not been replaced with the legal and contractual ones. The resultant loss of IP could have been avoided as well as the loss of respect for the company that resulted. The test legends ranged from *test* to paragraph long descriptions of different cuts of meat. The more distributed the responsibility for the overall configuration of databases become the greater opportunity there is for data errors. CM had been central to the beta test but assumed that someone else would be replacing the test legends with the real ones. The lack of a comprehensive implementation plan with defined roles and responsibilities was not deemed as critical to the implementation.

6.3.3 Lack of Data Cross-References and Coordination

This condition occurs between documents, design teams, department, business units, and partners. In its simplest form, no cross-reference between the original source and items using it as the starting point is documented (e.g., leveraged from report XYZ or A is superseded by B). Other examples are as follows:

- One team designing a part that interfaces with another without the knowledge that the interface has changed.
- One organization designing an IT solution based on existing technologies not realizing that a new replacement system is in beta test and the cross-platform data dictionary they are designing will be obsolete before their project is completed.
- Development of corporate yearly profitability projections based on month-old data that does not account for cancellation of a major program.

The library science concepts of cross-indexing data on multiple levels is just as applicable to industry regardless of market sector as it is to the Bibliothèque nationale de France. We see this increased need for specificity and cross-referencing in most service industries, online marketing smart merchant agents, and in the medical profession.

The implementation of International Classification of Diseases (ICD)-10-CM* for medical coding is an example of this. ICD-9-CM utilized the same code for similar injuries on opposite limbs. ICD-10-CM provides much greater specificity with approximately 68,000 different codes while allowing for the addition of new codes compared to 13,000 codes of ICD-9-CM (see [Figure 6.2](#)).

This increase in specificity is similar to the change from a bar code to quick response (QR) codes to radio frequency identification (RFID) (see [Figure 6.3](#)).

Like many things, much is gained and much is lost with every new capability. ICD-10 implementation refined granularity pertaining to patient diagnosis. This allowed a personal configuration history to be available with a corresponding increase in coding capability as well as database complexity. Use of evolving technologies such as RFID presents challenges for sound configuration data management in other ways. Inventory checking and increased granularity in the information available at the point of use pertaining to the product is made available as is the capability of those in a military situation to run increased risk of equipment loss, as data pertaining to container content can be targeted by those wishing to divert those items for their own use.

* Centers for Disease Control and Prevention. (2012). *International Classification of Diseases—Tenth Revision—Clinical Modification (ICD-10-CM)*. Atlanta, GA: U.S. Government.

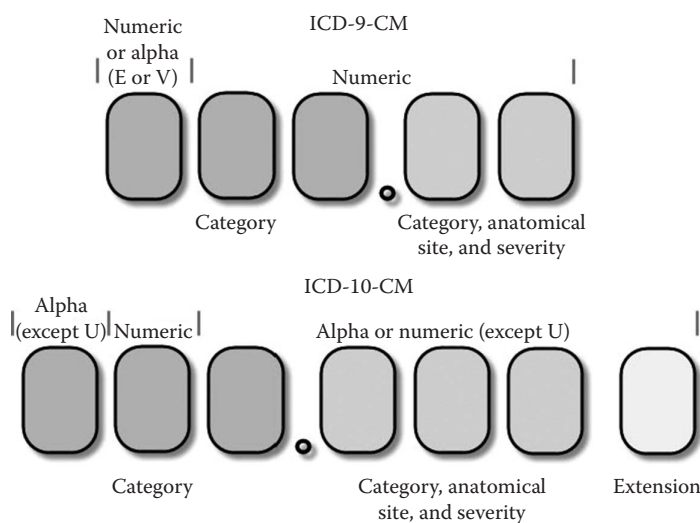


Figure 6.2 ICD-9-CM versus ICD-10-CM code schema.

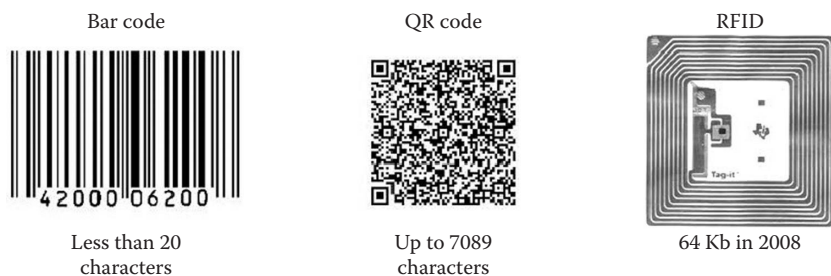


Figure 6.3 Barcode, QR code, and RFID.

6.3.4 Inadequate Data Definition Resulting in the Data Being Misinterpreted

ICD-10-CM changes the data definitions from what was contained in ICD-9-CM to eliminate issues resulting from data being misinterpreted. This is accomplished in two ways. Procedural terms have been modified and diagnostic codes now reflect laterality and detail regarding medical conditions as shown in the table.

ICD-9-CM Coding and Diagnosis	ICD-10-CM Coding and Diagnosis
453.41 Venous embolism and thrombosis of deep vessels of proximal lower extremity	I82.411 Embolism and thrombosis of right femoral vein

Data definition errors have led to some rather spectacular failures in the engineering world as well. English versus metric conversion or lack of it resulted in the loss of Mars Climate Orbiter in 1999. The software interface specification required data to be provided in metric units but had actually been written in Imperial, also known as English units by the contractor Lockheed Martin. Jet propulsion laboratory (JPL) used the correct metric units. Instead of impulses needed for maneuvers

being transmitted to JPL in Newton-seconds, they were provided in pound-seconds or a 4.45 error factor, which over time resulted in the spacecraft being approximately 47 km above the surface rather than the planned 150–170 km.*

In some cases, definition refer to data table locations that have a different name than the one intended. This may result in another form of data definitions resulting in data being misinterpreted. Should *source* be confused with *result*, then software-dependent systems could easily be over or under taxed with a resultant systems failure.

<i>Line</i>	<i>Input</i>	<i>Source</i>	<i>Result</i>
1	A1	1.8	.6
2	A48	2.7	.8
3	A109	3.1	.9

6.3.5 Inadequate Data Safeguards

Every piece of information that is generated by a company is subject to loss of one kind or another.

- File media becomes obsolete and the means to retrieve it is not maintained.
 - Data records for a standard production item were converted to flat-film reels as technology improved aperture cards (kinds of microfilm media).
 - Due to the growing lack of availability of readers and printers combined with concerns about the environmental hazards associated with the print media utilized; a ban on the use of aperture cards and other kinds of microfilm was put into effect within a green company.
 - Readers and files in the reader area were destroyed.
 - Destruction represented a loss of 25 years of engineering heritage.
 - A duplicate set of cards and tapes stored in a location other than the readers for disaster recovery were located.
 - One CM department member knew of their existence. It was not documented.
 - A nondisclosure agreement was put into place with a third party to convert the images to sequenced PDFs of the correct document size (e.g., all sheets of a single document were collected in a single PDF).
 - Data was eventually loaded into the PD/LM system.
- File media is assumed to be of one kind but is actually of another kind.
 - Data management procedures required that a 3.25 in. disk containing a native and PDF file of all engineering were collected along with the paper copy representation.
 - 1987: The CM department used Macintosh products.
 - 1995: Engineering mandated a move to personal computers (PCs).
 - 1998: A decision was made to move to a PD/LM system.
 - 1999: 3.25 in. disks were unreadable and assumed to be corrupted.
 - 90% of the disks were reformatted for reuse before it was discovered that the data was still readable with a Macintosh (One Mac FX was still used as the contractually specified platform).

* Harland, D.M., and Lorenz, R.D. (2005). *Space Systems Failures: Disasters and Rescues of Satellites, Rockets and Space Probes*. London: Praxis Publishing Ltd.

- The company moved to a PD/LM system and flat-file vellums and paper copies were scanned to PDF if they could be found with an estimated loss of 15% of the existing product line engineering heritage and an 80% loss in readability as the scans had been done at 150 dpi (dots per inch) versus 300 dpi.
- No consistently funded and applied data upgrade functionality.
 - The Space Transportation System launch of STS-135 in 2013 was made using a suite of mission control ground equipment based on the Intel 086 chip architecture. Replacement parts were being sourced on eBay.
- Standard file retention and destruct policies are applied to nonstandard programs.
 - Mission life for an earth observatory was extended 14 years well beyond its planned three-year mission life.
 - Record retention files were scheduled for destruction at launch plus 10 years.
 - Data management had the foresight to mandate that records be retained for a minimum of 15 years and that they are contacted prior to any data destruction.

6.3.6 Multiple Sources of Truth for the Same Data

File server management at the customer's house was assigned to the contractor's configuration manager. Access to the server was limited to the customer, the contractor's configuration manager, contractor's systems engineers, and contractor's product leads. Strict rules were agreed to between the customer and the contractor regarding data transmission to the customer's site.

Subsystem engineers at both the customer and contractor's house disregarded the rules of controlled files. Just prior to acceptance the customer's IT department ran a file redundancy review on the server and as many as 30 copies of the same document with different file saved dates were discovered. All documents had the same file name.

The data listing was provided to the contractor's configuration manager for analysis. A task order for 120 hours was negotiated and implemented for the contractor configuration manager to purge the customer's file system of all nonofficial copies so that a single point of truth remained.

6.3.7 Too Much Data and Not Enough Intelligence

One of the great challenges of all data users is to put that data into context, so that it can be used. Placing data in its proper context takes a proper grasp of the data source, its relationship to other data, and place of origin and frequency of use. A formula such as Plank's constant $6.62606957E-34 \text{ m}^2 \text{ kg/s}$ is static data. There is little likelihood that the formula will change and it is hard to misinterpret by those who use it.

Dates are static but contextual data. The date 12/11/06 could mean any of the following if the contextual date schema is not known, documented, and disseminated.

- December 11, 2006
- 12 November, 2006
- 2012, November 06

Dates may also lead researchers astray. In preparing this book and researching the evolution of parts of it, the location of various events was a key factor. What we know as the Gregorian or western calendar was adopted to bring the date for the celebration of Easter to the time of the year in which the First Council of Nicaea had agreed upon in 325. Under the Julian calendar the

date of Easter continued to drift further forward from the spring equinox due to the lack of a leap year to account for the difference between lunar cycles and the calendar. The Gregorian modification added an extra day to February to every year exactly divisible by four except in years exactly divisible by 100 unless the year could be exactly divisible by 100 and by four. Pope Gregory's bull in 1582 implemented the Gregorian and the date March 10, 1582, was followed by March 21, 1582, skipping 10 days to realign March 21 with the vernal equinox. Due to differences between the Greek Orthodox Church and the Roman Catholic Church, the Gregorian calendar was not adopted by Greece until 1923.

Unfortunately the Gregorian calendar was not accepted everywhere at the same time and the Bull had no influence in non-Catholic countries. The 13 colonies that would eventually join to become the United States of America adopted the change in 1752 with an 11-day jump. Alaska adopted the Gregorian calendar in 1867 along with a change in the International Date Line, which moved from its eastern to western boundary causing Friday, October 6, 1867, to be followed again by Friday, October 18, 1867. Dates are further complicated by the fact that January 1 was not always considered the start of the New Year. During the middle ages, many Christian countries moved the New Year from January 1 to other important festival dates such as December 25, March 1, March 25, Easter, September 1. As a result, dates can easily be interpreted out of context and they must either be normalized or otherwise explained. Dates referenced in this book have not been normalized unless done by the authors of the source material.

6.4 A Strict Data Diet

Many adherents of both “traditional” and “new” CM were found to hold to the belief that all configuration data is controlled data and that configuration data falls into the two broad categories of (1) data pertaining to the configuration required to assure product conformance and (2) data specified as deliverable places this data in a distinct subset of all data relative to the product. They were also convinced that this encompassed the entirety of the controlled data that fell under the purview of their profession. Chapter 8 will explore the validity of this assumption. As pointed out in the introduction to Chapter 1, data management is part of CM; however, it has a much broader reach than simply the management of data associated with a configuration item identifier or CI identifier. Data management applies to all data regardless of form or format that is received or generated by a company in their daily business activities.

This idea of a strict data diet limited to managing only data associated with a deliverable item or associated to a data requirements listing (DRL) begs a few questions concerning where both “traditional” and “new” CM appear to be heading. MIL-HDBK-130, ISO, and EIA requirements to which many now cite as their CM guidance are clear to state that CM must be sized to the environment to which it is applied. GEIA-HB-649* goes further in declaring that on commercial programs the line between reviews and audit is blurred and to some extent nonexistent, whereas in a government-based market, the difference is very distinct. This places a greater reliance on the CM professional to not only understand the specific guidance of their profession but also understand the environment in which it is being implemented.

The days of data being limited to reports, drawings, analysis, and version description documents for executable software are long past. Configuration managers currently must contend with

* TechAmerica. (2005). *GEIA-HB-649, TechAmerica Bulletin: Implementation Guide for Configuration Management*. Washington, DC: TechAmerica Standards & Technology Department.

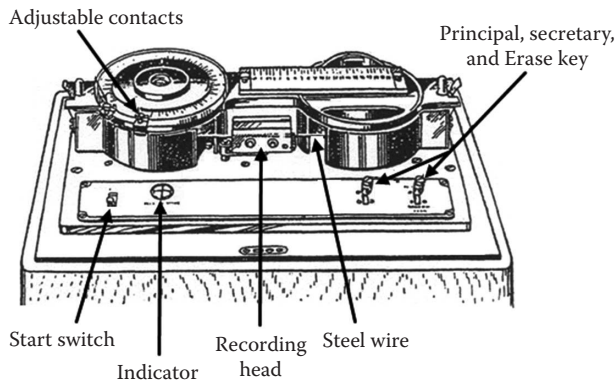


Figure 6.4 Dailygraph wire recorder 1930s CE.

DRLs consisting of articulated models, STEP, or other files. On the horizon is an environment that many CM professionals were found to be reluctant to plan for. This includes the following:

- 3D printing technologies where the idea of a paper representation of a manufactured item is as relevant as using a wire recorder to hold music or dictation (Figure 6.4).
- The implantation of quantum computing.
- Database transfers.
- The expanding roles of social media, real-time video capabilities, and text messaging in a business environment.

6.4.1 3D Printing

This statement may appear to be futuristic to some. Our ability to create a model of something in a design program and print it in a variety of materials will radically modify how data is managed and how designs are conceived of. It is going on at present. Suddenly the idea of having a product baseline of anything simply to assure producibility of a vetted design is complicated.

3D technologies eliminate much of what engineers normally do in the area of design. They are no longer limited to the fabrication of components using traditional mills, lathes, forgings, and electric discharge machining. When combined with sophisticated design iteration tools, designs become more fluid maximizing distribution of static and dynamic loads. Using additive manufacturing, the need for tooling and jigs to support complicated Shielded metal arc welding, gas tungsten arc welding, tungsten inert gas, metallic inert gas, and laser weldments is eliminated. The 3D process builds the support as the object is printed. NASA estimates the reduction in fabrication time for one of its 3D-printed propellant distribution and the engine nozzle from 18 weeks to 2 weeks and the savings on material to be over 60% as there is no scrap.

Some 3D designs cannot be realized in paper space from a computer-aided design (CAD) output perspective unless you use slice views such as an magnetic resonance imaging (MRI), so that what we see as a DRL deliverable probably needs to be managed more like a cross between a thermal Model and a software executable. This is due to the iterative nature of the 3D design. Portions of the design that meet requirements (however you want to define that) become static like portions of the software code, as the rest of the design matures. Integration and test (I&T) activities can be run incrementally using 3D parts made with materials that can simulate the heat, stress, and wear

you would see to pinpoint areas of design concern before investing in a qualification unit. This reduces the need for multiple qualification units because some of the qualification concerns can be addressed before you do total qualification. Interfaces between parts can be printed using the final material and the rest of the item's structure can be printed in a lower cost material combining the two for testing purposes.

Configuration managers will think about IP and data marking differently. It is conceivable that in the commercial and government sales world that contracts for spares will be simply a catalogue of 3D print models that can be printed and use rights are leased for point of need manufacturing. Some sort of built-in counter that lets five copies be printed before the license has to be extended may need to be developed. Such concepts make how distribution statements, unlimited and limited or restrictive rights become convoluted or meaningless.

Latent defects and patent defects are also impacted. If the model developer specifies "Must be printed on a printer X or better which has been calibrated with each new material cartridge load" and the user prints at point of need and their printer X is out of calibration and they make a claim how would the contractor know that fact? This and other legal implications have yet to be studied in any depth. Safeguards would have to be built into the model so a third party is not able to modify the model and pass it off as just as good as original equipment manufacturer (OEM). If 3D printing evolves to the point of tissue replacement printed from you own cells (Say you lose an arm and they take healthy cells from your other arm and print you a new one while you are asleep in the hospital); what are the implications if a company such as Merck develops the gold standard model but your insurance, Medicare or Nationalized health care, has decided to use the generic equivalent from Joe's body parts.

Questions that all CM professionals should be pondering are as follows:

- Should the 3D construct in the modeling/design environment be controlled such as hardware, software, firmware, photos, thermal models, or as a new completely different form of configured object?
- What does on-demand manufacture at use site mean to acceptance and product warranties?
- How is IP monitored and controlled and what safeguards need to be put in place to protect the product design from being pirated or compromised (e.g., how do we protect the design from theft or alteration by a hostile party)?
- What is to keep a customer from sharing the 3D model with others?
- What happens to product liability if the model is printed using inferior materials or on an uncontrolled and managed printer?
- Does on-demand printing require on-site contractor personnel to be present with printing on contractor-owned printers?
- How are the configuration and legal considerations of a 3D model impacted by leasing the model to a third party for production?
- How are data retention timelines impacted if 3D models eliminate design obsolescence (e.g., if I can always make another exact copy of the product does the design every go *out of production*)?
- Do parts printed from 3D models constitute OEM parts if printed by a third party?

Let us explore this further. When you think of product design and development (PD&D), what comes first to mind? Is it the understanding of our business objectives (scope) followed by functional decomposition of requirements and allocating them to systems and subsystems to achieve that objective? Is it design to manufacture with designers, facility, and work center collaboration to

assure cost savings through coordinated and producible designs? Or is it early and iterative design validation prior to manufacture? However, you view it that additive technologies can play a major role in not only better designs but also less expensive manufacturing, which is quickly gaining mainstream acceptance.

I believe we're on the verge of a major breakthrough in design for manufacturing in being able to take something from the concept of something from your mind and translate that into a 3D object and really intuitively on the computer and then take that virtual 3D object and to be able to make it real just by printing it. It's going to revolutionize design for manufacturing in the 21st century.

Elon Musk*

The idea of being able to rapidly generate a prototype to validate solution through a construct of the proposed functionality, interfaces, and best-case design solutions was unheard of a decade ago. It is becoming the norm along with modified preliminary test to destruct (highly accelerated life testing) evaluations with a shortened test parameters based on wear parameters for differences on material properties (e.g., making a prototype of one material to validate testing parameters for another before final production and test. Additionally, high-quality prototypes in recyclable wax deposited in half thousandths layers using printers such as the Solidscape's R66 Plus can be made for visual evaluation and improvement prior to casting of a final product in titanium.

Once reserved to the fringes of aerospace in small development labs, the results of 3D prototyping are translating into the printing of 3D parts in aerospace applications. December 2013 saw the introduction of 3D-printed components created on a British Aerospace (BAE) Tornado fighter, GE Aviation's LEAP engine will use 3D parts, and NASA announced the successful development of a 3D-printed rocket engine component. Rolls-Royce, Pratt & Whitney, and GNK aerospace are also investing in additive manufacturing of finished products. An early 3D-printed part is shown in Figure 6.5.

Several obvious advantages of the 3D capability soon become apparent. With additive processes, costly material such as titanium is utilized only in required quantities (adjusted for finish). In a production environment, prototyping of designs that would not be possible, that

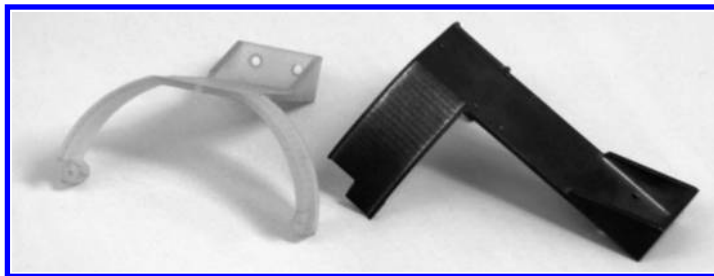


Figure 6.5 3D prototype and final part.

* Brewster, S. (2013). "Elon Must shapes a 3D virtual Rocket part with his hands." <https://gigaom.com/2013/09/05/elon-musk-shapes-a-3d-virtual-rocket-part-with-his-hands/>. Accessed April 22, 2014.

consume many hours, or those that would be cost prohibitive using standard manufacturing methodologies can be explored. In the field product, improvements can be scanned, prototyped, and more rigorously tested prior to being incorporated into the product line. One of the problems with earlier prototypes is their ability to stand up to the sort of tests that the final product would experience. For example, nobody would place a stereo lithography part on a vehicle and expect it to survive vehicle durability and reliability testing. Those concerns are reduced through 3D printing.

The greatest challenge is for designers in aerospace to rethink what is possible outside of traditional manufacturing methods and available tools. In many cases, the need for complex fixtures and tooling to aid complex assembly and welding operations are eliminated reducing costs and design time. Let us put this into perspective. Rapid prototyping in 2012 was estimated as a \$2.2 billion industry. On October 14, 2013, Chris Fox of Pddnet.com stated a business insider quoted Goldman Sachs as saying 3D printing is “one of eight technologies that are going to creatively destroy how we do business.”

Assume that you have just received a contract to produce replacement mechanical piece parts for a product with faulty or nonexistent design data packets. The customer can provide a copy of each part from inventory but due to concern about material fatigue wishes your company to reevaluate the part and beef up the design to eliminate the problem. Under normal PD&D operations, critical parts data is obtained in your dimensional lab and provided to the designer. Once the design is captured, improvements can be explored that mitigate the customer’s concern production and test can start.

New technologies allow 3D scanners to be used to establish a cloud mapping of the part that is then ingested into a CAD package, where any part irregularities are corrected and material fatigue concerns are mitigated. The configuration-controlled model is then converted to the file type utilized by an additive manufacturing machine and a print on-demand capability results at a substantial savings over the cost of reverse engineering each part using data from a dimensioning and tolerance analysis of the part. The cloud map, original CAD ingestion, and all versions are under configuration control.

6.4.2 Quantum Computing

The development of quantum computing and the introduction of products such as the D-Wave Two,* which operates at 0.038889K or if you prefer -273.111111C or -459.6F , will radically change the way software and computer data are managed (Figure 6.6). As quantum computing evolves, configuration and data management methodologies associated with traditional base 2 systems will need to morph to encompass data that can exist in multiple states at the same time instead of a polarized true or false state. Originally postulated by Richard Feynman such digital data is represented in quantum bits (qbits) rather than bits.

The D-Wave Two has 512 qbits resulting in a theoretical 2^{512} or $1.340781\text{e} + 154$ operations simultaneously. Continued testing of the capabilities will determine if the creator’s claims are valid. Regardless of the true capabilities after the benchmarking testing is completed the preliminary testing results are impressive. What additive printing portends for manufacturing quantum-computing capabilities being pioneered at D-Wave Systems, IBM, Microsoft, and others will see the same kind of developmental continuum seen at the start of the PC resulting in the Power Mac G4, which first offered more than 1B floating point operations per second. Given a similar

* D-Wave Systems Incorporated, Vancouver, British Columbia, Canada.

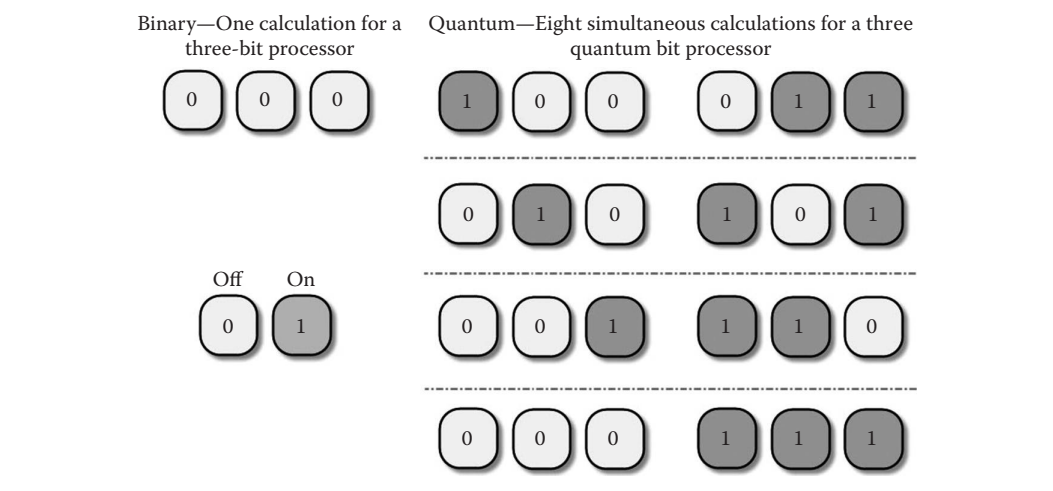


Figure 6.6 Binary versus quantum computing.

trajectory, it is not inconceivable that everything we know and manage in the hardware and software realms, as configuration managers will be unrecognizable in two decades.

It is incumbent on the CM community at large to start addressing these developments as they appear simply because the traditional methods of thinking about not only data but all aspects of the CM are impacted.

6.4.3 Database Transfers

CM in support of systems engineering may be tasked with ingesting customer performance requirements into a database such as Siemen’s team center or dynamic IBM rational object oriented requirements system (DOORS), where requirements are tracked and incrementally closed out as the development moves from a functional to a product baseline. This activity requires a great expenditure of human resources on the customer and contractor’s sides (Figure 6.7).

Some companies are now partnering with their customers to transfer requirements from the customer to the contractor in database for rather than the traditional statements of work, data requirements lists, systems specifications, interface control specifications, and drawings/documents (Figure 6.8).

This move is seen as a great potential for cost avoidance in cost-constrained procurements. The net effect is similar to moving from a best-of-breed approach in information data management systems implementation to a totally integrated solution.

6.4.4 Social Media, Real-Time Video/Images, and Text Messaging

6.4.4.1 Social Media

Social media such as Facebook is credited with changing up events worldwide from flash crowds, partnering between like-minded people, tipping the scales in favor of one political candidate over another, and other events generally external to the standard paradigm associated with configuration-controlled items. Social media is also playing a much greater role in professional networking and was used exclusively to gather information. LinkedIn was used in the writing of this book.

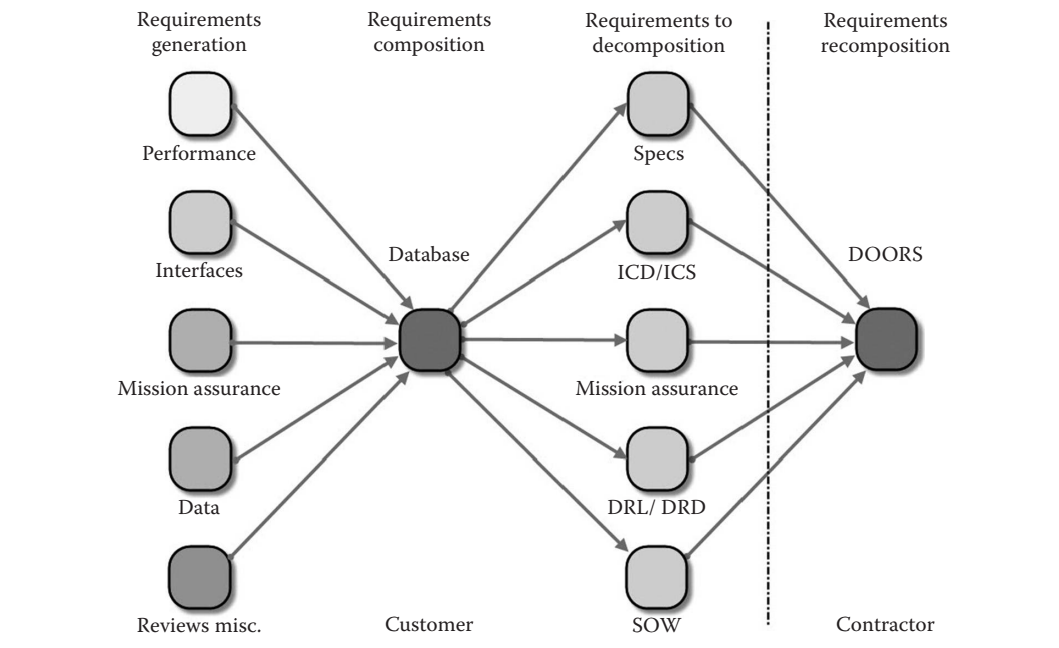


Figure 6.7 Traditional contracted requirements versus database transfer.

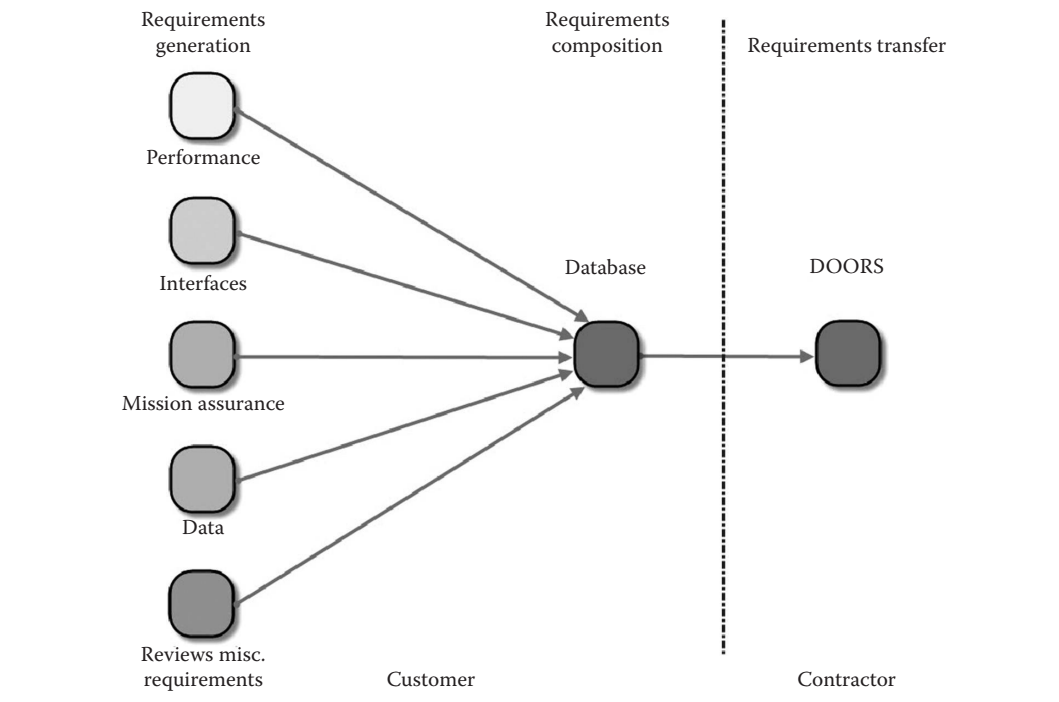


Figure 6.8 Database transfer with no decomposition.

Facebook, Flickr, FeedBurner, SurveyMonkey, YouTube, and Twitter have found a place on the home pages of most corporations. It is only a matter of time before further acceptance of these and other communication types are applied to the management of product development and result in new ways of viewing data management.

6.4.4.2 Real-Time Video and Other Images

This capability exists on most personal communications devices as well as dedicated digital image-capturing devices. Devices such as the GoPro, JVC Adixxion, Emerson Go Action Cam, Spypoint, Vivitar, Sony, BlackView, Sunco Dream, Veho, and others have met the need for personal image capture and are finding use in cleanrooms assisting with load transfers in and out of vertical thermal chambers. The inherent ruggedness of the designs also makes them candidates for other applications, where eyes are needed to manage critical operations unobservable except by mirror.

Video and still image naming conventions generally are not addressed in configuration and data management plans despite the pictorial record (including video capture being critical to meeting requirements by inspection). When naming conventions are specified, they are often addressed by many companies using the *American Standard Code for Information Interchange* convention such as YYYY-MM-YY_0001.ext (e.g., 2016-02-28_0001.mov or equivalent) with no other tie to the operation, item, or content. Ideally such data forms a part of the acceptance data package or variance approval package and must be tied to it in some retrievable way.

One solution to this could be capturing the images specific to the observation in a report or other document released in the PD/LM system and placing them in the document bill of materials of the part, test, or variance with copies of the native file(s) as associated versus native files. Regardless of methodology, the items are rarely properly managed often due to their volume.

6.4.4.3 Text Messaging

WhatsApp is a Facebook-owned unlimited international text messaging application. Text messaging as a means of gathering quick answers to questions in a fast-moving enterprise environment is gaining acceptance. Capabilities such as those offered by WhatsApp will play a major role in the international business environment for communications that do not contain critical to the business information. This technology needs to be followed and data management implications need to be studied in light of text string capture and export as well as text stream encryption as the tools see wider implementation.

CM, as envisioned in ISO, Institute of Electrical & Electronic Engineers (IEEE); EIA; and other standards, handbooks, and guidelines, will continually be subjected to technological advances that the organizations writing the documents will not be able to encompass quickly enough. As a result, it is incumbent upon the CM practitioner to become adept at evaluating the new technologies and informally agree on a forum for addressing the CM impacts of these technologies.

6.5 CM and Levels of Quality Business Systems Management

GEIA-859 contains two views of a four-level document hierarchy (Figure 4 and Table 4) that should be expanded to include metadata and guidelines. Levels increase from the general to the specific as the level number increases. One implied goal is to create levels I through IV documentation that

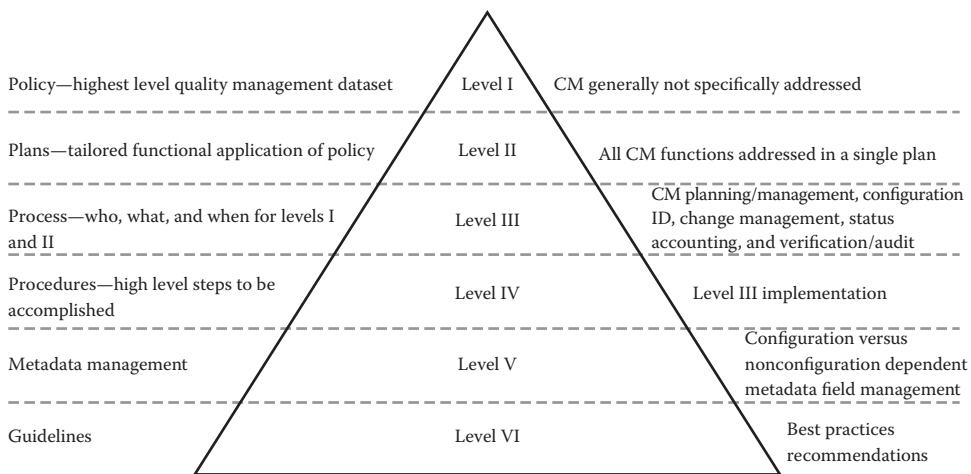


Figure 6.9 Six-level data structure.

does not have to be deviated from on any program or project. The only way this can be accomplished is to keep all levels I through IV documentation at a very high level.

A revised six-level data hierarchy is much more useful to CM of products in a database environment is shown in Figure 6.9.

CM of six levels of plans, policy, process, procedures metadata management, and guidelines was found to vary within the companies studied in preparation for this book. In many cases, configuration control was assumed by the organization responsible for mission assurance and despite the data associated with levels I through IV being released in a PD/LM system members of the CM organization were delegated a stakeholder role on specific documents rather than a release management role. This is and of itself was not surprising, as many configuration roles are performed by organizations other than those holding a CM organizational designating. No company-level CM plan detailing the allocation of these CM activities to other functional organizations or the relationships between them was found to exist. What follows is a summary of the consensus view of levels of control for the various levels of quality management documents in a company with regard to CM department involvement in their management.

Another goal is to avoid higher level documentation from placing requirements on lower level documentation that drives cost. A requirement levied in a policy to always use the latest template for a report, drawing format, report, and so on is innocent on the surface but sets the company up for findings of noncompliance when the system is audited by external organizations. A clear distinction between auditable requirements and unauditable requirements must be established (e.g., any documentation below level IV is unauditable). Arguments that the use of company templates for things such as variances need to be auditable by outside organizations are flawed. Use of some template for a variance may well be a requirement, but templates may be specified or modified for a program based on contractual or other requirements and should not be subject to audit except by the customer or program that mandated the use. Arguments that all audit findings need to be disclosed to a customer is also flawed if those *findings* are against requirements below level IV. Any noncompliance with items below level IV is simply an observation.

6.5.1 Level I, Policy Management

CM activities are not generally defined as a separate policy; however, all policies are subject to standard vetting with stakeholders, approvals, and release via change control and top-level application of CM is inherent in these documents. The change control function may be delegated to the quality business system functionally but that transfer needs to be documented in a company level CM plan. Additionally, all data releases should be consistent with established change control requirements and should utilize the same PD/LM system used for management of other data. In many ways, policy can be seen as the mission-level requirements that are performed by different organizational entities.

6.5.2 Level II, Plans Management

If level I documentation is the mission statement it follows that level II plans take on the role of mission subelement descriptions. CM activities are generally defined at this level in a single plan subject to standard vetting with stakeholders, approvals, and release via change control. The change control function may be delegated to the quality business system functionally, but that transfer needs to be documented in a company-level CM plan. Additionally, all data releases should be consistent with established change control requirements and should utilize the same PD/LM system used for management of other data. The plan should not identify level III or lower level documentation. In rare cases, CM plans may exist for management of all other plans and level II through level IV documentation. While not a requirement, there are distinct advantages in having an enterprise-wide configuration and data management plan defining the roles of each organization relative to CM activities (e.g., allocation of CM activities to IT, quality business systems management, program management, product management, design libraries, design media, systems engineering, training, certification, finance, contracts, facilities, etc.).

CM should be a stakeholder on all other plans. The more vertical a company's organizational structure, the more critical it is for the CM to understand the direction where other functional areas are moving toward so it can adjust to support them. The role of stakeholder becomes increasingly important in level III and level IV documentation.

6.5.3 Level III, Process Management

If level II mission subelement descriptions it follows that level III processes take on the role of mission subelement systems specifications. Level III processes should not refer to the specific level IV documentation that implements them just as subsystem specifications do not call out the specific documentation that meet the requirements defined within it. Level III documents provide very high-level descriptions of who, what, when, where, and why activities are accomplished are generally defined in. It is recommended that elements associated with the CM of three basic roles perform the following:

Product CM:

- Configuration planning and management
- Product identification
- Supplier management
- Interface management

- Configuration identification
- Configuration change management
- Approval of design and changes
- Configuration status accounting
- Configuration verification and configuration audit

Program interfaces with:

- Project management
- Engineering
- Production
- Finance
- Legal
- Contracts
- Supply chain management
- Facilities

Tools management:

- PD/LM
- Report generation

Almost all of the companies studied as part of the research phase for this book were found to be silent regarding CM program interfaces and tools management in their efforts to reach ISO certification. Unfortunately, they relied on the guidelines identified in ISO 10007* in their quest to become ISO certified. ISO 10007 is product-centric and ties back to ISO 9001.† Equal attention needs to be paid to ISO 10006‡ regarding program interfaces and such implementation policy is critical.

6.5.4 Level IV, Procedures Management

If level III processes take on the role of mission subelement systems specifications, it follows that level IV procedures take on the role of subsystem requirements implementation. Level IV procedures should not refer to any level V or level VI documentation. Procedures should be extremely well vetted with all stakeholder organizations and should not assign responsibilities to other organizational elements (e.g., a production procedure should not assign a task to mission assurance, contracts, or CM).

If such an interrelationship exists, then these organizations should be stakeholders and each organization would have a suitable level IV document supporting the requirements with the requirement defined in the organization's level III policy. It was generally found that CM procedures were overly complex and at too low a level to facilitate the flexibility needed in the current nimble business environment often written with the mantra of process is everything. While this

* ISO. (2003). *ISO 10007:2003, International Standard—Quality Management System—Guidelines for Configuration Management*. Geneva, Switzerland: ISO.

† ISO. (2008). *ISO 9001:2008, Quality Management Systems—Requirements*. Geneva, Switzerland: ISO.

‡ ISO. (2003). *ISO 10006:2003, Quality Management Systems—Guidelines for Quality Management in Projects*. Geneva, Switzerland: ISO.

precept of ISO/IEEE 12207* should be understood, it should be viewed in light of systems and software engineering and software life cycles and not as a blueprint for the entire quality business system approach.

Procedural statements such as “The first release of a document or part is considered a revision and must be processed using an engineering change order (ECO). ECOs shall be created by the document originator with all affected items being identified on the ECO affected items. The ECO proceeds through one of the PL/DM system workflows shown below. ...” should simply read “The PD/LM system shall be used to capture all revisions and versions of documents and their associated elements.”

All detail as to the specifics of PD/LM use should be reserved for incorporation into a handbook.

6.5.5 Level V, Metadata Management

Metadata falls into configuration-dependent metadata field management versus nonconfiguration-dependent metadata field management.

6.5.5.1 Configuration-Dependent Metadata Field Management

This metadata type is controlled by the release documentation [e.g., ECO, engineering change request (ECR), etc.] and consists of the following data fields:

- Object number (e.g., document or part/assembly identifier)
 - It is recommended that a revision level never show up with an associated part or assembly.
 - This is generally a misunderstanding of requirements resulting from drafting board practices of including the product structure on the face of the drawing instead of using a separate parts list.
 - PD/LM systems decouple these elements and the disposition of related parts are enough if the quality system is properly implemented.
- Object revision
- Object title/description (should match the title of the object. If a drawing with title is instrument mechanical interface control drawing (ICD/MICD), the object title/description should be instrument mechanical ICD not instrument MICD)
 - Program name should not be in the title of any document as it is a metadata field and prohibits design reuse without expenditure of additional dollars to change.
- Change number (e.g., ECO and ECR)
- Responsible engineer (staffing does change during the life of many products and the last revision of the object should always reflect the current responsible engineer.)
- Revision level (e.g., A, A1, A2, ... B or 1.0, 1.1, 1.2 ... 2.0 ...)
 - It is recommended that this data field not be subjected to ASME restrictions unless contractual.
 - The prohibition against the use of revisions O, Q, S, X, Z because they look like the numbers 0, 0, 5, 8, 2 is a holdover from the days of drafting boards and flat files used to hold vellums.

* ISO. (2008). *ISO/IEEE 12207:2008, Systems and Software Engineering—Software Life Cycles*. Geneva, Switzerland: ISO.

- Revision state (e.g., preliminary, review, approval, etc.)
- Record creation date (e.g., for any record or change type)
- Stakeholder comments (e.g., reviewer comments)
- Stakeholder approve or reject date

6.5.5.2 Nonconfiguration-Dependent Metadata Field Management

This metadata type is not dependent on the release documentation (e.g., ECO, ECR, etc.), considered to be managed as an administrative function and consists of the following data fields:

- Program work authorization number (e.g., project number)
 - As a design proceeds through the product life cycle, the project charge number may change from funded research and development to design and to production and then to disposal
 - Each phase may have a different number
 - Many companies also issue different numbers as the product moves from one baseline to the next
- Program name (program names change as a product goes through its life cycle)
 - It may be called one thing during the bid and proposal or concept development phase, something else during design, and something else again after delivery
- Contract number (may change several times over the life of a product)
- IP legend application
 - Generally the best solution is to apply after the document release rather than embedded in the document to facilitate design reuse
- Distribution statements (generally a U.S. Defense department requirement and is subject to change as the program moves from development to production)
- Life cycle phase
- Change analyst (staffing does change during the life of many products and the last revision of the object should always reflect the current CM analyst)

The distinction between the two kinds of metadata is critical to program performance and earnings before interest and taxes. By decoupling specific metadata field from the change agent (ECO, ECR, etc.) the configuration manager is able to rapidly access the state of the uncoupled data fields and manipulate them through upload and replace methodologies in the database itself saving thousands of hours over the 10–20-year life of many hardware items.

Examples of such an administrative change could be reclassification of an allocated baseline to a production baseline. This capability necessitates a firm grasp of database management and presupposes that capability resides within the company to adequately manage PD/LM metadata (Figure 6.10). It also presupposes that the PD/LM implementation does contain the capability to manage each change agent and each object independently by latest release (or pending) change level, so that the change is applicable to data at a single level of release status and not to all levels.

6.5.6 Level VI, Guidelines Management

Guidelines are generally regarded as a documentation of best practices relating to specific functional areas and may contain information specific to a particular tool or process implementation.

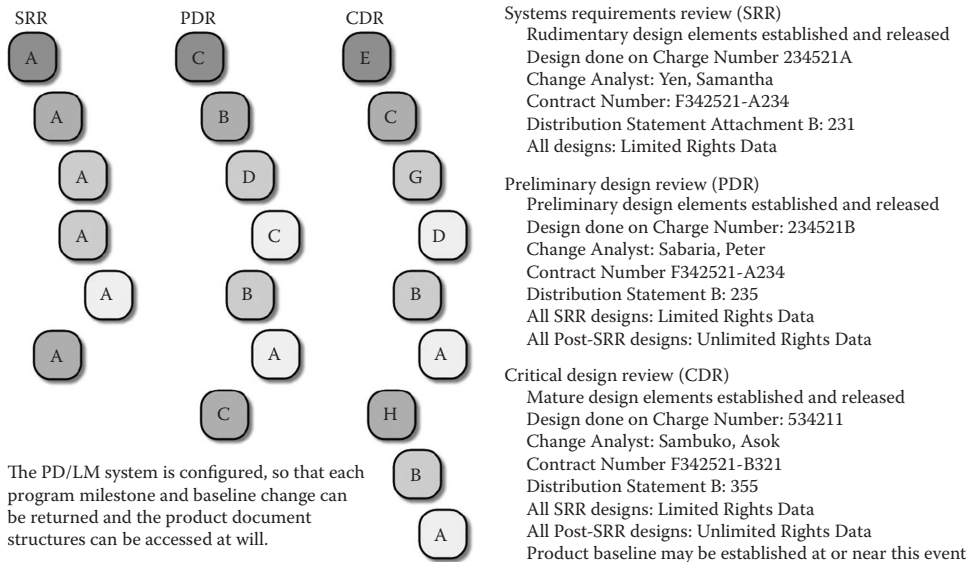


Figure 6.10 Metadata management.

Management of guidelines in the larger context requires change control in the classical sense with review by the applicable stakeholders and subject to revision or version control. In some cases, guidelines may take the form of handbooks. It is critical that performance to guidelines not be subjected to audit by external entities and there needs to be a clear statement that this is the case in the level I through level IV quality documents. Guidelines and handbooks should be purged of all “shall” statements (as the word “shall” indicates the requirement is mandatory) and while performance of employees in annual reviews may include in principle adherence to such things as a CM handbook or PD/LM best practices, ISO, and customer audits should never audit to that level. In many companies, level VI data is never acknowledged as existing in level I through level IV documentation for just this reason. Those companies refer to this level VI documentation as information that is ancillary to company operations.

6.5.7 Level I, II, III, and IV Requirements Management and CM Planning

Our research indicates that despite a sophisticated management system across all market segments, there is very little implementation of any form of requirements management system associated with Level I, II, III, and IV data. Companies that were well versed with managing technical requirements in its products and on its contracts using DOORS or other tools did not have any similar implementation on company level imposed requirements.

The lack of a system showing the interrelationships and dependencies between policies, plans, processes, and procedures made management of requirements and requirements conflict resolution a slow and costly process. It also put these companies at risk of violation of their ISO and other certifications simply because of conflicting requirements in released Level I, II, III, and IV data.

CM has to be implemented at the enterprise level and not simply implemented at a program or contract level if it is to be an effective management tool.

Chapter 7

Configuration Management

7.1 Questions to Ponder

- What tools and techniques can we use to identify configuration items (CIs)?
- Explain how configuration management (CM) impacts our product performance; link this explanation to limit curves.
- What is Das V-Modell and how does this German tool translate to contemporary views of CM?
- Explain and defend the impacts of poor or *ad hoc* configuration and change management on organizational exposure to risk.
- How does CM control drawing changes?
- What sort of software and hardware items should be put under CM control?
- Should an organization's processes fall under configuration and change management control?
- What does it mean when we say “trace requirements through to test cases”?
- What happens when we miss requirements or depending requirements on our CM activities?

7.2 Introduction

We thought it would be fitting to start this chapter with the following quotation.

The lack of modern Enterprise CM processes in large organizations is rapidly becoming a major barrier to the deployment of reliable, secure, and correct products and systems. Those who know CM, know that it is everywhere. If you understand it, you see it daily, and even hourly. Just listen to the news or read the newspaper, and observe how many issues are faced by organizations that lead to extreme costs, poor performance and undelivered products. These are nothing more than a failure to apply the fundamental principles of Configuration Management. Many in business or the government are unaware of CM or may not see any reason for CM at all.

Are they correct? Or are they limiting the practice of CM, ignoring the obvious, or even damaging it—or their careers and ours? We can either embrace it as control function, “a series of ‘checks and balances’ throughout the life cycle of a system or systems or we can ignore it at a costly price (i.e. invalid data, uncontrollable or excessive costs, failed programs and inferior products).

Configuration Management (CM) is a common phrase yet usually misunderstood; yet it is the most important and often neglected business process of any organization. It allows managers to better identify potential problems, manage changes, track progress and performance of any product during its lifecycle, while complying with laws through recordkeeping, performance metrics, and recovery needs (knowing what you have, why it is, what changes have been applied and why baseline). So, what is CM anyway? In layman’s terms, it is the plan (or blueprint) for a product, a process or a document before, during its lifecycle and beyond. It seems obvious, yet many people have no idea what Configuration Management is, how it is performed, or even how to begin doing it. Some are overwhelmed by it, believing CM to be too difficult or too costly. Then, they tend to discount it or just assume someone else is performing it as part of some support function. Many organizations continue to apply conventional configuration management methods, then blame this core discipline for failures, or abandon CM altogether out of frustration. Practitioners of CM often face constraining resources in their organizations with widespread unawareness of CM and lack the expertise in organizational dynamics (politics) to sell or enforce their CM concepts—outside of their own group. In the past, budgets were often trimmed of CM-related costs even before the program or project is funded in a misguided attempt to save money or to even use it as a sort of financial cushion for contingencies. In today’s environment, this practice is totally unacceptable. CM has a major role to play in the planning for, procurement and lifecycle of any system or product as another related function, Project Management.”*

The standard definitions of configuration management (CM) have been interpreted over time in light of the needs of one market sector and then further refined within that market sector, narrowing the understanding of the philosophy and definitions until the reasoning behind the need to manage configurations has been lost. CM reaches across every market sector and is known by many different names. Chapter 5 referenced the November 26, 2013, at 12:00 hours, Eastern Standard Time, Food Seminars International sponsored a seminar using WebEx “Using Traceability and Controls to Reduce Risk and Recall: Integrating Food Safety Systems.” The announcement for the seminar stated:

This webinar will cover the concepts needed to enable the use of commonly collected data into a meaningful system designed to meet FDA, supply chain, and company requirements. A complete integrated food safety system design will be reviewed. An understanding of how to integrate data that food supply chain members already possess will enable players to protect their companies - the food they ship and the customers they serve.

* Wasson, J. (2008). *Configuration Management for the 21st Century*. Retrieved November 23, 2013, from <https://www.cmpic.com>, <https://www.cmpic.com/whitepapers/whitepapercm21.pdf>.

Risk reduction, supplier control, traceability and minimizing recall damage are all critical components of any food safety plan. Regardless of a company's position in the food supply chain, dependence on those companies one up and one down the ladder creates liability and exposure no one wants to think about.

Areas covered in this webinar are as follows:

- Legal Issues: Food Safety Modernization Act (FSMA), FSIS, Current Good Manufacturing Practices (CGMP)
- Recall
- Traceability Through Long Processes and Zones: (Farm, Blend Operations, Distribution, Picking Operations, Retail)
- Electronic Real-Time Traceability Systems
- Integrated Food Safety System Design and Functionality

Relate the subject of the Food Seminars International sponsored seminar to the definition of CM provided below from Australia. You will find that these are all issues related to the management of the configuration of an item through all phases of the product life cycle.

“CM is the most important discipline for the establishment and maintenance of technical integrity of material” AND “With the increasing sophistication, complexity and cost of modern systems, Defense is demanding the more effective use of Technical Data to improve operational capability and readiness at a lower life cycle cost.” In the past fifty (50) years technology has evolved from resistors and switches to vacuum tubes to transistors to integrated circuits, etc, etc. and the requirements for effective design and management have increased a thousand fold demanding the need for more sophisticated management of the assets and documentation.

CM is often looked to help answer most continuing management questions:

- What is the requirement?
- How is it designed?
- Why is it designed in the way that it is?
- Does it interface with anything?
- Were there design changes?
- Why were the changes made?
- Where is everything?
- What state is it in?
- What is it doing?
- Is it deployed correctly?
- What does it have to do with my problems?
- What if we change it?
- Do we need more/less of it?
- Can we get rid of it?
- What is affected by changing or removing it?*
- Who is paying for it?

* Australian, Technical Regulation Army Material Manual, Department of Defence, Canberra, ACT, Australia.

7.3 Overview of CM

CM is seen by many as very much a product of the ability of *Homo sapiens* to produce more than one copy of items so nearly identical so as to be hard to distinguish from one another without the reliance on information associated with the particular build of each item. This capability to produce tangible and intangible goods has evolved over time and the concept of nearly identical has come to mean different degrees of precision to different points in our collective history. A variance in size of the arrowheads associated with the Terracotta Warriors of less than 1 cm down to less than 0.22 mm in 210 BCE at one time was accepted as identical parts. Production of exact copies of executable software from giants such as Microsoft Corporation with a variance dependent on only the physical makeup of the media it is housed on would have been unthinkable yet is commonplace today. Yet even such precision as is available through digital video discs (DVDs) and Blu-ray discs are not without CM issues. Many titles on Blu-ray discs (*Iron Man*, *Saving Private Ryan*, *Star Trek: The Next Generation* boxed sets, Madonna's *MDNA World Tour*, and others) have been recalled due to configuration issues.

7.3.1 History of CM

What follows is a brief history of CM development from a U.S. government perspective. Similar developments have occurred in every nation and in every market sector. It is not intended to be a complete listing of the entire history but a representation of the major documentation influencing the genesis of how CM is viewed in the United States. It is very important to recognize that the basic tenants established by the documents cited further exist wherever CM is practiced regardless of country.

How CM is viewed in the United States, commercially and internationally, is changing due to technological advances, global competition, and competitiveness. The essence of CM remains the same despite the methodologies such as how it is done in one company, market subsegment, and market segment or what department is tasked with doing CM functions. Each individual performing a CM function must understand how it is evolving to maximize the benefits derived from it in the form of higher quality, lower cost, and being able to locate critical data quickly. Changes due to technological factors and their impact on business are major factors that should be taken into account. If the technology is not understood and as a result not fully utilized to achieve the desired cost control, it will weigh heavily on those performing CM functions.

The specific names and the associated definitions in accordance with these documents may be so different as to be unrecognizable by many in a strictly U.S. government sales environment. Most definitions, therefore, must be taken loosely with a view to understand the intent of the author, and the intent of the concept behind the specifics to gain a better understanding of the CM process. The great reduction in government specifications and standards and the acceptance in nongovernment-funded industries of CM terms require that those performing CM have a global perspective. Not all definitions have transferred to the commercial sector, and individuals performing CM are known as change managers, database administrators, document control specialists, software control specialists, product definition professionals, or infrastructure coordinators.

Words such as “data” should be interpreted to instead mean information, as data has specific connotations and information is more widely understood. Words such as “standard” and “standardization” need to be put into context and tempered with an understanding of what

standardization is and that standards are not static but driven toward change. Casey C. Grant, describes it in these words,*

Ancient World

One of the earliest examples of standardization is the creation of a calendar. Ancient civilizations relied upon the apparent motion of the sun, moon and stars through the sky to determine the appropriate time to plant and harvest crops, to celebrate holidays and to record important events.

Over 20,000 years ago, our Ice Age ancestors in Europe made the first rudimentary attempts to keep track of days by scratching lines in caves and gouging holes in sticks and bones. Later, as civilizations developed agriculture and began to farm their lands, they needed more precise ways to predict seasonal changes.

The Sumerians in the Tigris/Euphrates valley devised a calendar very similar to the one we use today. 5,000 years ago, the Sumerian farmer used a calendar that divided the year into 30-day months. Each day was divided into 12 hours and each hour into 30 minutes.

The Egyptians were the first to develop the 365-day calendar and can be credited with logging 4236 BC as the first year in recorded history. They based the year's measurement on the rising of the "Dog Star" or Sirius every 365 days. This was an important event as it coincided with the annual inundation of the Nile, a yearly occurrence that enriched the soil used to plant the kingdom's crops.

Industrial Revolution

With the advent of the Industrial Revolution in the 19th century, the increased demand to transport goods from place to place led to advanced modes of transportation. The invention of the Railroad was a fast, economical and effective means of sending products cross-country. This feat was made possible by the standardization of the railroad gauge, which established the uniform distance between two rails on a track. Imagine the chaos and wasted time if a train starting out in New York had to be unloaded in St. Louis because the railroad tracks did not line up with the train's wheels. Early train travel in America was hampered by this phenomenon.

During the Civil War the U.S. government recognized the military and economic advantages to having a standardized track gauge. The government worked with the railroads to promote use of the most common railroad gauge in the U.S. at the time which measured 4 feet, 8 ½ inches, a track size that originated in England. This gauge was mandated for use in the Transcontinental Railroad in 1864 and by 1886 had become the U.S. standard.

20th Century

Cities experienced tremendous growth in the 20th century, bringing increased prosperity to America and attracting more and more people to urban centers. As cities became

* Grant, C.C. (2007). *A Look From Yesterday to Tomorrow on the Building of Our Safety Infrastructure, Official Contribution of the National Institute of Standards and Technology; Not Subject to Copyright in the United States.* Quotation is from the *NIST Centennial Standards Symposium*, NIST, Boulder, CO. March 7, 2001, from http://www.nist.gov/manuscript-publication-search.cfm?pub_id=200080.

more sophisticated and their infrastructures more complex, it became apparent that a unique set of national standards would be necessary to ensure the safety of city dwellers.

In 1904, a fire broke out in the basement of the John E. Hurst & Company Building in Baltimore. After taking hold of the entire structure, it leaped from building to building until it engulfed an 80-block area of the city. To help combat the flames, reinforcements from New York, Philadelphia and Washington, DC immediately responded—but to no avail. Their fire hoses could not connect to the fire hydrants in Baltimore because they did not fit the hydrants in Baltimore. Forced to watch helplessly as the flames spread, the fire destroyed approximately 2,500 buildings and burned for more than 30 hours.

It was evident that a new national standard had to be developed to prevent a similar occurrence in the future. Up until that time, each municipality had its own unique set of standards for firefighting equipment. As a result, research was conducted of over 600 fire hose couplings from around the country and one year later a national standard was created to ensure uniform fire safety equipment and the safety of Americans nationwide.

Standardization is an ongoing CM activity. The October/December 2011 Defense Standardization Program Journal* reported,

Standardization also facilitates radical changes. For example, Turkey, which entered NATO together with Greece in 1953, changed its 630-year-old military map symbols and the colors used to denote friendly and opposing forces through the implementation of NATO a Standardization Agreements (STANAGs). Indeed, many nations use only NATO operational STANAGs and no longer produce their own. Examples of the contribution of standardization to military operations are innumerable. In fact, without standardization, multinational interoperability could not be achieved, and NATO operations would not be possible.

The publication also contained articles on “First-Ever Transition of a NATO Standard to a Civilian Standards Development Organization, NATO Revises CM Guidelines, and NATO Adopts ISO/IEC 15288.”

The History

- Army, Navy, Air Force (ANA) Bulletin 29 (1953)
 - Established the engineering change proposal (ECP)
- ANA Bulletin 391 (1956)
 - Defined ECP priorities
 - Expanded application of configuration beyond the airplane business sector.
- MIL-D-70327 (1959) engineering drawing requirements (forerunner of MIL-D-1000 and to some extent MIL-STD-100)
 - Established two drawing classes
 - Referenced and pulled together some 30 related military specifications
 - Established the rules for part numbering, serialization and interchangeability

* DOD, U.S. (2013). *The Defense Standardization Program Journal*. Retrieved December 26, 2013, from <http://www.dsp.dla.mil/>, http://www.dsp.dla.mil/APP_UI/displayPage.aspx?action=content&accounttype=displayHTML&contentid=75.

- Air Force Systems Command Manual (AFSCM) 375-1, configuration management during the definition and acquisition phases
 - Seen as the first CM “Bible.”
 - Pulled together the now “Classical.” Elements of configuration management (identification, control, status accounting, and audits)
 - Established a government CM office
 - Established a “uniform specification program”
 - Instituted “first article configuration inspection,” The predecessor of the physical configuration audit physical configuration audit (PCA)
 - Introduced the idea of a “compatibility” ECP
- AFSCM 375-7, configuration management for systems, equipment, munitions, and computer programs
- NPC-500-1 (NASA) Apollo configuration management manual—almost identical to AFSCM 375-1
- NSA/CSS 80-14 (NSA) configuration management*
- AMCR-11-26 (USA) configuration management*
- AR 70-39 (U.S. Army) configuration management*
- AFR 65-3 (U.S. Air Force) configuration management*
- MCO 4130.1 (U.S. Marine Corp.) configuration management*
- AMC Regulation AMCR 11-26 (Army) Army’s equivalent of AFSCM 375-1
- NAVMATINST 4130.1 (U.S. Navy) Configuration Management—A Policy and Guidance Manual

Starting in the 1960s the U.S. government attempted to amalgamate and standardize its CM requirements with the result that by the early 1980s, the requirements landscape looked much different (Figure 7.1).

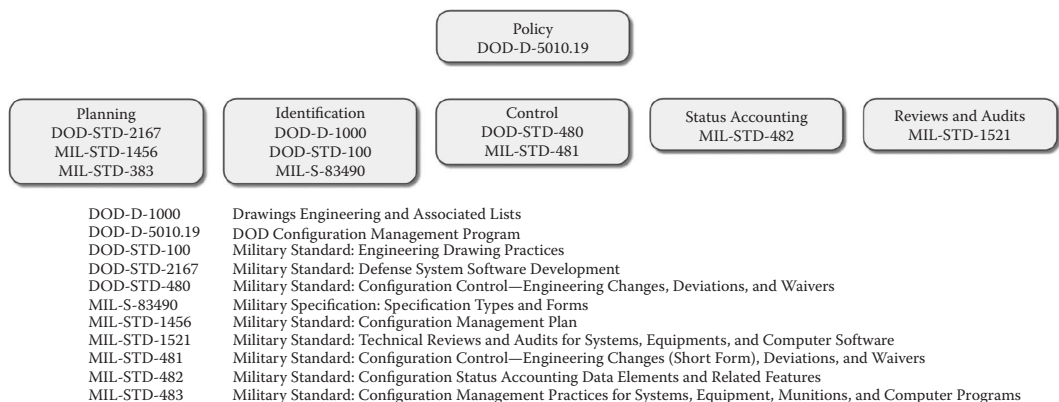


Figure 7.1 U.S. DOD requirements 1985 CE.

* Contextually the same as they comprise the joint regulation on configuration management of the U.S. Department of Defense (DOD).



Figure 7.2 CM implementation as seen by U.S. DOD 1985 CE.

This resulted in the areas of responsibilities, shown in Figure 7.2, for all CM and can, for our purposes, be considered as the CM fundamentals on which all aspects of CM seen across product lines in every market sector are evolved.

Please do not be confused by the previous statement, as it is purposely a generality. Certainly CM existed before the U.S. military in all market segments. Many areas, such as manufacturers of medicines and medical equipment, have such stringent standards that those CM activities imposed on contractors by the U.S. and International Standards Organization (ISO) certification can be viewed as the minimum necessary to assure duplicate copies of products are procured that meet acceptability norms.

Evolution of CM-related standards and guidance documents have continued. A continued divergence in product and product sector unique requirements is a continuing trend that has resulted in heated disagreement over the meaning of basic terminology simply due to refinement of practices specific to a single instance of CM.

Hardware-centric configuration managers argue with software configuration managers over concepts such as branches and twigs being a software product structure. Tool-specific requirements also generate their own unique to tool CM language, which will in turn fall by the wayside, as new tools appear leaving only a basic understanding of how CM activities evolved to rely on. This Tower of Babel effect will be discussed further in Chapter 10.

Chapter 13 provides a list of current CM-related standards.

7.3.2 Das V-Modell

German V-Model “Das V-Modell” (Figure 7.3) is the official project management methodology of the German government. It is directly intertwined with CM activities. There is a lot of confusion when discussing V-Models, as the concept has been found to be applicable to multiple disciplines and subdisciplines, most notably in software development.

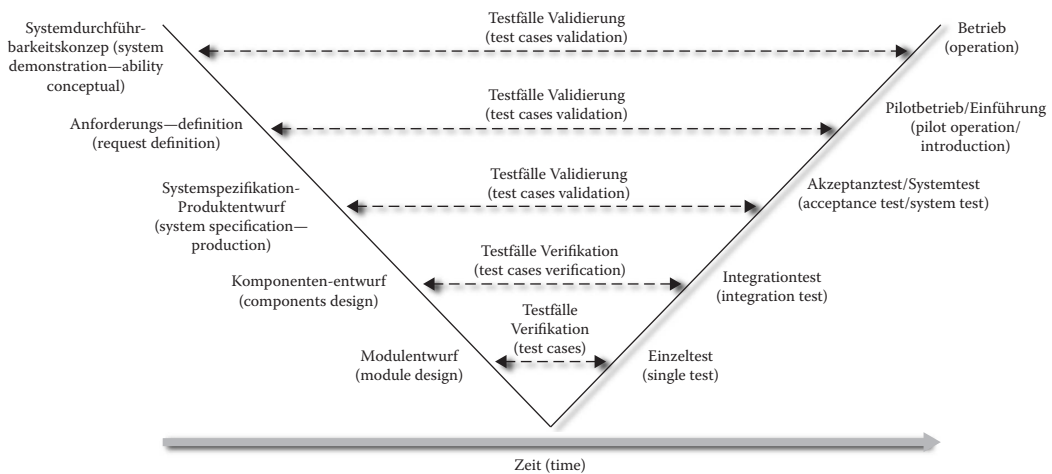


Figure 7.3 Das V-Modell.

As with the history of many things, the V-Model concept evolved independently in Germany and the United States in the 1980s. The German version was developed by Industriebetriebe mbH (IABG) in Ottobrunn, near Munich, in cooperation with the Federal Office for Defense Technology and Procurement in Koblenz, for the Federal Ministry of Defense. The U.S. version was developed for satellite systems involving hardware, software, and human interaction. The first U.S. V-Model appeared in a proposal from Hughes Aircraft in 1982 for the U.S. Federal Aviation Administration's advanced automation system program. From the V-Model came our current conceptions of allocation, validation, and verification.

7.3.3 What Does CM Apply To?

In the narrow sense, as defined by the regulations cited in Section 7.3.1, CM applies to software, firmware, hardware, and drawings among other things. In a much broader context, CM applies to everything in some regard or another. This includes any item that it is necessary to know the provenance of and in a different context how something is hooked together with other items. Under this broader interpretation and somewhat outside the context of the current suite of standards, this includes art, music, literature, companies, organizations, people, architecture, community, town, city, state, national infrastructure, scientific research as well as all tangible and intangible goods. Understanding the configuration of anything requires the application of CM to establish that elusive thing known as “provenance.” Many practitioners of CM will disagree with this statement yet it is an irrefutable fact that unless a configuration is known our species is at a disadvantage. To put this in context, we need to go back and explore how we arrived at our current needs to understand the world around us and how we arrived at where we are today.

Our ancestors understood where the fruits and vegetables grew with the movements of the animals they used as a food source as well as the vegetation those animals consumed throughout the seasons. They knew the configurations of the animals. They understood how to harvest each type of creature in the best season and what each portion could be used. Such knowledge led to tanning an early form of process, the fact that a mammal generally has enough brain matter that when mashed in warm water along with its liver, the urine from its bladder cure process to make leather

for clothing.* They knew that deer harvested in the fall had the best skin for buckskin leather. They knew the configuration of materials such as the types of wood and rocks for clubs, knapped tools such as chopping tools, hand axes, knives, and spear heads. They know how to utilize every bit of bone, meat, skin, feathers, plant fibers, fruits, and seeds to the best advantage. They understood that plants with four-petal flowers produced seeds and fruits generally harmful to our species and those with five-petal flowers were generally edible. Hunter-gathers knew these things. Tools they kept were minimal. Those who survived learned how to make everything else they needed. A lost arrow did not mean a loss of the hunt or the group's survival. More could be easily made. This did not negate that they knew and practiced the management of configurations and the data associated with them. In many cases, they outlived species they were contemporary with, which is a testament not only to the adaptability to change of *Homo sapiens* but also to the understanding of the changing configuration of the environmental niche they inhabited.

Boucher de Perthes (1788–1868) and his contemporaries had shown, as early as 1850–1860, that humans had lived at the same time as animal species that had disappeared at a very early period. The finding made by Larte and Christy in the shelter of Madeleine (in the Dordogne) of a drawing of a mammoth on a fragment of mammoth tusk may be said to have given a double proof that humans were contemporary with the mammoth.†

These nomadic ancestors eventually formed groups, tribes, seasonal communities, towns, cities, states, and nations; as their societies grew, the complexities of what they had to know became more complex. Community living led to the specialization and refinement of manufacture and commerce. Individual knowledge became group knowledge and group knowledge became guild knowledge. This resulted in a dispersed and shared capability. One could trade your arrows for shoes made by someone else, trade livestock for grain and grain for metal goods, pay a portion to a group to hire and pay someone to protect themselves and their fields from the folks over the hill. Suddenly the configuration and content of your flock, fields, your household, your larder, and your purse became more important than where the nearest source of flint or when the edible berries were going to be ripe. That was the worry of the green grocer of the day, as you were providing wool to the weavers' guild. You could pay the grocer for your fruit so he better do his bit. The rudiments of trade, intellectual property, trade, legal concepts, management of data in the form of yield, exchange rates (e.g., 1 lamb = 1 pair of shoes, 3 fish = 1 measure of grain) and ways to keep track of it (bullae, knots on a string, cuneiform, ruins, etc.) developed. The locals you paid to protect you got organized and demanded standardization of the tools they used. Someone wanted a set of crockery, the same as the ones used by the head man. Everyone wanted better control over the exchange rate. Every measure of grain needed to be equal in weight. Exchange rates changed: 1 weight of fish = 1 weight of grain. Suddenly quality mattered. So it went through the ages with everyone wanting and needing to know the configurations of things around them.

Every guild, individual, and community had a way to do things. The standardization of the exchange rate for gems, where 1 carob seed equaled a carob weight stone (now called a "carat weight"), became more refined as carob seeds varied too much in size; other standardizations took place. Accounting methods, units of measure, accounting practices, quality (purity, fabrication, etc.), performance, and other things measurable went through the process. Management of configurations, processes, weights and measures, time, ocean currents, and information about those configurations evolved in every market segment in every country. CM, data management, and

* Recipe from Jaeger, E. (1999). *Wildwood Wisdom*. Shelter Publications, Inc, Bolinas, CA.

† Bordes, F. (1968). *The Old Stone Age*, Translated from the French by J.E. Anderson. Weidenfeld & Nicolson, London.

status accounting exist universally. Knowing that you have an extra five pound not in the boot of your car data or one more royal coachman fly in your fly box is as much CM as the management of a multinational project such as the International Space Station.

Generically knowing the configuration of something is having enough information about it that you know where and how it came to be, as it is as well as the requirement to know where it is and how it differs over time until the point that information is no longer relevant.

CM, as practiced in accordance with the standards, specifications, handbooks, and other source material shown in Chapter 13, is a very limited subset of the whole that pertain to specific industries, customers, and products. Yet they are no more important in the broader context of CM than understanding that the CM of issues involving our food supply is equally important.*

What follows are a series of definitions relating to software, firmware, and hardware from U.S. MIL-STD-483A, configuration management practices for systems, equipment, munitions, and computer software (1985-06-04). This document was chosen as it represents what many firms selling to the U.S. government feel is the quintessential source for what they consider CM.

MIL-STD-483A: 1.3 Application. Configuration management requirements established by this standard apply during the applicable system life cycle phases of configuration items whether part of a system or an independent configuration item. Contracts invoking this standard will specifically identify the appropriate applicable paragraphs and appendixes or portions thereof as defined in the contract work statement depending upon the scope of the program, other contractual provisions, and the complexity of the configuration item being procured. The contractor shall ensure that all software, hardware, firmware and documentation procured from subcontractors is generated according to the requirements of this standard.

7.3.3.1 Software Items

MIL-STD-483A: 5.1(e) Computer Software logically distinct part of a Computer Software Configuration Item (CSCI). Computer Software Components may be top-level, or lower-level.

MIL-STD-483A: 3.4.7 Computer Software Configuration Identification. CSCI specifications, design documents, and listings shall define software requirements and design details for a single CSCI. The subparagraphs below identify the specifications and design documents of the CSCI.

7.3.3.2 Firmware Items

MIL-STD-483A: 5.1(n) Firmware. The combination of a hardware device and computer Instructions or computer data that resides as read-only software on the hardware device. The software cannot be readily modified under program control. The definition also applies to read-only digital data that may be used by electronic devices other than digital computers.

* Warriner, K. (2013, December 19). *Food Seminars International, Food Safety Culture: When Food Safety Systems Are Not Enough*. Retrieved December 19, 2013, from <http://foodseminars.net/>, <http://foodseminars.net/product.scj;sessionId=9A15A4DB9773831A41A5B6D46E006C1F.m1plqscsfapp03;productId=163&categoryId=1>.

7.3.3.3 Hardware Items

MIL-STD-483A: 5.1(f) Configuration item. Hardware or software, or an aggregation of both, which is designated by the contracting agency for configuration management.

MIL-STD-483A: 5.1(q) Hardware Configuration Item (HWCI). See configuration item.

7.3.3.4 Drawings

We have looked at drawings and drawing requirements briefly in Chapter 1. Drawings are included in this chapter as many people doing configuration relate to the word in their daily lives. Yet as with many terms used in CM “drawing” may be understood to mean many different things when viewed from the international and market segment perspective. In the broadest sense, a drawing may be defined to mean: “Any documented record from which an end item may be produced. Including but not limited to the formulation of chemical compounds (solids, liquids, gasses); hardware, firmware; software; patents; and licensable processes.”

The U.S. American Society of Mechanical Engineers (ASME) Y14 series of documents identify specifics for “drawing” formats and types. It must be remembered that this series if written from a mechanical engineering perspective only. While it serves the CM community well in most cases, it is not as far reaching as will be required when the broader definition of a configuration item (CI) is introduced raises the question, “If a drawing creates item identification and no drawing is produced from the drawing model yet the model can be printed in 3D or sent in the form of a STEP* file to be produced on computer numerical control (CNC) machines or after conversion to a STL, OBJ, X3D, Collada or VRML97/2 file for common 3D printers, is our concept of item identification outmoded?”

From a practical sense the answer is no. Although drawings have been utilized before the 1800s to provide a pictorial representation of the object being produced, a drawing is not specifically required for item identification purposes. Documentation is required, however, and the concept that a drawing is the only form of documentation considered rather than a single form of documentation that may be considered is evolving.

While much confusion still exists between the concepts associated with CM, as provided in the primary specifications and standards, perhaps the clearest conceptualization is provided in GEIA-HB-649, Table 2.

- *ANSI/EIA 649-B, TechAmerica Standard*: CM Standard, Table 2[†] provides us with the following summarized picture:
 - Document definition
 - A self-contained body of information or data that can be packaged for delivery on a single medium. (The medium may be paper, photograph, digital files, optical computer disk, magnetic, electronic storage, or a combination thereof.)
 - Aliases, related terms, and examples
 - Examples of documents include
 - Records

* ISO. (2002). *ISO 10303-21:2002, Industrial Automation Systems and Integration—Product Data Representation and Exchange—Part 21: Implementation Methods: Clear Text Encoding of the Exchange Structure*. ISO, Geneva, Switzerland.

[†] ANSI/EIA 649-B, TechAmerica Standard: Configuration Management Standard, TechAmerica, Washington, DC.

- Specifications
- Engineering drawings
- Drawing lists
- Pamphlets
- Reports
- Standards

For a meaningful definition of drawings, we have started with MIL-STD-100G, Engineering Drawing Practices (1996-09-09) as our source material for the ASME standards. The ASME standards establish many drawing types and classifications:

- ASME Y14.100, Engineering Drawing Practices
- ASME Y14.24, Types and Applications of Engineering Drawings
- ASME Y14.34, Associated Lists
- ASME Y14.35, Revision of Engineering Drawings and Associated Documents

ASME organizes drawings into broad classifications. Some of which are said to “create item identification.” This is, in ordinary terms, another way of saying there is enough information on them to make something. The term “does not establish item identification” simply means that you have insight or information but it is not sufficient to make something.

Drawing types that establish item identification ASME Y14.24

- Detail drawing (mono detail and multidetail)
- Assembly drawing (assembly and inseparable assembly)
- Hardware installation drawing (only if creating a work package or kit)
- Altered item drawing
- Selected item drawing
- Modification drawing (when required for control purposes)
- Wiring harness drawing
- Cable assembly drawing
- Printed board and discrete wiring board drawing sets (printed wiring assembly and Printed Wiring Board [PWB])
- Microcircuit drawing set
- Kit drawing
- Tube bend drawing
- Matched set drawing

Drawing types that do not establish item identification ASME Y14.24MIL-STD-100F:

- Layout drawing
- Arrangement drawing
- Interface drawing
- Identification cross-reference drawing
- Mechanical schematic
- Electrical diagrams
- Functional block diagram
- Single-line schematic diagram

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- Schematic diagram
- Connection diagram
- Interconnection diagram
- Logic circuit diagram
- Envelope drawing
- Undimensioned drawing
- Contour drawing
- Software installation drawing
- Alternate parts drawing
- Drawing tree

Design information drawings (do not establish item identification) ASME Y14.24

- Layout drawing
- Contour drawing
- Installation drawing
- Interface drawing
- Mechanical schematic diagram
- Single line diagram
- Schematic diagram or circuit diagram
- Connection diagram
- Interconnection diagram
- Wiring list
- Logic circuit diagram
- Drawing tree

Control drawings (establish item identification) ASME Y14.24

- Procurement control drawing
- Vendor item drawing
- Source control drawing
- Envelope drawing
- Identification cross-reference drawing
- Microcircuit drawing set

Lists (do not establish item identification) ASME Y14.34

- Artwork list (AL)
- Data list (DL)
- Index list (IL)
- Parts list (PL)
- Wire list (WL)

List prefix identifiers ASME Y14.34

- AL, DL, IL, PL, WL

CM, as established by these standards, is not necessarily concerned with all documentation associated with the management of the configuration. It is concerned primarily with the documentation that establishes a CI's provenance.

For general purposes, a drawing such as “Study of a Tuscan Landscape (1473)”^{*} is an expression of communication in visual form. It contains details that would enable a knowledgeable person to construct items depicted based on its content. It is conceivable that as the cross-market segments and international aspects of configuration are understood that simply, the term “information” will suffice regardless of format with the single criteria that from it a product can be made. In a similar way, pictures left in the minds of the listeners painted at one time all that was necessary for knowledgeable craftsmen to fabricate a similar item. The premise is born out in the explorations of people such as Thor Heyerdahl in his *Kon Tiki*[†] balsa raft and *Ra*[‡] papyrus reed boat but by Tim Severin, who painstakingly researched and built a boat identical to the leather curragh,[§] believed to have carried Brendan on his epic voyage to the North American coast. The meticulous trial-and-error research leading to these voyages by both Heyerdahl and Severin would have been common knowledge at the time the stories were first told.

Undoubtedly, the configurations of items whose pictures were drawn in oral traditions were managed. They were reproducible. They were as nearly identical as it was necessary for their intended use. Oral traditions painting similar pictures exist today in sagas such as the Finnish epic known as the *Kalevala*.[¶] The British folksong *John Barleycorn* is a similar form of oral tradition pertaining to the process for making the beverages such as whiskey and beer with broadside (also known as a “broadsheet”) copies dating back to the sixteenth century. Scottish songs with a similar theme exist such as the “Quhy Sowld Nocht Allane Honorit Be” from as early as 1586.^{**}

A modern incarnation of the idea that with a sound practical understanding of the craft to enable a competent individual to produce something is seen in the relatively recent change from detailed written directions and installation drawings to the relatively simpler arrangement drawings used when connecting modern electronics devices using wireless technologies. Michael Jakubowski, the founder of Open Source Ecology, has leveraged this idea of the competent person forward in “The Global Village Construction Set (GVCS),”^{††} which is a modular, Do It Yourself (DIY), low-cost, high-performance platform that allows for the easy fabrication of the 50 different industrial machines that it takes to build a small, sustainable civilization with modern comforts.

7.3.3.5 Specifications

The word “specification” is of Roman origin and comes from the word “species.” Under Roman law, the term “specification” refers to the acquisition of a new (nova) species arising from a change of species. Ownership over this new species (generally as we discuss it here a manufactured article)

^{*} Da Vinci, L. *Verrocchio's Workshop, 1466–1476 (CE)*. (Study of a Tuscan Landscape was drawn when Leonardo Da Vinci worked in Andrea del Verrocchio's workshop during his 10 year there thought to be 1466 to 1476.)

[†] Heyerdahl, T. (1950). *The Kon-Tiki Expedition: By Raft across the South Seas*. Rand McNally & Comp, Skokie, IL.

[‡] Heyerdahl, T. (1971). *The Ra Expeditions*. Doubleday, New York, NY.

[§] Severin, T. (2005). *The Brendan Voyage*. Gill & Macmillan Ltd, Dublin, Ireland.

[¶] Lönnrot, E. (2008). *The Kalevala: An Epic Poem after Oral Tradition*. Oxford World's Classics, New York, NY.

^{**} Bannatyne, G. (1896). *The Bannatyne Manuscript*. Retrieved on May 20, 2014, from https://openlibrary.org/books/OL7034966M/The_Bannatyne_manuscript.

^{††} Open Source Ecology. (2014). *Open Source Blueprints for Civilization Build Yourself*. Retrieved July 25, 2014, from <http://opensourceecology.org/#sthash.BtrJ7jWL.dpuf>.

was defined under Roman law by Procukians that the manufactured article should be held to belong to the creator of the article. In a conflicting view, Sabinus/Cassus held that the manufactured article should belong to the owner of the material substance.*

In many ways, both arguments are with us today and define how new products are viewed from the standpoint of not only laws governing sales to the government but also sales in the commercial marketplace. These concepts also flow back into the degree of risk a contractor assumes when involved with government contracts. Under government contract provisions, goods, and services may be obtained under commercial terms and conditions (such as FAR Part 12), where the contractor assumes all risk and the product and all residual materials belong to the contractor (just as they would in the commercial marketplace until point of sale. Goods and services may also be obtained under government terms and conditions (reference FAR Part 15, “Contracting by Negotiation”), where everything produced under the contract or ordered under the contract resides with the government. In 2013, this was increasingly true in the United States even with firm-fixed price contracts under FAR Part 15.

The Roman idea of species and subspecies is well known in the natural sciences as the scientific name. It involves a two-part taxonomy known as “binomial nomenclature” that allow scientists regardless of nationality to specifically identify every species past or present. A similar taxonomy is used in language-defining the relationships between words. This concept finds its way into CM methodologies such as those defined in the TechAmerica Standard ANSI/EIA-836-B-2010, “Configuration Management Data Exchange and Interoperability,” canonical model of data transfer using a data dictionary.

Additionally, the idea of specifying something that exists has found its way into a methodology for identifying something that does not exist. It is in this context that most CM practitioners are most familiar with it. In addition to the specifications previously identified in Section 7.3.1, specifications as used in this sense of defining a valid set of requirements, which are used to form a product’s functional baseline, have long recorded history that includes the Egyptians, Greeks, Aztecs, Romans, Norseman, Huns, Saxons, Germans, French, Russians, and Chinese. A fair summation of the history of specifications is that every advanced civilization has some evidence of their existence. The first requirement for specification preparation in the United States is MIL-S-6644, “Instruction for Preparation of Specifications,” April 13, 1953. These specification requirements continue to evolve. In the United States, the current requirements are defined in MIL-STD-961, “Specification Preparation.”

Traditionally the adage “If you can’t draw it you can’t spec it” was challenged early on and has been gradually replaced in some engineering circles with “If you can’t imagine it you can’t spec it.” Many countries utilize a six-part engineering specification.

1. Scope
2. Applicable documents
3. Requirements
4. Mission assurance provisions
5. Preparation for delivery
6. Notes
7. Addenda

* Zulueta, F.D. (1946). *The Institutes of Gaius*. Clarendon Press, Gloucestershire.

Descriptions are reduced to their technical essence and the specification identifies what is required not how to do it. Ronald Schumann* states

A formal specification is intended to be a document that clearly and accurately describes the essential technical requirements for items, packing, materials, or services, and that includes the procedures by which a determination can be made that the requirements have been met.

Currently three major divisions of engineering specifications are used.

1. Performance specification

- a. A specification that states requirements in terms of the required result with criteria for verifying compliance, but without stating the methods for achieving the required results. A performance specification defines the functional requirements for the item, the environment in which it must operate, and the interface and interchangeability characteristics.

2. Detailed specification

- a. A specification that specifies design requirements, such as materials to be used, how a requirement is to be achieved, or how an item is to be fabricated or constructed.

3. General specification

- a. A general specification is prepared in a six-section format and covers requirements and test procedures that are common to a group of parts, materials, or equipment.

The evolution of specifications progressed from the general to the specific leading to an almost crippling case of micromanagement through specifications. At one time, in the United States, there were 24 data item descriptions related to specification types. This resulted in a change of focus and the current trend to provide only the level of detail needed to adequately specify an item.

When writing a specification, it is important to consider the following questions:

- Is the requirement stated real?
- Is there any way it could be misconstrued?
- What am I asking the designer to do?
- What am I doing to the company or contractor?
- How will the customer react to this specification?
- Have all the necessary requirements been stated?
- Will the customer know exactly what we are providing?
- Are there any *gold plated* items that increase cost?
- How will someone prove the requirements are satisfied?
- Are the requirements bounded or open ended?
- Is there enough information to assure that each requirement can be satisfied by an artifact (test, analysis, demonstration, and inspection)?
- Are references tailored to bound additional cost drivers?

* Schumann, R.G. (1980). *Specifications, Issue 13, Government Contracts Monograph Government Contracts Program*. Reprinted with permission of the George Washington University, Washington, DC.

- Are the designer's prerogatives restricted or is there enough flexibility to facilitate a cost-effective design solution?
- Have I fallen into the trap of stating requirements are as implemented in another document or is the specification self-contained?
- Have I specified as requirements compliance with other documents that are not required or contradictory?
- Have I eliminated all "to be determined," "to be resolved," "to be negotiated," and "to be specified" statements?
- Have I progressed from general to specific requirements in each section?
- Have I used the word "shall" to mean a provision that is binding on the contractor?
- Have I used the words "should" or "may" to mean a provision that is nonbinding on the contractor?
- Have I used the word "will" to mean a provision that is binding on the customer?
- Have I included a clear order of precedence regarding the hierarchy of referenced documentation (e.g., the requirements in specification section 3.0 take precedence over documents referenced in Section 2.2.1 of the specification)?

It is critical that all requirements be clear, concise and valid in terms of CM. In addition, they should be uniquely identified in order to create a traceability of the requirement to the end configuration. Requirements flow from the highest level to lowest level is needed to tie the artifacts such as test and inspection results to the product configuration.

Ronald Schumann goes on to state

Probably the most fundamental cause of undue restrictiveness in specifications is the writing of specifications to describe features of a particular item believed to be capable of satisfying the customer need, rather than to describe the need itself and those details of design or performance which are in some way necessary to satisfy the need.

Part of the CM task in this setting is to assure that a clear trace of requirements is established from the contract downward. One essential element of this is the generation of a contract specification tree as part of the overall product documentation tree. Think of these trees as a document bill of material (BOM).

7.3.3.6 *Material Lists*

Lists of material in the sense of the existing standards associated with DOD, American National Standards Institute, ASME, ISO, TechAmerica, and others consist only of the items that are incorporated into or used to produce the item. They do not include hardware and software items or configurations used in the manufacturing process. The determination of these items is generally associated with procedures and facilities the effort is performed in. Cleaning is an example of this. A drawing may state clean in accordance with cleaning standard C1. This cleaning standard discusses the steps to use, the facility it takes place in, the materials required (gloves, chemicals, disposable items, etc.) drying times between each step, and bagging of the item to assure it does not get contaminated. With the development of electronic tool to facilitate linking of data, the current practice involves many companies identifying the expendable

materials in the item product structure with the documentation pertaining to it and its use in the BOMs for the expendable item.

This presents CM challenges as most product data management (PDM) and product life cycle management (PLM) tools are not properly configured during the tool implementation phase. This results in few safeguards against circular references in the associated databases. Understanding the database and how it is populated by the PDM or PLM tool as well as having a copy of the database that can be used by CM personnel to try out modifications to their material list strategies is critical to avoiding these issues. Material lists should be thought of in the context of documents associated with the item being produced and those items that lose their individual identity (e.g., items consumed) to make the item being produced.

7.3.3.7 Document Material List (Document BOM)

Every document can be said to have a BOM. It consists of documents referenced in the document itself. Where companies traditionally go wrong when portraying this in the product data/life cycle management (PD/LM) database structure is simply due to not paying attention to the order of precedence of the documentation. The order of precedence once established and followed will eliminate circular references (Figure 7.4).

A good example of this is in the area of contracted items. The simple order of precedence is

- The subcontract
 - The subcontract calls out the statement of work (SOW) and the specification or control drawing

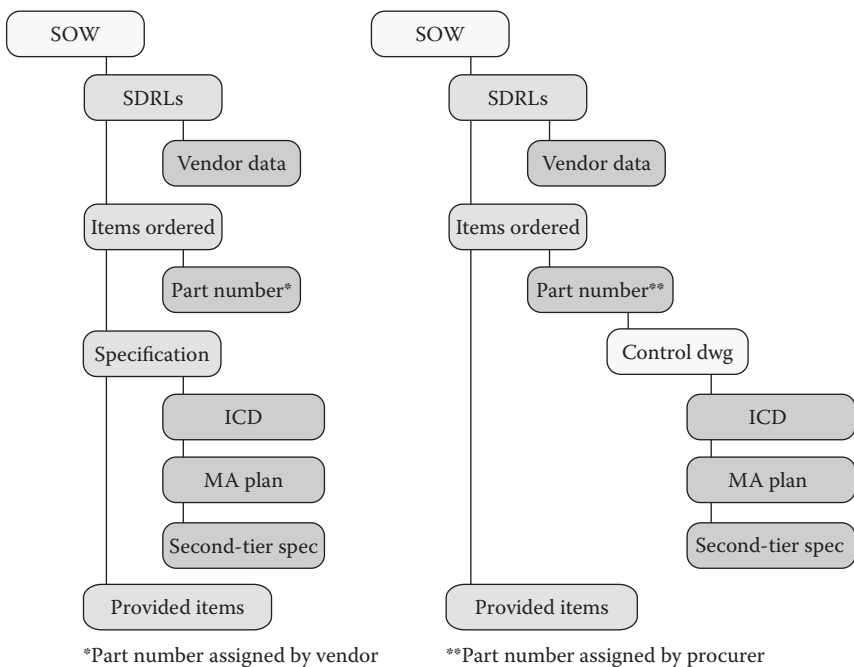


Figure 7.4 Document BOM.

- The SOW
 - States that it takes precedence over the specification or the control drawing
 - States what items are being provided by the contractor to the subcontractor
 - States what items are being provided by the subcontractor to the contractor
- The specification or control drawing
 - Interface control drawing
 - Mission assurance requirements (MAR)
 - Any lower level specifications

Under this order of precedence, lower-tier documents do not call out higher level documents. [Figure 7.4](#) shows the document BOM structure in cases where the number for the item being procured is either assigned by the supplier if ordering with a specification or by the procured if ordering with a control drawing.

Document BOMs within the product data/life cycle management (PL/DM) system when tied to metadata fields allow automated generation of various kinds of status and accounting information such as drawing trees with the associated revision status. The document structure creates a BOM of its own called the “table of contents.” In a similar way creating contracts through carefully managed BOM configurations is very efficient as much of the contractual text is repetitive between one contract and the next, between one specification and the next or between one SOW and the next.

7.3.3.8 Produced Item Material List (Item BOM)

Produced item BOMs are rather straightforward but still have circular reference issues. These again are tied to order of precedence. The item produced contains the document that defines it and not the other way round ([Figure 7.5](#)).

7.3.3.9 Manufacturing Lines

Management of manufacturing lines in a CM perspective may appear alien to many who have only worked in an environment where CM activities are performed in accordance with set definitions for a single market segment such as government sales. Under the government sales perspective very strict interpretation of not only the definition of CM but also interpretations of the scope of CM itself exist. Often the resulting CM implementation is extremely limited in scope. Unfortunately, in many companies, this has resulted in a very limited understanding of CM responsibility and accountability, which results in many key elements not being managed, placing the company in a less than profitable position. It was noticed that in conjunction with some applications of CM implementation, a basic understanding of contractual limitations as well as a lack of understanding of basic business functions resulted in small to moderate scope creep on projects that impacted profitability by as much as 5%. When compared with other projects of similar size and complexity in companies with a broader understanding of contracts, program management, finance, and supply chain by the CM staff profitability increases more than offset the additional staffing required to adequately manage the programs.

Increased profitability, lower price points, increased quality are critical to a company’s survival in government and nongovernment markets. The firms that have done best in each of these areas view CM from a broader perspective and it forms part of their cultural business ethic and is engrained in their approach to quality business practices.

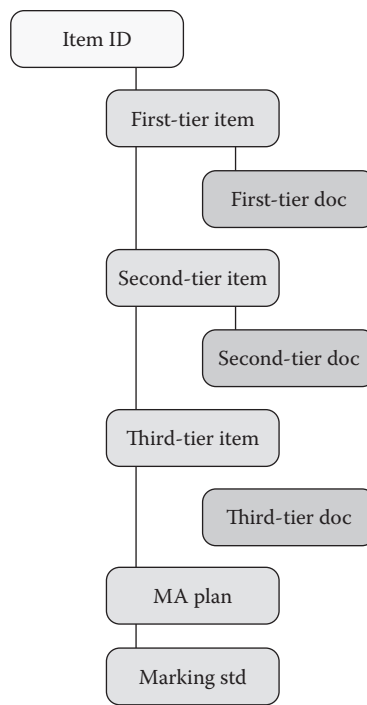


Figure 7.5 Produced item BOM.

7.3.3.9.1 CM and Performance Optimization

Performance optimization and CM is viewed differently by each of the functional resources identified in Chapter 3. Each has a specific idea of what CM methodologies provide to help them accomplish the specific role they play in the product life cycle. Each is part of the entire scope of the application of CM methodologies in any market segment. In this case, the sum of the parts is not greater than the whole. Application of any business methodology cannot be applied to a single function, by a single department, for a single market segment or applied to one regional or state production facility. It must be embraced by an enterprise as a way of doing business not as something that can be applied as an associated function. ISO and Electronic Industries Alliance (EIA) standards are based on this crucial concept and CM methodologies are found throughout.

CM binds Kaizen, total quality management, just-in-time manufacturing, lean process, and information data management systems together. Figure 1.9 provided a view of market performance interdependencies. Performance optimization is dependent on the exploitation of these interdependencies in a way that capitalizes on lessons implemented as opposed to lessons documented. Too often companies add additional process to shore up what is perceived as a process failure due to lessons learned activities without driving deep enough to find the true root cause, which in 85% of the 300 cases investigated would have reduced process instead of increasing it.

Chapter 1 provided an introduction of the subject from an environmental or biological perspective. It is one method of looking at the subject found to be easily understood. Yet it is only part of the story. In a similar way, chemistry students are often introduced to the atom starting with Thales of Miletus and Democritus before moving deeper into the subject by exploring the contributions of John Dalton, J. J. Thompson, Max Planck, Albert Einstein, Ernest Rutherford,

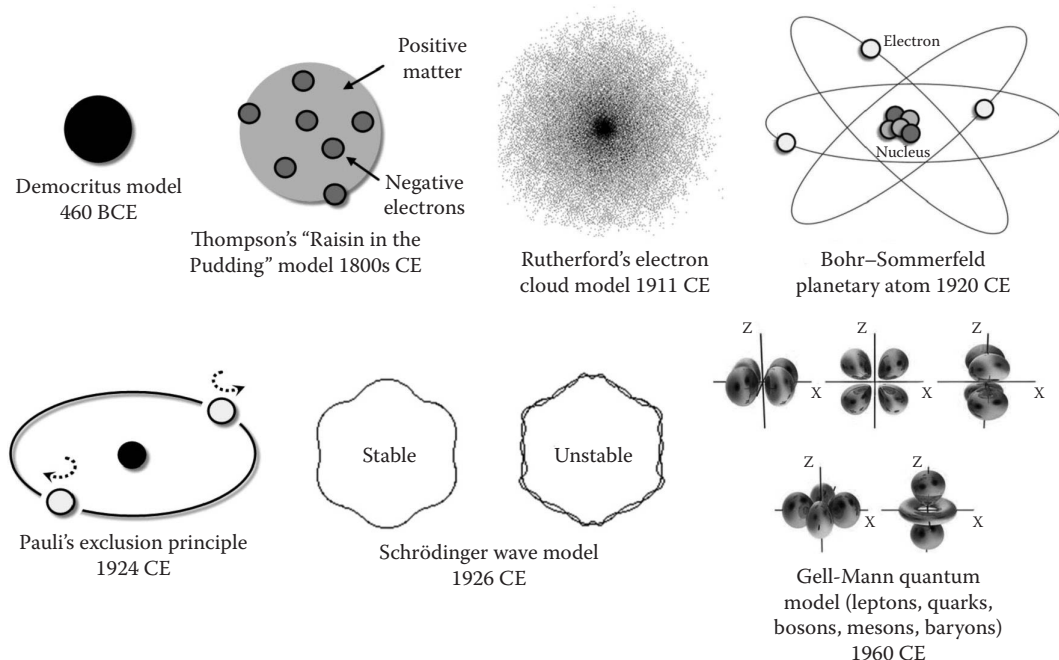


Figure 7.6 Atomic theory evolution.

Niels Bohr, Arnold Sommerfeld, Wolfgang Pauli, Louis de Broglie, Werner Heisenberg, Erwin Schrödinger, Max Born, James Chadwick, Paul Dirac, Hideki Yukawa, Murray Gell-Mann, and Yuval Ne'eman. The evolving theoretical view of the atom is shown in Figure 7.6.

Moving from the simplistic to the complex let us delve deeper into CM as it applies to the marketplace and performance optimization. Perhaps it is best understood in the automotive market segment. A summary of work done by Takahiro Fujimoto is explained subsequently.* Quotations from Fujimoto's work are indented.

A company's capability is an organization's overall capability to evolve competitive routines even in highly episodic and uncertain situations. These include the capability to learn from mistakes, making good decisions, and grasping the competitive benefits as well as capitalizing on unintended consequences and resultant synergies.

An evolutionary framework is particularly useful when it is obvious the system was created as more than someone's deliberate plan for survival.

Systems emergence can occur through many different paths or a combination of them.

Random trials: Outcomes are not predictable so you might as well try everything.

Rational calculations: Objectives are deliberately chosen to satisfy or maximize organizational objectives.

Environmental constraints: Internal (managerial perceptions) and external (laws and regulations, market pressure, etc.) constraints may in fact enhance competitiveness.

* Fujimoto, T. (1999). *The Evolution of a Manufacturing System at Toyota*. Oxford University Press, New York, NY.

Entrepreneurial vision: The vision of a gifted leader may trigger actions that breakdown or remove constraints.

Knowledge transfer: May be either push (driven by the source organization) or pull (adopter–imitator takes the initiative).

This product development evolutionary model can mean different things to different people. It negates the fact that systems evolve not through natural selection but through conscious effort working in tandem with firm, industry, and market factors with the resultant synergies of improving technologies. One key to the process is a total systems informational perspective of the entire manufacturing system and product life cycle (Figure 7.7).

Information is central for two reasons: first, the notion of organizational routines as informational patterns—something like the gene unit of DNA “information”—is a logical consequence of evolutionary thinking; second information is the common element that flows through the product development, production and supplier systems.

Information is broadly defined as intangible patterns of materials or energy that represent some other events or objects, rather than tangible objects themselves. By this definition, knowledge, as well as skills, is also regarded as a kind of human embodied information asset. In the present framework, the information that runs through a manufacturing system is considered value-carrying information, meaning that it is expected to attract to attract and satisfy customers when embodied in the product and delivered to them. In this context a manufacturing routine is nothing but a stable pattern of information flow and asset embedded in a manufacturing system.

Take, for example, a successful product like the Toyota Camry. When a customer buys this car and uses it every day, what he or she consumes is essentially a bundle of information delivered through the car rather than the car as a physical entity. Each time the consumer drives it, he or she is aware of the Camry’s style, visibility from the cabin, feel of the seat, sound of the engine, feel of acceleration, road noise, squeaks and rattles of the dashboard, and so on. The customer also remembers the price paid

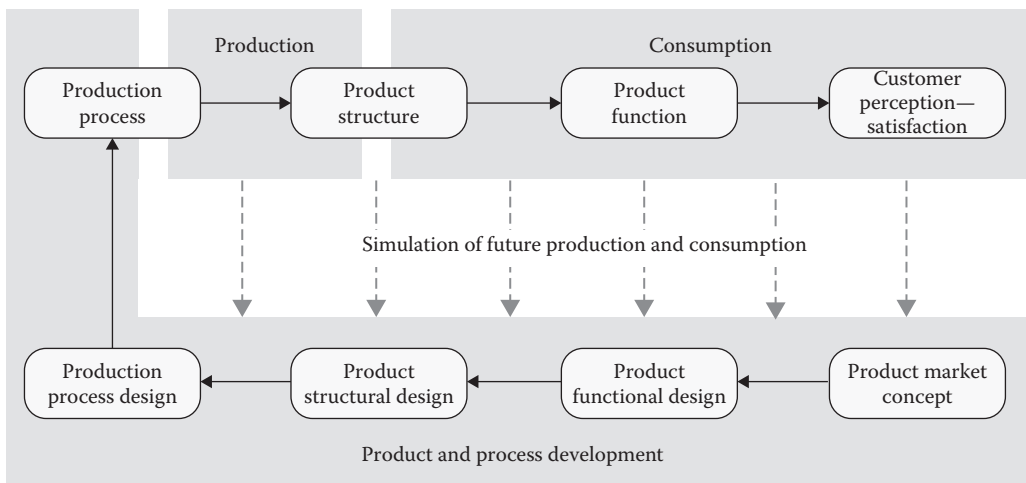


Figure 7.7 Product development model.

for the car, and how economically it operates, its breakdowns and repairs, praise of the car from friends, even reactions of people on the street. Therefore, he or she continuously interprets and reinterprets all of these informational inputs, which translate into overall customer satisfaction or dissatisfaction.

This is a very different approach to information management as it relates to a unique to program CI in the government sales sector. It is also one of the reasons that successful companies in the government sales market segment succeed while others struggle.

Fujimoto analyzed the evolutionary aspects of organizational capabilities at Toyota and other Japanese automakers in general and found a consistent thread in the evolution of performance optimization.

Routines for problem identification: Stable practices to help reveal and visualize problems, transfer that information to problem solvers, and maintain problem awareness.

Routines for problem solving: Refined capabilities for searching, simulating, and evaluating alternatives; coordinate skills, responsibility, authority, and knowledge for solving problems and communicate those to the organization.

Routines for solution retention: Capabilities for formalizing and institutionalizing new solutions in a standard operating procedures, providing stability for those who perform the work.

Evolutionary learning capability: A company specific ability to cope with a complex historical process of capability building (also known as multipath systems emergence) that is not totally controllable or predictable.

The combination of these elements results in a hybridization of capabilities inherent from the factory floor to the marketing to product design/development to strong partnerships with vendors through leveraged innovation that incorporates innovations in work design and technologies.

Starting with the NATO CM Symposium Group discussions regarding a CI and comparing it with the Fujimoto observations, we find that it does not go far enough regarding supporting information.

By necessity, CM in a market performance optimization environment requires a still broader interpretation of what constitutes a CI like that proposed by Geza Papp.*

A configuration (configured) item is defined as any product that requires formal release and control of supporting documentation prior to acceptance by the user; where the supporting documentation is detailed with sufficient precision for all internal and external stakeholders to understand. A configuration item may be assigned relationships with other configuration items.

This requires a simplified definition of data or information and its management.

Control and availability of all information necessary to the improvement of product and company market viability and company compliance and awareness of environmental constraints.

* Dirk Wessel. (2013). *What Is a Configuration Item and Which Consequences Does the Selection of CIs Have to Your Organization*. Consultant on NATO standardization to OSD, ATL. LinkedIn NATO CM Symposium Group moderated by Dirk Wessel started on July 1, 2013. Reprinted with the permission of the author.

It also results in the CM team proactively managing change and acting as the point of dispersal of change in a customer-driven rather than customer derived requirements environment. This is implemented in different market segments in different ways. One implementation example is that of Nokia Networks* who state:

Bringing together our NetAct Optimizer and Configurator with customized tools and services, we'll help you bring your management and optimization into a single solution.

You'll get a centralized view of your operations so you can easily manage your optimization and configuration program.

You'll also be able to reduce your integration and maintenance costs with all your management operations in a single solution.

Every day a quarter of the world's population connect using NSN infrastructure and solutions. Our Multi-Vendor Configuration Management and Optimization solution comes with best in class functionality, built on our deep understanding of access and core technologies.

To others, it might be how well data files are cross-connected in a database or how many clicks it takes to find information in a PD/LM implementation. It may be the elimination of specified elements of the entire scope of the CM process if they are not applicable to the specific product or product line.

One thing is clear from both personal experience and industry surveys conducted by the authors is that CM implementation directly impacts the bottom line and sound decisions by the CM professional relative to management of the configuration of an item can make or break the product, its spot in the marketplace, and the company's longevity.

7.3.3.9.2 CM and Cost Optimization

Cost optimization in an environment where production runs in the million units is much different than cost optimization in a program driven by a single customer with limited quantities. The fundamental difference lies in the end objective and how it has to be approached. The dollar savings through minor improvements over a million units can be substantial. The same improvement in a production run of a single unit may not pay for the cost of processing the change.

Consider the differences in savings involved in manufacture of the bell housing discussed in Chapter 1 as it pertained to design reuse. Machining is the preferable method up to 10 units at which point forging becomes more economical with an initial savings of 50% per unit. The break-even point considers lead time as well as material and production savings. This differs slightly from the 67% savings realized at unit number seven cited in the Forging Industry Association literature.[†] Once the breakeven point is reached, additional cost savings result due to the continued amortization of the nonrecurring cost spread over the entire production run until such time as

* Nokia Networks. (2014). *Solutions*. Retrieved June 10, 2014, from <http://nsn.com/>, <http://nsn.com/portfolio/solutions>. Reprinted with the permission of Nokia Networks, formerly NSN, is the world's specialist in mobile broadband, providing network infrastructure software, hardware, and services to the world's largest operators. Nokia Networks is one of Nokia's three businesses.

[†] Forging Industry Association. (2007). *Long Lifecycle Plus High Performance Makes Forged Components Lowest Cost*. Retrieved on July 25, 2014, from www.forging.org.

forged part quality is reduced due to die wear which accounts for 70% of die failure.* Replacement dies can then be obtained at a reduced cost as there is no recurring design. The predicted die replacement can be determined using finite element modeling. This reduces in machine set-up. When combined with workflow modification (optimized press speed, die temperature, die materials, work piece material, friction, lubrication, and resultant heat transfer due to thermal softening) in a just-in-time environment a significant increases in die life results.

If the production run is large enough, dramatic savings can be realized in energy costs and materials alone by moving to powder metallurgy technologies. Powder metallurgy allows production of components with near net shape, intricate features and close dimensional precision, finished without the need of machining.

CM influences on cost optimization take other forms as well. Staying in sync with market and technological trends can result in company-wide savings while increasing customer satisfaction. Often this takes the form of automation of status and accounting functions and data management capabilities. In some industries, it is possible to track a semi-customized order of a commercial product through the entire production flow and know the status of every component starting with the order number. In other market segments, the actual cost to produce each component is so well known that informed decisions can be made regarding the effect of changes of outwardly appearing minor modifications. One instance discovered in our research showed that the simple act on the part of a lead design engineer of opening the diameter of a through hole to ease assembly of the top assembly actually resulted in an \$850K implementation impact to production tooling on the factory floor. The change implementation saved an estimated \$50K leaving the remaining \$800K to be absorbed out of company profits.

On a major satellite program the configuration manager reacted to a request from a customer engineer to modify the format of documentation required for a contractual status report with no change in the data item description associated with the report, no change proposal, and no change to the contractual data item description. At the end of the program it was found that taking of direction from a government official with no authority to request, direct or authorize such changes had cost the company in excess of \$500K, a violation of the contract, and a profit reduction of that amount in contract closeout. When asked about the change the government employee stated that to make the change through the contract would have taken too long. The senior configuration manager stated that they always did their very best to please the customer and they had no idea that what they were doing would end up costing so much.

Gladwell talks of this in *blink*[†] when describing the \$10 million acquisition of a sixth-century BCE kouros statue of a boy by the J. Paul Getty Museum in California. After an extensive investigation of the work, they agreed to buy the statue and put it on display in the fall of 1986. Yet when it was shown to experts outside of the museum such as Federico Zeri, Evelyn Harrison, Thomas Hoving, and George Dontas, they could tell instantly it was a forgery. This was more than the team at the Getty was able to understand after more than a year.

Intuitive understanding, as described earlier, is not a by-product of a person's genetic code but a by-product of a person's intimate familiarity with all elements of their chosen field. These specialists had seen and studied thousands of statues and found elements of the Getty acquisition as distasteful to them as the scent of wine that is starting to go bad is to a well-versed sommelier.

* Groseclose, A.R. (2010). *Estimating of Forging Die Wear and Cost*. The Ohio State University, Columbus, OH.

† Gladwell, M. (2005). *Blink: The Power of Thinking Without Thinking*. Little, Brown and Company, Park Avenue, NY.

Some would call the kind of intuitive understanding described in blink as common sense. As Voltaire observed, “Le sens commun n’est pas si commun.”* This is true of management tools such as CM. The question many starting a career in CM ask is, “how do I gain the knowledge necessary to become a good configuration manager?” The question is a valid one and the answer is complicated by the fact that most entering the profession have no training in it and often rely on what is written down in whatever standards they are told apply. A good configuration manager needs to know CM in all its details and manifestations. He/she not only needs to be a visionary who is familiar with the requirements that pertain to the product throughout its life cycle and the development of the product itself but also should be capable of recognizing and orchestrating the complexities of the data associated with the product.

As engineers in the robotics field are discovering what is written down, what is relayed verbally, and what is seen visually, what is measured empirically has left them woefully unprepared for designing a robot that can walk, run, and climb with the ease of a person. The same applies to development of an intuitive feel for the application of CM.

In the final analysis all of the standards developed are no more than guideposts along the way and they offer little help if you do not understand where you have been, where you are, where you are going, and how you recognize that you have arrived. In a way, it is like a Zen puzzle; when CM is in balance, you will learn to recognize it. What it takes to bring it into balance requires a deep understanding of the professional environment and a developing situational awareness of the influence of each input, constraint, and mechanism influencing the outputs.

Perhaps the single most important understanding that the CM professional can develop is a clear understanding of how the business operates, so that informed choices based on available options can be made. Among other things, this will facilitate properly the vetting of changes with all stakeholders, so that a valid analysis of exactly what the impact of the change is can be made. As configuration managers become seasoned in their profession, they will develop an intuitive feel for the interrelationships and cause and effect of change.

The second most important understanding that the CM professional can develop is a clear understanding of how the tools used in the company are interconnected. The PD/LM system database structure must be understood at least conceptually to allow the tool to be used as a tool. If the tool is not understood, it is very hard to use it to best advantage. Put another way, if you tell someone that a knife is a screw driver, how long will it be before they understand its primary purpose is to cut things. Understanding how the tools are designed allows the knife to be used as a knife, as well as an understanding of how to keep it sharp and optimize its design for the purpose at hand. All PD/LM systems are generic when they come out of the box. As the workflows and metadata fields are created specific functionality is defined. In much the same way, a knife in the rough state is good for spreading things. As its purpose is defined its nature becomes more specific.

Read all of the applicable regulations and standards with a sense of what they are about and not specifically what the words say. Look at company policy, procedures, practices, and guidelines to get a feel for how the regulations and standards are manifested in company documentation. Go back and read the regulations and standards again and trace the specific requirements back through the company documentation. Perform a second trace through the company documentation to see how

* Voltaire, F.M. (1764) quotation “Common sense is not so common.” *Dictionnaire Philosophique*. p. 866. Accessed on November 22, 2013, from <https://books.google.com/books?id=8hkVAAAAQAAJ&pg=PA866&lpg=PA866&dq=Le+sens+commun+n%27est+pas+si+commun&source=bl&ots=3zxq7YMIae&sig=8X-I6m0ol6zziN6tSTsdfCF2P3M&chl=en&sa=X&ei=dsGdVLqNH82WyASNh4KgAw&ved=0CFgQ6AEwBw#v=onepage&q=Le%20sens%20commun%20n'est%20pas%20si%20commun&cf=false> p886.

company policy, procedures, practices and guidelines are interrelated. Ask questions if you do not understand something and become an expert in the area if no other expert exists.

Let us put the above in context using the automobile as an example. The automobile like any other machine, program, or biological entity must be in balance for it to operate properly. By paying as much attention to the feel of the vehicle (sounds, performance, appearance) it will provide years of service. It will corner properly, stop properly, and do all the things it was designed to do. The driver need not understand how to design, manufacture, or repair a suspension system to know that a shock absorber needs to be replaced or the impact of properly inflated tires on the performance of the vehicle. The driver should read the owner's manual to understand how each subsystem is used, where the vehicle jack is located, what is required for routine maintenance, and the periodic maintenance schedule.

The same understanding of how regulations and standards are implemented in company policies, procedures, practices, and guidelines when combined with a basic grasp of the external to the company regulations and standards allow the configuration manager to know how issues in one piece of the management system influence the overall performance of the entire infrastructure. This is where cost savings and profitability can be greatly influenced by

- Management of the configuration of the systems used to create, produce, market, and improve it.
- Implementation of changes to external influences.
- Consolidation of engineering, financial, mission assurance, production, supply chain, contracts, and traditional CM information tracking systems into a single database.
- Evaluation and implementation of proposed changes to internal requirements or to the product itself.
- Retooling workflows and automation of labor intensive repetitive tasks such as re-entering metadata associated with an engineering order if it is contained on the affected item.

Simply understanding the steps required providing internal access rights to a program or product line server or intranet site can have a substantial payback. In one firm studied a net savings of \$580K over three years resulted by putting in place an automated permissions request workflow and aligning server and intranet functionality. Because most CM activities grew out of and have strong ties to older paper-based systems there is much to be gained by a careful examination of how those systems have translated into or are being influenced by PD/LM systems.

Smart CM or what is known as “turbo CM” allow the selection of the right set of CM requirements based on the context they are used in.

7.3.4 CM Process Elements

If we return to Figure 1.1 from MIL-HDBK-61, we find the representation of typical inputs, constraints, mechanisms/facilitators, and outputs associated with CM and with the development of any product. They are interpreted in Sections 7.3.4.1 through 7.3.4.4 along with an expanded definition of each from a commercial product perspective.

7.3.4.1 Inputs

Inputs to the evaluation of the scope of CM applicable to the product come from many sources. CM implementation is never a case of one size implementation fits all products. CM also scales

by type of product and market segment. What is considered critical in the food industry in terms of traceability is much different than what is considered important in the toy industry or aerospace industry. Items of importance and the effort expended to satisfy meeting the specific management of each also change over the product life cycle. As a result inputs also change over the life of a product. Events leading up to qualification and acceptance are much different than those once the product is sold and the logistics or maintenance phase starts. The CM professional needs to not only recognize the place in time the product exists in but the floating nature of the focus of CM activities in synergy with it. The same care to requirements elicitation must be given throughout the product life cycle by the CM professional as given by the concept development team when formulating a products entry into the marketplace or if a specific to customer build to customer-stated and derived requirements. Typical inputs include the following:

- Market evaluation
- Program initiation
- Systems level requirements
- Analysis
- Customer needs, wants, and desires
- Stakeholder needs, wants, and desires
- Performance measurements
- Internal and external communication
- Other analysis
- Maintenance strategies

7.3.4.2 Constraints

Constraints placed upon the CM process may be unique to the product, market segment, company, city, state, nation, and in some cases international. They should not be considered obstacles but challenges to be addressed and opportunities that result from them. Samsung's introduction of a 128G V-NAND SSD 24-layer 3D flash memory chip in 2013, stepping around the 30 nm spacing issue required to eliminate transistor cross talk and breaking the Moore's law perception is an example. Xerox's drastically reducing the number of parts needed to make a copier through reevaluating the copier configuration in the 1990s is another. Typical constraints are as follows:

- Governmental restrictions (local, state, national, and international)
- Environmental concerns
- Resource sustainability
- Perception
- Test market
- Timing of competitors products
- Resources (facilities, monetary, personnel, etc.)
- Time
- Inadequate planning
- Inadequate preparation
- Stockholder expectations
- Materials

7.3.4.3 *Mechanisms/Facilitators*

Facilitators to the CM process are those management and support functions, process and quality infrastructure, facilities, and teaming agreements that not only increase the capabilities available to perform CM functions but also improve them and their effectiveness.

- Management support
- Supplier teaming and synergy
- Sales
- Facilities
- Training
- Policies, procedures, practices, and guidelines
- Tools and infrastructure
- Information Technologies Systems (IT)

7.3.4.4 *Outputs*

As soon as all the inputs, constraints, and facilitators are balanced against each other, outputs from CM activities assure the continued viability of not only the product in the market segment but also the company.

- Consistent and appropriate implementation
- Verifiable safety
- Adequate data to mitigate constraints and associated reporting
- Product image
- Stronger supplier base
- Increased quality, reduced cost, and higher earnings before interest and taxes (EBIT)
- Improvements in processes
- CM consistent with the scope of the product

7.3.5 *Requirements and CM*

Requirements directly impacting decisions regarding the right sizing of the CM activities associated with a particular product, program, market segment, industry, or associated with the planned national or international distribution of the item come from multiple sources.

7.3.5.1 *Scope Trace through Requirements*

Two common phrases used in engineering circles are “functional requirements consolidation” and “functional decomposition of requirements.” It is tied to an approach broadly applicable to management of requirements and requirements document generation.

The process of functional requirements consolidation ([Figure 7.8](#)) starts with requirements identification, requirements evaluation, requirements allocation to documentation (SOW, specifications, MAR, contract terms and conditions, etc.), documentation generation, and verification of included data requirements tie out.

Each requirement is assigned to a single document to establish one source of truth for that requirement. The artifact proving that each requirement is met is clearly defined in the document and the data submission is captured in the data requirements list (DRL).

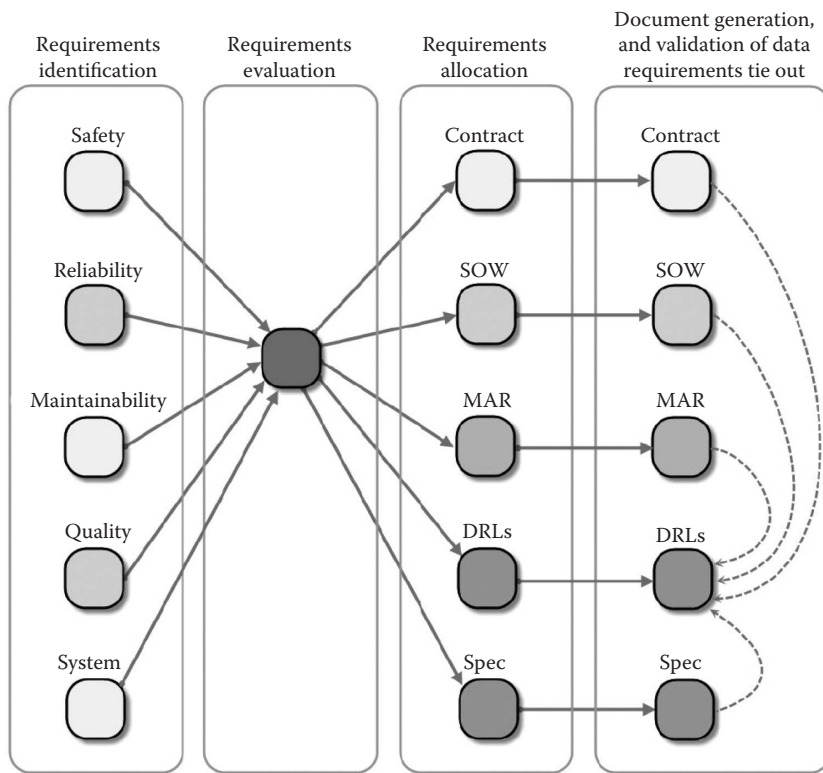


Figure 7.8 Functional requirements consolidation.

The process of functional requirements allocation starts with requirements documentation (SOW, specifications, MAR, contract terms and conditions, etc.) and the allocation of each requirement to the components, mechanisms, and subsystems of the finished product. A single requirement such as a specified mean-time-between-failure (MTBF) may be allocated to every subsystem and all electrical components with an internal data collection activity feeding into the final reliability calculation. In a PD/LM environment, the component and subsystem analysis documents would form the document BOM for the final systems level mean time between failure reports. System level MTBF antecedents are shown in [Figure 7.9](#).

This simple view of the allocation of a single requirement is to produce elements, generate data antecedents, and consolidate that information into the final artifact to document compliance. This process is repeated throughout the product development phase for each requirement. Software and model requirements are allocated in a similar way.

7.3.5.2 Requirements and CM Overview

Often it becomes advantageous to reallocate requirements from one subsystem to another due to cost, schedule, technical risk, consumer mandate, or changes in capabilities or need. This would be impossible without the generation of subsystem-to-subsystem interface requirements lists, giver–receiver lists and the establishment of requirements tracking mechanisms to facilitate change management and evaluation. The lack of any one of these tools can lead to additional costs

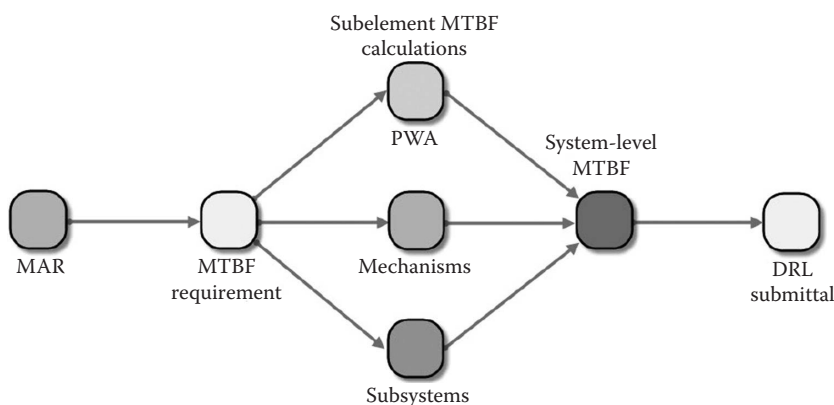


Figure 7.9 Systems-level MTBF antecedents.

as evidenced on a recent space instrument. The optics subsystem assumed that the electrical subsystem was responsible for the wiring harness used between the two subsystems. The electrical group assumed that the harnesses were being provided by the optics group. A few weeks before system integration and test it was discovered that no cables had been designed or build. The root cause issue was considered a failure to generate the necessary Interface control drawings (ICDs) and giver–receiver lists.

On another program, the diameter of a launch vehicle was increased to accommodate a larger payload. Guidance control and other components were attached to a shelf of fixed width on the inside of the stage. The change was not properly coordinated during the configuration control board review and as a result not known or understood by the entire organization, resulting in no plans to perform another weight and center of gravity calculation or to properly flow down the impact to the structure to all organizations. This error also manifested itself in one missile stage being redesigned to make the structure stronger and the addition of an extra hole to accommodate one more fastener without involving the interfacing stage design team in the change review process. The interfacing stage was unaware of the addition of the mounting hole with the result of stages that could not be assembled together costing hundreds of thousands to develop an adapter ring (see [Figure 7.10](#)).

The requirements in both the wiring harness case were known but not defined in the CM implementation. A distinct trend has been observed since the 1990s of companies merging CM, data management, status and accounting, and records and release functions in an attempt to gain efficiencies in the CM process. This is a different approach than was observed prior to 1990 when records and release, status and accounting, data management were training steps to the role of the configuration manager. There is now often confusion between the role of systems engineering and that of CM. There need not be, as the roles are quite distinct. Systems engineering in conjunction with other program management members assess all technical requirements and their allocation. As requirements are refined and derived requirements identified and allocated the role of the systems engineer evolves to one of managing total system performance and operability. The configuration manager manages the specific configuration, its baseline as well as controls all data associated with it so the system's engineer has ready access to all associated information.

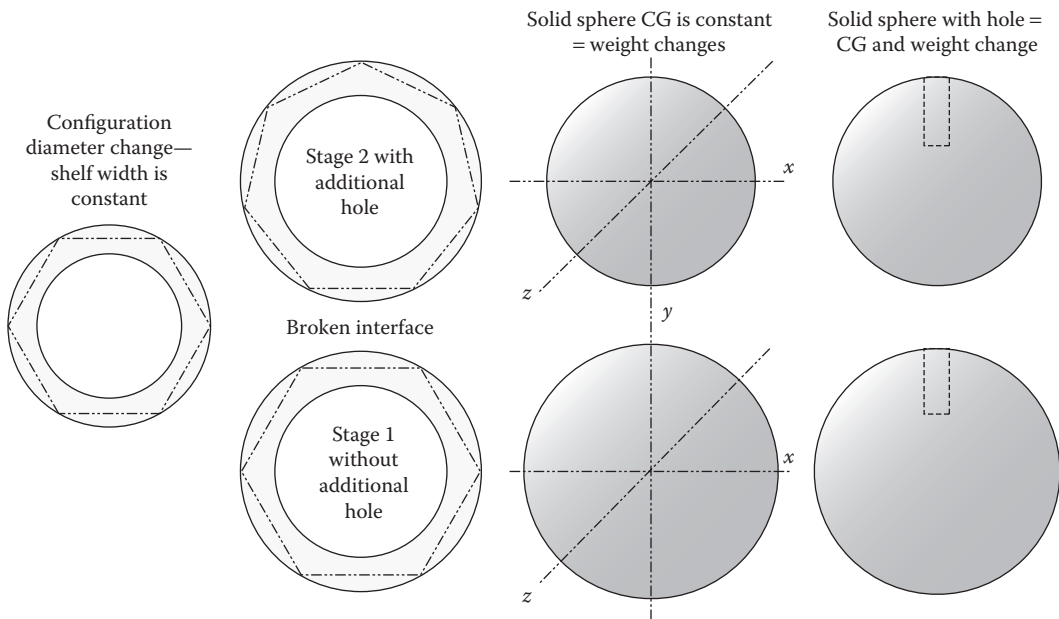


Figure 7.10 Launch vehicle diameter change.

$$\partial X_i / \partial X_n$$

Figure 7.11 The partial of everything with respect to everything else.

Gentry Lee* in his 2005 presentation, “So you want to be a Systems Engineer,” at the Jet Propulsion Laboratory states that the role of systems engineering is to understand the partial derivative of everything with respect to everything else (Figure 7.11).

What this translates into is that their primary role is to know how every electrical component, mechanism, and subsystem affects the operation of the entire product. This ability allows the systems engineer to make informed trade-off decisions that pertain to design trade studies, subsystem functionality, and requirements allocation as well as to apply that understanding during the Test, Inspection & Evaluation Master Plan Organized phase as well as redesign activities for the next-generation product associated with deployed product customer issues and feedback.

In a similar way, the role of CM is to understand and link the partial derivative of any piece of product information to all other pieces of product information in a way that it is easily understood and usable. There can be no self-defined boundary that constitutes CM and there is no cookbook, standard, or procedure that will define the entirety of the work scope. In many ways, CM must perform the same least-squared analysis for interrelated data that the systems engineer prepares for system-to-system connections. If you give good systems engineers one piece of data about their

* Chief engineer for the Planetary Flight Systems Directorate at the Jet Propulsion Laboratory and noted Science Fiction Writer and co-developer of the COSMOS television Series, <http://space.nasa.gov/index.php?page=videos>.

program, it is like injecting a dye tracer into the blood stream and they know with certainty how that information reacts with every other subsystem in the entire system.

If you provide good configuration managers a finite element model of a particular system, they know how it relates to every piece of data that was used in its creation as well as every piece of data that flows downstream from it; how it impacts company policies, procedures, practices, and guidelines; and how it relates to documentation requirements, if a deviation to a requirement must be taken and why. The top characteristics of a good configuration manager (leveraged from Gentry Lee's list for systems engineering) are listed as follows:

1. Intellectual curiosity about the product.
 - a. If you don't know what it is, what it does, how it is structured you can't manage it or anything related to it.
2. A big picture view of the relationship of CM with other functions and organizations.
 - a. Understand how you can best support them.
3. A big picture view of other functions and organizations as they relate to CM.
 - a. What they do?
 - b. How are they interdependent?
 - c. What are the critical concerns of each organization?
 - d. How are they met?
4. Connections with the product—it can't be done in a vacuum.
 - a. What is it?
 - b. What does it do?
 - c. What do other organizations need to know?
 - d. Why it is important?
5. The ability to recognize and trace the interrelationship between all information elements associated with a product and establish meaningful data links between them to facilitate data mining.
6. The ability to recognize the impact of a change as it relates to the internal and external requirements and do trade-offs between how a specific dataset is formulated so all requirements are satisfied.
7. Comfort with change.
 - a. All requirements cannot be defined for any product
 - b. Requirements evolve over time
 - c. Sometimes you go through the critical design phase and have to go back to conceptual evaluation
8. Comfort with uncertainty.
 - a. You will never be able to define what finished looks or feels like
9. Self-confidence and humility.
 - a. Know what you know
 - b. Know what you don't know
 - c. Don't be afraid to say that you don't know
 - d. Ask the right questions so you can learn what you don't know
10. Proper application of process.
 - a. Understand why it was created
 - b. Understand how it can best be applied
 - i. Knowing only process and standards does not make a great configuration manager
 - ii. Knowing no process or standards is not much better either

7.3.5.3 Success Criteria

Successful CM implementation as a management tool needs to be evaluated from a variety of viewpoints. A single project can have a very successful implementation at the expense of the product program or the company. Projects or program management teams going rouge are not common but the results are short lived and self-serving. This is generally evidenced on small projects, where the program team makes decisions that run counter to the norm for political advantage. One common example of this is a program manager mandating that all data deliveries and data tracking be done by general and administrative function, so that the costs are spread across the entire general and administrative base and not as a direct charge to the project, product, or program. This does two things.

1. The true cost of CM is not known.
2. The particular project, product, or program falsely shows increased cost control and profitability at the expense of every other program in the company.

7.3.5.3.1 CM Success

Often the total impact of CM cannot be measured in the day-to-day flow of a product through any single phase of its life cycle. One must step back to do a meaningful assessment and ask what may at first glance appear to be rather simple questions.

1. Am I better off using the CM methodologies than I am without them?
2. Can I easily find information about anything pertaining to the configuration?
3. Can I trace the design solution path from initial requirement through trade studies to preliminary design, final design integration and test, sales, and maintenance?
4. Can I find all trade studies performed that reevaluate other alternatives that may have become a more viable solution due to changes in tools and technologies?
5. Can I retrospectively review the genesis of the product's current form, so that false starts and other development issues can be evaluated for process and design improvement?
6. Can I find cross-linked data to see if these same issues existed on other programs in the past to develop internal standards and training so critical internal intellectual property and design know-how is not lost (The "Magic Sauce" is lost every 12–15 years in the space launch booster area and this is not un-typical in other industries.*)?
7. Can I do all of these things for a program that has been closed for 10 or more years?
8. Were all design teams on the same page or was there a breakdown in communication relative to design restraints, goals, and design evolution?
9. Were the internal subsystem-to-subsystem ICDs and giver–receiver lists managed properly?
10. Did we have the proper level of change management?
11. Were we tracking the right information necessary to assure success, what did we forget, why did we forget it, and what was the impact?
12. Were test and test temporary configurations managed with the same degree of control as other program elements?

* Ross, L., and Nieberding, J. (2010). *Space System Development: Lessons Learned Workshop*. Aerospace Engineering Associates LLC, Bay Village, OH.

13. Can I easily return to the design and contractual technical baseline at any point in the life cycle of the program (e.g., revision of every document associated with any product event: preliminary design review, critical design review, integration and test, functional configuration audit, PCA, delivery) to support design divergence for a similar product?
14. Do I have adequate traceability so that at any point in the production cycle, I can truly know all differences between what was designed and what was produced including all material nonconformances and part substitutions?
15. If there is an industry-wide alert on defective parts can I find out within minutes everywhere the suspect part is used on all of my products?
16. Do I know the differences between the internal policies, practices, procedures, and guidelines at the start of the product life cycle and those that exist now, so that I can do cost impact evaluations?

This is a sample list and a company's internal definition of success may or may not include them. A company should never evaluate CM success upon strict compliance with ISO, EIA, or other guidance documents. It is critical that it should be evaluated on its benefit to the product itself, customer satisfaction, and EBIT. One often stated objection to implementing some aspects of CM is that CM adds cost. The statement is true. The use of any management tool adds cost. What needs to be considered is not what it costs but what it saves. David Harland and Ralph Lorenz have documented the impact of inadequate CM and state the following truism, "engineering is the art of doing with one dollar what any damn fool can do with two."*

The dropping of the U.S. National Oceanic and Atmospheric Administration (NOAA) N-Prime weather satellite (Figure 7.12) on September 6, 2003, due to the undocumented removal of adapter plate bolts resulted in \$135 million to the nearly completed \$233 million satellite is but one example of the impact of a poorly implemented CM approach. The cost to correct the resultant damage to the satellite was paid out of company profits. The damage to NASA, NOAA, the contractor's reputations, and to the perception of the aerospace sector cannot be measured.

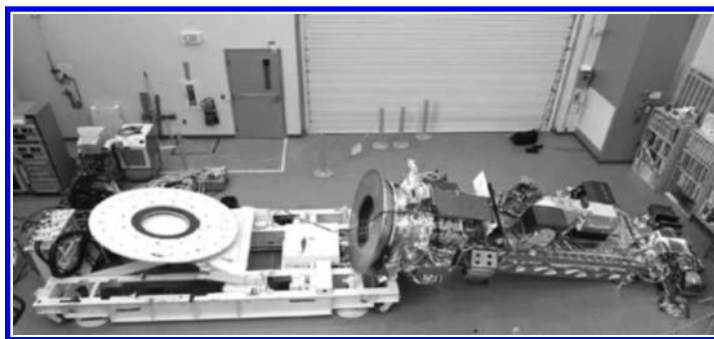


Figure 7.12 NOAA N-Prime mishap. (Image from NOAA N-Prime Mishap Investigation Final Report, NASA September 13, 2004.)

* Harland, D.M., and Lorenz, R.D. (2005). *Space Systems Failures: Disasters and Rescues of Satellites, Rockets and Space Probes*. Praxis Publishing Ltd, London.

7.3.5.3.2 Project, Product, and Business Success

Angeline, a blogger at projectmanagementcommunications.com in Sidney Australia, in response to a question on this subject (<http://pm.stackexchange.com/questions/3122/definition-of-project-success>) states (paraphrased):

A project can only be successful if the success criteria were defined upfront (and I have seen many cases of projects that skip that part). When starting on a project, it's essential to work actively with the organization that owns the project to define success across three tiers, which are as follows:

- *Tier 1—Project completion success:* This is about defining the criteria by which the process of delivering the project is successful. Essentially, the classic questions such as “are we on time, budget, on scope, quality?” are addressed here (adapted to whichever project management method you might be using). It is limited to the duration of the project and success can be measured as soon as the project is officially completed (with intermediary measures being taken of course as part of project control processes).
- *Tier 2—Product/service success:* This is about defining the criteria by which the product or service delivered is deemed successful (e.g., system is utilized by all users in scope, uptime is 99.99%, customer satisfaction has increased by 25%, etc.). These criteria need to be measured once the product/service is implemented and over a defined period of time.
- *Tier 3—Business success:* This is about defining the criteria by which the product/service delivered brings value to the overall organization, and how it contributes financially and/or strategically to the business. Examples include financial value contribution (increased turnover, profit, etc.), competitive advantage (x points of market share won), and so on.

7.3.5.3.2.1 Greater Than or Equal to Overall Success — You can be successful on one tier but not others. Ultimately I think tier 1 matters little if tiers 2 and 3 are not met, and the overall success needs to be defined and agreed as part of this exercise.

From this definition, successful application of the CM activities is much more than how well a program or product perceives it. It must be viewed from the perspective of its effect in all aspects of the business and if the product and business are not a success as measured by predefined criteria then the CM application has failed.

7.3.5.4 Good versus Poor Requirements

A standard concept in contract law is that any disconnect in the way requirements are written are construed against the preparer of the document. For those with little training in the area of requirements generation, it is often hard to distinguish a good requirement from a poor one. The test is rather simple and based on the following questions

- Is there a valid need for the requirement?
 - What happens if the requirement is not stated?
 - If the answer is nothing, then it is not a good requirement.
- How is the requirement verified?
 - What method is used?
 - What constitutes success?
 - What artifact is required?
 - Because a requirement is a single entity ... it passes or fails as one piece.

- Who or what decided the need for the requirement?
 - It needs an identifiable source.
 - Is it derived?
- Is the requirement attainable?
 - Is it technically feasible?
 - Does it fit within budget, schedule, and other constraints?
 - If it is technically feasible and you cannot afford it due to other constraints, it is not a requirement but a goal.
- Is the requirement clear?
 - Does it express a single thought?
 - Is it concise?
 - Is it unambiguous?
- Does it pass the reasonable person test?
 - Are the terms used misleading?
 - Can 10 people from different organizations read it and all come to the same conclusion as to what it says?
- Does the requirement state what is to be accomplished?
 - Requirements do not provide design solutions!
- Are you deferring?
 - Do you specify operations to be performed rather than a requirement?
 - “Clean all assemblies in accordance with the Mission Assurance Requirements Specification” is deferring and not a requirement.
- Have you made bad assumptions?
 - Have you assumed that those performing to the requirement use the same tools and methodologies as you do?
- Are the requirements traceable?
- Can they be sorted as to priority?
- Do they stand alone or must attributes or modifiers be added to them to make them intelligible?
- Have you used a word that will drive costs?
 - The word “support”?
 - Support is a proper term if you want a structure to support 50 kg weight
 - It is incorrect if you are stating that the system will support certain activities.
 - Other words and phrases to avoid are
 - But not limited to
 - Etc.
 - And
 - Or
 - Minimize
 - Maximize
 - Rapid
 - User-friendly
 - Easy
 - Sufficient
 - Adequate
 - Quick

- Have you mixed subjects?
 - Does the requirement apply to only one system or subsystem?
 - You have defined a subsystem solution.
 - Requirements need to be written at the highest level possible and not define or limit the solution set.
- Are the requirements single or cumulative?
 - The transporter shall withstand
 - Crosswinds of 100 kph or
 - Ice loading of 28 cm or
 - Hail up to 9 cm
 - The transporter shall withstand
 - Crosswinds of 100 kph or
 - Ice loading of 28 cm or
 - Hail up to 9 cm
 - The solution sets for each example are different
 - 9 cm hail traveling at 100 kph with an ice loading of 28 cm is much different environment than each evaluated one at a time.
- Do you have the same or similar requirement in more than one place in the document?
 - It need only be cited once.

The process of requirements generation necessitates the understanding of certain terms and how they are used. What follows has an accepted contract law legal basis. The words “shall,” “will,” and “should” when used in defining requirements need to be considered terms of the art of requirements writing and not as terms used in everyday speech.

Requirements use *shall* and each requirements applies to a single thing (e.g., each requirement must be in a single sentence).

- *Bad*
 - The system shall accept credit cards and accept pay pal
- *Good*
 - The system shall accept credit cards
 - The system shall accept pay pal
- *Bad*
 - The system shall work with any browser
- *Good*
 - The system shall work with Firefox
 - The system shall work with Internet Explorer
- *Bad*
 - The system shall respond quickly to user clicks
- *Good*
 - The system shall respond within 10 ms to any user click

Statements of fact use *will* and are not subject to verification

- Generally will is used for things the customer provides to the supplier
 - The procurement office will provide supplier access to the data repository for delivery of supplier documentation

Goals use *should* and not specific requirements. *Should* statements can be considered as nice to have items.

The system should be designed to minimize return to factory repairs.

Must has not been used in requirements as it has never been defined in a court of law and there is no documentation specifying how it is different than or if it is the same as *should*.

It is essential that each requirement be very simple to understand. Each requirement can usually be written in any one of the following formats:

- The System shall provide ...
- The System shall be capable of ...
- The System shall weigh ...
- The Subsystem #1 shall provide ...
- The Subsystem #2 shall interface with ...

Consider the following functionality drivers from MIL-STD-490* and IEEE P1233.† Many of the following items are often overlooked.

- Communication
- Deployment
- Design constraints
- Environment
- Facility
- Functional
- Interface
- Interfaces
- Maintainability
- Operability
- Performance
- Personnel
- Privacy
- Regulatory
- Reliability
- Safety
- Security
- Test
- Training
- Transportation

7.3.5.5 Elicitation

Requirements elicitation also known as requirements gathering is part of the configuration manager's tool box. All requirements cannot be collected from the customer or from a single

* DOD, U.S. (1985). *MIL-STD-490a, Military Standard Specification Practices*, U.S. Department of Defense. U.S. Government, Pentagon, Washington, DC.

† IEEE. (2009). *IEEE-P1233, IEEE Guide for Developing System Requirements Specifications*. IEEE, Piscataway, NJ.

organization in the concept development phase of a new product. Good requirements development hinges on inputs from the customer and all stakeholders as well as observations, intended use, prototyping, design teams, lessons learned, market survey, interviews, role playing, identification of known–unknowns, speculation on unknown–unknowns, and an evaluation of the total scope of the system throughout its life cycle. Christel and Kang* stated the challenges come from three distinct areas.

- *Problems of scope:* The boundary of the system is ill-defined or the customers/users specify unnecessary technical detail that may confuse, rather than clarify, the overall system objectives.
- *Problems of understanding:* The customers/users are not completely sure of what is needed, have a poor understanding of the capabilities and limitations of their computing environment, do not have a full understanding of the problem domain, have trouble communicating needs to the system engineer, omit information that is believed to be *obvious*, specify requirements that conflict with the needs of other customers/users, or specify requirements that are ambiguous or untestable.
- *Problems of volatility:* The requirements change over time. The rate of change is sometimes referred to as the “level of requirement volatility.”

Rzepka decomposes the requirements engineering process into three activities.[†]

1. Elicit requirements from individual sources.
2. Insure that the needs of all users are consistent and feasible.
3. Validate that the requirements so derived are an accurate reflection of user needs.

The requirements elicitation is more than this. It is the creation of a synergistic understanding of all requirements of the item by all members of the team, including customers, developers, and end users, and then documenting them in a way that is necessary, verifiable, and attainable. During the analysis process many items perceived as requirements by those involved in the process may turn out to be something completely different.

It was found that in many market segments and in many companies no attempt was made to differentiate between requirements, design solutions, and nonrequirements (desirements). This was simply due to a lack of understanding of the requirements elicitation process combined with a lack of understanding of the end goal of the process and the preferences of the individuals involved. Once the requirements elicitation process is clearly stated, such issues would be resolved by themselves.

Several useful views of the requirements elicitation process are defined in the following paraphrased information from Christel and Kang, whose developmental model is shown in Figure 7.13.

* Christel, M., and Kang, K.C. (1992). *Issues in Requirements Elicitation*, Technical Report CMU/SEI-92-TR-012, ESC-92-TR-012. Software Engineering Institute Carnegie Mellon University, Pittsburgh, PA.

† Rzepka, W.E. (1989). A requirements engineering testbed: Concept, status, and first results. *Proceedings of the 22nd Annual Hawaii International Conference on System Sciences*, Kailua-Kona, January 3–6, pp. 339–347.

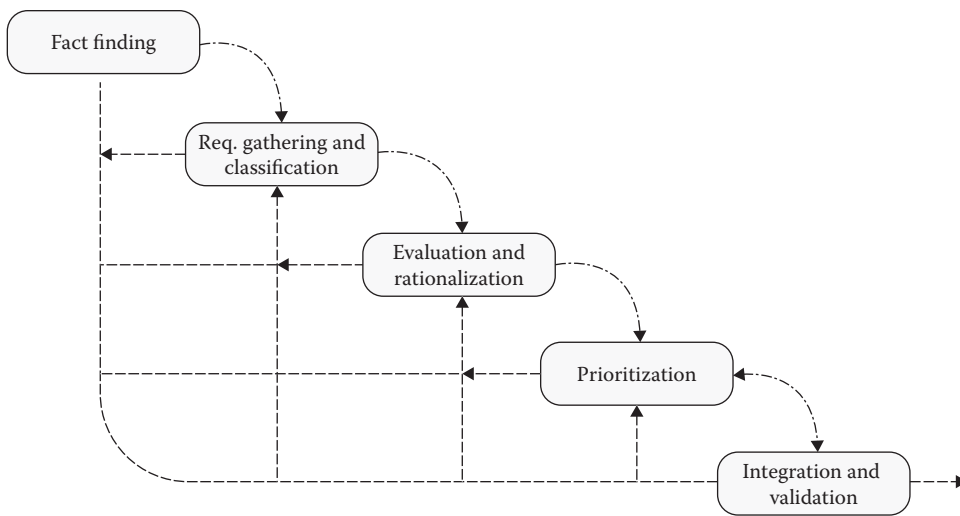


Figure 7.13 Christel and Kang requirements elicitation model.

Issue-based information system (IBIS): A structuring method that allows the rationale underlying requirements to be organized and tracked. IBIS has a number of advantages. It is easy to learn and use. An indented text system was used in an early implementation of a tool for IBIS, and it was well accepted because the users were already familiar with the components (personal computers and text editors) used for the tool.

Domain analysis: The definition of features and capabilities common to systems in advance of development, providing a means of communication and a common understanding of the domain.

- Facilitates communication
- Defines system boundaries
- Defines partitions, abstractions, projections
- Allows for opposing alternatives marking conflicts to facilitate resolution
- Makes it easier for the analyst to modify the knowledge structure

Joint application design (JAD), an IBM Corporation trademarked item: JAD's main theme is to bring together representatives with management authority and accountability into a structured workshop to foster timely decision making. JAD consists of five phases, which are as follows.

- Project definition
- Research
- Preparation for the JAD session
- The JAD session
- The final document

Controlled requirements expression (CORE): A requirements analysis and specification method that was developed in 1979 and refined during the early 1980s. It has not been used very much in practice in The U.S. Rome Laboratory's (previously Rome Air Development Center's) work on the requirements engineering environment (REE) includes the CORE method. CORE can be considered as a paradigm in which the requirements specification is created by the customer and the developer, not one or the other. It is based on the principle

of first defining the problem to be analyzed, breaking it down into viewpoints to be considered, and gathering and documenting information about each viewpoint. This data is then further analyzed and structured, an enhanced graphical representation of the data for each viewpoint is created, and then the viewpoints are examined in combination rather than in isolation. The last phase of the method deals with constraints analysis, in which nonfunctional requirements such as cost and time windows are identified and the earlier phases are reviewed with respect to these nonfunctional requirements.

Quality function deployment (QFD): “An overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production.” The initial steps of QFD can be described as being “simply a system of identifying and prioritizing customer needs obtained from every available source.” QFD is a concept that applies well to requirements elicitation, especially to an elicitation model where the customer’s voice is the driving force behind requirements creation.

Soft systems methodology (SSM): It is the essence of a methodology as opposed to a method or technique in that it offers a set of guidelines or principles that, in any specific instance, can be tailored both to the characteristics of the situation in which it is to be applied and to the people using the approach: users of SSM have to discover for themselves ways of utilizing it, which they personally find both comfortable and stimulating. Such is the variety of human problem situations that no would-be problem-solving approach could be reduced to a standard formula and still manage to engage with the richness of particular situations. Flexibility in use is characteristic of competent applications of SSM, and the reader should not look for a handbook formula to be followed every time. SSM is applicable to “messy, changing, ill-defined problem situations.”

User skills task match (USTM): A user-centered approach to requirements expression. USTM is structured into three stages of description (describing a product opportunity), analysis (identifying a high-value solution), and decision making (delivering a business solution). It is a collection of techniques and methods designed for use by the key stakeholders in the development of initial requirements for *generic* systems. Generic systems are defined as those that are designed to satisfy the needs of many different customers or markets.

Paisley: Views the requirements specification as an executable model of the proposed system interacting with its environment. Paisley models a system as a series of asynchronous interacting processes, but is criticized as being “a textual notation that is difficult to understand.” Paisley specifications are *operational* in that they are implementation-independent models of how to solve a problem, rather than just being statements of what properties a solution should have. More recent papers on Paisley focus more on specification than with requirements elicitation and analysis.

Scenario-based requirements elicitation (SBRE): Features the parallel development of requirements and a high-level design, the use of scenarios to communicate the behavior of a design, and an evaluation function to assess the suitability of the design. SBRE also recognizes the importance of an issue base with which the issues that arise during the elicitation process are maintained. Scenarios are used to structure the early interaction between users and designers in order to quickly develop a set of initial requirements. The author suggests that because scenarios have low cost and limited expressiveness, they “seem most appropriate for communicating specific system features in situations of high uncertainty.”

Jackson system development (JSD): Involves specifications consisting mainly of a distributed network of sequential processes. It has been used primarily on data-processing applications. The major criticisms of JSD are that it is a very different *middle-out* approach, the design

is performed in a very fragmented manner, and that it may not apply well to large systems as there is no hierarchical representation or any overall view. JSD can be used to structure elicitation, but is often used at a later development stage.

Structured common sense: A formalized outgrowth of CORE and contains the following steps:

- Agent identification (based on CORE's viewpoint hierarchies)
- Physical data flow analysis (derived from structured systems analysis)
- Action tabulation and description (derived from CORE's tabular collection)
- Causal tabulation and special case analysis

Regardless of the methodology chosen the goal is to capture all requirements. Often requirements may not be understood by everyone making input to the elicitation process. Equal consideration must be made, for example, in the elicitation process for determining data fields in a PDM or PLM system. Do you have a requirement to report on distinct classes of procurements? If so, that data needs to be stated as a requirement for PD/LM system content associated with vendor items (specifications, statements of work, control documents, etc.). Metadata fields need to be created to capture data pertaining to sources of supply so that the information can be mined later.

Metadata fields also offer a convenient way for a company to give access into the PD/LM system to its suppliers and customers. Specific metadata fields can be used to limit access to data not particular to a vendor or customer. A customer may be given rights to see everything associated with a program name. A supplier may be given access to everything in the system associated with that supplier. In each case, the PD/LM access is tied to a specific metadata field. Using this method, suppliers and customers can only see their data and are locked from accessing data in the PD/LM system.

7.3.5.6 Prioritizing and Tracking

Determining what is important to prioritize and track is not unlike management of your schedule for any day of your existence. While the outward aspects appear to be very similar, once you take a closer look, you will find that you are in a constant state of change. It is an intricate dance between your goals for the day and the environment with which you interact. The same is true of CM implementation. Once the requirements are defined, there is a progression of the product through the stages of the product life cycle. The main elements are prioritized and tracked change as it moves through each phase. The focus of CM also changes in each phase.

Prioritizing and tracking of the right informational elements at any point in time is not unlike the job of a sommelier when paring wine with a master chef's creations. Just as the sommelier takes the time to understand the sense of taste and what flavors and scents go together to provide a pleasure for the pallet, the CM professional must understand the sense of what is required throughout the life of a program and present a solution set that should seamlessly meld with the needs of all who rely on them.

This may sound like a philosophical discussion but it is not. Anyone with the proper aptitude can follow a recipe and make a meal. The difference between a cook and a chef is that the chef can start with a walk through the market and intuitively understand how to weave the products available to them to create something new and fitting for that moment in time. They do not need or use a recipe book except as a reference. The chef is like the program's system engineering manager.

The configuration manager is like the sommelier. The chef and the sommelier are a team as are the systems engineering manager and the configuration manager.

If you want to see what this sense of cooking rather than the traditional text book approach looks and feels like a good start is to view a few episodes of the BBC series *Two Fat Ladies*.^{*} Once you have done, then refer to any recipe booklet for the same dish. You will immediately discover that truly understanding something is vastly different than knowing it. One can cite chapter and verse and still not understand what it means and what it implies.

Just as the sommelier is guided to the right wine pairing for any dish the configuration manager is guided by the complexity and understanding of the product, the stated requirements, the derived requirements, internal and external regulations, policies, and procedures. So how does the aspiring CM professional learn these skills? What follows are a selection of observations on just that gathered over a period of years, which are as follows:

- Teach yourself to see the interrelationships between things. One way to open you mind to doing this is to play the game Tangoes[†] once a day, whenever you are on an airplane and whenever you are looking for an answer and it eludes you.
- Bring large puzzles down to size and relate them to something you know.[‡]
- Develop critical thinking skills and recognize that it is easier to do a minor course correction once started than it is to start in the first place.
- Perform or participate in an N-squared analysis (Figure 7.14) as it pertains to CM on every new program until you can do it intuitively.
- Determine what your educational acumen is and shore up the soft spots.
- Seek to understand everything you can about the product, how it works, and what subsystems drive others.
- CM is not limited to the release of changes and delivering data to a customer. It is not following process 1 then process 2 and then process 3. It is only by knowing the product and what you want to do with it throughout its life and only then applying the correct process elements in the correct way to achieve the desired results. There is a great deal of difference between the paint by number picture of anything and the original.
 - If you are procuring a complete technical data package when the data is maintained by the original manufacturer simply because you have always done so is not reason enough to expend the money and time to do so. You have to understand why you are doing so and what end result it supports.
- Add value. Do not simply keep the piece by trying to accommodate everyone. Push back with sound reasoning if you know a request is not within the scope of the program or management objectives.
- Do the very best you can today and learn to sleep well knowing that tomorrow you will have to re-prioritize and occasionally go back to the beginning and start over.
- Understand that you and others will make mistakes. Understand the risks and have a backup plan in place to mitigate those risks in case the approach you take does not work.

^{*} Llewellyn, P., Geilinger, S., and Field, A. (Directors). (1996). *Two Fat Ladies*. [Motion Picture], BBC, London.

[†] Based on the ancient Chinese Tangram puzzle. Also see Read, R.C. (1965). *Tangrams: 330 Puzzles*. Dover Publications, Mineola, NY.

[‡] Angier, N. (2009, March 30). The biggest of puzzles brought down to size. *The New York Times*.

<i>CM Analysis</i>	<i>External Regs</i>	<i>Internal Regs</i>	<i>Contract</i>	<i>SOW</i>	<i>Specification</i>	<i>MAR</i>	<i>DRLs</i>	<i>Mechanical</i>	<i>Electrical</i>	<i>Etc.</i>
<i>External Regs</i>	<i>External Regs</i>									
<i>Internal Regs</i>	Update G2.5.9	<i>Internal Regs</i>								
<i>Contract</i>		Dev req to G3.2.1	<i>Contract</i>				H.52 & I.27 not covered			
<i>SOW</i>			Attach A	<i>SOW</i>						
<i>Specification</i>			Attach B	Reference 2.1	<i>Specification</i>		23 TBDs impact SE-4			
<i>MAR</i>		Alternate procedure	Attach C	Reference 2.2		<i>MAR</i>	5.2.1 to 5.2.5 not included			
<i>DRLs</i>		Dev req to G3.2.19	Exhibit 1	Reference 2.3			<i>DRLs</i>	ME-1 to 23	EE 1-18	
<i>Mechanical</i>								<i>Mechanical</i>		
<i>Electrical</i>							Dev req to G7.2.14	I-ICD	<i>Electrical</i>	
<i>Etc.</i>										<i>Etc.</i>

Figure 7.14 N-squared activity.

7.3.5.7 Relationship between Requirements and CM

There is no set of rules that can be established for a single product or a single phase of the product. There is no set of CM requirements that define everything that the configuration manager must be aware of. There is no set of requirements that can be written that define everything that a system, project, and a product has to meet to be successful. At times, the stated requirements are poorly defined or simply overlooked.

Every requirement has associated information that requires some degree of CM. The more critical the information is to the product, the higher the level of management associated with it. Well-written requirements will have a single information artifact. Poorly written requirements may have multiple or nested information artifacts. All written requirements when taken together a subset of the information associated with performing CM.

There is a difference between cited requirements and derived requirements. It is in the area of derived requirements that most CM activities fall short. Many in CM do not recognize the total scope of the activity and think that CM ends with the delivery of the product or in some cases the last delivery of informational data associated with a DRL. That is simply not the case. CM goes well beyond these events and in some cases may last for hundreds if not thousands of years.

Have you ever been to Europe? Have you ever wondered what the purpose is of the ball on the steeple of many of the churches in Switzerland and Austria? On the first look, it appears to be part of a lightning strike mitigation system similar to the lightning rods commonly used on most large structures. While that may be the secondary purpose, the real purpose in many communities is to hold the architectural drawings for the church itself, so that if it is ever damaged or destroyed, it can be replicated with an identical copy. This represents the implementation of an implied requirement for disaster recovery as well as sound CM and European community records retention.

A requirement to provide a vacuum bake-out plan leads to the derived requirement to have a vacuum chamber large enough for the purpose that can be heated, that it can be cleaned, that it has the requisite uninterruptable power supply, some form of instrumentation and perhaps feed-through plates for added instrumentation. The requirement to deliver a reduced thermal model in a specific format has a derived requirement that it your suppliers provide component and subsystem models that can be integrated into that format, with a defined structure and compatible data parameters.

As an exercise, assume that you are responsible for evaluating a vendors CM systems and the only criteria in your internal policies, procedures, and practices is the following statement.

Certified suppliers shall have an ISO certified configuration and data management that is also compliant with AS9100-2009, Quality Management Systems—Requirements for Aviation, Space and Defense Organizations.

- What is the real requirement and where do you start?
- How extensive is the task at the vendor?
- What specifically do you look for?
- Is it as simple as asking to see the certification from an independent certification organizations like the British Standards Institute for ISO and Smithers Quality Assessments for AS9100-2009 or is something more required?
- What is implied by certification?

The same thought process is inherent in assessing requirements and assuring that they are met.

7.3.5.7.1 Requirements Allocation Within CM

Elicitation, as discussed in Section 7.3.5.5, purposely left out the next step in the process as it relates to CM. In systems engineering, after elicitation is completed, the requirements are allocated to the design, manufacturing, mission assurance, and other functions. Understanding the functions within configuration allows the same kind of allocation to take place with regard to those functions. Some requirements will align with data management, records and release, and status accounting, whereas others will remain at the top level of CM. Further graduations will occur based on what the requirement pertains to project completion success, product/service success, or business success. This is where an N-squared analysis is very helpful as the exercise will firmly establish where each requirement comes from and the planning that is associated with it.

Requirements originating internal to the company as a result of compliance with legal statutes naturally fall to business success. Requirements originating internal to the program as a result of the program plan or the contract and its attachments naturally fall to project success. Requirements related to a specific product only naturally fall to product/service success. The time and attention paid to each will vary over the life cycle of the product. Setting up the response and management methodologies will test the configuration manager's strategic capabilities more in the company success realm and their tactical capabilities more in those requirements relating to product/service success.

7.3.5.8 Logistics

All of the activities associated with CM that culminate with product sales are simply a well-orchestrated precursor to the operational phase. In some industries, this is known as the "logistics phase" and if the configuration has not been properly managed, it can put the company in a loss position relative to customer satisfaction, market share, and profitability. This is where a great configuration manager is easily distinguished from a not so great one.

We have touched on logistics a few times in the previous chapters to give you a feel for what may be involved and we will address it again in Chapter 8, as it relates to inventory management. So far we have not given you a definition of what logistics or specifically how it relates to CM. One current definition of logistics is:

Logistics is the management process that assures resources of any description are available when needed. Items managed by a logistics function can include energy, communication, networks, information, physical items (food, materials, equipment, parts) and people. It may involve material handling, production, packaging, inventory, transportation, warehousing, and security. Logistics activities can be modeled and optimized using simulation software. The goal of logistics is to minimize the need for excess resources of any kind. The operation of a just-in-time manufacturing process relies heavily on the logistics function. In such a manufacturing scenario; materials and other resources arrive in the production flow minutes before they are needed so that parts inventory is minimized and factory through-put is maximized.

Logistic activities pertain to procurement, production, distribution, after-sales support, disposal, green technologies, global, and domestic activities as well as product warranties and warranty and license pass through from component and subsystem providers. The management of the information associated with each of these activities as well as the maintenance and current configuration

happens all around us. In the commercial market sectors, electronic devices and database prompts are established to facilitate the maintenance of purchased items and to gather data regarding customer satisfaction with those products. Examples of this are as simple as a red engine light on a vehicle dash to indicate a recommended service based either on the number of miles driven since the last counter reset or the time elapsed or a combination of both. The e-mail you receive from a medical provider reminding you of an appointment is a logistics activity as is the satisfaction survey you complete once any service has been completed.

Logistics combines elements of project completion success, product/service success, and business success. In a fielded product, if the design did not build in the capability to self-verify the need for a logistics activity that information must be tracked by an individual. Self-verification is most often associated with electronic or electromechanical devices. The low battery indicator and the signal reception indicator on a personal communications device are built in. The activity associated with evaluating the version level of the software suite you have on your computer and notifying you a newer version is available is a self-verification activity. The specific configuration of a one-off or limited production run of an automobile or other transportation device may not have such embedded logistic elements.

Depending on the complexity of the product and its price point the degree of logistical activity involved will vary. The more expensive the item is the more support is generally available and planned for. During the early years of radio and television the cost of components associated with radio and television receivers were more expensive than the labor costs to repair them and a wide network of certified repair specialists, analytical devices such as the oscilloscope and replacement vacuum tubes (in American English—tube, or thermionic valve or valve in British English) components were common. Today, a nonspecialty radio that has better reception, higher reliability, and a lower production price point is generally considered not worth the effort to repair and no logistic provisions have been made to support it other than in the accessory market. Radio receivers like those produced by AOR, Atlas, Collins, Drake, Eaton, Elecraft, Grundig, Hiberling, Icom, JRC, Kaito, Persues, Tecsun, Ten-Tec, and Yaesu tend to have higher levels of logistics support.

This reflects a continuance of the trend that started with logistic support activities during World War I. If the cost to repair is higher than the cost to replace stock; a new item is ordered instead of repair parts being ordered—except in those cases where the item is repairable in the field by the user and critical to the mission objective (e.g., issue ground troops a repair kit for their fire arm that includes things such as firing pins and replacement springs but do not stock replacement caps for their canteens). Refinement in logistics management continues to evolve as demonstrated by the Plateforme d’Echange Normalisée et Centralisée d’Information Logistique (PENCIL) initiative. PENCIL will establish a new way to share logistics data between French Army and industry based on PLCS/STANAG 4661 and is scheduled to go live in the fall of 2014.

How a company determines the logistics repair or replace and warrantee activities for a product is often dependent on company culture and philosophy. Companies such as Timex have a very simple approach stated as their limited warrantee that has been tested over many years. They may repair your watch by installing new or reconditioned and inspected components or replace your watch with an identical model.

It may also be mandated by regulation or specific to a contract. Regardless of the source of the requirement or the application of it and what it entails, CM is a key player and must consider what is required at the start of a new project as part of CM planning.

DEFINE THE INTERRELATIONSHIP OF CM TO FUNCTIONAL RESOURCES



Chapter 8

Configuration Management Support of Functional Resources

8.1 Questions to Ponder

- Identify the areas of manufacturing most critical to be under configuration management (CM) control.
- What is the relationship between inventory control and CM?
- Demonstrate how CM works with
 - Engineering (new products)
 - Engineering (adaptations of existing products)
 - Manufacturing
 - Command media
 - Contracts

8.2 Introduction

Often, the relationship between configuration management (CM) and data management (DM) activities, as it applies to other organizations, is overlooked to the detriment of project or program. This chapter will align CM and DM activities to each of the support functions identified in Chapter 3. The activities described against each of the functional resources are typical and not all inclusive. Although the functional resources (see Chapter 3) include contracts and are intentionally centric to contracted work in many areas, what follows should be ready with a broad interpretation. A contract or program can be with the public at large, with an internal organization, or in a contractor or subcontractor/vendor relationship.

A description of the sectional content of Chapter 3 (e.g., Sections 3.3 through 3.10.1 directly relate in Sections 8.3 through 8.10.1) followed by a time-phased implementation plan (see Section 8.11) for providing CM support across all of the functional areas is discussed in subsequent sections.

8.3 CM and Project Management

CM activities tie to program management. They vary from program to program and from program to project based on variations in regulatory compliance, market sector, product mix, customer base, and product market sector. CM support is centric to assuring that the product is documented to the degree necessary to assure acceptance, reproducibility, acceptance, and post-acceptance activities, and to project communications.

8.3.1 Acceptance

CM activities include preparation of acceptance documentation including certificates of conformance (COC) or other specified forms such as the U.S. government's DD Form-250, "Material Inspection and Receiving Report" (MIIR). One often overlooked CM acceptance activity found on many U.S. government programs is the need to document formal acceptance of all data deliverables that required approval during the life of the program. Instructions for DD Form-250 contained in the U.S. Department of Defense (DOD) and U.S. Federal Acquisition Regulations (FAR) Supplement (DFARS) Appendix F specify in F-301(b)(2)(iii)(B) that the shipment number for the last DD Form-250 is designated by adding a Z to the end of the shipment number. This is generally referred to as a Z-Code DD Form-250 with data acceptance being the last activity when all contract requirements have been met after acceptance. In the case of the DOD, DD Form-250 is supplanted by the Wide Area Workflow Receiving Report (WAWF RR) with DD Form-250 preparation being on an exception basis. Use of DD Form-250 is at present the norm for some other U.S. government agencies such as NASA. Both DD Form-250 and WAWF RR are multiuse vehicles as described subsequently.

8.3.2 DD Form-250 Use*

The WAWF RR and DD Form-250 are multipurpose reports used*

1. To provide evidence of government contract quality assurance at origin or destination
2. To provide evidence of acceptance at origin, destination, or other
3. For packing lists
4. For receiving
5. For shipping
6. As a contractor invoice [the WAWF RR or DD Form-250 alone cannot be used as an invoice however, the option exists to create an invoice from the RR or a combo (Invoice and RR), both of which minimize data entry]
7. As a commercial invoice support

8.3.3 CM and Project Integration Management

As companies move toward domestic and international collaboration through leveraged innovation, where a very high degree of transparency is required between all stakeholders, CM is being looked as the primary means to assure that all elements are on the same page. This is different than project communication.

* U.S. DOD FAR Supplement (DFARS) Appendix F, F-103 Use.

CM is the process of assuring that the correct data are disseminated and that the individual elements working to bring product to market understand what is required of each other. This can take the form of giver–receiver lists, interface control drawings, specifications, statements of work, and the long-held traditional forms of documentation. Unfortunately, these often fall short of what is actually required.

In one of the firms studied, the basic principles involved with discussions and examples of how a documentation is generated (e.g., what formats are used) went far beyond the typical reply of MS Word, PowerPoint, Excel, computer-aided design (CAD), Visio, and so on. The task was to apply intellectual property (IP), Technical Assistance Agreement (TAA), and U.S. International Traffic in Arms Regulation (ITAR) legends using a tool that applied the legends with the help of a pull-down menu during the export process from the product data/life cycle management (PD/LM) system, allowing a single document to be used on multiple programs and the transmittal of the document to multiple customers and vendors. A team of the top talent in the company were pulled together to assure the implementation was clean.

After 10 weeks of effort, the solution was rolled out and it proved to be a failure simply due to the fact that oftentimes book-form engineering is used with pages within a single document in both portrait and landscape. Interestingly, this was a known but not a disseminated fact, as book-form drawings consist of a coversheet with subsheets generally the bill of materials (BOM) and notes followed by larger size sheets (sheet 2 and subsequent) in a different size. Standard sheet sizes are shown in Figure 8.1.

In many ways, CM is the activity associated with not only the management of configuration and data associated with those products but also the management of the infrastructure required to assure the product can be managed.

CM also includes the management of information distribution, information description, information scheduling, progress reporting, the escalation (resolution) process, and the associated administrative closure.

8.3.4 CM and Scope Management

Figure 3.4 shows how requirements are allocated from the product level (often referred to as the “functional baseline”) to associated systems, subsystems, and components to create the allocated baseline. It further shows how artifacts proving that each element has met the requirements so

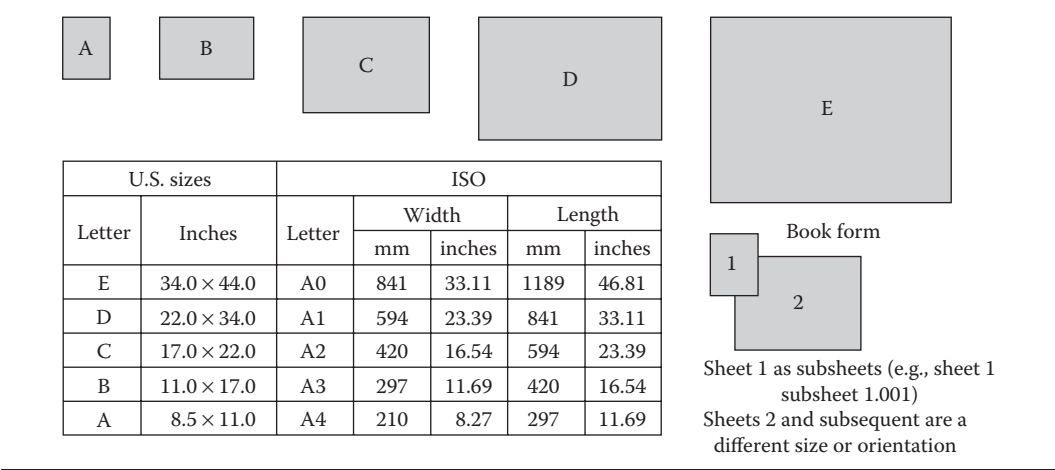


Figure 8.1 Standard sheet sizes in the United States and metric.

that functional audits are successful. Scope management from a technical view is the process that assures technical requirements are understood and that uncertainties are eliminated to the extent possible. The faster all to be determined (TBD), to be specified (TBS), to be reviewed (TBR), and to be negotiated (TBN) are closed, the firmer the technical requirements become. When used, TBD means a variable to be defined by the proposer, TBS means to be specified by the customer, and TBR means to be reviewed and subject to revision.

There are other requirements in any product's life cycle that must also be allocated downward in the same way. Reviews such as those shown in Figure 5.8 fall into this category. These reviews are most often delineated in the work statement. Typically, they are also tied to development program and cost events. On programs with milestone billing, the contractor is paid when the milestone is completed. Below is one such milestone payment description:

Payment shall be made to the contractor upon successful completion of the Preliminary Design Review defined in Statement of Work Section 3.3.2.1.

A review of statement of work (SOW), Section 3.3.2.1, reveals that there is a tie out to the associated data item delivering the preliminary design review (PDR) presentation but no description of what *successful completion* actually means. The lack of such a definition is effectively another TBS in the documentation often overlooked until after the review is held with no closure in place between the customer and the program. This places the contractor at considerable risk. Successful PDR completion could mean any of the following:

- PDR was held
- All customer and contractor action items are closed
- All contractor action items are closed
- All customer and contractor action items mutually agreed upon as critical (e.g., must be resolved prior to continued work) are closed

The question arises, "Who is responsible for finding these and getting them resolved?" Ultimately, it is the program manager and the program management team. CM is part of that team and unless what constitutes a successful PDR completion is predefined; customers may request additional data during the review. This increases the scope and cost of the review. If the data are managed, it presupposes that the requirement for the data is understood and if not understood that a closure plan is in place to assure understanding is reached. That in itself says that if CM is not assigned the task of owning the closure plan, then it is a major player in not only closure itself, but in identifying the need for such a plan.

Many CM practitioners will not agree with this view and see the identification and closure of risks as the responsibility of the program manager, contracts, systems engineering, or some other organization yet fully accept that they play a significant role in configuration control boards (CCBs) often acting as the co-chair with engineering management, the chair itself, or at least the secretariat of the CCB. These three CCB roles require that CM evaluate changes for all impacts including risk to closure and payment. This requires that they work closely with the entire program management team taking active and participatory ownership of scope management.

8.3.5 CM and Time Management

Perhaps the most recognized proponent in the United States for process efficiencies through motion study is the team of Frank Bunker Gilbreth Sr. and his wife, Lillian Evelyn Moller Gilbreth. They

were acutely aware that if the process was evaluated to eliminate wasted motion, the workflow was more efficient. Lillian continued the pioneering work running the consulting firm Gilbreth, incorporated long after Frank's death in 1924 outliving him by 48 years. The Gilbreth's methodology differs from other kinds of efficiency management such as Fredrick Winslow Taylor. Taylor's focus was reduction of process times rather than improving system process. Time management efficiencies through process in the CM area directly impact the entire program life cycle.

This may be exemplified by looking at the web-based oracle agile PD/LM system. As typically implemented, Oracle AGILE requires an engineering order (EO) for all releases of documents and any associated parts. One would expect this to be the case. Oracle agile even allows the creation of an EO from the document object itself. What does not happen is the auto-population of all of the metadata fields on the EO itself. These metadata fields are generally company defined and implementation rollout specified denoting

- Document number
- Document name
- Work authorization (WA) of root charge number
- Configuration item identifier (CII) number

This means that the EO originator must fill these metadata fields prior to the EO being moved to the review or approval states in the workflow. Companies using the oracle agile PD/LM system can choose to accept this or, as the release process owner CM, can choose to circumvent the time required to accomplish this activity by creating a generic EO, document object, and associated parts for each program. EO will have the document object and the associated parts on its "affected items" tab. By then providing a link to the EO in the CM plan, those doing releases have a prototypical EO. As the EO, document object, and associated parts can be saved with a new identifier as much as 10 minutes per item can be saved as a process improvement.

Looking at CM and its related activities that involve other functional resources from this perspective forms much of the grist in the process improvement mill, allowing companies to maintain a competitive edge. This is important to remember as ultimately time management is directly associated with cost management, which will be further elaborated in Section 8.3.7.

8.3.6 CM and Project Communications Management

Information distribution, information description, information schedule, and progress reporting are all CM- and DM-centric activities. CM acts as the program manager's point of contact for maintaining information access and storage as well as permission structures for program servers, intranet sites such as SharePoint, site interlinks to assure a single point of truth on the site and assuring data links are maintained.

8.3.7 CM and Project Cost Management (Earned Value Management)

The example of metadata and the oracle agile PD/LM system when evaluated for anticipated cost savings on a program results in a positive impact of over \$150,000 to the program bottom line.

8.3.7.1 Assumptions

- Average billable engineering rate of \$200/hour
- 1000 drawings (90% of the metadata carries forward from revision to revision)

- 3000 parts (90% of the metadata carries forward from revision to revision)
- Five EOs per drawings (90% of the metadata carries forward from revision to revision)

8.3.7.2 Calculation of Cost Avoidance

- $1000 + 3000 = 4000$ items revised
- 4000 items revised + 1000 EOs for initial release = 5000 objects each revision
- 5000×10 minutes = $50,000$ minutes spent imputing metadata for first release
- $50,000$ minutes/ 60 minutes = 833.3 hours
- 833.3 hours $\times$ \$200 per hour = \$166,666.67 saved for first release
- $\$166,666.67 \times 90\% = \$150,000.00$ saved per EO after initial release
- $\$150,000.00$ saved $\times 4 = \$600,000.00$ saved for four EOs after initial release
- Total savings = $\$600,000.00 \times \$166,666.67 = \$766,66.67$ cost avoidance.

8.3.7.3 Total Program Cost

Total program cost (TPC) must be defined in terms that CM can understand. It is not a concept that CM as a discipline is used to thinking about or implementing. CM as practiced in the U.S. government sales market segment has sequestered itself from those it supports across the industry and at the companies they are part of (the company). As a result, many tools utilized by these CM practitioners are of limited use to both internal and external customers.

The TPC approach means that CM has to look at their tools with a broader perspective and understand how others use them, how CM uses them, and the cost benefits of their continued use.

If a single click or mouse movement for those using the tool is deleted, it generates a large cost savings over the life of any program and results in a more satisfied customer base.

8.3.7.4 Value to the External Customer

Value to the external customer in its simplest form can be summed up as satisfying internal and external customer requirements. The following is from the perspective of U.S government programs and should be adapted to fit project/programs to align with the program/project contextual requirements:

1. Making external customers succeed
2. Providing good hardware, software, and services below cost and on schedule
3. Meeting the minimum requirements of the contract
4. Establishing and maintaining a congenial and candid working relationship with the contracting officer and the contracting officer's representative and their DM staff
 - a. Listening to their needs
 - b. Evolving the structure of how data are tracked and reported to maximize their use

Anything done beyond this in performance on any program is extra, unless it is required to meet external requirements that are federally mandated or needed to keep International Standards Organization and other certifications (e.g., AS9100).

8.3.7.5 Value to the Company

Value to the company (VTB) must be defined as maximizing earnings before interest and taxes (EBIT) and bottom-line profitability. It also means that the implementation of decisions must meet the company's core initiatives such as diversity, sustainability, and safety while being the first choice provider of its goods and services.

VTB also means making hard decision and broadening the involvement of CM across traditionally drawn lines by being proactive instead of reactive and protecting the company's interests through ethical decisions combined with a sound management schema of not only any associated product structure but also the data structure and contractual and technical baseline.

8.3.8 CM and Project Quality Management

8.3.8.1 Protection from Audit

Protection from audit is the component of the CM charter that ties directly into a sound management schema of not only any associated product structure but also the data structure and contractual and technical baseline. It includes things such as

1. A single source of truth
2. Maximized use of current tools
3. Maintenance of a library of all contract documents in their conformed state (current contractual state) along with copies of all lower level versions or revisions throughout the life of the contract

8.3.9 CM and Project Risk Management

Risk management is a multifaceted approach to either eliminate or reduce risks over the life of a program. Some elements related to CM have been discussed as they specifically relate to time management, communications management, and project cost management. All of the recommendations made in Section 8.11 are related to project risk management.

Perhaps one of the most important aspects of risk management is associated with CM tools. Many organizations do not have a truly integrated information technology (IT) infrastructure either closely tied to CM or reporting through CM. Decisions can be made in such cases regarding the company's *tool suite* that do not support ongoing programs or projects.

In response to the *end of service* announcement for selected International Business Machines (IBM) rational products shown in [Figure 8.2](#), one company surveyed reported that IT in conjunction with the software engineering department determined there was no impact, as the company was moving away from this particular product. This determination led to a decision of not migrating to the newer versions of the software, and plans were made to deactivate existing licenses internal to the company, forcing an earlier migration to the new tool suite.

Unfortunately, software CM on several major orbiting spacecraft with a remaining mission life of between 3 and 15 years relied on the tools to maintain the orbiting software. The impact assessment IT and software engineering had not included anything other than new development in their decision tree, nor did they socialize the withdrawal date of the software with stakeholders outside the two departments. Information instead came from software CM in a LinkedIn forum.

<i>Program Number</i>	<i>VRM</i>	<i>Withdrawal From Support Date</i>	<i>Program Release Name</i>
5724-X73	7.1.0	April 30, 2015	Rational Synergy
5724-V66	7.1.0	April 30, 2015	Rational Synergy
5724-X80	5.2.x	April 30, 2015	Rational Change
5724-V87	5.2.x	April 30, 2015	Rational Change

Figure 8.2 End of service IBM rational selected products 2015. VRM, Virtual Resource Manager.

A similar error occurred at a different company studied. The firm's business was centric to a specific customer who mandated the type and version of the software used for documents and drawings in all of its contracts. Contracts with the customer totaled in excess of \$8.2 billion. Company IT decided that it was in the company's best interest to move all of the computers to the latest version of all user software and rolled out the implementation on a Saturday upgrade. Unfortunately, the new software suite was not fully downward compatible. Although it could open files from previous versions, it did not allow saving of files in the lower version. Data deliveries to the customer on all programs were impacted. Data were rejected as noncompliant with contractual requirements and payments to the contractor were withheld.

The effort to reinstate the previous version of the software suite so that the data would be compliant with contractually specified formats and versions ended up costing the company in excess of \$150 million.

8.3.10 CM and Action Item Lists

During the later portion of the 1990s and carrying through to the present, emphasis was placed on managing the typical work day through the use of pre-printed daily, weekly, and monthly planners. The concept was touted as the next step in personal time management under the guise that if your day, week, and month were organized, your life would be organized as well and that would leave more time to concentrate on the things in life that mattered.

On one large program, management issued these daily, weekly, and monthly planners to the entire staff and mandated their use. Employees were instructed to start with the monthly planner, expand in the weekly planner, and further expand in the daily planner of all activities being performed. They were further informed that all actions should be prioritized.

Six weeks into program implementation, it was noticed that the program was behind schedule and over cost. Being a proactive manager, a team of experts was called to facilitate improvement only to discover that more time was spent in keeping the daily, weekly, and monthly planners so that the employees could pass program manager enforced audits than was being spent actually working on the program.

The recommendation was to stop what had been implemented and to move into an integrated action item list. CM working with the lead systems engineer, program planning, and the program manager generated an integrated action item list.

8.4 CM and Engineering

One long-time and highly respected CM practitioner when asked what CM did for engineering replied, “CM manages the engineering infrastructure, infrastructure improvements and documentation providing configuration status accounting data as required so that engineering can do its job.” Although this is an oversimplification, it is not far from the truth in many of the highly integrated organizations studied prior to beginning of this book. Examples of this concept can be found in most of the chapters and will become more evident as we move into Section 8.11.

8.5 CM and Production

In a CM audit in 2011 against AS9100 requirements implementation, the auditor asked three critical questions:

- How do you configuration control the models and files in the CAD databases?
- How do you configuration control the files provided to the production floor for use in your numerical control machines and additive printing?
- How have you verified that only the current models and files are used during the production process?

These questions point out an aspect of CM that is occasionally overlooked. If you do not know what has to be managed, you may not be managing it. The discovery of what has to be configuration managed presupposes that the practitioner has a basic understanding of the tools used by every functional resource and how each output from the CM implementation interfaces with those resources.

It is not enough to follow a checklist. CM has to understand why the items are on the checklist to begin with and evaluate the currency of those items against the current company environment.

8.6 CM and Finance

Finance, as defined in Section 3.6, relates to company finance. Each year the finance department prepares justification for tax write-offs associated with research and development expenses related to technological improvements. These often take the form of company research and development but also are inherent in all firm-fixed price work. The customer (internal or external) is paying a firm-fixed price to the design, development, fabrication, test, and post-acceptance activities associated with a product. The contractor provides whatever it takes in the way of talent, facilities, and innovation required.

The data required are gathered over the operational life of each program along with the costs associated with each innovation. CM working with program cost management generally is assigned the task of performing this activity.

8.7 CM and Legal

The legal department assures compliance with all regulatory requirements as well as the protection of the company’s IP rights. In its role as the organization releasing EOs, CM professionals are critical not only to disseminating IP plans and markings but also to assuring that only properly marked data are provided to customers, vendors, and strategic partners.

They also assure compliance with national data rights protection such as the U.S. ITAR of specific marking associated with TAAs with international partners or customers.

8.8 CM and Contracts Department

As pressures increase to keep nondirect charges down, significant pressure is placed on all contracts departments with a resulting decrease in contracts staffing as well as a greater reliance on CM to assist in associated DM activities given to less experienced contract professionals in times past.

This generally includes items such as

- Maintaining a conformed (cut and paste) version of the entire contract and contract technical baseline
- Assuring that change proposals include the proper forms, formats, and proposed language that represent the intent of the change including proper wording of new requirements, so that undocumented TBS requirements do not exist
- Preparing acceptance paperwork, such as the MIIR (DD Form-250), certificates of completion, and so on
- Acting as the interface between contracts and property management to assure that all customer and contractor property is clearly identified
- Auditing of mitigation activities

These processes will be addressed in more detail in Section 8.11.

A contract is an agreement for a lawful purpose that consists of an offer and acceptance with specific terms made between two or more competent parties in which there is a promise to do or refrain from doing a certain thing and an acceptance of that promise in exchange for some form of valuable consideration.

The recent move in the United States to allow electronic signatures on real estate transactions is not the norm. Most of the market segments still rely on a manually signed contractual instrument except in those cases where the transaction is over the counter. A signature is also required for the purchase of prescription medications. Although most dispensers of prescription drugs do not have a CM department by name, they still have very sophisticated DM activities often networked across the regions druggists and medical providers to assure patient safety. In such cases, the patient can be considered to be a configuration item or configured item.

A typical U.S. government contract has four parts and 13 sections. The order of precedence is as follows:

- Part I takes precedence over Parts 2, 3, and 4.
 - Contract Sections A through H
- Part II takes precedence over Parts 3 and 4.
 - Section I
- Part III takes precedence over Part 4.
 - Section J
- Part IV takes precedence over nothing.
 - Sections K through M

The intent of the parts and sections in U.S. government contracts is included in most contracts for goods and services in commercial and international contracting. Sections are as follows:

- A. Solicitation/Contract Form
- B. Supplies or Services and Prices/Costs
- C. Description/Specs/Work Statement
- D. Inspection and Acceptance
- E. Packaging and Marking
- F. Deliveries or Performance
- G. Contract Administration Data
- H. Special Contract Provisions
- I. Contract Clauses
- J. List of Documents, Exhibits, and Other Attachments
- K. Representations, Certifications, and Other Statements of Offerors
- L. Instructions, Conditions, and Notices to Offerors
- M. Evaluation Factors for Award

8.9 CM and Supply Chain Management

The relationship between a company and its suppliers is as much the same as the relationship between the customer and the contractor.

CM should maintain a hard copy of the conformed subcontract and attachments for the supply chain manager to assist with program discussions with the vendor and to answer program audit questions.

This may appear to be at odds with the advent of automated CM tools. In those cases where the subcontract and changes to it are managed in a CM tool that tool can be used. Generally, across the many industries and product sectors evaluated, it was found that this was not the case. Like contracts, subcontracts along with the exhibits, attachments, and appendices were found to require manual rather than electronic sign off. PD/LM and the *legally recognized* version was the paper copy not its electronic equivalent.

Supply chain management is responsible for assuring that subcontract requirements are met. This includes the following:

- Proposal management to and from the vendor
- Management and evaluation of supplier data submittals
- Source-selection activities
- Vendor site surveys to evaluate the acceptability of their internal functions including CM

Everything that a program transmits to the customer, the supplier provides to the contractor. CM functions are reversed in the relationship in supply chain functions. Instead of evaluating the acceptability of product prior to submittal to a customer, the CM is integral to evaluating the acceptability of products provided by the vendor and assuring they are properly evaluated and accepted.

8.10 CM and Facilities

The configuration of the facility infrastructure is as important to the function of the company as the understanding of the product produced is to the customer. This includes the certification and maintenance status of all company-owned facility infrastructure as well as the management of the associated provenance of each item.

8.10.1 CM and Property Management

Many of the support functions CM provides to contracts manifest themselves in an interface with property management. This includes coordination of receipt, use, marking, and tracking of customer-provided property as well as control of property associated with a program/project culminating in the transfer or accountability and shipment of finished products to the customer. In many organizations, program property audits are done as a joint effort by the CM and program/project quality assurance.

8.11 Time-Phased CM Activities

What follows is a set of recommended CM activities generally associated with company functional resources. In many cases, questions such as what has to be done as well as why it is important have been addressed. It is not meant to be all inclusive but rather typical of the generic activities outside of what was observed as the norm in the majority of companies evaluated.

It is written assuming a contract relationship exists between the contractor and a U.S. government agency. It can be applied conceptually to the *quasi-contractual* relationship existing within a company and between different subsidiaries of a company. As with all CM activities, a department named CM may not be the functional organization in any one company performing the tasks despite the tasks being CM in nature.

8.11.1 At Award

8.11.1.1 The Contract

Working in concert with the program contract manager, the program configuration manager must obtain a complete copy of the contract and all associated contract documents. Each document needs to be carefully examined for contractual CM requirements, data submittal requirements not contained in the data requirements list (DRL), disconnects between contract parts or documents, and a watch list that if not socialized to those supporting the program will result in unallowable costs. This evaluation also includes a CM analysis of unspecified TBS items exposing the program and company to risk.

The contract is kept under configuration control with all changes being managed using a formal change evaluation and implementation process.

8.11.1.2 Contract Provisions and Reference Documents

8.11.1.2.1 What Has to Be Done?

The program configuration manager or their designee needs to find full-text copies of every referenced provision that is cited in the contract and put them in one or more documents.

FAR clauses need to be collected into a single editable document such as MS Word in order by numbering and not segregated by contract section for ease of use.

FAR Agency supplement clauses such as the DOD, NASA, and Air Force supplements each need to be in a separate document again by number and not by contract section.

The same thing must be done for each non-FAR provision such as those involved with U.S. Uniform Commercial Code (UCC) or international contracting.

If a contract clause says to do something in accordance with another cited clause or FAR, UCC or other provision that exists in the contract, copies of those documents also need to be found and put in the program document repository.

It does not stop there. As all of the contract attachments including the SOW, specifications, mission assurance requirements, and DRL requirements are implemented by the contract, full-text copies of these documents as well as any compliance document and reference documents listed in them also need to be gathered. Should a compliance document in turn have requirements, documents and reference documents need to be gathered. It is recommended that this process continues until the lowest level source documents are reached.

8.11.1.2.2 Why It Has to Be Done?

This is any contractor's first line of defense against customer and internal audits. Often, auditors will find a clause in the contract, pull the latest version from their sources, and audit a contractor against the latest requirements. Unfortunately, requirements evolve over time and the clause they pull may not be the clause that is contractually binding on the program. If the contractor does not have a copy of the binding clause in its program document library to prove that the program is compliant with them, they have lost the battle and may have to spend resources to comply with the more stringent requirements.

Often, requirements implemented in specifications and other attachments are buried as low as level 12 and will cause contractors compliance issues. It is a sound CM practice to work with contracts to add a special provision to the contract that limits compliance to the third level only.

8.11.1.3 Hidden Data Submittal Requirements

8.11.1.3.1 What Has to Be Done?

Every contract document has to be carefully reviewed to find and plan for data submittal requirements that are not part of the DRL. The CM practitioner must do this from the tops down and tie it out from the bottoms up. This means that the review of the contract, its provisions, and each section needs to be carefully read and submittals must be documented. The list of hidden data submittal requirements must then be compared to the DRL list for possible duplicates, and if possible, a no-cost proposal submitted to the customer to add the new items, so that they are captured in a single document.

During this step, the CM practitioner must also take advantage of the doing it smart mantra and also identify disconnects between contract parts or documents and a watch list that if not socialized to those supporting the program will result in unallowable costs.

Culprits include but are not limited to incident reporting, reporting damage to government property, Federal Information Processing Standards, IT security plans, submittals of new technology rights, submittal of a final scientific or technical report, undocumented TBS requirements associated with reviews, and so on. CM needs to pay particular attention to buying office unique requirements and those hidden in the text of FAR clauses.

8.11.1.3.2 Why It Has to Be Done?

Traditionally, CM was tasked to review every draft contract that was bid on and assure that every requirement for submittal of data was captured in the DRL for the program. In many companies, this no longer happens. This forces CM to do it after award.

Without proper identification and planning for submittal of all contractual data, the company is not compliant with the contract. This results in the following:

1. Loss of good will on the part of the customer
2. The extra expense of responding to audit findings
3. Withholding of payments and lower award fee resulting in a hit to EBIT

By reading through the documentation once with an eye to accomplishing several purposes, the CM practitioner not only becomes more familiar with the contract structure itself but also saves time doing several readings to find all the information.

8.11.1.4 Disconnects between Contract Parts or Documents

8.11.1.4.1 What Has to Be Done?

During the review of documentation, the CM practitioner needs to keep an eye open for disconnects between contract sections. This is one of the worst trip wires that a contractor can experience.

Disconnects generally always exist between DRL delivery requirements, deliverable items list (DIL) requirements, and packaging and marking requirements. (Note: Some contracts do not have a DIL but instead use Sections B and F of the contract for deliverable items and their delivery date.) To list all the places the author has found them would expand this document by separate chapters dedicated to each buying agency and buying office within that agency that have been worked with. Let it suffice that no contract is clean in this area.

Pay special attention also to any reference to the company documents in customer documents. One program evaluated was written up for having references in the customer-provided SOW to documents that required the company to use a paper-centric release system that had been obsolete at the company for over a decade as the company was now PD/LM centric.

8.11.1.4.2 Why It Has to Be Done?

After source selection activities are finished, contractors often run into instances where the actual contract they sign doesn't accurately reflect what was negotiated. This leads to contractors who do not proactively do a complete contract review being blindsided by missing or conflicting contract requirements.

This has resulted in products being delivered to the wrong place; "Ship to" and "Mark for" addresses differing between different parts of the contract sections and the DRL and data item descriptions; and worse. Pay particular attention to any shipping instruction for noncritical receiving.

8.11.1.5 The Watch List

8.11.1.5.1 What Has to Be Done?

During the review of documentation, the CM practitioners need to keep their eyes opened for contract provisions that may cause trouble during program performance if they are not

socialized to everyone on the program. Many of these can be gleaned from lessons learned from other programs.

These have included failure to pay attention to clauses prohibiting flying on other than U.S. flagship carriers, NPR 6000.1, “Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components”; limits on overtime pay; and time limits of inspection of systems records.

Each item found needs to be documented and socialized. In many cases, the program manager may request CM assistance in generating a risk mitigation plan for each item.

As additional lessons learned items come up, they should be added to the watch list.

8.11.1.5.2 Why It Has to Be Done?

A few hours spent at the start of the program can save hundreds of thousands of dollars and valuable schedule later. Trouble for the contractor can take many forms including not having clear language that establishes what constitutes acceptance for any given deliverable or review and certain costs such as flying on a non-U.S.-owned airline being determined to be unallowable. It impacts cost and schedule to correct these errors and has a direct impact on EBIT.

It may also result in weeks if not months of internal and external action items to clear up if found too late and to generate root cause documentation.

8.11.1.6 Contract Status Worksheet

Sound management of the configuration of the deliverables is tied directly to the sound management of the contractual technical baseline. There are many ways to do this. Perhaps the easiest way is to create and maintain over the life of the contract a spreadsheet that tracks the contract sections and attachments in column headers against a row for each authorized change to the contract.

A second tab on this spreadsheet can be used to track each task order (TO) on the contract.

At the top level, the contracts manager maintains traceability of contract documents against proposals and contract modifications through the work authorization system.

The contracts manager generally does not maintain traceability of contractual documents against proposals, and contract modifications. This is a task that CM is uniquely fitted to do as part of the proposal synergy with the CCB process.

8.11.1.6.1 What Has to Be Done?

At program award, CM needs to create a method for tracking the revision and changes to all contract requirements against the change proposals, customer contract change requests, and the implementing contract modifications. CM also needs to create a tracking method for making sure that all TOs under a contract are identified; the price, schedule, and deliverable items are tracked; and the TO is closed.

Experience has shown that a single spreadsheet is suited for this activity and lends itself if properly configured for providing graphical status to the program. In some cases, minimal reporting is needed other than to assure the program understands know where they are and where they have been.

8.11.1.6.2 Why It Has to Be Done?

Loss of control over the contract technical baseline is a disaster. Once the technical baseline is lost, there is no way that a contractor can stand before the customer and unequivocally state that the item being delivered meets the contractual requirements.

Although others may be responsible for generating the requirements verification matrix, it is the configuration manager who has the prime responsibility for assuring that the program staff understands the genesis of each change to the current and evolving contractual technical baseline documents.

8.11.1.7 Setting Up a Conformed Contract and Contractual Data Repository

One of the greatest services we can provide to the program management team is the maintenance of a conformed contract. A conformed contract is defined as a copy with every change documented in it. It is essential in several areas. The following are some among them:

1. Knowing what the contract actually says at a point in time
2. Identifying which modification added each requirement and what that requirement was
3. Tying requirements to bid assumptions and customer acceptance of those assumptions to avoid scope creep from the customer and volunteerism internal to the program
4. Being able to evaluate new changes against the contract
5. Tying out TBD, TBN, TBS, and TBRs in the contract baseline
6. Being able to properly plan and work on the program, assuring contractual requirements are met

8.11.1.7.1 What Has to Be Done?

At contract award (CA), a location has to be established as the historical document repository for the program. This should be identified as “Contract at Award.” Every document that was gathered as part of Section 8.11.1.2 has to be included.

Once this repository has been created, the entire directory will have to be cloned as the current contract. It is this set of documents that will be conformed to reflect the current contractual baseline. The current contract should also contain all contract modifications and TOs as well as approved major and critical variances (deviations and waivers). Down revisions of superseded documents are kept for the mission life of the program in a data archive.

CM should also maintain a hard copy of the conformed contract and attachments for the program manager to assist with program discussions with the customer and to answer program audit questions.

This may appear to be at odds with the advent of automated CM tools. In those cases where the contract and changes to it are managed in a CM tool, that tool can be used. Generally, across the many industries and product sectors evaluated, it was found that this was not the case. Contracts along with the exhibits, attachments, and appendices were found to require manual rather than electronic sign-off. PD/LM and the *legally recognized* version was the paper copy, not its electronic equivalent.

8.11.1.7.2 Why It Has to Be Done?

The ability to stand before a body of auditors and state that the company understands, has properly managed the contract technical baseline, and that the hardware meets all contractual requirements

are some things few contractors can do with any certainty. This ability has been lost over time as companies move toward a matrixed support model.

Systems engineering may track elements of the baseline and the program manager may believe they are tracking it all. The contracts manager may have copies of all of the contract modifications in one file, a copy of the awarded contract in another, and copies of some parts of the contract somewhere else. Without a conformed contract, no one has the complete picture.

CM professionals are uniquely trained to do document management and as a result are very suited to doing this task.

8.11.2 Critical Noncontract-Related Activities

Every contract requires that several things happen as part of the infrastructure management at program start. Are there special things in the contract that have to be planned for and tied out? How are resources going to be managed? How are you going to approach CM? Each will be addressed in the following paragraphs.

8.11.2.1 Findings, Tie Outs, and Next Actions

The configuration manager should approach every contract from day one with the view to understand exactly what it is going to take to close out the contract. Part of what CM brings to the program management team is an understanding and tracking of closed items and how to tie out open items so they become closed. This process of identifying something that is an open requirement and its tie-out is essential.

Examples include the following:

Not recognizing that there was a requirement for the company to buy and provide launch insurance on a major program until it was too late to broker a cost competitive agreement with the insurance providers.

Not acting on a statement in the program Statement of Work (SOW) that the contractor needed to come to an agreement with the customer on what constituted “acceptance” six months prior to the acceptance review until the review took place.

Missing a requirement to provide an Emergency Reaction Plan for the life of the program.

CM does not have to be the one who is responsible for performing the work to make sure that everything is tied out. The CM role is one of requirement identification, tracking, and resolution (e.g., getting the item on the things to be worked list and actively tracking the items to closure).

8.11.2.1.1 What Has to Be Done?

The days when any corporation could afford to stand up an army of CM professionals on a program with distinct specializations such as specification writing, vendor SOW preparation, supply chain audit support, vendor survey for compliance with CM standards and methodologies, change managers, and a document subject matter expert (SME) for each document invoked by the contract are over.

Instead of assuming that someone else was tasked with looking over the documentation with an eye toward closing out the contract programs now need to do it with limited staff. What

this comes down to is the fact that every program configuration manager should have read and retained a working knowledge of everything in the following documents:

1. SOW
2. Customer specifications
3. Mission assurance requirements
4. DIL
5. Government/customer-furnished equipment/materials/property/data list
6. Contract provisions
7. Interface requirements documents
8. Organization conflicts of interest plans
9. IT security plans
10. Program management plans
11. Mission assurance plan
12. Environmental verification requirements
13. Special calibration requirements
14. Award fee and milestone payment plans
15. Integrations and test plans
16. DD Form-254 security plan or equivalent

If it is truly a CM responsibility to do DM in the broadest sense, then part of the task is to identify, assign, monitor, and complete the status of items that need to be tied out.

8.11.2.1.2 Why It Has to Be Done?

Occasionally, in every individual's life, they forget to do something like locking the front door when they leave on vacation only to find that when they return they have lost all of their possessions or perhaps only a single item of great value.

Every open item that is not tracked to closure is an unlocked door and the things we lose are very valuable.

The company loses credibility in the eyes of the customer, recovery is very expensive, and they also lose a bit of self-respect and industry respect as well as future business.

8.11.2.2 Resource Assessment and Management

Every craftsperson who is really good at their job knows that they have to understand their customer's needs and what resources are available to meet those needs. Expert craftspeople are masters at applying them in the most beneficial and economical way possible. If this is not done, it limits the chance of success, drives cost and/or schedule, and results in an often inferior result.

Resources take the form of

1. *Budget*: Time and money
2. *People*: A talent assessment weighed against item 1 and the cost to train them
3. *Practices*: Sifting through mandatory and nonmandatory past practices to find those that may apply and tailoring them for the job at hand
4. *Physical tools*: Computers, desks, file cabinets, server space, local area networks

5. *Electronic tools*: Spreadsheets, process automation, PD/LM systems, manufacturing/material resource planning systems, anomaly, and corrective-action tracking systems
6. *Mentors*: People who can guide someone through the requirements

8.11.2.2.1 Budget

Budget is much more than the program schedule and negotiated price for the job and how much of it is allocated to CM. The CM schedule and cost allocation varies due to current and proposed labor rates and overheads, withholding of management reserve and the grade level of people assigned to a program.

Budgets are generally assigned and allocated to CM based on the experience of the program manager with CM capabilities and how satisfied they were with CM performance on their last program. If CM had not properly shown value for the money spent, the department may be viewed as a necessary evil. If CM was proactive on all fronts in accordance with the charter given to the department, then budgets would be properly allocated and their worth would be measured according to a different scale.

The business unit and program expect CM to do all of the necessary tasks without waiting to be assigned to them. This places a great responsibility on CM, as it requires a larger systems view of what is required by the contract as well as a refined sense of situational awareness and a very proactive stance when it comes to implementing the program.

Many CM professionals interviewed struggled with this concept as they are used to waiting until someone calls them or e-mails them prior to taking any action. In the competitive marketplace, the company cannot afford CM to be inward looking and reactive. It mandates that CM be outward looking and proactive. It is a difficult transition for some with great rewards to all once the transition is made.

8.11.2.2.2 What Has to Be Done?

Although we tend to think of nonrecurring cost budgets in the form of employee head count, it must always be remembered that two employees who have the same training and time in their labor grade are not equal in all respects, nor are the tasks assigned to them equal in all respects.

An excellent employee match to a program with a specific contract structure and a particular customer in one case may not be the best match for the same task with a different customer or contract structure.

Difficulties are also incurred in making the transition from a vertically integrated program management structure or integrated project team to a horizontally integrated management team, where different organizations provide their services to multiple programs at the same time in the hope of quickening the pace of synergistic solution sets across multiple similar products.

Often, to have an employee assigned to a single program or set of programs that cover a long duration may actually do more harm to the company in the long run. It tends to freeze the employee into a *one size fits all* mode of CM implementation. Twelve years after moving to a PD/LM system, one company surveyed still has a single program that is using paper release methodologies because that system is contractually mandated. CM personnel working exclusively on such a program will only understand that release system although their department peers will have evolved to a different CM methodology.

Change is a good thing; change is constant. CM practices globally are evolving rapidly to leverage new tools and processes that are associated with them while remaining true to basic CM principles. The time spent to keep current with changes in regulatory and guidance documents and to continually improve not only an understanding of what we are doing, why we are doing it, and how we are doing it is very important. This knowledge must be tempered with an assessment of how best to apply it to the current program or project to minimize costs while still meeting contractual and internally driven requirements.

The specific first CM task required of a person assigned to a program should be to honestly evaluate their own capabilities against the requirements. Their second task should be to identify areas that they are weak in so that a proper mix of talents can be applied. The positive result is that CM is not expending large amounts budgets unnecessarily and failing. The key for every CM professional is to understanding what they don't know and ask for help.

This is not to say that every such task must be assigned to an SME. Training is critical to the success of a program as well as to the success of each individual. It means that if it is a point-in-time issue, which only happens once in every program, then it is more cost effective if an SME comes in and does that task in a few hours of mentoring, rather than the program/project CM spending weeks and then calling in the SME to clean up the work that was done.

It is critical for the program configuration manager to work closely with the program business analyst (BA) to establish and document the approach to be taken to add CM hours to changes. Generally, CM effort equals 5%–7% of the engineering base hours on all engineering change proposals, contract change proposals, and TOs negotiated on the program. If the bid is for 100 added hours, CM should be added in at an additional 5–7 hours. Often, this does not occur and CM budgets are eroded over the life of longer programs whereas the budgets of organizations supported increase during the same time frame as does the scope of the CM effort.

8.11.2.2.3 Why It Has to Be Done?

Part of the job of the leads and managers in any industry is to move people from their comfort zone after the proper assessment of each individual's capabilities. This is not done for the purpose of forcing someone to become great at something that they do not have the aptitude for. It is done to develop the gifts they do possess while making them aware of their own limitations. This hopefully engenders in them a deep appreciation for the areas that they are weak and sensitizes them to the need to ask for help when confronted with their personal limitations.

If a CM professional is doing the same job for more than three years, then it is time to think about a different assignment. Three years is the average time before a company's internal infrastructure capabilities require updating. Individual programs may last from four to 30 years. When a configuration manager is assigned to a program, let's refer to it as program Alpha, they implement their configuration management activities based on the requirements and tools current at that point in time. Program Alpha is in essence isolated in time from improvements to tools and methodologies that evolved after the date the program was awarded.

Over time improvements in configuration management tools and methodologies are made; but program Alpha is not required to adopt them as it would impact the company's relationship with the program's customer. Within a period of four years improvements in configuration management tools and methodologies are so great that much of what the configuration manager on program Alpha is doing is no longer applicable on a new program award. The program Alpha configuration manager's knowledge of how configuration management is

implemented at their company is out of date and they must be re-trained before being assigned to a new program.

Budget increases for CM are often overlooked on programs unless CM is an active participant in the proposal and change process. CM needs to be their own advocate if budget increases are going to be properly bid, negotiated, and allocated. One company surveyed decided that bid and proposal funds could be stretched if they used past actuals in CM to cost new business. After an analysis of recent programs for CM charges (and software CM charges), one program stood out as having a CM effort equals 3% of the engineering base hours. An executive challenge was made to bring in the new program at the same percentage.

The bid was successful. After three months, it became apparent that CM had been under scoped. An evaluation of the program having a CM effort equals 3% of the engineering base hours turned out to have also had 20 hours a week of unpaid and undocumented overtime for its entire life and was actually running (had CM been funded) at almost 9% due to the number of deliverables and the complexity of the program. By the time the error had been identified, six other programs had been awarded based on the same cost model to the company with the same built-in budget issue.

8.11.2.3 IP Plan

When assessing IP requirements, each contract must be evaluated against the contract requirements that drive it. Part of a contract may be under the U.S. government FAR Part 12 rules for commercial contracting, where the IP belongs to the contractor. Another part of the contract may be under FAR Part 15 rules for “Contracting by Negotiation” with restricted and limited rights non-FAR Part 15 commercial or international environment.

8.11.2.3.1 What Has to Be Done?

CM needs to work very closely with the contracts manager and the technology and IP department to document, assert with the customer, disseminate, and implement a clear IP making schema that protects the company IP.

The task of dissemination and implementation can be daunting if the CM professional is not comfortable with making reasonable determinations or is not clear as to which documents are to receive what form of IP marking.

8.11.2.3.2 Why It Has to Be Done?

FAR Part 15 requirements for data marking are clear. If the data are not properly marked, the customer may remove all markings and use the data any way they like. This includes providing it to competitors. Data that are not marked properly will erode a company’s competitive edge, and the technological differentiators that make the company the clear choice to meet a customer’s need disappear.

Working in the FAR Parts 15 and 12, commercial and international product sectors are challenging, and it is not easy for someone outside of the CM to be able to work across them easily. The CM professional can expect to be involved in providing lots of guidance in this area. The IP plan is a great help.

8.11.2.4 DD Form-254 and “For Official Use Only” Marking

The U.S. government defense programs contain what is known as the “DD Form-254,” DOD Contract Security Classification Specification. This form may contain a section pertaining to “For Official Use Only” (FOUO) markings. This section is very often misunderstood by companies, their customers (if a subcontractor to the prime contractor on a U.S. government contract), and in some cases by the U.S. government contracting officer for the program.

FOUO markings are simply a reminder to the U.S. government that they need to take a closer look at the document prior to releasing it pursuant to any Freedom of Information Act (FOIA) request.

FOIA requests have nine exemptions due to issues of sensitivity and personal rights. They are listed in Title 5 of the U.S. Code, section 552 which states

(b) This section does not apply to matters that are:

1. (A) Specifically authorized under criteria established by an Executive Order to be kept secret in the interest of national defense or foreign policy and (B) are in fact properly classified pursuant to such Executive Order;
2. Information related solely to the internal personnel rules and practices of an agency;
3. Information specifically exempted from disclosure by statute (other than section 552b of this title), provided that such statute (A) requires that the matters be withheld from the public in such a manner as to leave no discretion on the issue, or (B) establishes particular criteria for withholding or refers to particular types of matters to be withheld; FOIA Exemption 3 statutes;
4. Trade secrets and commercial or financial information obtained from a person and privileged or confidential;
5. Inter-agency or intra-agency memoranda or letters, which would not be available by law to a party other than an agency in litigation with the agency;
6. Personnel and medical files and similar files the disclosure of which would constitute a clearly unwarranted invasion of personal privacy;
7. Records or information compiled for law enforcement purposes, but only to the extent that the production of such law enforcement records or information (A) could reasonably be expected to interfere with enforcement proceedings, (B) would deprive a person of a right to a fair trial or an impartial adjudication, (C) could reasonably be expected to constitute an unwarranted invasion of personal privacy, (D) could reasonably be expected to disclose the identity of a confidential source, including a state, local, or foreign agency or an authority or any private institution that furnished information on a confidential basis, and in the case of a record or information compiled by a criminal law enforcement authority in the course of a criminal investigation or by an agency conducting a lawful national security intelligence investigation, information furnished by a confidential source, (E) would disclose techniques and procedures for law enforcement investigations or prosecutions, or would disclose guidelines for law enforcement investigations or prosecutions if such disclosure could reasonably be expected to risk circumvention of the law, or (F) could reasonably be expected to endanger the life or physical safety of any individual;
8. Information contained in or related to examination, operating, or condition reports prepared by, on behalf of, or for the use of an agency responsible for the regulation or supervision of financial institutions; or
9. Geological and geophysical information and data, including maps, concerning wells.

Because DOD contracts are issued subject to FAR requirements and the FAR is a federal statute much of what is associated with them is excluded from FOIA requests under exclusion 3 above.

In the final analysis, all FOUO markings really apply to are covered by Exemption 4, trade secrets and commercial or financial information obtained from a person and privileged or confidential:

- Contractor's progress, status, and management report
- Cost performance report
- Integrated master schedule
- Contract funds status report

These fall under Exemption 4 of the FOIA which are confidential business data. Should the program manager and contracts department declare these as not being confidential business data, then nothing on the program has to be marked with an FOUO legend.

FOUO marking instructions need to be added to the program CM plan and is part of the CM planning and management function.

8.11.2.5 CM Plan

CM plan content is covered in many guidelines and requirements documents and may be specific to particular commodity types. Generic plan content, as outlined in the GEIA-HB-649, CM Standard, needs to be tailored to the commodity type with different specific planning if the product is hardware, software, firmware, models, support services, analysis services, and so on.

Occasionally, it may be advisable to develop a single CM plan for all programs of a certain type. This single plan is then supplemented by a unique program addendum. This approach presents several advantages over having a unique CM plan for each program.

It allows for the incorporation of modifications to the CM plan template for the company to be made once for all programs under the umbrella of the business unit plan rather than updating one plan per program. It maintains consistency of approach to CM with a unique set of customers and assists in managing audits and limiting findings.

It also facilitates efficiencies as all programs falling under the single-plan approach are managed the same way, using the same workflows and the same signature authorizations.

8.11.2.5.1 What Has to Be Done?

Occasionally, it may be advisable to develop a single CM plan for all programs of a certain type (program types may be by commodity or by contracting method such as Firm Fixed Price, Fixed Price Incentive Firm target, etc.). This single plan is then supplemented by a program unique addendum for each program the plan applies to:

1. Contract number
2. CII numbers
3. Top assemblies for each contract hardware, software, or other deliverable items*
4. Program CM contacts, flight and non-flight collection numbers
5. Configuration baselines
6. Product data management (PDM) system workflow for a standard EO
7. Document approval requirements and distribution
8. Document review criteria and instructions

9. IP markings
10. Data right assertions
11. ITAR-designated official and requirements
12. Links to the SharePoint program site
13. Server file path and who to contact for access
14. IP plan number, contacts, and guidance
15. Contract data requirements list management and distribution
16. Cover letter requirements
17. Deliverable item preparation requirements*
18. Product classification
19. Contract documents in the PDM system
20. All deviations to the program CM plan
21. Hardware quality assurance document number
22. Links to document templates for SOWs, specifications, drawings, system engineering reports, and special instruction regarding program unique abbreviations
23. CCB
24. Acceptance documentation and its preparation*

The CM plan addendum is the first-level communication document between CM and all program personnel. It should include all the information of that any person assigned to the program.

8.11.2.5.2 Why It Has to Be Done?

The number one complaint on programs reviewed was found to be a lack of consistency in the CM approach to program implementation and start-up. Multiple requests were documented that asked the CM to use a single document or presentation that will answer the majority of the questions someone joining the program needs to start work and which can be used as a reference point for the life of the program.

8.11.2.6 DRL Tracking System

DM is critical to program success. It included tracking of DRLs due to the customer as well as tracking of DRLs received from program vendors.

Many companies are moving toward database-centric data tracking where multiple deliveries of one DRL can be scheduled, reminders sent, and automated workflows used to facilitate delivery to the customer.

This was not observed to be the norm across many business sectors. Often, it was found that spreadsheets were used to track deliverables very effectively. One program studied was with the NASA Goddard Space Flight Center (GSFC). It used a PowerPoint format to provide DRL performance status to the GSFC and NASA management chain. GSFC found this approach helpful as the format allowed it to be incorporated into presentations to NASA headquarters.

* A major disconnect was found in most of the programs evaluated as to who is responsible for preparing the COC, DD Form-250, or other acceptance document. With the exception of perhaps small-study efforts, it is recommended that this be the responsibility of the configuration manager.

8.11.2.6.1 What Has to Be Done?

CM coordinates the customer DRL submittals with the program and they collectively determine the best way the company can meet the data-reporting requirements with the minimum of expended effort. Many new tools are available for assisting with DRL tracking, due date notification, and status.

One particularly attractive approach is to release the customer's DRL requirements document in the PD/LM system after creating each DRL as a document object and including these in the DRL attachment BOM in an unreleased state for the length of the program. These DRL objects act as collectors for released document and other artifacts that are generated to meet the DRL requirements. As DRLs are released and submitted to the customer under their unique item identifier, they are added to the DRL collector under the DRL attachment.

Vendor DRLs are likewise released in the PD/LM system forming the BOM of the SOW sent to the vendor. As DRLs are received from the vendor, they are put into the PD/LM system for review and added to the DRL collector under the SOW to the vendor. One method of accommodating vendor DRLs in a PD/LM system is shown in Figure 8.3.

8.11.2.6.2 Why It Has to Be Done?

The lack of attention to DRL submittal requirements will delay payment of the final invoice on a program, may result in rejected invoices against milestone billing events or award fees, and will result in erosion of our credibility with our customer base.

As all DRLs are captured in the PD/LM system, indentured BOM reports can be generated from the system either in portable document format (PDF) or as a spreadsheet form to submit with the acceptance document associated with data on the program. Generally, this is a certificate of completion, DD Form-250, or equivalent and is the last such acceptance document on the

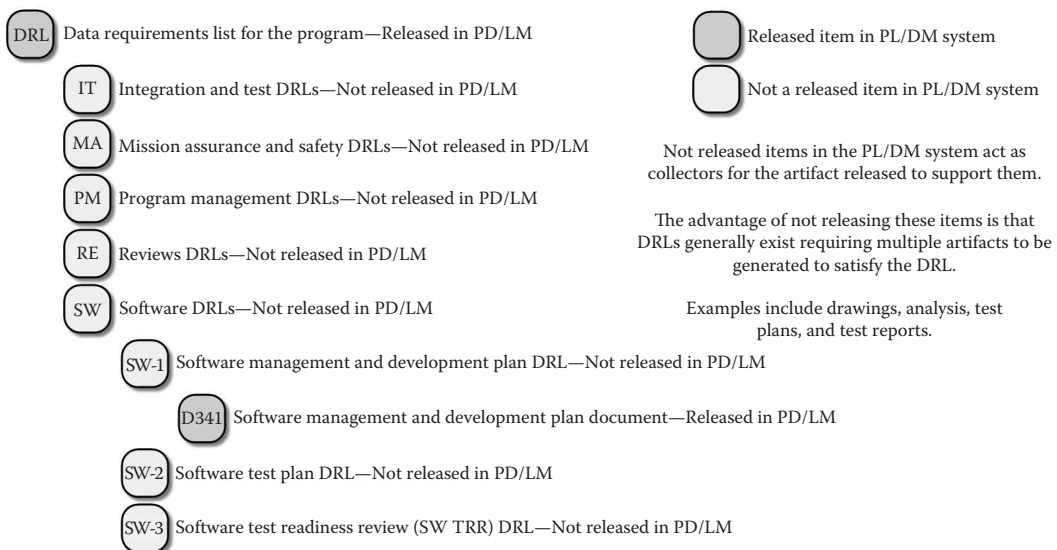


Figure 8.3 DRLs in a PD/LM system.

program or project prior to the program or project entering the post-introduction activities associated with the growth and maturity phases of the life cycle. In the U.S. government programs, this may be referred to the maintenance or logistics phase.

This is a critical portion in the DM of the CM task.

8.11.2.7 DRL Cover Letters

Many programs for items developed for a customer require that a cover letter accompany each DRL or other submittal. With the advent of delivery via electronic media, this can be an expensive luxury and generally a systematic holdover from paper systems that has not yet been purged from the customer's internal procurement guidelines. Whenever possible, CM should work with the contracts department (or legal as applicable) and attempt to delete the cover letter requirement from the contract during the bid and proposal activities. When this is not possible, the next option is to attempt to provide a monthly or quarterly summary of transmittals only.

Evidence of delivery is manifested by the date time stamp on the site electronic media data are delivered to. It forms the official record receipt date in the customer's DM system. This evidence is accepted by most nongovernment customers.

Should the customer mandate a cover letter, it is not wise to insert scans of a signature into the cover letter electronic file, unless it is obvious due to pixalization that the signature is a scan. These signatures can be copied and applied fraudulently to other documents not originating from the company.

8.11.2.7.1 What Has to Be Done?

After the program configuration manager has reviewed the contract delivery requirements, they need to coordinate with the business unit program CM lead to determine the most cost-effective method of meeting those requirements. The determination has to be made after considering all contract requirements as well as any special agreements may have in place with the buying entity or with the specific buying office.

8.11.2.7.2 Why It Has to Be Done?

The cost of creating, signing, scanning, tracking, and maintaining files for documents over the life of a program is not trivial. The cost of preparing 500 letters alone (not unusual for a small program) is estimated at 125 hours or about \$20,000, if you assume a billable rate of \$200/hour. Larger programs may have as many as 10,000 separate data transmittals and as a result 10,000 separate cover letters that must be written, coordinated, signed, transmitted, and tracked. This is 20 times the amount used to calculate the impact noted earlier and equates to an expenditure of approximately \$400,000. By eliminating the requirement, the company bid becomes much more cost competitive and less prone to audit findings.

8.11.2.8 Standardized Data Distributions Internal and External

There is very little need in an environment that is based on electronic approvals and distribution not to standardize the flow of critical information to internal and external customers via electronic notification. Often, the CM professional has a strong understanding of DRL distribution statements or a heritage of working on paper programs, where very limited distribution was the

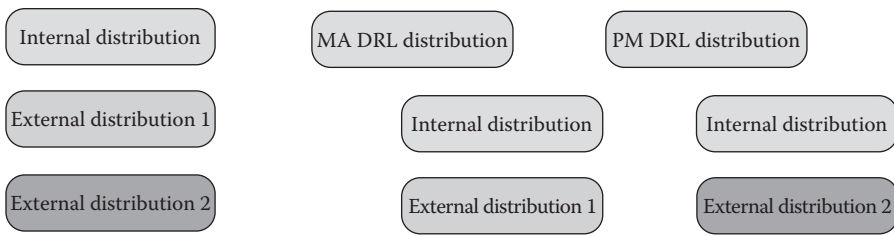


Figure 8.4 Distribution groups.

norm instead of the exception. In the evolving nature of distributive program infrastructure, the opposite is the norm. Notification that data have been transmitted can go to a broader range of customer people. Distribution groups (Figure 8.4) are easy to create in most e-mail systems with the advantage that larger distributions can be created as a combination of a standard distribution group plus a unique to a DRL subject such as financial management. As a result, new groups can be created that require less maintenance than one group for each DRL. Changes to customer personnel or internal personnel need to be only made in one group, and as that group is a member of a larger distribution, the change propagates to those other groups.

User groups can also be generated in PD/LM systems to notify key departmental representatives of every PD/LM release. The same methodology can be used.

8.11.2.8.1 What Has to Be Done?

Working with the contracts manager, program, and customer CM office generates distribution lists of internal and external personnel who will be notified of every DRL transmittal along with their e-mails. Create a program DRL distribution groups in your e-mail system and use them for each DRL delivery to the customer.

Working with your program representatives, lead systems engineer, program manager, and mission assurance manager generates a list of key the company personnel who should be notified of every PD/LM release on the program. Once this list is established, create a program EO distribution object in the PD/LM system as a global group and use it as part of the distribution of each released EO. PD/LM systems generally accept any alphanumeric as the object name. Use this to your advantage. User groups should be named simply so anyone can find them. If the program name is “Rohit,” the user group name could be “Rohit_EO_Dist.” This facilitates having a backup in the CM release process. If someone is out of the office, the approval authority is delegated inside the system.

8.11.2.8.2 Why It Has to Be Done?

Part of the failing of any organization is its lack of communication or its inability to fully distribute information, so that everyone is working to the same documentation set and document revisions.

Information is power only when it is freely shared among all parties who have a need to know. If this information is sitting on a server, in an engineering notebook, it is useful only to the person who knows it exists. Once distributed to those who need it, information can change the entire effectiveness of the organization.

8.11.2.9 The CCB

Part of the CM function as generally accepted is for CM to act as the secretary (e.g., secretariat similar to the secretary for a corporation rather than the administrative assistant) to the CCB. Without a good CCB minutes regardless of who may chair, run, or act as the secretary, the program technical baseline is soon lost. Remember that only three organizations exist for the life of the entire program. These are program management, finance, and CM. CM by necessity often takes on the role of program knowledge manager. It is in this role that the CCB needs to be viewed. Notes taken in the moment regarding decisions must be recorded in the context of the program and not the moment. If a CCB is to decide an issue of reallocation of design work from the electrical department to a company's harnessing group recording the fact the allocation took place without also recording what the underlying cause was that lead to the change captures information that is useless in the future.

8.11.2.9.1 What Has to Be Done

A meeting should take place between CM, program manager, financial BA, and lead systems engineer and contracts manager to determine CCB structure, attendance, and requirements.

CM participation in the CCB process is necessary so that proposals can properly be evaluated for changes to CM requirements, completion criteria be discussed, adequate tracking to the contract technical baseline be maintained, and the negotiated changes to the contract properly disseminated and socialized with the product area managers, product area leads, and program personnel.

CM should create a CCB tracking spreadsheet that ties CCB actions to the implementing documents on the customer's side (TOs, contract mods, etc.) as well as to proposals and transmittal letters from contracts to the customer.

A copy of the contractual documents should also be kept that tracks the as-proposed changes, so that when a modification to the contract is made, the company and the customer know if a modification is being made out of the proposed sequence. This happens more often than many would believe. Often, contractors have had as many as five proposals in the customer's review process at one time. All of these could have an effect on the same document paragraph. When proposals submitted later are approved first and earlier proposals approved after them, the language in the contract modification can undo the updates associated with the later proposal as illustrated below:

Proposal 1: Modify paragraph 3.4.1 from "5 Philly cheese steak sandwiches and 1 salad" to "6 Philly cheese steak sandwiches and 1 salad."

Proposal 2: Modify paragraph 3.4.1 from "6 Philly cheese steak sandwiches and 1 salad" to "7 Philly cheese steak sandwiches and 2 salads," this change is predicated on prior approval of change 1.

If proposal 2 is approved before proposal 1 and you do not know what is predicated on you will have the following:

Modification 1: Modify paragraph 3.4.1 from "6 Philly cheese steak sandwiches and 1 salad" to "7 Philly cheese steak sandwiches and 2 salad."

Modification 2: Modify paragraph 3.4.1 from 5 Philly cheese steak sandwiches and 1 salad" to "6 Philly cheese steak sandwiches and 1 salad."

Someone is not going to get their sandwich or their salad unless it is known that the modifications are out of order with the proposal submittals and makes sure that before the modifications are signed by both parties they are corrected.

8.11.2.9.2 Why It Has to Be Done?

An analysis of over 60 programs, spanning a period of more than 30 years, indicates that “If you don’t know where you are going and you don’t know when you are going to arrive do you never know where you are?” To effectively manage a program from the CM perspective, the contractor can never lose the contractual technical baseline. If they do, there is no way that the company can stand up in front of any customer or auditor and state that the thing we built actually meets the contractual requirements.

It is incumbent on the configuration manager to make sure that the baseline is managed and that the company knows what each modification does, how it ties back to what was bid, and on what that bid was predicated. In many cases, this management requires that change language in an already submitted proposal must be updated to account for out-of-sequence approvals of changes submitted later.

8.11.3 Hardware Quality Instruction and Software Quality Instruction

Programs often issue what are known as a “hardware quality instruction” (HQI) and “software quality instruction” (SQI) documents informing those working on programs critical information regarding process inspections, documentation reviews, customer flow-downs, and so on. These are released after a formal review like any other program document. CM plays a critical part in assuring that the HQI and SQI contain no errors relative to item identification, quality levels, referenced document numbers and descriptions, or PD/LM system collection identification that may tie into a nonintegrated information DM systems. Such errors can cause major performance issues during program performance.

8.11.4 The Program Data Repository Basics

Many companies have several types of data repositories that CM is responsible for either setting up and managing or using. Each type is generally for a specific purpose and may be a subset of the entire data repository structure for a program. Within this distributed data structure, the CM department only controls a portion of all CM activities that are going on at any point and time. The CM practitioner understands that DM and configuration status and accounting encompass activities such as hardware and test anomaly reports, supply chain interfaces with the PD/LM and procurement systems, and the resultant ordering of supplies and services from vendors, financial reporting and status, and employee records.

The three main data repositories the CM uses are program specific: intranet, servers, and program-related PD/LM structure based on program metadata. Each repository has its own strengths and weaknesses. They will be addressed in turn.

8.11.4.1 Program Intranet Site

As many companies move toward current intranet technologies to manage documents not requiring strict CM, versioning control is a distinct improvement over server structures and will become more common across all industries over time. Not everything can be migrated from company file servers to intranet sites at present. Both have distinct advantages and disadvantages, and a balance between the two needs to be found and maintained until such time as intranet technologies improve to allow larger file sizes and servers such as file redundancy analysis to assure a single point of truth exists.

8.11.4.1.1 Strengths and Weaknesses

Intranet sites offer the following advantages over servers:

- The ability to link to data contained elsewhere allowing for a single point of truth instead of multiple points of truth. A server may contain several copies of the same document with the same file name that are not identical. Intranet use may not completely eliminate this but it is significantly reduced as items can link to other intranet pages or provide a direct link to the PD/LM system.
- Check-out and check-in capabilities exist with versioning control.
- Easily maintained permission structures.
- Quick access to data with searching capabilities.
- The ability to have multiple people editing the same document without conflicts.

Many intranet implementations were observed to have the following drawbacks:

- File sizes are much lower than those accommodated by servers.
- Certain file types (extensions) are not allowed.
- Many offending characters exist that cannot be used on file names.

8.11.4.1.1.1 Site Names

Site names may not contain the following characters: \/: * ? " < > | # {} percent & " ~ +

You cannot start a site name, sub site name, or a site group name with an underscore (_) character or with the period character (I recommend avoiding the (_) underscore in site names)

You cannot use the period character consecutively in the middle of a site name

You cannot use the period character at the end of a site name

8.11.4.1.1.2 File Names

Invalid characters: " # percent & * : < > ? \{ } ~

You cannot use the period character consecutively in the middle of a file name

You cannot use the period character at the end of a file name

You cannot start a file name with the period character

8.11.4.1.1.3 Folder Names

You cannot use the following characters anywhere in a folder name or a server name:

~ # percent & * { } \ : < > ? / | "

You cannot use the period character consecutively in the middle of a folder name

You cannot use the period character at the end of a folder name

You cannot start a folder name with the period character

- A limit of single directory/file name length—128 characters (including file extensions)
 - This is the same limitation on the company servers
- Use of underscores in file name in Intranet is not recommended

8.11.4.2 Program Servers

At one time, program servers were the data repository of choice and supplemented the hard copy files that were used for document release and control. Since the 1980s, this has been changing. Today, with the advent of very sophisticated PD/LM systems as well as expanded database tools and infrastructure, it is clear that only a mix of all the tools available will meet the growing immediacy needs to have information readily available.

8.11.4.2.1 Strengths and Weaknesses

Servers offer a way to store data files and organize them through using an indented directory structure that is both available and at a price point that is relatively inexpensive. Seldom access files can be stored on servers with a lesser accessibility and cost by eliminating such niceties as hot swappable drives and redundant mapped and synced server structures.

They are, however, limited as listed below:

- A limit of single directory/file name length including file extensions.
- No versioning control.
- Directories and files are easily deleted or moved if the user is not careful.
- File lack of availability on items not accessed regularly due to system issues, upgrades, and IT backup pressures to not keep backups after certain time periods.
 - Some IT organizations were found to maintain no backups older than three months.
 - Seldom accessed data may become corrupt with no capability to restore a noncorrupt copy as a backup no longer exists.
- Corruption of PowerPoint and other files due to issues with archiving software at the IT backbone level or due to other issues.
- Propagation of multiple uncontrolled copies of the same document, which are not identical but rather works in progress with risk of people working to a noncurrent copy.
- Inadvertent creation of new subdirectories with permissions that are different than the directory it resides under causing issues with data access.
 - Generally, data access is a string progression downward requiring access to all levels above the directory data resides in rather than non-nodal where data can be accessed directly without relying on a string of permissions to the top directory.
- Complicated permissions structures.

Each of these will be addressed in turn.

8.11.4.2.1.1 File Path Length Limit — The entire file path length limitation is easily exceeded with the trend of making file names as descriptive as possible. Unfortunately, the IT backbone is not able to provide the server user a warning that their file names are exceeding the maximum path length as they are loaded. This results in what looks like a reasonable set of nested directories and subdirectories and files on a server under an existing directory structure with no ability to access them later as they are longer than the file length limitations of the server operating system. This is more common on some server software platforms than others. Many times file lengths are imposed by the server software provider and not due to limitations of the server itself.

8.11.4.2.1.2 No Versioning Control — The lack of versioning control means that without looking at the document properties you cannot tell which copy is the latest copy. There is no single point of truth. Workarounds must be set up to clearly establish within the file name itself the version. This is often accomplished by adding the date in the file name. Unfortunately, there is no standard for doing this across the industries evaluated. As a result, users may not be able to quickly evaluate one version against another without much research. Often, two copies of the same file may exist in different sub-directories that are in fact identical but as one is a copy of the other, it will have a different date in the file properties. This necessitates performing a document comparison in the word processing program.

By putting the entire date in YYYY-MM-DD format, the ASCII formats used on the server will sort the file by date. Unfortunately, this cuts into the total file path length that is available.

8.11.4.2.1.3 Files Being Moved or Deleted — It is extremely easy to inadvertently have clicked on a directory, subdirectory, or a file and thinking you have let all the pressure off of the mouse key drag it into another directory or delete it completely from a server. There is no safeguard against this. CM can play a critical DM role as the focal point for finding such lost directories and files and working with IT to recover them. The first step is always to search on the entire directory for the missing file name or directory name. Only if it is not found and moved back to its proper place in the directory structure should IT be contacted for a server restoration. Server restoration of even a single directory can result in the company having to unnecessarily spend funds to recreate newer versions of documents that such a restoration overwrites.

It is recommended that the CM professionals request that IT generate a complete directory structure of any program server. This will allow rapid searches for the directory name and content to assist in recovery of deleted or moved files or directories. Experienced CM professionals have stated that most often directories and files have been moved into other directories rather than deleted. Without a listing of the server directories, it is often not easy to know the real name of the directory that being searched.

8.11.4.2.1.4 File Corruption — Unfortunately, files do become corrupted. Files that in the past have lent themselves to becoming corrupted are PDFs and PowerPoint. It is recommended that a zip file be created for all PowerPoint presentation material on a server, as zipped files are not generally archived. Periodic issues have also been observed with “.jpeg” and other image file formats, which are being corrupted due to viruses or not being able to be opened due to software upgrades.

8.11.4.2.1.5 File Propagation — Many in the engineering community like to save a copy of the documents they work on to their computer desktop. They may also keep a copy in their functional subdirectory on a server. This presents issues on several fronts.

- There is no single source of truth for the document’s released or approved version state, which is an audit issue.
- Changes to the document that were made at the time of PD/LM release, distribution, and implementation may not be captured on the desktop or functional subdirectory copy.
- Changes to the desktop or functional subdirectory copy for modification and use on another program may not be using the latest document.

Information technology systems (IT) can run a search on the program server that identifies all cases where two or more copies of a document exist. It is recommended that the CM professionals request that this search be run once a quarter. This can generally be requested at the same time as a request for a complete directory structure of any program server used.

Once duplicate files are identified, the CM professionals should work with the organization that has the duplicate copy to either delete it from the server or to put in a shortcut to the source of truth.

8.11.4.2.1.6 Differing Permissions — Access to directories and files on a server are controlled in two ways. Access can be granted directly or by creating a permissions group. It is easy to tell which of these two methods are used on any server by going to the root directory of the server and looking at the permissions for the subdirectory in question and opening the security tab.

Permissions that are granted to one directory are generally propagated down through the entire subdirectory string as each new directory is created. Any directory that has a limited permission access is referred to as *locked down*.

Occasionally, other directories are intentionally moved into a locked down directory and directory access issues arise. Because these moved directories inherited permissions from the directory under which they were created, those permissions move with them. If individuals are not in both the top directory the subdirectories were moved to and the directory the subdirectories were moved from, they can no longer access the moved data.

8.11.4.3 PD/LM Systems

The technologies used to perform change management and some configuration status and accounting are evolving. PDM systems will become product life cycle management (PLM) systems and they will become ever more integrated in order to fulfill the ever-growing need for cost control, supply chain interface, data mining, and reduction.

Between 1996 and 2012, one company moved from an IBM-based records and release system to C-Gate to Oracle Agile user-based interface and one major Oracle Agile upgrade to a web-based interface. In each instance, the ability to perform as a company to a higher standard was improved. Similar changes are taking place in every functionary discipline in most companies. CM can greatly influence how new tools are accepted by those it supports.

8.11.4.3.1 Strengths and Weaknesses of PD/LM systems

PD/LM systems strengths include the following:

- Track and manage all changes to product-related data
- Spend less time organizing and tracking design data
- Improve productivity through the reuse of product design data
- Enhance collaboration
- Is generally keyed into or integrated with supply chain management
- Are very flexible in how it is used

These strengths can be leveraged in many ways and CM can help make or influence intelligent decisions in their use.

PD/LM systems weaknesses include the following:

- Data mining is dependent on the quality of the data being input—garbage in garbage out holds true.
- The database is case sensitive.

- Searches do not always yield what the user expects due to the user not adding the wildcard “*” prior to the number they are searching for.
- Searching for historical data may not yield the results the user is looking for due to the lack of consistency in how the files may have been migrated from previous systems (e.g., “SYS200” is not the same as “SYS-200”).
- Data can easily be locked down by the user, leaving them with no access if they mistakenly add a program or other name to the distribution field for which they are not a member.
- Multiple ways of doing the same thing can lead to confusion by the user.
- Datasets in pull-down menus need to be constantly monitored against the controlling document to keep them in sync.
- A user can add a proxy to sign for them when they are out, but proxy assignments will not agree with the sign-off matrix of the program for which the work is being approved.
 - Unless proxy assignments are authorized in the change management section of the CM plan, it will result in an audit finding of noncompliance with released program documentation.
- The PD/LM system may allow the use of I, O, Q, S, X, and Z in production release revisions.
 - There may be a violation of the company’s drafting manuals if it is predicated on lettering prohibitions utilized in older paper-based systems.

8.11.4.4 *PD/LM Product Structure*

The PD/LM product or BOM structure forms the roadmap for any manufacturing resources system. It must be complete from the lowest piece part through the top assembly for the item being produced.

Similarly, incomplete product structure in the software world will result in missing elements when the software item is built.

Incomplete document BOMs will have an immediate impact on the ability of the program or project to rapidly access critical data.

8.11.4.4.1 *What Has to Be Done?*

Relationships are established in the BOM of each part, assembly, or document

8.11.4.4.2 *Why It Has to Be Done?*

Should the product structure be incomplete or broken, items that are required for the build will not be transferred over to supply chain management for procurement system or incorporated in the build in software. Hardware items will experience parts not being on hand, inability to plan and manufacture items required for assembly, and loss of schedule and profit. Software items will not be properly compiled.

8.12 *The First 90 Days and Beyond*

This is the most critical period of the program’s performance, as this is when major agreements and decisions are made that will influence the working relationship between the customer and the company as well as how work will be done on the program. The core team on the program

(program manager, financial BA, contracts manager, lead systems engineer, CM, and the functional support areas) have the responsibility to establish sound working relationships with their counterparts. They also have the responsibility to work off as many inconsistencies as they can in the contract to assure that TBDs, TBNs, TBRs, and TBSs are defined and any ambiguous or unclear portions of the contract are identified and corrected.

This is also the time frame that much of the background infrastructure work that configuration manager does on a program is set in place that will assure the program has the tools needed before they are due. The configuration manager should look on each new program not as a continuation of what the configuration management professionals have been doing on their last assignment, but to move the state of the art forward by leveraging off from the last program anyone in CM has worked and applying the collective lessons learned of the department to each new program start.

Only by doing this, can the CM assure they are utilizing all of the current tools available and that they do not repeat the mistakes of the past. One mistake particularly noted in those new to configuration management was waiting for someone to send the configuration manager an e-mail to assign them a task. The configuration manager to work must be proactive!

8.12.1 The 90/90 Rule

Discussions with program support personnel and program managers at the company and at their customers have clearly shown that 90% of the decisions that drive program costs are made in the first 90 days of a program. These decisions include a determination that management tools are or are not developed, clear channels of internal and external communication are or are not established, and what role each organization will or will not play.

The configuration manager not only needs to involve in the program discussions relative to these decisions but also needs to critically examine how configuration management intends to support the program and the program management team. In some cases, the program manager and others will have set expectations based on previous experiences with CM support. These experiences could have been good and they could have been bad.

8.12.1.1 Setting CM Expectations

CM needs to sit down with each member of the program management team and do an assessment of the following:

- Their expectations of CM
- What worked for them in the past
- What did not work for them in the past
- How it could have been better
- Their concerns relative to the program, cost, and schedule

After this information has been obtained, the program configuration manager needs to evaluate the needs, wants, and goals of the rest of the program management team with CM requirements, lessons learned, and the available CM tool suite to arrive at a best-fit scenario for the program.

Once this has been done, key players can be called together for a discussion where CM addresses the concerns expressed by the program management team and explains how those needs can be met. Several important considerations must be made during the preparation for this meeting that

hinge on the following question: “By doing what you are proposing are you negatively impacting cost, schedule, or risk?”

8.12.1.1.1 Reducing Cost

Cost can be defined in many ways. There is reducing cost and there is cost avoidance. Put in another way: “Are you doing things so well that it cost less to do them” or “Are you doing things so smart that it gives you time to do something else that needs to be done.” In many cases, CM influences both. By seeing the whole picture, CM is able to determine the actual needs and arrive at an implementation solution that may initially allow attention to be directed to other critical items. This can have the net result of greater positive contributions in these other areas supported.

If our implementation of DRL tracking and status or other reports is so complicated that it takes the non-CM user 10 minutes to find something, it may inadvertently add 10,000 hours in wasted time on a program. Eliminating a single click on a server or intranet site has tremendous payback. Costs can also be reduced or avoided if CM looks for nontraditional methodologies to the company, but industry-standard methodologies to support to a program. The cost of one highly paid senior engineer to perform a data reduction task is comparable to three entry-level CM specialists. By assigning non-critical tasks to entry level configuration managers, the senior engineer is now free to do work that is in keeping with their expertise. This action grows the ability of the CM person performing the task, how CM is viewed by the community at large as well as reducing the bottom line cost of the program.

8.12.1.1.2 Reducing Schedule

Schedules are always changing and each functional lead has their own. These roll into the program schedule. By presenting as nearly a common set of interfaces with tools, servers, intranet sites, CM plans, and CM-controlled functions, CM can either reduce or increase the schedule time. One of the greatest complaints that have been documented in the research done prior to the writing of this book is the lack of a consistent progression in CM implementation. One CM professional may take CM implementation to the highest level of excellence, whereas on the next program the CM professional will revert to methodologies that have not evolved for a decade. We each have “our hot buttons” things that we insist on not because they are necessarily right or the best but simply because they are familiar based on our personal history and that often drive frustrations with CM on the programs and inside the organizations CM supports.

CM is most effectively received and supported within a company when the organization makes sure that a seamless approach to end user support it provided. CM implementation succeeds when there is a constant striving to improve the CM infrastructure and tools that lie behind that infrastructure.

8.12.1.1.3 Reducing Risk

Risk reduction takes many forms on a program. There are three main types:

1. Cost
2. Schedule
3. Audit

It may appear trivial on the surface but everything CM does on a program or project affects each of these in many ways. Every signature on an EO in the PD/LM system at one company surveyed cost \$50. Adding one signature to all EOs may appear trivial until it is put into perspective. One program analysis showed an impact of \$240,000, which could have been booked as profit (3400 drawings plus 1400 system engineering reports times \$50—not included are the number of changes to those documents that each has to be evaluated or nondrawing or System Engineering Reports such as the view graph packages for reviews. The true impact on the program was approximately a quarter of a million dollars higher).

There is also a schedule hit due to an extended sign-off loop accompanied by an audit risk should the cost impact drive the program into an overrun. Rarely are the number of signatures mandated by a company or specified by contract. Analysis of over 15,000 PD/LM EO approvals indicated that after the fourth signature is obtained, additional signatures do little to assure that the change has captured all impacts. Tabletop reviews prior to beginning of the EO in the PD/LM system were found to be less costly resulting in an efficiency gain with an associated cost reduction of over 30%.

8.12.2 *Proposals and CM Budget*

CM hours are traditionally reduced during the proposal phase for the initial award in an attempt to make the cost number fit in the anticipated *winning bid* cost widow. CM hours were generally found not to have been bid for change proposals once a contract is awarded. The CM function is a critical part of the program infrastructure and hours need to be increased as the program grows due to proposal activities. Put in another way, CM is part of the *marching army* costs on any program. Increases in scope in other portions of the program drive CM scope and as a result CM cost and schedule.

The program configuration manager needs to reach out to the program manager and the financial BA to assure CM hours are included in every change proposal that is prepared on the program after award.

Historically, on program and the business unit programs, the CM effort on added scope from change proposals equals 5% of the engineering base. This can be adjusted upward to 7% if the proposal is in the high-risk category.

If CM budget is not increased throughout the life of the program through change traffic, much of what we need to do for the program will not be properly funded. Some programs are extended from the initial period of performance to as much as 12 years. Trying to accommodate this kind of scope growth using the CM dollars initially bid for the program means that CM may find itself in a financial bind with only enough funding to do the minimum required to release engineering and transmit data to the customer.

8.12.3 *CM Interfaces*

CM may enjoy a positive working relationship with the business unit and program management staff. This is generally due to being proactive and finding innovative ways to accomplish the CM tasks set forth in the contract. The relationship is supplemented by knowing the internal and external CM customers, anticipating their needs and how best to fill those needs within the limitations of the tools CM has at its disposal and the constraints of the program. It can be just as easily damaged by not being proactive.

8.12.3.1 *Internal CM Interfaces*

Each person in the CM support organization should take time to talk to the leads on the program they are assigned. Each organization has special needs. A few things to watch out for are listed as follows:

- Does the person you are helping use the PD/LM tool on a daily basis (mechanical, electrical, I&T)?
- Does the person you are helping only release documents sporadically throughout the program life?
- Do they want a lesson or do they want to only know one thing?
- Never point someone to a document and tell them to read it.
 - Seeing someone do it may be all it takes.
 - Everyone learns differently.
- Never quote rules and regulations at them—they called CM because they read them and do not understand them.
 - Talking to and conversing with are two different things.
- Sit down with them if possible instead of sending e-mails.
 - If an e-mail string is longer than four replies, it is time for a meeting.
- Be consistent—most people in a program organization work several different programs and CM cannot be changing the rules every time a new program starts.
 - If the rules are changing, provide them a gap analysis explaining what has changed and why.
 - If you are not sure how something was done on the last program someone worked on, talk to the configuration manager on that program.
 - You cannot do a gap analysis if you do not know how wide the gap is.
- Be flexible, learn how the CM department does it now.

In one company studied, CM had made system wide decisions that affected CM implementation each year for 18 years. Every improvement made either reduced the overall cost or was a cost avoidance. These improvements were not retroactively implements (flowed across all active programs); but simply phased in when a new program started.

In this same company, CM staff was being reassigned at the 18-year mark from a program that had existed for 20 years. These individuals had used the same antiquated processes and tools for the entire program life as they were mandated by the customer instead of being self-imposed. All of those reassigned to new programs had to be trained in the current suite of CM tools and processes. The sudden transition to a PD/LM system from using a paper system for 20 years was so great that many of those being transitioned quit the company in frustration.

The road to continual improvement in CM once started must flow across the entire department and all programs. The approach taken by the company being discussed resulted in disenfranchising those assigned to existing programs whenever an improvement was implemented.

Do not be afraid to fail when making suggestions for improvements. Every good idea can be used. Perhaps not at the time and place it was originally thought of but perhaps downstream when business conditions allow it. What is being proposed may in fact impact another organization. Improvements need to be based on things that will make it easier, faster, and less expensive for everyone not just for CM.

8.12.3.2 Know Your Internal Customer

Some organizations only release a few documents once each program. They will never become PD/LM experts. By the time they have to use what CM needs to teach them about the PD/LM system a second time, several years may have passed and they will need to be trained again. Such organizations often willingly provide additional budget to pay CM to generate their changes, document objects, and BOMs in the PD/LM system, as it saves them money in the long run.

If assigned a new program, call a meeting with the rest of the CM department to review how the department has traditionally worked with an individual or an organization. Do this before reacting to any request for support that believed not to be a CM responsibility.

It will enable you to work effectively with the individual(s) and go a long way toward maintaining or improving how CM is perceived by the business unit and program.

Oftentimes, CM can accommodate these needs by thinking about them instead of reacting to them. Occasionally, CM professionals lose track of what they are really on a program to do. They are so used to limited budgets that they have decided to stop thinking and simply react. This is the fastest way known to erode the credibility of the department.

CM needs to balance use of the tools available the smartest way they can with those critical thinking skills developed over the years.

Take time to read what comes across your desk. No company pays employees to be an automaton. They expect a high degree of professionalism. Distribution of data by the configuration manager conveys to the recipient that the configuration manager agrees with the content. Bad information is distributed with “apparent” configuration management concurrence if the data is not reviewed for correct prior to distribution. Sitting silently in a meeting and seeing others going down the wrong path is CM approval of the decision. CM silence may result in the company investing in doing something that you by your silence made them do that was not required.

8.12.4 Program Do's and Don'ts

Each program is a living and breathing entity that can be successful or not depending on the actions of those working on it. There is no cookie-cutter approach that will fit every program's needs and no minimum set of things that CM needs to do to help make it a success.

Each program is a challenge, and with the start of each new program, the company has the chance to make better-informed decisions and to create an environment, where CM at the company aligns itself with how CM is performed outside of the company. This synergy between knowledge management and CM is critical.

What follows is based on decades of experience. It can help in many instances.

DO

Assume

- Spend time to understand critical issues and spend time helping people with those time-specific critical issues
- Listen with the view of understanding the intent of the conversation rather than just the words
- Seek to understand the goals and needs of the program manager and lead systems engineers

- Pay attention to other people's hot spots—when they call you their problem is the highest thing on their priority list
- Put CM priorities on the back burner at times for the good of the program and seek extra help when you need it
- The tools and things CM developed on the last program may not be good enough today
- Look at the program from the program manager's perspective—the more you understand the programmatic needs, the better you will understand how CM can meet those needs
 - Although the program manager's perspective is only one piece of the larger CM picture, it is critical to being able to envision how configuration is implemented to address.
- Every day will be a learning experience and department capabilities will grow from having an open mind
- Ask questions in areas to which you are unfamiliar. This will avoid serious errors that could go all the way up the management chain

DO NOT

Assume

- That everyone knows what CM does on a program. Much of what CM does they will never see
- That everyone understands why CM has to do certain things
- That your CM be greeted with open arms if you expect to teach everyone how to do things in the PD/LM system and become frustrated when they call for help
- That CM can live on past good deeds and accomplishments
- That CM knows everything there is to know about what the program needs
- That CM knows everything there is about how the company works
- That CM does not have to understand the agreements and working history that has been established between the CM department and the program organizations
- That if it a process is not yet documented in the company that it is prohibited
- If something is not specifically authorized by process or procedure by the company, then it cannot be done
 - Procedures and processes come into being by doing something new responsibly with a sound documented business case for decisions that are socialized across the rest of the business

Do not let yourself believe that

- CM can do the job without understanding the contract parts that apply to CM or better than the contracts manager
- CM can do the job without interfacing with your peers and program personnel
- CM can do the job without being part of the program management team
- CM can do the job without looking at what CM is posting as an engineering change request without reading it to see if it makes sense
- CM can do things the same way as on the last program worked and be successful
- CM does not have to do whatever it takes to provide an end product that makes the customer successful while maximizing profitability. This may include having someone send a document and requesting that CM format it, apply IP statements to it, and get it into the PD/LM system to release

- CM can properly function without weekly interface with the program functional leads and other program critical functions
- The contract and contractual requirements documents are not under CM

8.12.4.1 CM as a Service Organization

CM should never make it more difficult for anyone else to do something in order to make it easier for the CM department to do something. The only exception to this is in those cases where adding a little extra work for everyone results in greater paybacks than the total amount of effort expended.

A general definition of CM as a service organization is

CM provides support to others in a way that is seamless, comprehensive and eases the way so they can complete specific tasks needed for program performance while meeting program or project commitments levied through internal or external contracts. It anticipates the needs of those it supports before they arise and makes significant contributions to the overall goals of the organization by being proactive.

8.12.5 The Many Faces of CM

CM has many different faces or if you prefer hats that the CM professional needs to learn to wear comfortably.

CM also has many faces or hats that the engineering staffs believe are owned by CM that are not in truth owned by CM. In their eyes, their belief is the truth and CM must be aware of the perception and assume the responsibility to work issues that may exist in these areas as well.

8.12.5.1 Presenting a Coordinated Face to the Customer

A company should always speak with one voice to the customer. In some cases, the company may have several programs with the same buying office and that makes this harder to do. CM plays a very important role in this area.

It is recommended that the CM program managers for all programs with the same buying office stay in constant coordination with each other and use the same formats for reporting DRL status and other status to that buying office. It makes it easier for the customer and allows people to back each other up with less transition time.

8.12.5.2 Domestic ITAR Marking Inconsistencies

Should the guidance given by the designated ITAR official and the contract be different CM should hold off on providing anything to the program until after a meeting can be set up between CM, legal, and the designated ITAR official. The purpose of this meeting is for CM to broker an agreement between the parties and see to it that ITAR training on the program is provided. The contract and the designated ITAR officials should never be in disagreement relative to domestic ITAR legends.

8.12.6 The Property Management Interface

The more a CM professional knows about property management, the better it is for the company. Traditionally in programs, CM prepares DD Form-250 or COC and property management prepares the associated DD Form-1149.

CM has to be tied into the property management process not only to be able to provide guidance to property management on what unit price to put on DD Form-1149, but working with contracts to assure that residual property on the program are properly transitioned off of the program at when it ends.

8.12.6.1 DD Form-250, Material Inspection and Receiving Report

On many programs, it is CM's responsibility to complete DD Form-250 (Figure 8.5) and provide it to contracts management. Contracts management coordinates it with the customer's buying office to assure that the "Ship to," "Mark for" billing office and other information are acceptable. Once this has happened, CM needs to provide a copy of the document to property management, so that they can prepare DD Form-1149.

In order to prepare DD Form-250, CM needs to work in concert with contracts and the financial BA to assure that the unit and extended prices shown on the document are correct.

There are nuances to DD Form-250 that often get the company into trouble. Some of these include the following:

- Improper shipment numbers in block 2—they have to match the contract DIL or contract line item numbers whichever is applicable to the program.
- Improper dates in block 3.
- Improper acceptance points in block 8.
- Improper prime contractor information in block 9.
- Improper administered by information in block 10.
- Improper payment information in block 12.
- Improper shipped to information in block 13.
- Improper marked for information in block 14.
- Improper item number in block 15.
- Improper stock/part number information in block 16.
- Improperly filled out blocks 21a and 21b.
- Improper use of block 22.
- Incomplete information in block 23.
- Forgetting that the last DD Form-250 on the program has a "Z" appended to the shipment number in block 2.
- Not getting DD Form-250 signed off in at least block 22 and DD Form-1149 signed by both the losing and the gaining contracting officer prior to shipment.
- Because major variances (major and critical deviations and waivers) are a departure from the technical requirements baseline, all approved major variances need to be attached as an addendum to DD Form-250 along with full text copies of the approved documents.

In some cases, acceptance cannot take place until some event has taken place. On a spacecraft program, this may be on orbit acceptance after a specified time period for instrument dry-out in vacuum, subsystem-by-subsystem checkout after thermal balance is achieved, and then instrument checkout, as well as a complete set of spacecraft functional on orbit tests, are complete. Such acceptance is documented in block 22b of DD Form-250. This should not preclude the contracting officer from signing block 23.

MATERIAL INSPECTION AND RECEIVING REPORT						Form Approved OMB No. 0704-0248	
The public reporting burden for this collection of information is estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0248), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE ABOVE ADDRESS. SEND THIS FORM IN ACCORDANCE WITH THE INSTRUCTIONS CONTAINED IN THE DFARS, APPENDIX F-401.							
1. PROCUREMENT INSTRUMENT IDENTIFICATION (CONTRACT) NO.			ORDER NO.		6. INVOICE NO./DATE		7. PAGE OF
2. SHIPMENT NO.		3. DATE SHIPPED		4. B/L		5. DISCOUNT TERMS	
				TCN			
9. PRIME CONTRACTOR CODE			10. ADMINISTERED BY CODE				
11. SHIPPED FROM (if other than 9) CODE			FOB:		12. PAYMENT WILL BE MADE BY CODE		
13. SHIPPED TO CODE			14. MARKED FOR CODE				
15. ITEM NO.	16. STOCK/PART NO. DESCRIPTION (Indicate number of shipping containers - type of container - container number.)				17. QUANTITY SHIP/REC'D*	18. UNIT	19. UNIT PRICE
							20. AMOUNT
21. CONTRACT QUALITY ASSURANCE					22. RECEIVER'S USE		
a. ORIGIN ☐ CQA ☐ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents. DATE: _____ SIGNATURE OF AUTHORIZED GOVERNMENT REPRESENTATIVE: _____ TYPED NAME: _____ TITLE: _____ MAILING ADDRESS: _____ COMMERCIAL TELEPHONE NUMBER: _____					b. DESTINATION ☐ CQA ☐ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents. DATE: _____ SIGNATURE OF AUTHORIZED GOVERNMENT REPRESENTATIVE: _____ TYPED NAME: _____ TITLE: _____ MAILING ADDRESS: _____ COMMERCIAL TELEPHONE NUMBER: _____		
23. CONTRACTOR USE ONLY _____ _____ _____					Quantities shown in column 17 were received in apparent good condition except as noted. DATE RECEIVED: _____ SIGNATURE OF AUTHORIZED GOVERNMENT REPRESENTATIVE: _____ TYPED NAME: _____ TITLE: _____ MAILING ADDRESS: _____ COMMERCIAL TELEPHONE NUMBER: _____ * If quantity received by the Government is the same as quantity shipped, indicate by (X) mark; if different, enter actual quantity received below quantity shipped and encircle.		

DD FORM 250, AUG 2000

PREVIOUS EDITION IS OBSOLETE.

Reset

Figure 8.5 DD Form-250, Material Inspection and Receiving Report.

8.12.7 DD-1149, Requisition and Invoice/Shipping Document

Once DD Form-250 is completed and socialized with the contracting officer, CM provides a copy to the property administrator on the program with a request that DD Form-1149 to be prepared. When DD Form-1149 is received back from property management needs to be checked against DD Form-250 for accuracy.

This is part of the checks and balances that CM provides to property management and the program.

Once DD Form-1149 is reviewed and corrected, both DD Form-250 and DD Form-1149 have to be provided to the contracting officer through the company contracts. After the documents are signed off, the shipper is prepared.

When delivering an item from one U.S. government program to another, the contracting officer on the losing program and the contracting officer on the gaining program both need to sign DD Form-1149 prior to shipment.

8.12.8 Shippers and DIL Deliveries

There are often mandatory inspections that have to take place and container marking requirements that have to be met. CM is a key player in making sure that these take place. Each delivery should be planned, coordinated, and moved through the system by a team of production and CM. There needs to be stop and take assessment points along the process. The following questions need to be answered:

- Is DD Form-250 signed?
- Is DD Form-1149 signed?
- Does the shipper have notes in it that copies of the signed DD Form-250 and DD Form-1149 have to be in the shipping container with the originals in the contracts department's hands with a copy delivered to CM?

8.12.9 Certificates of Conformance

COC content contains much the same general information as a DD Form-250 using a less formalized format. The COC will identify the customer, item contracted for, item identification, quantity, unit price, unit of measure, extended price, all approved variances, and be signed by the company prior to signature by the customer.

8.13 Summary

Good CM practices are critical to the survival of any organizations regardless of which company you may work at. CM activities can be performed by one department or allocated across many departments. It is as important in the maintenance of an IT infrastructure as it is in maintenance of the configuration of a facility, piece of capital equipment, or a system or service sold to a customer.

How CM is implemented by the CM department within a company may embrace all aspects of CM as envisioned by the regulatory and guidance documents, may embrace a subset of them, or may be further reaching in scope. CM as practiced in a company is entirely dependent on the

allocation of responsibilities for performance of CM activities to one or more departments or the assumption of other department responsibilities to the CM department.

To truly implement the meaning behind the words “CM is chartered to perform Configuration Management, Data Management, Configuration Status and Accounting and Records Management in the broadest sense of the words” is a far reaching goal.

It presupposes that the CM practitioner has a firm grasp of the financial implications of the tasks they perform and the decisions that they make but that they also understand the risk posture of the program that they are assigned to and the direct impact that they have on meeting program risk and profit goals.

DEFINING CURRENT PRACTICE



Chapter 9

Configuration Management Baselines

9.1 Questions to Ponder

- Illustrate how product growth planning is accomplished via development baselines in an incremental and iterative development methodology.
- What mechanism drives functional baseline alterations?
- What mechanism drives allocated baseline alterations?
- What mechanism drives product baseline alterations?

9.2 Introduction

The idea of a baseline or baselining is not a new concept. The definition of a baseline as a point of reference from which a thing may be measured existed long before the advent of configuration management (CM) as a profession. During the performance of any project, program, or contract baselines exist in multiple forms. The fact that they are point-in-time definition often generates great confusion for those new to CM.

The following are the critical concepts to remember:

- It is a snapshot in time.
- It is a commitment point.
- It is a control point, also known as the point of departure.
- It is a way to measure where a product really is.
- It is controlled externally by a customer or it is established internally depending on where they occur and on the individual content of the review or the context of that review.

Just as a datum is a set of values to define a specific geodetic system with differences being known as a “datum shift,” East and West map coordinates of the Earth are established using lines known as “longitude.” These lines pass through the axis of rotation at points known as the “North” and

“South” poles. The Earth’s magnetic poles are not aligned with its axis of rotation. To read a map of the Earth’s surface, a datum shift known as a “declination correction” is made. Declination corrections are indicated on the map. The declination corrections for several locations on March 8, 2014, are shown below.* As can be seen, declination corrections are not static due to shifts in the magnetic fields of the Earth.

- *Afghanistan*: Kabul 2° 52′ 25″ E changing by 2.1′ E per year
- *Argentina*: Buenos Aires 8° 18′ 21″ W changing by 9.8′ W per year
- *Australia*: Canberra 12° 18′ 0″ E changing by 0.5′ W per year
- *Austria*: Vienna 3° 38′ 56″ E changing by 6.1′ E per year
- *Belgium*: Brussels 0° 27′ 22″ E changing by 7.7′ E per year
- *Botswana*: Gaborone 15° 29′ 10″ W changing by 2.0′ W per year
- *Brazil*: Brasilia 3° 38′ 56″ E changing by 6.1′ E per year
- *Canada*: Ottawa 13° 31′ 26″ W changing by 2.6′ E per year
- *China*: Beijing 6° 36′ 49″ W changing by 3.2′ W per year
- *Costa Rica*: San Jose 1° 11′ 53″ W changing by 7.5′ W per year
- *Denmark*: Copenhagen 2° 59′ 54″ E changing by 7.6′ E per year
- *Egypt*: Cairo 4° 3′ 33″ E changing by 5.2′ E per year
- *Fiji*: Suva 12° 17′ 45″ E changing by 0.6′ W per year
- *Finland*: Helsinki 8° 10′ 19″ E changing by 7.7′ E per year
- *France*: Paris 0° 0′ 15″ E changing by 7.7′ E per year
- *Germany*: Berlin 3° 7′ 24″ E changing by 7.0′ E per year
- *Iceland*: Reykjavik 14° 51′ 18″ W changing by 16.8′ E per year
- *India*: New Delhi 0° 53′ 40″ E changing by 1.4′ E per year
- *Italy*: Rome 2° 33′ 50″ E changing by 5.7′ E per year
- *Japan*: Tokyo 7° 6′ 20″ W changing by 1.0′ W per year
- *Kenya*: Nairobi 0° 32′ 47″ E changing by 3.3′ E per year
- *Korea, South*: Seoul 8° 2′ 13″ W changing by 2.0′ W per year
- *Mauritius*: Port Louis 18° 16′ 18″ W changing by 3.2′ E per year
- *Mexico*: Mexico City 5° 5′ 40″ E changing by 6.7′ W per year
- *New Zealand*: Wellington 22° 16′ 7″ E changing by 1.5′ E per year
- *Norway*: Oslo 2° 24′ 26″ E changing by 8.9′ E per year
- *Russia*: Moscow 10° 32′ 49″ E changing by 6.3′ E per year
- *Senegal*: Dakar 7° 51′ 36″ W changing by 7.0′ E per year
- *South Africa*: Pretoria 17° 44′ 26″ W changing by 4.2′ W per year
- *Spain*: Madrid 1° 14′ 29″ W changing by 7.4′ E per year
- *Sweden*: Stockholm 5° 18′ 5″ E changing by 8.0′ E per year
- *Switzerland*: Bern 1° 30′ 40″ E changing by 6.7′ E per year
- *Turkey*: Ankara 5° 16′ 36″ E changing by 5.3′ E per year
- *United Kingdom*: London 1° 7′ 26″ W changing by 8.5′ E per year
- *United States of America*: Washington DC 10° 53′ 23″ W changing by 0.9′ W per year
- *Venezuela*: Caracas 11° 58′ 13″ W changing by 5.7′ W per year
- *Zimbabwe*: Harare 8° 12′ 45″ W changing by 0.4′ E per year

* Calculated using NOAA. NOAA, U.S. (2014, July). *Magnetic Field Calculators*. Retrieved July 2, 2014, from <http://www.ngdc.noaa.gov/geomag-web/#declination>.

The degree of inclination shift East calculated over time for Carson City, Nevada, is shown in Figure 9.1.

Baselines defined by CM guidance documents and regulations also experience shift over time (Figure 9.2). IEEE Standard 828-2012* states “A baseline provides a logical basis for comparison. A specific version of a single work product by itself, or a set of work products together can be

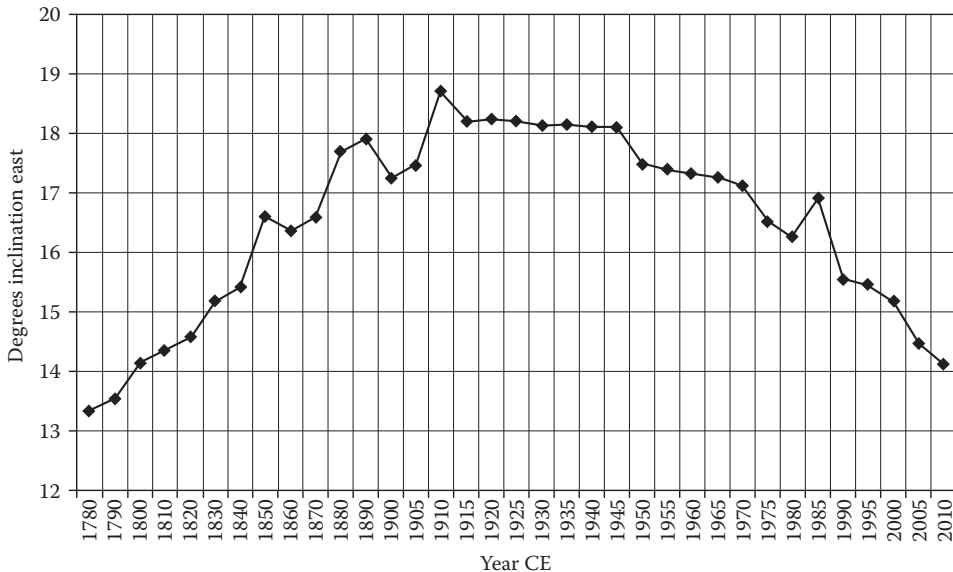


Figure 9.1 Inclination shift in Carson City, Nevada.

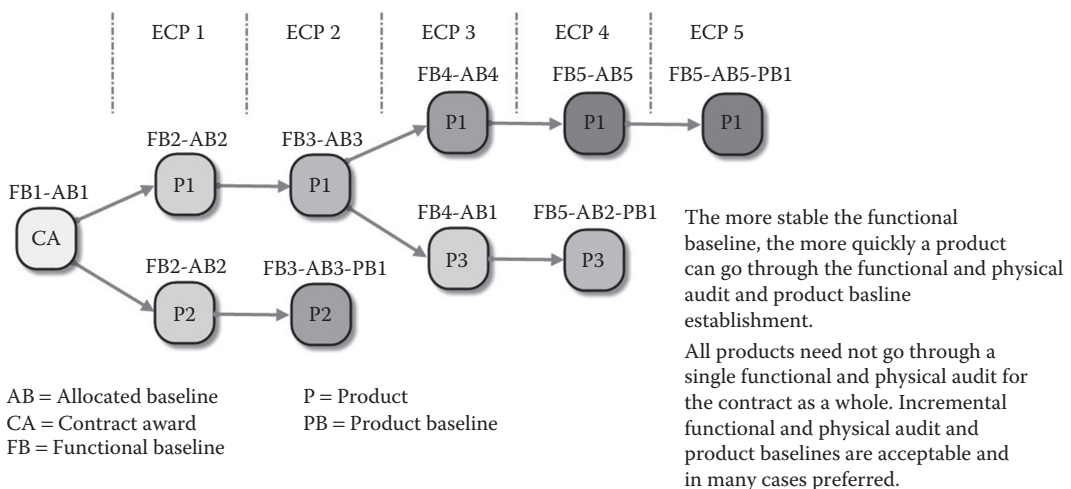


Figure 9.2 Requirements drift versus baseline.

* IEEE. (2012). *IEEE-828-2012—IEEE Standard for Configuration Management in Systems and Software Engineering*. IEEE, Piscataway, NJ.

established as a baseline.” It goes on to state that “During the course of product development, a series of baselines is established, enabling assessment of the evolving product’s maturity at different points in time.”

The program technical documentation forms what is known as the “functional baseline.” It is very dynamic over the life of a program. Changes to the program technical documents occur for a variety of reasons. Often specifications contain to be determined, to be reviewed, or to be specified requirements. They may also contain to be negotiated paragraphs or items. As the program progresses, these items are replaced with hard values or ranges that pertain to performance. Referenced documents in specifications or mission assurance requirements (MARs) may be modified to accommodate changes to statutory requirements. Interface requirements may change due to the capabilities of the other contractor if the customer is the systems integrator. Each such change ripples through the documentation and establishes a new functional baseline. This in turn creates a new allocated baseline with the associated design changes to accommodate it.

A recent very successful weather instrument program was required to comply with 58 different technical documents, which formed its technical or functional baseline. Over its decade-long developmental life, more than 238 changes occurred to the technical or functional baseline. Each of these changes impacted some portion of the allocated requirements baseline which in turn rippled through the developmental effort as well as the resultant end product. Some of the requirements documents changed as many as 26 times. This often-overlooked aspect is due to the program volatility resulting in the allocated baseline declaration being made multiple times. Some requirement allocations may remain static over the life of the program, whereas others drift rapidly and still others drift until months prior to acceptance of a product baseline for that particular element of the design.

If we step back from ANSI/EIA 649-B-2011 and look at the commercial processes with a systematic view, it is generally accepted that commercial firms have well-developed CM implemented in a far-reaching approach that firms relying on government sales can only dream of emulating. Commercial practices for the maintenance of products such as automobiles are incredible. True form, fit, function, and quality of original equipment manufacturer parts are available for products produced decades earlier. We will explore this further in Chapter 10.

Considerations must be given during the CM planning stage to accommodate such baseline movement. In many cases, they are tied to the nature of the program itself. Programs that also have a logistical component resulting from post point-of-sale customer support in the form of services or maintenance need to encompass functional, allocated, and product baselines for those logistical field and depot-level maintenance elements. This is in addition to any accommodations made for the end product itself. This is not a new concept and has been a part of the industrial base for decades. Leveraging the engineering and manufacturing development portion of Figure 5.8 forward, we arrive at Figure 9.3. We often find confusion as to what specific items should be identified as a configuration item (CI), as generally each such item will have its own allocated and product baseline. This implies that validation and verification audits will be performed on each. It is often easy to get lost in attempting to determine what the minimum CIs are, how to select them, and why they are selected.

From a commercial perspective, this starts with a predetermination of what portions of the final product are deemed cost effective to repair or replace. These items fall into two broad categories:

1. Parts that can be ordered and replaced by the owner (also known as “field level maintenance”)
2. Parts that can be ordered and replaced only at a repair facility (also known as “depot level maintenance”)

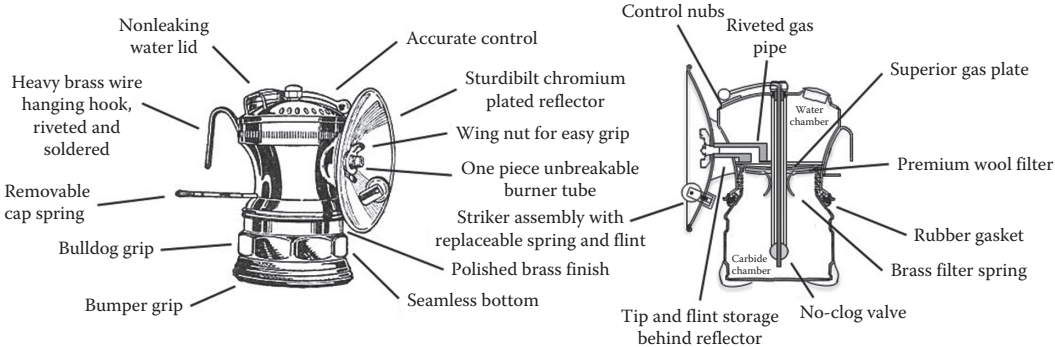


Figure 9.4 Auto-Lite™ carbide mining lamp. (Courtesy of Universal Lamp Co., Chicago, Illinois; Foreign Office: London, England—Oxford House.)

THE UNIVERSAL SUPPLY BOX

COMPLETE ASSORTMENT
OF REPAIR PARTS
FOR ALL MAKES OF
ACETYLENE MINE LAMPS

PACKED IN A HANDY
SHELF BOX

WHAT THE BOX CONTAINS
AND RETAIL PRICES:

3 Dozen Felts at 2 for 5c.....	\$0.90
3 " Round Gaskets at 2 for 5c.....	.90
3 " Flat Gaskets at 2 for 5c.....	.90
3 " Lava Tips at 2 for 5c.....	.90
18 Packages Flints at 5c.....	.90
1 Dozen Springs at 5c.....	.60
1 " Set Screws at 5c.....	.60
1 " Knurled Nuts at 5c.....	.60
	\$6.30

FOR A BRIGHT LIGHT USE THE AUTO-LITE

Figure 9.5 Logistical aspects of the Auto-Lite.

the lamps were marketed, as shown in Figure 9.5. In addition, Auto-Lite sold “The Universal Supply Box” that contained an assortment of repair parts used in most major competitor’s lamps. Such kits could be acquired by stores that did not specialize in mining supplies or carbide lamp sales much as vacuum cleaner belts are often available in today’s food marketplaces.

- Bumpergrip
- Ceramic and brass gas tips

- Superior gas plate
- Removable cap sprint
- Lamp brass bottom replacement
- Lamp brass filter spring
- Chromium reflectors (multiple sizes)
- Steele gas tip reamer
- Striker assemblies
- Striker flints
- Striker back nut
- Striker cap
- Tip protectors
- Rubber gasket
- Wing nuts
- Wool felt filters

The following sections will explore the basic tenants of the configuration baselines discussed in the current International Organization for Standardization (ISO) and Electronic Industries Alliance (EIA) standards. The role of CM is intertwined throughout the program and contractual infrastructure and not just with CIs. Chapter 8 addressed these other CM activities as they relate to the program and specific functional resources. Baselines or baselining is an adjunct to those activities what many feel as the crux of CM as a whole.

9.3 There Are Many Baselines

Section 5.2.5 of ANSI/EIA 649-B-2011* provides a generally accepted guidance regarding the functional, allocated, and product baselines as well as developmental configuration or design release baseline. Baseline relationships are shown in [Figure 9.6](#).

Many events such as a verification audit or a validation audit are known by many different names in different industries and in different countries. It is incumbent upon the CM professional to become adept in ascertaining the sense of what something is called and apply that root-level understanding in CM implementation and not fixate on specific words used by other firms to describe a particular CM function. As CM standardized guidance documents such as ISO and EIA gain acceptance, terms will become standardized.

An example of this seeking to understand may be seen in an evaluation of the product life cycle phases described in Chapter 1 against how they are defined in the company that relies on contracted awards as their source of revenue. Such a company may view the development phase as a program implementation phase, which happens after contract award rather than the start of independent development. In a similar way, the government may view development as a needs assessment for a particular mission such as a new aircraft. The CM professional needs to adapt and accept the role of a master chef rather than a cook. A cook relies on a recipe. Without one they are lost. A master chef can create a delicacy using the ingredients at hand.

* TechAmerica. (2011). *ANSI/EIA 649-B-2011, TechAmerica Standard: Configuration Management Standard*. TechAmerica, Washington, DC.

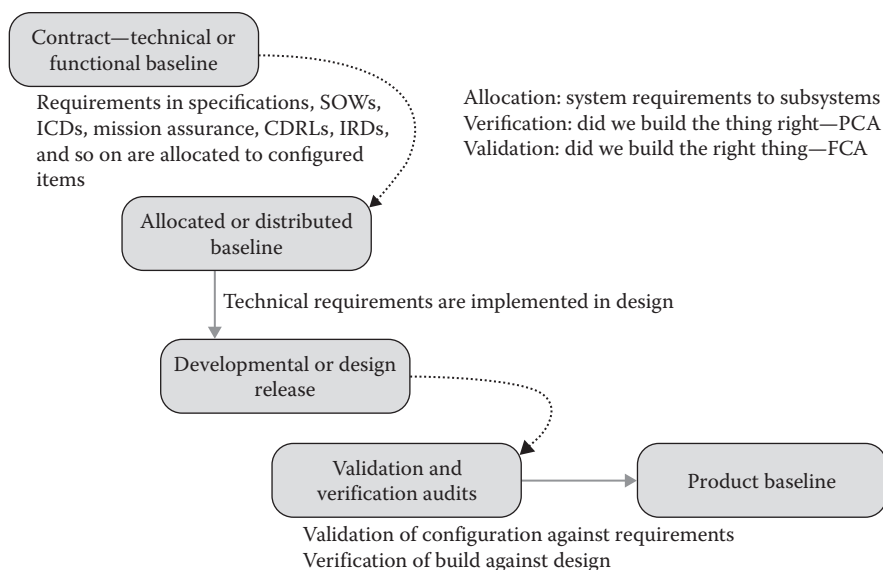


Figure 9.6 Baseline relationships.

9.3.1 Functional

Functional baseline is an integral part of the development phase of the product life cycle. It defines what the product is supposed to do, the regulations involved, the cost points and schedule, the target market, and other requirements such as testing, qualification requirements as well as acceptance and delivery/distribution criteria. ANSI/EIA 649-B-2011 is couched in terms of CM from the perspective of a prime contractor or a subcontractor, rather than from the perspective of a company providing goods and services to a public sector. The ANSI/EIA 649-B-2011 definition reads:

Functional (aka, Requirements) Baseline

The customer baseline established for a product when the contract or order is placed, representing the firm performance requirements for the product. The requirements are normally documented in a specification. The customer with whom the functional baseline is established may be one of the following:

- An external customer, i.e., a buyer for whom the product is to be developed and produced
- A management level or function within the organization, such as a marketing department, that represents many customers.

9.3.2 Allocated

Continuing with the ANSI/EIA 649-B-2011 definitions we find:

Allocated Baseline

Subordinate functional baselines are established for major components of complex products (configuration items) where it is determined that a separate specification of

performance requirements is appropriate. These subordinate “allocated requirements,” or “allocated” baselines, as they are frequently referred to, often establish requirements for suppliers of components of the complex product. In that case, the performing activity for the complex product assumes the role of customer to the supplier of the component. Requirements allocated to the supplier must be consistent with the requirements baseline for the complex product. Allocated baselines are of concern to the customer for the complex product only if contractually stipulated, or when allocated baselines are employed to incrementally verify performance of the complex product. The Allocated baseline approach allows complex work to be appropriately divided and assigned to subordinate work teams, while still ensuring that all of the above tier requirements have been “consumed” and allocated downward to the lowest appropriate level of design responsibility.

The functional and allocated baselines are often blurred in commercial development, with the allocation of requirements to systems and subsystems occurring as part of concept development rather than in stepped phases as in design development work that is in response to a request for proposal or a request for bid. Some recent LinkedIn discussions groups maintain that “... commercial development may use configuration management methodologies but they are not doing configuration management.” Perhaps the greatest reticence to acceptance of CM activities using the words “configuration management” is due to the practitioners of the discipline who are centric to the government sales market sector. They view CM from the focus of government sales with a long tradition of what some have defined as “old” CM dating back to 1966 with AFSCM 375-1. Many current CM guidance documents are leveraged forward from this government sales perspective rather than a discipline perspective that addresses all market segments.

9.3.3 *Product*

In the commercial world, a product enters the introduction phase of the life cycle after verification and validation activities have been completed. Extensive product testing and refinements are made during the prelaunch of commercial items. Components, subassemblies, assemblies, and the product itself have defined maintenance activities, repair manuals, user manuals, and parts inventory at dealers or authorized repair facilities. Often, strong partnerships under leveraged innovation development carry over into these logistical support functions.

Returning to ANSI/EIA 649-B-2011 definitions, we find:

Product Baseline

A baseline is normally established for a product at the end of the definition or development phase, when the design of the product is “frozen” for the Build phase. The establishment of the product baseline normally represents a change in the management level involved in configuration control. It is considered a customer-owned baseline where the customer could be a change authority internal to the enterprise or an external customer with a contractual relationship to the enterprise. This “product” baseline is highly significant because it normally becomes the basis for commitments for such things as production resources, materials, sales literature, training devices and material, and operating and service instructions. It is defined by the complete set of current product configuration documentation constituting the current design release baseline. Once the product configuration is fixed, it is changed only through appropriate configuration change management action. Typically this baseline is established after verification

that the product is in compliance with its requirements baseline. When a customer purchases an already developed product, the current product baseline defines the configuration of the product to be supplied, unless a configuration change is approved. The unit(s) of product delivered in the current product baseline configuration may differ from the configuration of earlier units, delivered to a previous baseline configuration.

The standard points out that the product baseline can either be owned by an internal or external customer. This is a very important distinction, as it attempts to include products developed to internal requirements for an external market segment as well as products developed entirely for an external customer such as for government use.

Looking at the Auto-Lite miner's lamp from this perspective, each of the component elements has the potential of being designated a CI incorporated into an all-inclusive CI, the lamp itself. To lend clarity to this concept of what is managed as a CI and as a result goes through verification and validation, it requires that we break the components into the categories of

- Product-specific design, development, and fabrication by the company
 - Company-designated CI
 - CM within the company itself
- Product-specific design, development, and fabrication by a supplier
 - Supplier-designated CI purchased as a part number
 - CM at the subcontractor
 - Purchased using a specification and statement of work
 - May be part of a leveraged innovation approach with the supplier being a partner in the development process
- Use of parts existing in the marketplace
 - May have been a CI at some point in the past
 - Currently available as a part number
 - Greatest concern is conformance to tolerances and quality

9.3.4 Developmental

ANSI/EIA 649-B-2011 refers to this as the design release configuration for good reason.

The set of design information incrementally released to date by the developing activity for a product during a product's definition (development) phase.

9.3.4.1 Design Implications

Each change processed after the initial release of the design modifies the design release configuration. Configuration status accounting reports on the current design configuration of any part, subassembly, assembly, or end product (these words are used loosely and include models, software modules as well as 3D printing image files) will yield different results depending when the report is generated until the product baseline is established. Such reports are simply a point-in-time picture of the design at a particular time stamp (e.g., the year, month, day, hour, minute, and second the report is run).

Many of the companies studied during the preparation of this book acknowledge the fluidity of the design release activities and chose to make no attempt to identify it as a separate state of existence within the product data/life cycle management (PD/LM) system itself (e.g., a separate

baseline). Their reasoning is that while the functional, allocated, and product baselines have specific contextual meaning, the design configuration is intrinsic to the design process itself and not critical to the artificially set review of the design itself such as a preliminary, critical, or test readiness review. As such the time spent capturing a design release configuration is an exercise that can be performed *ad hoc* or on demand at any point in time after the release of the first piece of engineering.

Occasionally, companies surveyed included “design release” or other “developmental” activities as a baseline event between the allocated and product baselines. This choice resulted in audit findings, as there was no easy way within the PD/LM system to move a design from one baseline state to another without a great expenditure of labor. Interestingly, those firms that decided on this alternative had no way to return to the functional, allocated, design release, or product baselines within the PD/LM system with the result that the only configuration status accounting data retrievable was the design release configuration. There simply were not the necessary data hooks in the PD/LM system programming to allow this to happen.

9.3.4.2 Change Implications

Where the moving design release configuration data comes into its own is in the analysis of change impact. Configuration status and accounting reports, if properly programmed, do facilitate an evaluation of design interdependencies. This requires very careful attention not only to the product structure but also to the document structure. Such design interdependencies can be improved if the PD/LM system used is capable of establishing not only familial relationships of the affected item but also nonfamilial relationships of the related item external to the direct parent–child hierarchy, as shown in [Figure 9.7](#).

Assuming that all familial and nonfamilial relationships are established between items in the PD/LM system, assessing the true impact of a proposed change can be evaluated with a higher percentage of capturing all impacts of a change than when such impacts are based on the designer’s evaluation alone. Despite best efforts, design impacts are often overlooked during change evaluation. The design impact evaluation error rate in a horizontal functional organization has been observed over a period of 37 years and was found to be over 20% greater than in a vertically oriented program structure. This is not to imply that vertically oriented program structures are error free or that horizontal program structures are error prone. What is evident from the companies studied is that there is a greater need for communication tools such as the familial and nonfamilial relationships capturing capabilities present in most modern PD/LM system. Even greater benefits exist if the PD/LM system is integrated with the production system so that once identified change impacts through final disposition of the affected items can be scheduled and verified.

9.4 Triggers for Moving from One Baseline to the Next

The events that trigger the establishment of a baseline and the movement of a design from one baseline to the next are often defined by the nature of the product itself. In the case of the Auto-Lite miner’s lamp, every modification to the lamp design after first unit production established a new allocated and a new product baseline. These updated designs and the resultant baselines were mandated by the marketplace based on customer feedback and the necessity to maintain market share in the mining equipment market segment. The rise in popularity of the sport spelunking

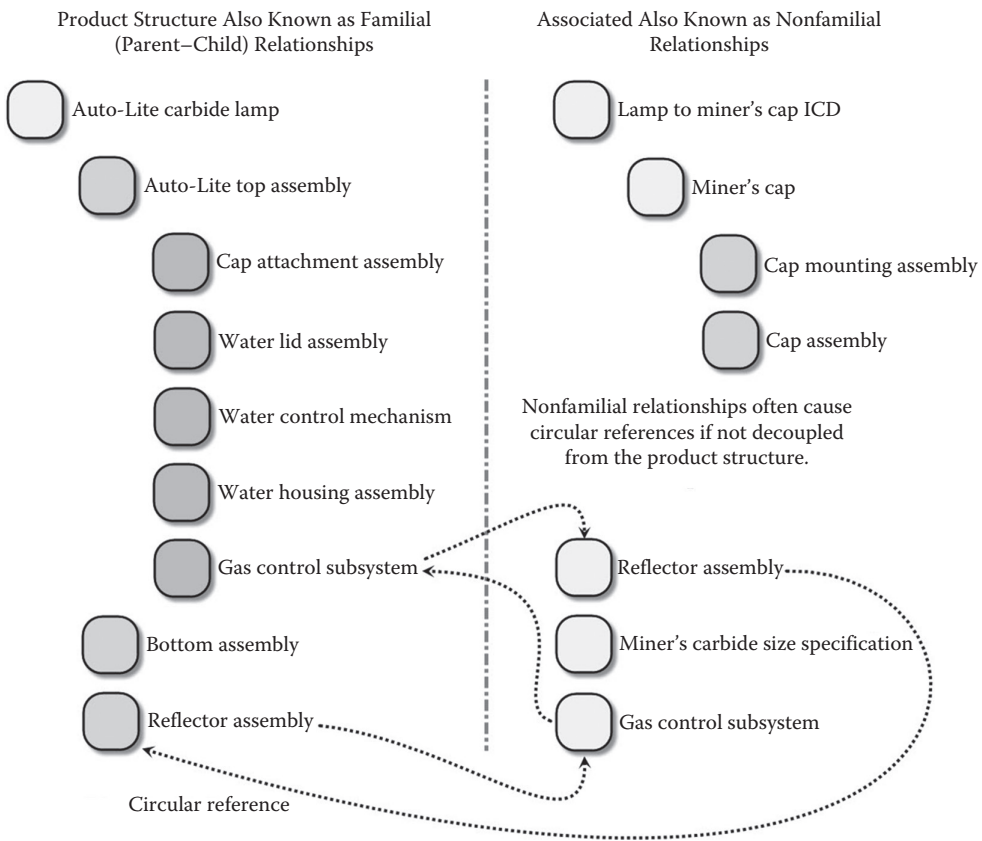


Figure 9.7 Familial and nonfamilial PD/LM structure.

artificially kept the market vibrant long after the need for mining using carbide lamps started to dwindle.

Contractual relationship such as with a government or as a subcontractor often includes set events that determine the movement from one baseline to another. Occasionally, the results of an event such as a critical design review or a validation audit will necessitate the design be modified to meet the functional baseline technical requirements. This is generally due to loss of the functional allocations or a loss of change control due to poor change impact evaluation. In such cases, delta preliminary design, critical design, and validation events become a necessity.

9.4.1 CM Implications of a Product Baseline

Once an item has been validated and the manufacturing against engineering has been verified, the product baseline is established. The design is said to be frozen and it is turned over to a much stricter level of management with changes being approved by a body other than the design activity itself. This may be a product control team within the company or it may be the customer buying office.

The idea of minor or class II changes become mute at this point as *customer* approval is required for any modification including part substitutions during the fabrication process or design updates

due to part obsolesce. This aspect of a product baseline is often not fully understood by the engineering staff in those cases where the product is designed for a government and there is no intent to build a second unit. There is no engineering reason for a government customer to mandate a formal functional configuration audit (FCA) or physical configuration audit (PCA) to establish a product baseline on a contract for a one off fabrication.

Validation and verification are required but a formal FCA or PCA implies the establishment of a design that is needed for multiple quantities of the same item. PCA in such cases may include complete disassembly of the first or second unit produced (the first unit may have been used for item qualification activities) and measuring each physical part to its associated drawing requirements for tolerance of manufacturing, surface coatings as well as reassembly using released assembly drawings. One PCA we are aware of took six weeks to accomplish these activities.

We are also aware of cases where government contractors have knowingly used a redline engineering system, did not incorporate these redlines, and as a result failed not only to disclose the fact redlines existed but also delivered a technical data package to the customer that was impossible to build, negating the contractual requirement to develop such a package to maintain the industrial base. This double bookkeeping of the actual design versus the released design was cited by several government personnel as detrimental to all contractors as well as to those relying on the deployment of functional systems to the individuals in harm's way.

STS-41-C was NASA's 11th Space Shuttle mission. One objective of the mission was to repair the malfunctioning Solar Max satellite. Added multilayer insulation attachment points on the redlined engineering were not incorporated into the released *product* baseline documentation and interfered with a special capture tool, called the "Trunnion Pin Acquisition Device" (TPAD). Three attempts were made using the TPAD. Eventually, Solar Max was commanded from the ground to enter a slow spin and the satellite was captured using the "Canadarm" Remote Manipulator System arm and redeployed. The lack of clean configuration documentation resulted in a one day extension to the STS-41-C mission as well as a near critical expenditure of the orbiter's reaction control system fuel.

One beneficial outcome of the Solar Max experience and similar events is a marked trend by industry to limit redlined engineering to test documentation during the test phase with a requirement that all such redlines be captured in the PD/LM system.

9.5 Baselines and Configuration Identification

So far, we have discussed the essence of a configuration baseline. What remains is the relationship between baselines and configuration identification. On the surface, configuration identification is rather simple. It simply implies that a product is identified in a way that distinguishes it from every other product produced by not only your company, but from every other company producing similar products. We can call this configuration granularity. Other forms of granularity exist in CM such as data granularity associated with medical coding, as touched in Figure 6.2. For CM purposes, granularity is defined as the degree of identification required to provide the level of understanding necessary to distinguish one thing from another. In the case of ICD-9 versus ICD-10, the level of granularity increases to more clearly identify procedure and injury location.

In a similar way, proper configuration identification facilitates post-delivery support and maintenance of a product in the production baseline as well as ensuring that the correct part

configurations are used during final assembly, test, and qualification activities. Traditional practices such as assigning a single configuration identifier to a family of a printed wiring boards despite board unique white wire changes modifying board functionality are giving way to utilization of item identification for each unique configuration. Tracking item lot date codes for electrical components to the installed location on a wiring board is increasingly mandated in government MARs.

The tie or relationship between configuration identification and baseline state has also seen a dramatic shift over the last two decades in many companies where the government sector is not their primary income source. This shift has resulted in items being re-identified as they move through the design, development, fabrication, and test cycles. Figure 10.1 concerns only the part number identification process at these companies.

9.5.1 Phase-Based Item Re-Identification

Often, item re-identification, as it moves between one baseline and the next, is more sophisticated in some business sectors than in others. The reluctance to re-identify parts as they move from prototype to product development, to fabrication, to test, and to distribution is taken as the normal flow. Two distinct versions of phase-based item re-identification were observed.

Item re-identification is also more sophisticated in software CM than in hardware CM. One approach to a phase-based part re-identification system is shown in [Figure 9.8](#). Suffix designators are used to denote items as they are tested, accepted, and passed out to assure that applicable items are properly tracked and not comingled in inventory.

9.6 Validation and Verification in Nongovernmental Sales

The most sophisticated implementation of configuration principles is always found in those industries where human health is involved. On April 10, 2014, Food Seminars International offered a seminar with the title “Validation and Verification 101: What you need to know.” To those who are governmental sales centric, this may appear to be an odd topic for the food industry; however, on closer examination, the need to understand the differences between the U.S. Department of Agriculture and the Codex Alimentarius Commission, established by FAO and World Health Organization in 1963, as a product moves along its life cycle is part of product CM. Perhaps another factor in the advances made in the market sector where health is involved is that verification at hazard analysis critical control points and critical control points encompasses validation throughout the process with a distinct focus on product risk (microbiological, physical, chemical, or allergenic) as well as process capability. The lack of robustness in the process has direct implication to human longevity.

In many other product sectors, this real-time need to assure product to rigorous standards, although the same in basic CM principles, takes on unfamiliar forms of processes that are much more flexible and capable than those used in the relatively static configuration environment of industries reliant on only governmental sales for their livelihood. Even firms with a small-to-medium governmental sales reliance as part of their entire product offering have an advantage in the area of CM implementation over those who do not have commercial sales of the same or similar items sold to government customers simply because those systems are required to survive in the commercial sector.

	<i>Prototype</i>	<i>Final Design</i>	<i>Fabrication</i>	<i>Test Complete</i>	<i>Acceptance</i>	<i>Phaseout</i>
Mark 1	1234567-101P	1234567-101	1234567-101	1234567-101T	1234567-101TA	1234567-101TAP
Mark 2*	1234567-201P	1234567-201	1234567-201	1234567-201T	1234567-201TA	1234567-201TAP
Mark 1	1234567-700	1234567-001	1234567-001	1234567-101	1234567-201	1234567-301
Mark 2**	2234567-700	2234567-001	2234567-001	2234567-101	2234567-201	2234567-301

* The first update after first sale is distinguishable as being part of the part family in the dash number.

** The first update after first sale is distinguishable as being part of the part family in the root number.

In all cases, part designs that are scrapped or discontinued are replaced with a new out of family item identification

Figure 9.8 Phase-based part re-identification.

9.7 Product Acceptance

The underlying purpose of CM as a profession culminates in the acceptance of the products produced for a customer. The discussion regarding verification and validation of processes in the food industry is related to products known as “nondurable goods,” as they are consumed upon sale or shortly after sale. Products such as mechanical devices are known as “durable goods.” In the commercial sector, for a one off or limited quantity sales, and in the governmental sales sector, two primary forms of acceptance are often utilized. These were discussed in Chapter 8 and are the DD Form 250 and the certificate of conformance.

Chapter 10

Configuration Control

10.1 Questions to Ponder

- What happens to your product and project when there is insufficient control over the configuration?
- How do changes during development impact the contract closure phase of the project? Describe the relationship between contract closure and configuration control.
- Draw an appropriate change management process for your company.
- List the sorts of items that should be addressed via configuration control.
- Why would we relax our configuration control during development? How can excessive controls impact the engineer's discovery process?
- Describe the activities associated with configuration status accounting. Do these help control the configuration? If so, how?
- Describe the activities associated with configuration verification and audit. Do these help control the configuration? If so, how?
- What role does configuration status accounting play in the control of configuration?
- Describe the objective of the functional configuration audit?
- Describe the objective of the physical configuration audit?

10.2 Management of a Configuration

Our research has shown a sharp division between market segments regarding not only what is deemed necessary to manage but also the depth in which it is managed, as it pertains to configurations. Perhaps the varying opinions and heartfelt discussions center on the word “configuration” itself rather than any deep-rooted disagreement pertaining to basic management concepts. Generically, this book may be viewed as a configuration and in some of the prevailing standards documents can be configured (configuration) items. Others practitioners maintain that management of configurations pertains only to hardware, software, and firmware. Regardless of the approach and mindset, configuration management (CM) is done at an enterprise level and not relegated to only items

predetermined to warrant it and requiring it to be labeled as a configuration item (CI). Practitioners participating on LinkedIn forums have been so bold enough to state that “CM is not practiced outside of the U.S. Government sales market segment and that while elements of CM do appear elsewhere it is not CM as CM is only tied to CIs and CIs only exist if you are a government contractor.”

Our research has shown that this U.S. government’s sales-centric view is simply due to hubris on the part of the practitioners and not based in fact. When questioned on the applicable aspects of CM, a few were aware of the entire picture and negated the fact that the U.S.-related CM standards were written primarily as guidance to U.S. government employees and adopted in various ways by the companies selling to the government. We feel safe in stating that no U.S. government standard or handbook was ever written to train government contractors in how to do CM. CM implementation by those contractors had to be deduced from the standards written by the government for government employees.

The thrust of these documents has been simply a description of what has to be done or how to do it from the government’s perspective. This trend continues today throughout much of the documentation that is cited by CM professionals as the driving force behind what they do.

Although there may be disagreement regarding document CIs, documents do require strict CM if they are deemed to be of significant value. This includes establishing within a company or customer’s organization a few simple rules that are crucial to communication and requirements traceability. The cost savings associated with having developed a standardized statement of work, specification, mission assurance requirements document, and interface control drawing format for use on every program is staggering. The key to success is not in the generic template but in never deleting a paragraph header. If a paragraph is not required, the paragraph number and heading is maintained and the next line is identified simply as “Reserved.” This means that all specifications will always have the same requirement in the exact same paragraph (e.g., within all specifications 3.2.4 is assigned to “Reliability” and addressed in the same place in every specification created). At the start of the program, all requirements are laboriously decomposed into functional requirements that are input into requirements management tool(s). Every “Shall” statement is assigned a separate identifier in the tracking system and each is in turn allocated to a system or subsystem. This kind of requirements management is shown in [Figure 10.1](#).

Unfortunately, in many companies evaluated over the years, a costly trend was observed. Documents renumber paragraphs with each new document created from a template. Paragraph renumbering was observed between revisions of the same document. Anytime the paragraph numbering is altered by deleting a requirement and its associated paragraph numbering, the entire process has to start over. This is a poor precedent to start as tremendous cost savings result when requirements traceability is preserved, as shown in [Figure 10.2](#).

10.3 CM Is a Management Tool

CM in the final analysis is simply a management tool like any other and it comes in many disguises. Sometimes, even CM professionals fail to recognize it. Sometimes, it is distributed to other organizations. Sometimes, it is consolidated in one organization. It always exists in some form regardless of who is doing it. It is all around us.

Do you have \$10 in your purse or wallet? What color is the pen in your pocket or purse? What is in your child’s lunch box today? What did you order the last time you had a bad meal? How many of the items you ordered from an Internet vendor have not been delivered yet? When is the mortgage payment due? When does the warranty on your car, dishwasher, TV, and washer expire? What

<i>Customer Req ID</i>	<i>DOORS ID</i>	<i>Unit Specification, 1-543A-78B-6 Revision A</i>	<i>Verification Method</i>
	PSS-35	3.2 Lifetime and Reliability	
	PSS-36	3.2.1 Mission Life	
Unit_Spec_010	PSS-37	The mission life of the unit shall be no less than 10 years after acceptance.	Analysis
	PSS-38	3.2.2 Storage Life	
Unit_Spec_010	PSS-39	The unit shall not be degraded during two years of storage.	Analysis
	PSS-40	3.2.3 Storage Compatibility	
Unit_Spec_010	PSS-41	The unit shall be designed to be compatible with ground storage requirement 3.2.2	Analysis
	PSS-42	3.2.4 Reliability	
Unit_Spec_010	PSS-43	Unit reliability shall be greater than 0.985 after seven years of operation plus two years of storage prior to operational use.	Analysis
	PSS-44	3.2.5 End of Life	
Unit_Spec_010	PSS-45	Unit reliability at end of life (EOL) at 10 years of plus two years of storage prior to operational use shall be greater than 0.975.	Analysis

Figure 10.1 Typical requirements tracking in DOORS.

<i>Requirements Change Preferred</i>			
<i>Customer Req ID</i>	<i>DOORS ID</i>	<i>Unit Specification, 1-543A-78B-6 Revision B</i>	<i>Verification Method</i>
	PSS-35	3.2 Lifetime and Reliability	
	PSS-36	3.2.1 Mission Life	
Unit_Spec_010	PSS-37	The mission life of the unit shall be no less than 10 years after acceptance.	Analysis
	PSS-38	3.2.2 Storage Life	
Unit_Spec_010	PSS-39	The unit shall not be degraded during two years of storage.	Analysis
	PSS-40	3.2.3 Storage Compatibility	
Unit_Spec_010	PSS-41	RESERVED	Analysis
	PSS-42	3.2.4 Reliability	
Unit_Spec_010	PSS-43	Unit reliability shall be greater than 0.985 after seven years of operation plus two years of storage prior to operational use.	Analysis
	PSS-44	3.2.5 End of Life	
Unit_Spec_010	PSS-45	Unit reliability at End of Life (EOL) at 10 years of plus two years of storage prior to operational use shall be greater than 0.975.	Analysis

Figure 10.1 (Continued)

Requirement 3.2.3 is found to be a duplicate of requirement 3.2.2.

The specification is updated to remove the duplication at revision B.

Preferred method preserves requirements traceability.

Preferred Method

Unit Specification, 1-543A-78B-6 Revision B

3.2 Lifetime and reliability

3.2.1 Mission life

The mission life of the unit *shall* be no less than 10 years after acceptance.

3.2.2 Storage life

The unit *shall* not be degraded during 2 years of storage.

3.2.3 Storage compatibility

RESERVED

3.2.4 Reliability

Unit reliability *shall* be greater than 0.985 after 7 years of operation plus 2 years of storage prior to operational use.

3.2.5 End of life

Unit reliability at EOL at 10 years of plus 2 years of storage prior to operational use *shall* be greater than 0.975.

Unit Specification, 1-543A-78B-6 Revision A

3.2 Lifetime and reliability

3.2.1 Mission life

The mission life of the unit *shall* be no less than 10 years after acceptance.

3.2.2 Storage life

The unit *shall* not be degraded during 2 years of storage.

3.2.3 Storage compatibility

The unit *shall* be designed to be compatible with ground storage requirement 3.2.2

3.2.4 Reliability

Unit reliability *shall* be greater than 0.985 after 7 years of operation plus 2 years of storage prior to operational use.

3.2.5 End of life

Unit reliability at end of life (EOL) at 10 years of plus 2 years of storage prior to operational use *shall* be greater than 0.975.

Not Recommended

Unit Specification, 1-543A-78B-6 Revision B

3.2 Lifetime and reliability

3.2.1 Mission life

The mission life of the unit *shall* be no less than 10 years after acceptance.

3.2.2 Storage life

The unit *shall* not be degraded during 2 years of storage.

3.2.3 Reliability

Unit reliability *shall* be greater than 0.985 after 7 years of operation plus 2 years of storage prior to operational use.

3.2.4 End of life

Unit reliability at EOL at 10 years of plus 2 years of storage prior to operational use *shall* be greater than 0.975.

Figure 10.2 Preserving requirements traceability.

is involved with and how much is it going to cost to re-landscape your front yard? What are the real costs and impacts of buying a new vehicle and when do you reach the breakeven point if you adjust it for depreciation, fuel costs, maintenance, and such compared with continuing to maintain your current vehicle? What is your blood type? What immunizations have you had? Are they current and what new ones do you need for that trip to the United States, Costa Rica, or India? What isle of the store is the coffee on? What is the expiration date of this product? How much cholesterol is in that taco, can of soup, ice cream, and latte? All are aspects of CM as they relate to an individual.

This leads to the question, “What is the purpose of CM?” At its simplest, CM is a way of thinking and managing information and change critical to product/program, enterprise, and regulatory aspects of anything. Judith Blaustein’s definition,* “CM acts as the DNA of systems,” is eloquent. It ties CM to the core of what it means to be human.

10.4 The CM Tower of Babel

Studies of the origins of language, their proliferation, and eventual collapsing back to basic new types reveals that at one point, nearly 400 different languages were spoken in Australia prior to European influences. These may have originated from a common root language or set of root languages with divergence occurring as the continent was peopled. Pidgin (simplified) languages may also have developed in trade situations that took on a life of their own adding to the linguistic base. Today, the indigenous linguistic base has collapsed to approximately 70 distinct forms, 40 of which are endangered and 15 are still widely used.

This offers insight into what is observed in CM terminology in many market segments today. Distinct divergence in CM-related terminology can be traced to the emergence of new technologies and new industry organizational subtypes resulting from those technologies. There is a non-linear expansion of not only terminology, but what appears to be a single-minded divergence of CM methodologies tied directly to technological innovation (Figure 10.3).

This has left many CM professionals rather adamant that there is old (e.g., old school) CM and something called “new” CM. LinkedIn discussion groups have also pronounced that four main CM types exist:

1. *Old CM*: Hardware-related CM
2. *New CM*: Software and firmware CM
3. *IT CM*: Information technology (IT) CM of servers and computing assets
4. Knowledge management CM

In actuality, CM is being implemented or it isn’t, there is no CM implementation specific to a single discipline or time. Terms like Old CM, New CM, IT CM, Knowledge management CM are meaningless. The specific linguistics used to describe CM implementation attributes will change with the market sector and are in vogue for a short time in many areas due to the current state of the tools used in each market sector. They are not driven by the management tool known as CM itself.

It is the premise of this book that management of configurations is ingrained in the human experience. As a management tool, it has existed since hunter-gather times and critical to the

* Judith Blaustein. (2013). *What Is the Purpose of CM?* Judith Blaustein of Blaustein and Associates. Accessed on November 13, 2013, from https://www.linkedin.com/groups/What-is-purpose-Configuration-Management-4393863.S.263480123?trk=groups_most_popular-0-b-ttl&goback=%2Egmp_4393863.

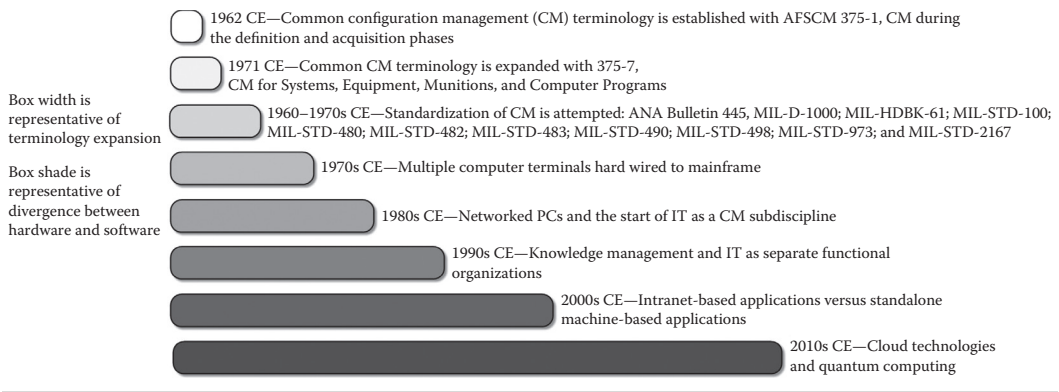


Figure 10.3 Events tied to CM language divergence.

present. As societies moved from a nomadic to a pastoral existence, the need to manage the configuration of the surrounding world became more complicated. Livestock were improved through selective cross-breeding with the hope of animals with greater physical bulk or better-tasting flesh or greater yield of milk or eggs. Grains were selectively harvested resulting in the plants so chosen developing a narrower viable ecological niche as well as larger seed yield.

During the period of the great guilds, apprentices learned all aspects of product CM associated with their trade. A master smith could start with raw materials and make everything required to set up a profitable enterprise in any village or town large enough to support their particular trade. Configurations of the tools, materials, processes, testing, and bringing product to market were understood and could be replicated or modified with a clear understanding of what was being done and why. A master tradesman was a living treasure and the physical embodiment of their craft. A smithy could stand unmolested by warring factions at any crossroads for generations due to the recognized value of the body of knowledge and capabilities of the smith in a respected and protected environment that transcended shifting political boundaries.

As societies grew, the markets providing the majority of consumable goods consolidated. Small firms supplying superior product succumbed to firms able to provide a similar but lesser product at a lower cost. Market variability was greatly eliminated in favor of consumables with brighter color that, while lacking in robustness of flavor, were available for longer periods and durable goods that, while not inspirational, were serviceable. Although one could still purchase specialty items, the cost of doing so outweighed the advantages. Many found little need to pay for porcelain dinnerware displaying their family crest when they could dine on dinnerware identical in every detail to that used by royalty at a lower cost?

Public and political backlash against inferior product or product deemed dangerous to government resulted in regulatory control. Court favoritism manifested itself in trade monopolies and government to government antagonism with trade sanctions. The economic engine often spurred on by government continued. Product became more complex and the management of product required new theories and in some cases old theories repackaged in current terminology. This is where we find the scope of management of configurations today.

Specialization of product has hidden the CM bedrock with detritus, making it hard to recognize the fundamental management principles. So what was that bedrock that has become obscured? Different organizations within a single organization see CM differently. Yet at that bedrock level, it is still CM. Put simply, everything involves CM from what is in one's billfold, to

what is in one's financial portfolio to what is in one's closet to what one eats for lunch all of the element required to prepare that lunch as well as everything around us manipulated by human kind since the beginning of time.

10.4.1 Use Drives the CM Planning and Management Systems Design

Chapter 1 explored adaptive radiation in engineering. This can be used as a metaphor for what is currently observed in the world marketplace as it is related to CM practice. The majority of market segments are driven to produce product acceptable to large purchasing base (this product type will be referred to as “multiple build end items” to simplify the discussion). A subsector of the sales in all market segments are low-volume highly specialized items (this product type will be referred to as “one-off end items” to simplify the discussion).

10.4.1.1 Multiple Build End Items

Interviews and online discussions during a period of 20 years with over 750 CM professionals in multiple market segments have culminated in a very interesting finding. The closer the CM professionals were to the commodity market, the better was their overall grasp of the full spectrum of managing configurations and the applicability of CM to their product. CM at each product level relies on sound CM of the items sourced from the level below. The more automated the production process, the more reliant the producer is on the consistency of those sourced items and the more catastrophic the results of poor CM.

During the early days of chemical formulations for scientific research and subsequently for mass production of medicines, the purity of the chemicals used was paramount. Only with the use of chemicals that were untainted by other elements or compounds could the effectiveness of medicinal compounds be quantified and replicated. This lack of CM in principle was one premise behind the inability of Dr. Robert Campbell to replicate a proven cancer treatment in the movie *Medicine Man*.^{*} Production of chemicals, chemical compounds, and other raw materials formed one end of the product supply chain. It also started the deepest root of the CM implementation of any product.

Multiple build end items are items sold to any customer without customization for that customer's unique needs. Automobiles fall into this category as do computers and almost anything the general public can purchase. Generally, any configuration an individual can order from all available options can also be ordered by someone else. Some multiple build end items may have limited product runs. Purpose build fly rods are an example. Due to the rapidly developing composites technologies, a company may decide to build 1000 units before changing technologies. The fact that the purchaser can have their name imprinted on the fly rod does not remove it from the multiple unit fabrication classification. Any other purchaser can have that same name imprinted on another copy of the 1000 unit run.

10.4.2 Six Sigma

What makes CM particularly challenging on multiple build end items is CM of processes and acceptance criteria to assure the suitability of all products sold. This leads us to a movement toward what is known as “Six Sigma.” Six Sigma methodology was originally developed by Motorola in

^{*} McTiernan, J. (Director). (1992). *Medicine Man*. [Motion Picture].

$z\sigma$	Percentage
1σ	68.27%
1.645σ	90%
1.960σ	95%
2σ	95.450%
2.576σ	99%
3σ	99.7300%
3.2906σ	99.9%
4σ	99.993666%
5σ	99.9994267%
6σ	99.999998027%
7σ	99.99999997440%

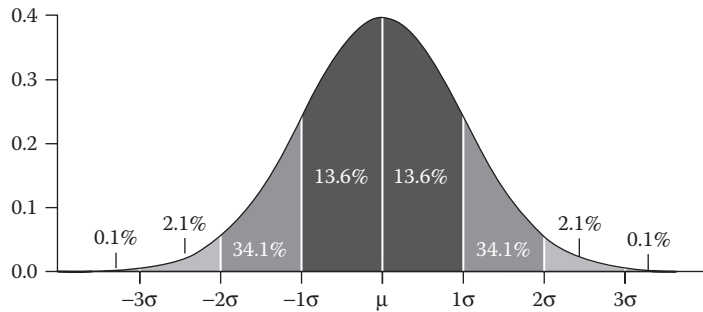


Figure 10.4 Rules for normally distributed data.

1968 and is deeply rooted in probability analysis and something called “root mean squared,” which helps to calculate how far something is (standard deviation) from the mean value of all things being evaluated. The math is relatively simple but can be dispensed with by understanding that Six Sigma is 6 standard deviations away from the mean on a normally distributed dataset. Something is said to be within one sigma of the mean if it falls within the range of -1 sigma to $+1$ sigma.

If a data distribution is approximately normal (Figure 10.4), then about 68% of the values are within 1 standard deviation of the mean, about 95% of the values are within two standard deviations and about 99.7% lie within 3 standard deviations. This is known as the “68-95-99.7 rule,” or the “empirical rule.” Processes that operate with “Six Sigma quality” over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities. A survey of multiple industries found that many firms are claiming Six Sigma capabilities that have never built anywhere near a million items. Many actually have only proven Two Sigma capabilities and are claiming Six Sigma capabilities based on forward-looking statements. This concept of standard deviations and their relationship to Six Sigma is easier to understand with a simple graph than with text.

10.4.3 Multiple Build End Item and a Product Baseline

Historically, product baselines were established for those items that were entering the U.S. government inventory in sufficient quantities to ensure uniformity of product. Design authority was removed from the product developer and design changes were elevated from minor to major (e.g., class II to class I). Internal to the government, the design was frozen and no changes could be made unless mandated by the government. The product baseline is established concurrent with functional configuration audit (FCA) and physical configuration audit (PCA) activities.

There is a long history of nonconforming product in the annals of every nation. Establishing a product baseline was seen as one way to limit and perhaps eliminate this issue in the post-inter-national conflict of 1918 referred to as “World War I period.” What followed eventually resulted in what can best be described as a form of administrative insanity resulting in product specifications for almost everything purchased by the U.S. military, including items such as MIL-F-3897, military specification fruitcake bar and MIL-C-1161, collar, dog, and leather.

During the post-Korean conflict years (1950–1953) in the United States, it was discovered that the administrative investment involved with management of the complexities of this approach outweighed the advantages, and many of the specifications associated with commodity items were

made inactive as better or equal products were commercially available for a much lower cost. The advent of International Standards Organization (ISO), standards have resulted in further savings on most multiple build items used by the U.S. government.

10.5 One-Off End Items

One-off end items were the norm prior to the industrial revolution and are found only in high-end products of any market segment.

Products developed specifically for government use fall into this category. With the exception of firearms, ammunition, and other defensive and offensive items carried by military personnel, most items rarely see production runs above ten thousand units. This has led to an interesting phenomenon relative to Six Sigma at some companies with a logic stream that runs like this:

- I am only producing one item
- I do not get paid if it does not meet acceptance criteria
- If it passes, then 100% of production units are accepted
- Therefore, the product when accepted is produced at higher than Six Sigma levels

Although the first three statements may be true, the fact remains that only a one-off capability has been demonstrated and the product is produced in a less than one sigma environment.

A second phenomenon has been observed in the U.S. government agencies relative to one-off end items. Despite the fact that only one such item will ever be produced (as is the case with an operation weather satellite), many contracts contain requirements for formalized FCA and PCA events and product baseline establishment and submittal of a technical data package (TDP).

It is understandable that an operational asset requires physical and functional evaluation. The cost associated with formalized audits and preparation of an engineering dataset of high enough fidelity to allow a second source to manufacture and test a duplicate item in an environment of rapid technological change must be questioned. Many electronic-based technologies refresh on about a three-year cycle with some refreshing in as little as nine months. Given an average three-to-five year design and build cycle for a single-instrument spacecraft, the technology being flown is outdated before ignition of the booster carrying it into space.

Parallels exist across all market segments and all customer bases. In the majority of cases, the producer does a much better job of maintaining documentation required to reproduce one of their products than the consumer. Consumer electronics is often in the forefront with updated owners, operations and repair manuals, parts, and upgrades available via web-based support sites.

10.6 Management of Change

Unmanaged change abounds in the natural world as flora and fauna adapt to environmental stresses around them. Certain species of rattlesnakes have been hunted in the United States to such an extent that the percent of snakes that fail to develop rattles has risen over time.

Unmanaged change in a company can have similar unplanned consequences. During our research, we found a great reluctance to fully document change unless directly associated with a product build document. Some form of engineering order (EO) was found for engineering change that included both a *was* and an *is now* comparison to assist in evaluating the change and as a

means of communication with internal and external stakeholders. The use of this comparison or document with change tracking was much less prevalent in modifications to company policies, procedures, practices, and processes.

A change to a more environmental-friendly process for applying conformal coating to printed wiring assemblies (PWAs) as a protection against humidity was implemented at one firm studied. Everything looked good on paper based on the producer's material data sheet (MDS) only to find some weeks after the new process was implemented that the new conformal coating was pulling away from the PWA surface. All PWAs coated during the time period had to have the conformal coat stripped away. Due to the components used, many capacitors were cracked during this cleaning operation further driving costs. Root cause analysis of the issue showed that no change impact assessment was done. No testing was done to verify the cross-compatibility of materials. No coordination of the change had taken place with the programs needing PWAs conformal coated.

10.6.1 Engineering Change Request

An engineering change request (ECR) or any form of change request (e.g., software change request, process change request, action request, etc.) is a documented lien against the item in the system. These change request liens can be against a single item or against multiple items.

Change requests are written in response to eight areas:

1. Design or other issues that surface through use or test
2. Component obsolescence, unavailability, or industry alerts such as government and industry data exchange program (GIDEP)
3. Product enhancements
4. Cross-functional incompatibilities
5. Administrative clean-up or typographical errors
6. Process changes
7. Regulatory changes
8. Requests from management

There is interdependency between change requests and the changes processed to implement them. This is shown graphically in [Figure 10.5](#).

10.6.2 Engineering Change Orders

Changes to documentation (e.g., drawings, analysis, specifications, policies, procedures, practices, and processes) as well as manufacturing and documenting bill of materials (BOMs) are made in most product data/life cycle management (PD/LM) systems using engineering change orders (ECOs) or similar mechanism. Changes authorizing a customer authorizing a contractor to start work also use a form of change order associated with an engineering change proposal (ECP) submitted by the contractor to the customer in response to a request for proposal.

The current trend in CM guidance documents is to classify these as major and minor.

Major are defined as those changes that impact

- Specified contractual requirements or product technical attributes
- An established product baseline
- Product safety

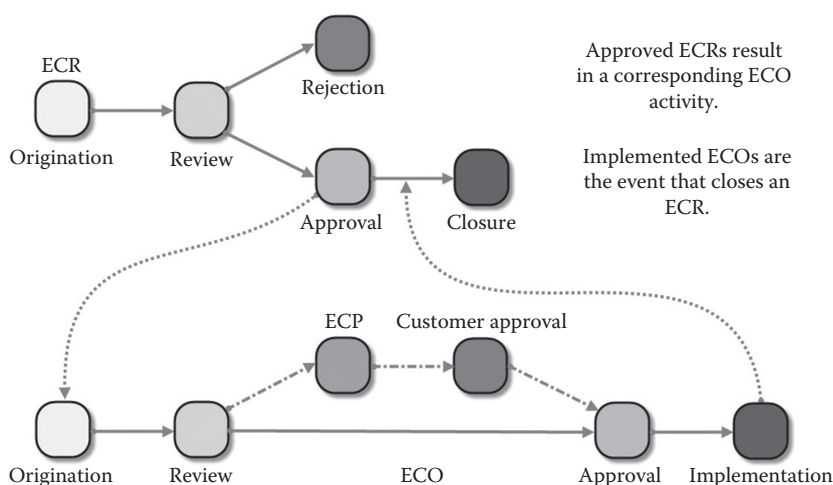


Figure 10.5 ECR-ECO interdependencies.

Minor changes are defined as those changes that impact anything else.

The definitions in MIL-STD-973, CM, are more concise.* What follows has been modified only to add in definitions for the acronyms used.

5.4.2.2.1 Classification of engineering changes. An engineering change shall be classified as Class I or Class II by the preparing contractor in accordance with this standard. Class I ECPS shall be referred to the Government for approval or disapproval. Classification disagreements shall be referred to the Government for final decision. A proposed engineering change to a CI, or to any combination or discrete portion thereof, shall be determined to be Class I by examining the factors below, as contractually applicable, to determine if they would be impacted as a result of implementing the change. The change shall be Class I if:

- a. The Functional Configuration Documentation (FCD) or Allocated Configuration Documentation (ACD), once established, is affected to the extent that any of the following requirements would be outside specified limits or specified tolerances:
 - (1) Performance.
 - (2) Reliability, maintainability or survivability.
 - (3) Weight, balance, moment of inertia.
 - (4) Interface characteristics.
 - (5) Electromagnetic characteristics.
 - (6) Other technical requirements in the specifications.

Note: Minor clarifications and corrections to FCD or ACD shall be made only as an incidental part of the next Class I ECP and accompanying Specification Change

* DOD, U.S. (1992). *MIL-STD-973, Configuration Management*. U.S. Government, Section 5.4.2.2.1 and 5.4.2.4.

Notice (SCN) or Notice of Revision (NOR), unless otherwise directed by the Government.

- b. A change to the Product Configuration Documentation (PCD), once established, will affect the FCD or ACD as described in 5.4.2.2, paragraph 1a or will impact one or more of the following
 - (1) Government Furnished Equipment (GFE)
 - (2) Safety
 - (3) Compatibility or specified interoperability with interfacing CIs, support equipment or support software, spares, trainers or training devices/equipment/software.
 - (4) Configuration to the extent that retrofit action is required.
 - (5) Delivered operation and maintenance manuals for which adequate change/revision funding is not provided in existing contracts.
 - (6) Preset adjustments or schedules affecting operating limits or performance to such extent as to require assignment of a new identification number.
 - (7) Interchangeability, substitutability, or replaceability as applied to CIs, and to all subassemblies and parts except the pieces and parts of non-reparable subassemblies.
 - (8) Sources of CIs or repairable items at any level defined by source-control drawings.
 - (9) Skills, manning, training, biomedical factors or human-engineering design.
- c. Any of the following contractual factors are affected:
 - (1) Cost to the Government including incentives and fees.
 - (2) Contract guarantees or warranties.
 - (3) Contractual deliveries.
 - (4) Scheduled contract milestones.

5.4.2.4 Class II engineering changes. An engineering change which impacts none of the Class I factors specified in 5.4.2.2.1 shall be classified as a Class II engineering change.

Confusion existing in the bidding and implementation of major (class I) changes when it comes to PD/LM systems primarily due to a lack of understanding on the part of engineering support organizations of contractual technical/functional baseline management.

Consider the following customer-requested requirements change when the contractor is working to an allocated baseline:

Vehicle gross combination mass (GCM) shall be reduced from 2500 to 2200 kg.

The resulting proposal is reviewed internally and a proposal is submitted to accommodate the change request. As there was no change to any of the vehicle-performance criteria, a lower weight solution was arrived at, which included changes to vehicle structural design as well as changes to materials. None of the changes could be implemented prior to customer approval. Yet after approval a new technical/functional requirements baseline was established and anything required to meet the new baseline is within the general scope of the modified contract. As a result, all of the changes that are processed to implement the weight reduction are minor changes.

Baselines impacts not only how a change is managed but also how it is implemented once approved. Consider the following customer-requested requirements change when the contractor is working to a functional baseline. The rules change once a functional baseline is established. The implementing

engineering changes are prepared in anticipation of the approval of the proposal, and the proposal and the changes are approved as part of the major change, as the contractor no longer has design authority.

Curiously, despite all of the advantages that exist in moving to a PD/LM environments, it was found that many companies are reluctant to fully commit to full PD/LM functionality. What follows is a list of the most common paper system rules found to have been leveraged forward in PD/LM implementation.

- Restricting the number of unincorporated EOs.
 - Incorporating advance EOs is an area of document control that requires latitude, which is hard to put into a black and white policy.
 - Rules such as a hard policy of advance EO incorporation; having five outstanding advance EOs is not advisable because in some cases the very first advance EO is so complex that it should be incorporated immediately.
 - In many cases, the advance EOs are needed in a hurry. If they pile up on a design that will never be produced again, it is not worth the cost of incorporating them after the fact.
- Prohibiting the use of revision letters “I,” “O,” “Q,” “S,” “X,” and “Z.”
 - This is a paper system holdover from the days when hardcopies of drawings and other documents were stored in filing cabinets. It was believed that “I,” “O,” “Q,” “S,” “X,” and “Z” could be mistaken for the numbers “1,” “0,” “0,” “5,” “8,” and “2” and this would lead to documents being misfiled.
 - It is not required if all the records are held in the PD/LM system.
- Including the PD/LM system metadata information on released engineering.
 - Program, prepared by, responsible engineer, revision history, contract number, U.S. contractor, government entity code (CAGE), dun and Bradstreet Data Universal Numbering System (DUNS) number, next assembly, and so on are all common metadata fields.
 - Repeating the information in the document released in the PD/LM system eats into the nonrecurring cost of the program.
 - It is also a potential source of audit findings.
- Hard copy signatures.
 - In a PD/LM environment, electronic signatures are used to release all documents that are not part of the contract between the customer and the contractor.
 - In many instances, even the contract is signed electronically.
 - The requirement to sign the face page of a document manually is redundant.

10.6.2.1 Review Changes

Review of change is often a weak area in many organizations and the review function differs depending if you are the customer or the contractor. Turning to MIL-HDBK-61A, CM guidance, the following figures are found to be representational of similar functions in all customer–contractor relationships* (Figures 10.6 through 10.8).

Inherent in the configuration control process is change as well as management of temporary departures from the technical requirements baseline for a limited number of deliverable units as documented in variances (deviations and waivers) as is the interplay of customer and contractor change process.

* DOD, U.S. (2001). *MIL-HDBK-61a, Military Handbook: Configuration Management Guidance*. U.S. Government, Figures 6.1 through 6.3.

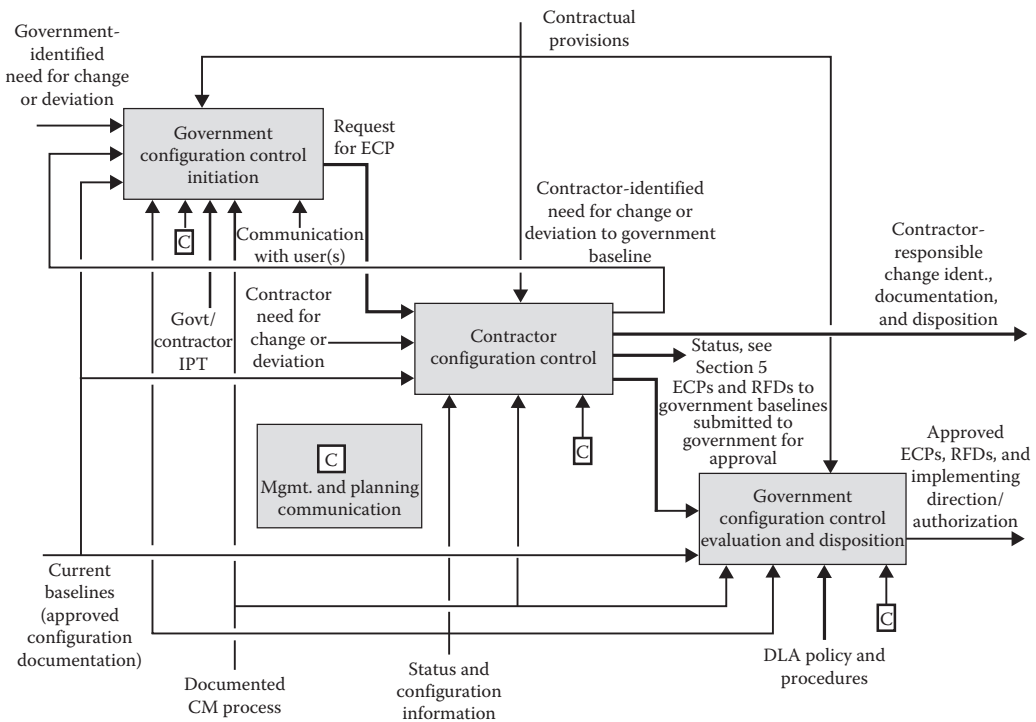


Figure 10.6 Configuration control process. (Data from DOD, U.S., *MIL-HDBK-61a, Military Handbook: Configuration Management Guidance*, U.S. Government, Figures 6.1 through 6.3, 2001.)

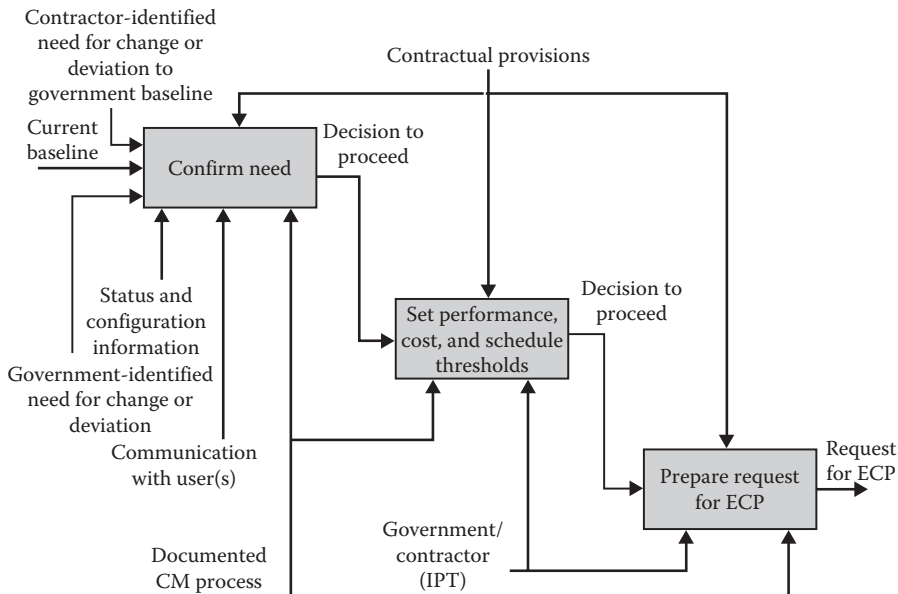


Figure 10.7 Government configuration control change initiation. (Data from DOD, U.S., *MIL-HDBK-61a, Military Handbook: Configuration Management Guidance*, U.S. Government, Figures 6.1 through 6.4, 2001.)

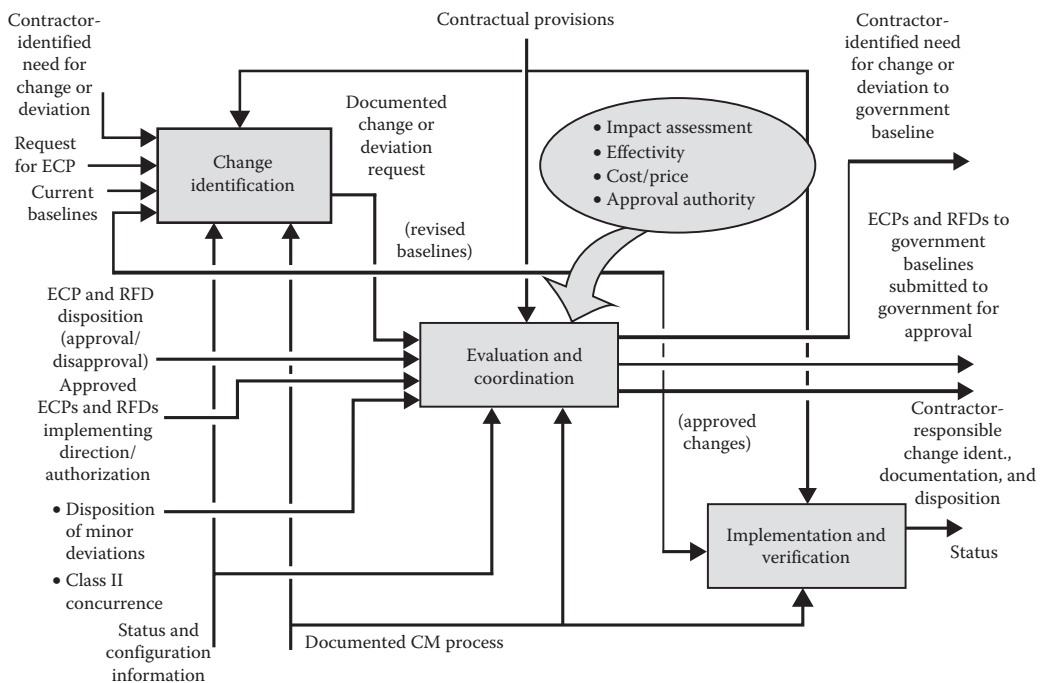


Figure 10.8 Contractor configuration control. (Data from DOD, U.S., *MIL-HDBK-61a, Military Handbook: Configuration Management Guidance*, U.S. Government, Figures 6.1 through 6.5, 2001.)

Figure 10.7 is representative of the role customer's play in driving change. When multiple contractors are developing products that form part of a larger assembly or system; changes made by one of the contractors can dramatically impact what the other contractors are designing. For example, if you are building the chassis for a vehicle that will be delivered to the customer for final assembly. The chassis must accommodate the engine, transmission, suspension, exterior and interior trims, and other subsystems from other contractors. Should the engine mounting location change, the chassis design will be impacted.

A Contractor's configuration control activity has many interdependencies with both internal and external sources. Central to this is the change review process.

10.6.2.1.1 Roles for the Review

One by-product of organizational decoupling of CM from the program/product development team is muddled change review. When coupled with a growing reluctance to include CM in all phases of the program life cycle, a lack of design continuity results.

The basic elements of change review are relatively simple.

- Who (needs the change?)
- What (is the impact?)
- When (is the change needed?)
- Where (in the product line must it be implemented?)
- Why (is it needed then?)
- How much (an impact is it and what will it cost?)

Actually, accomplishing the steps needed to answer these questions can be a little tricky. Figure 1.3 presented an analysis of the rising cost of product change over time. Overlaying the criticality of change review onto Figure 1.3 highlights a sharp rise in the degree of criticality of a complete review very early in development (Figure 10.9).

As can be seen adequate, review of change becomes critical very early in the program life cycle. How then should the roles for conducting change review be assigned? Certainly there is a change manager, stakeholders, the originator of the change document, an individual responsible for the design of the item(s) being changed, and a change release manager.

The change manager should be the individual on the team who has the overall responsibility for identifying the first- and second-level impacts of the proposed change. They work closely with the originator of the change document (ECO or equivalent) to assure all stakeholders are identified prior to the change entering the review process. This change impact assessment relationship is shown in Figure 10.10.

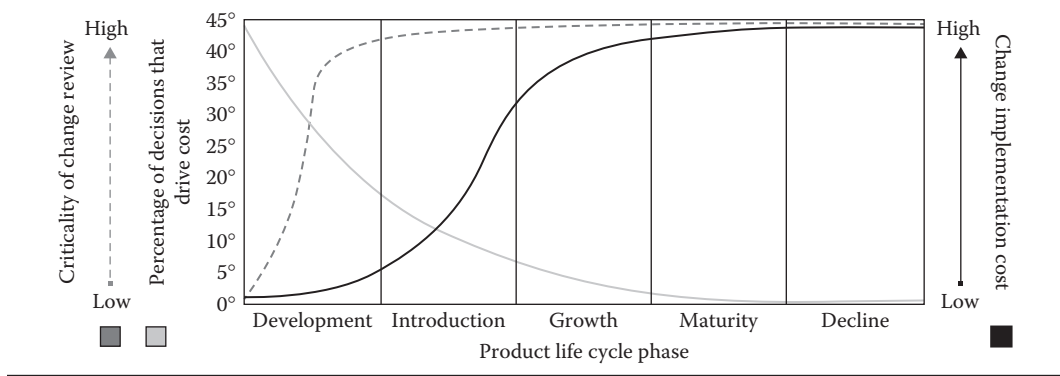


Figure 10.9 Increasing criticality of change review over time.

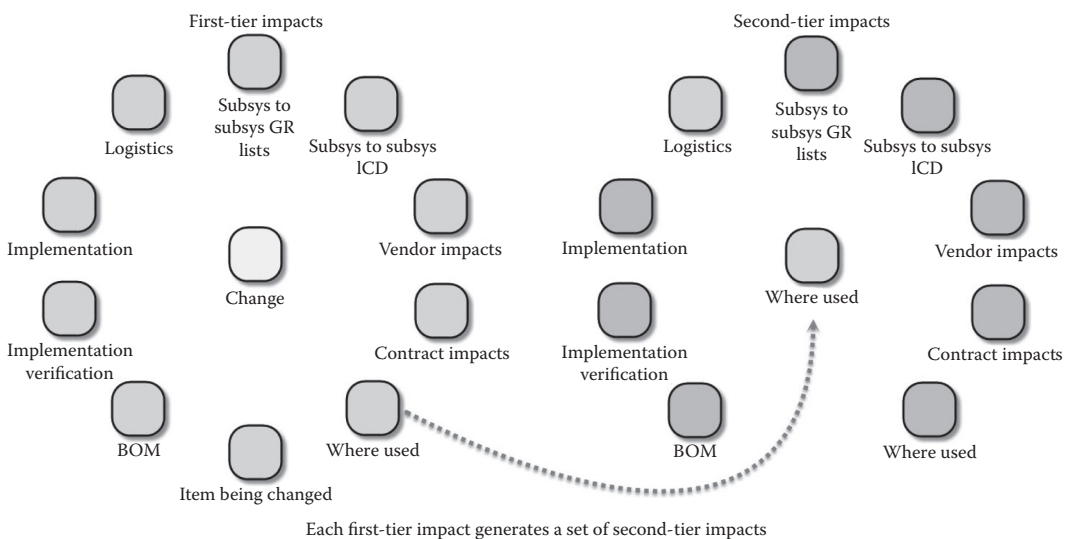


Figure 10.10 Change impact assessment.

- First-level impacts
 - The item being changed
 - The next higher level of assembly where the item is used
 - The previous level of assembly (items in the BOM)
 - Any contractual impacts
 - Any vendor impacts
 - Internal subsystem to subsystem Interface Control Drawings (ICDs)
 - Internal subsystem to subsystem giver receiver lists
 - Logistics impacts on previously delivered items and items waiting to be shipped
 - Implementation strategy
 - Implementation complete verification
- Second-level impacts
 - All impacts associated with higher- and lower-tier items in the total product structure

The owners of all first- and second-level impacts become change stakeholders. They in turn analyze the impacts associated with the change and provide feedback to the change manager and the originator of the change to assure all impacts are identified in the change document prior to review. The individual responsible for the design of the item(s) being changed, and the change release manager should be consulted throughout the initial assessment process.

10.6.2.1.2 How to Conduct the Review

The tendency to exchange information in a transactional environment as the written equivalent of a “sound bite” using text messaging, chat, e-mail, and other forms is increasing. Although some forms of information transfer can be expedited in this way, it is recommended that the initial evaluation of first- and second-level impacts as well as the coordination of those impacts with the stakeholders who will identify the third- and fourth-level impacts be held in a meeting environment. Meetings should be chaired by the change manager and co-chaired by the originator of the change document.

The synergy achieved in a meeting environment allows comments made by one stakeholder to influence how others in the meeting view the impacts and lead to better informed decisions as well as better analysis and implementation strategy.

Interviews held with over 4700 professionals involved with change review have generated the following set of guidelines:

- The meeting should be chaired by the change manager.
- The co-chair acts as the secretariat and takes notes regarding impacts and actions assigned.
- All one- and two-tier items are identified and provided to the stakeholders at least 48 hours prior to the meeting.
- Silence on the part of any individual indicates agreement.
- The chair will call on one stakeholder at a time and open discussions will take place after the stakeholder has finished.
- All stakeholders are expected to view the entirety of the change and not self-limit their participation to the specific item they are responsible.
 - For example, a change to a connector type may drive changes to on-board computers, wiring boards, thermal, structure, test equipment, logistics, integration, test, verification, existing analysis as well as the wiring harness design.
- The change will not be placed into formal review if there is any disagreement on how to proceed.

Although some may see this as an old school approach, it does work and works very well. Today's international collaborations often see these meetings taking place using teleconferencing, freeing stakeholders from the need to be physically present in one location but to include associates in the meeting who may later be tasked to work action items or research impacts to related systems and subsystems.

10.6.2.1.3 Capturing All Affected Items

Use of the process outlined in 10.6.2.1.2 above will drive out the majority of affected items. It is dependent on the level of experience of the combined team and their knowledge of the entire product life cycle as well as the infrastructure that support is for success. It may be necessary for the results of the stakeholder review to be independently assessed by a smaller team who are not so closely tied to the program/project should the magnitude of the change be high enough.

Every change manager has a blind spot. It may be due to the lack of knowledge, a change with impacts in areas they are unfamiliar, or simply an oversight due to overwork. This creates a risk that some affected items may be missed resulting in an incomplete impact assessment. The risk is mitigated through stakeholder review early on and increases the likelihood that all impacts are identified and understood. Every affected item is identified in the change and dispositioned during the change review and approval process.

10.6.2.2 Approval/Disapproval

After a review of the many automated workflows used in PD/LM systems, it was found that the following best practice was common.

Change approval or approval with comments was preferred over disapproval; however, it was incumbent on the change document originator to assure that all comments were incorporated prior to notifying the change release manager that the change was ready either for release or for transmittal to the customer for their approval prior to release.

Rejection of a change for any reason required the change to be returned to the pending state and to start the review and approval workflow over from the beginning. For this reason, rejection was not preferred. Approval with comments rather than rejection is preferred.

If an individual believes they should not be on the list of approvals a e-mail or phone call to the change originator is acceptable.

When a review was conducted prior to the change document originator placing the change into the approval workflow, the rejection incident rate fell to near zero levels (0.00032%).

10.7 Configuration Verification

Each approved major change creates a new functional baseline. These in turn is allocated to systems and subsystems and each allocated requirement needs to be verified. The overlaying assumption is that if each allocated requirement is verified, then the entire system in turn is verified.

10.7.1 Functional Aspect

Functional requirements are traditionally verified using four methods applied singly or in combination. Simplified examples of each method follow.

10.7.1.1 Analysis

Analysis as a form of evaluating an item's capabilities is a valuable tool when other verification methods cannot be used. A design element can be modeled against a predetermined norm to verify predicted performance against that norm. Operational conditions of spacecraft may exist that cannot be tested except in the space environment. Instead they are evaluated against what is known of the environment from spacecraft in similar orbits or missions.

10.7.1.2 Inspection

Inspection is a method of direct quantitative measurement. A nine-bolt attachment interface may exist that is represented by a master gage. Assemblies are inspected against the master gage to verify they meet the requirement.

10.7.1.3 Test

A requirement may exist for an aircraft to accommodate 196 pieces of luggage of a maximum specified size in the overhead compartments. A test is conducted with 196 pieces of rigid foam blocks of the specified size to see if they all fit.

10.7.1.3.1 Test Temporary Configuration

A product may be required to withstand a set of vibration frequencies and durations. Mass simulators are used instead of actual components during the test. Once the test is complete the simulators are removed and the product moves to the next assembly operation.

10.7.1.3.2 Test Fixtures

Test fixtures are used to assist with component-, unit-, and assembly-level testing. A fixture must be representational of both sides of an interface.

10.7.1.3.3 Simulators

Simulators are often the electronic equivalent of a test fixture. The simulator may be representational of the final assembly that software will be operating on and allow software to drive the final product in all of the scenarios required by the requirements allocated to the software system.

10.7.1.3.4 Test Anomalies

During the testing process anomalies can happen. An anomaly is simply a result that differs from expectations. Sometimes, the anomaly may be due to poor assumptions or faulty calculations being made regarding how the item will perform. In other cases, it is not so simple.

Voltage transients in electronic circuits may be observed. Each must be traced to its root cause and dispositioned. Voltage transients may be attributed to test equipment, power supplies, driving the circuit in a way it was not intended to be driven, or a number of other sources. If the observed behavior is repeatable, it helps with root cause analysis. If they happen only once, such anomalies

are said to be observed but unverifiable. Root cause analysis may indicate design flaws that must be corrected prior to product acceptance.

10.7.1.4 Demonstration

Demonstration is a form of validation utilized when there is no other way to prove a technical requirement is satisfied. A demonstration in the form of a life test may be run to prove that an actuator to meet a duty cycle requirement of 125,000 can actually do so. The actuator is placed in a test fixture and a minimum of 125,000 cycles are run. Often a demonstration will continue until component failure in order to evaluate expected component life and establish the recommended replacement cycle of the item.

10.7.2 Aids to Functional Aspect Verification

Aids to functional verification vary depending of the nature of the product itself. Verifiers may be used as a static analysis tool in very large-scale integration design, bridging the gap between layout syntax and some form of behavioral analysis.* This provides an adjunct to rule checkers used for the verification of low-level environment-dependent correctness conditions. Use of timing verifiers in lieu of complex simple protocol for independent computing environments circuit simulators are faster and provide as much the same information.

Functional block diagrams of systems, subsystems, and component families such as cabling have been found useful in not only analysis but also in resolution of test anomalies. Figure 10.11 is the functional block diagram of the attitude control and maneuvering electronics system of the U.S. Gemini spacecraft ca. June 1962.

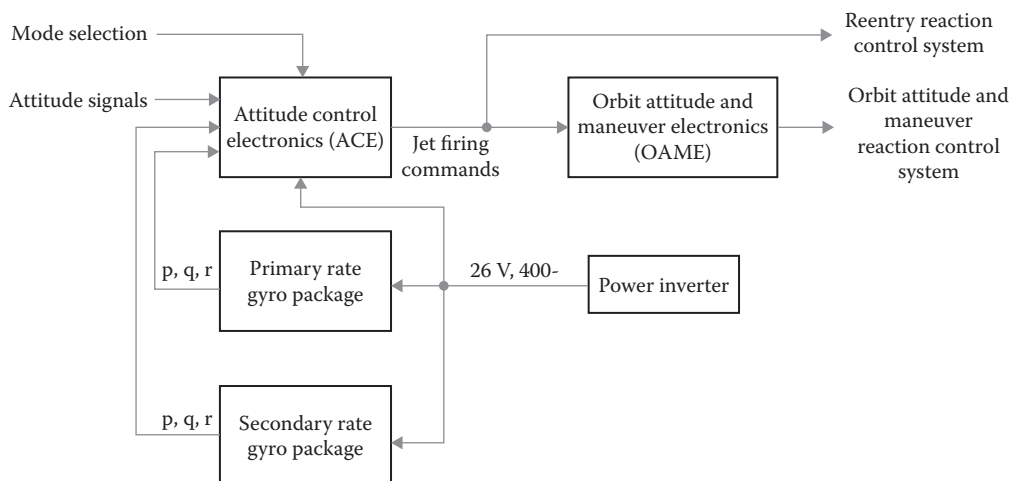


Figure 10.11 Gemini spacecraft attitude control block diagram.

* Rubin, S.M. (1994). *Computer Aids for VLSI Design*. Retrieved May 19, 2014, from <http://www.rulabinsky.com/cavd/text/chap05-4.html>.

10.7.2.1 CM and Test Execution Trials

Testing part of a configuration prior to completion of the entire deliverable often leads to early identification of design flaws. In a similar way, the execution of dry runs of the test itself will pinpoint errors in the test setup and testing assumptions. In either case, management of the configuration of the test parameters as well as the test setup, and controlled release of the iterations of the test parameters as well as the test setup and test results assures that the test is repeatable as well as all observed results and test procedure redlines are captured.

Countless failures in all market segments exist due to not incorporating test redlines and formally releasing them immediately after the test is complete. Test repeatability has been compromised as well in all cases where the test setup and the set up of all associated test equipment have not been documented.

The lack of documentation relative to the redlines made to procedures and the lack of documenting the complete test setup, including versions of the Mathcad and other setup parameters and software versions, on one major U.S. government program resulted in the inability of the original manufacturer to replicate the testing on the second unit build, costing the company hundreds of thousands of dollars in lost schedule and generation of a new testing program.

Similar issues frequently occur in the area of software and firmware development. In another firm, programming of programmable read-only memory (PROM) chips for multiple build test equipment indicated a released version 1.0 yet when several *qualified* test units were examined, the code version on the PROMs inside were found to range from versions 2.5–11.0. There was no record of the changes between versions, nor could evidence of any functional qualification testing could be found. To have PROM code updates, 110 units had to be recalled. The code itself was reverse engineered prior to a new set of code with a different software identification being loaded on the recalled units.

10.7.2.2 Subsystems (Product Subelement) Verification

It is easy to imagine the functional baseline as a hydra. Each requirement is a head that has to be fed. Each time a requirement is allocated to multiple subsystems (such as those having a hardware and software component), additional requirements are established. This is known as “requirements allocation branching” and is shown in [Figure 10.12](#).

A single requirement may include branching of down to the third or fourth level. Only when all heads have been fed and the entire set of allocated requirements have been met can the system functional requirements be said to have been verified.

Many may state that requirements tracking as well as keeping status on the artifact used to satisfy each requirements branching is performed by systems engineering. While that may be true in some market segments, it does not negate the fact that it is a function necessary to the management of the configuration, and in other market segments, this activity is part of a department that may be called “configuration management.”

10.8 Systems (Product) Verification

What then is this thing called “systems verification” or, more properly, “product verification?” It is that point in the development of a product where the producer feels satisfied that all requirements necessary to bring the product to market have been satisfied.

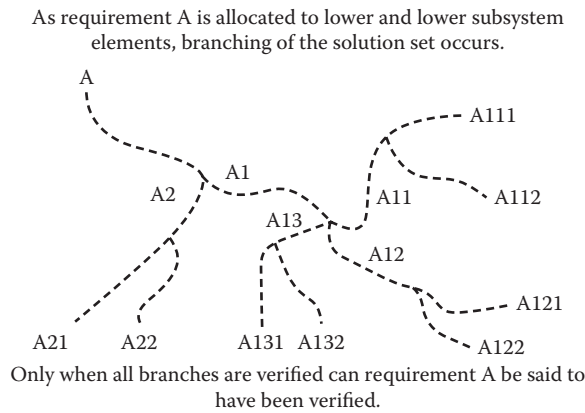


Figure 10.12 Requirements allocation branching.

Assume that the product being developed is a long-stem red rose with

1. Superior blossom shape
2. Large size
3. A long straight stem
4. A superior scent, which will last for three weeks after cutting.

Only when all four requirements have been met, it can be said that the product requirements have been verified.

While the CM of a rose may not appear to be complicated at first, the details associated with getting everything right are as complex as those associated with bringing any other product to market.

Products such as a new version of SolidWorks software for 3D development environment or a vehicle such as the Wiesmann MF5 roadster may have thousands of separate subsystem requirements. Each must be separately verified, an artifact under configuration release control documenting the requirement has been met and an overall gap analysis tying each of the lower requirements to a higher level one from lowest level to the top.

10.8.1 Live Fire Exercise

Many complex systems are put through a form of testing known as a “live fire exercise.” This is any set of realistic simulated scenarios using of the product in its intended environment. The terminology stems from weapons testing and like many terms associated with management of product configurations, it has become common throughout many market sectors.

After meeting all requirements, realistic total system verification is often called. This may take the form of beta testing in the software environment or some other form of total systems functionality test. NASA may require “test as you fly” exercises be run that can be considered life fire exercises in the broader sense. The use of a test mule in the automotive industry is a life fire exercise.

10.8.2 Analysis, Inspection, Test, and Demonstration Master Plan

Once the allocated baseline has been established and a determination has been made (if not stipulated by the customer), a secondary allocation and configuration tracking exercise begins. Items specified to be verified by analysis, inspection, test, and demonstration are assigned tracking identification numbers in the requirements verification and tracking system [such as dynamic object oriented requirements system (DOORS)] or spreadsheet. Where possible, document numbers are pre-assigned to each artifact. Actual vs. planned delivery of each item is statused against predetermined program completion schedules. This schedule becomes part of the analysis, inspection, test, and demonstration master plan.

This master plan is maintained as verification activities mature. Each artifact associated with the master plan is tied together in the PD/LM system as the program proceeds and incremental deliveries are made to the customer to meet any data deliverable requirements.

Incremental delivery is critical to program performance as it may be physically impossible to gather and deliver all required information to support requirements verification reviews and audits if it is not gathered as it is produced.

10.8.3 Requirements and Closure

How do you know you have met the target (project closure)?

Should the program/project have no requirements changes during the development phase, initial assumptions, allocated baseline, analysis, inspection, test, and demonstration planning will remain static over the cycle.

Once a single requirement is changed, it adds a degree of complexity to the process that is compounded with each new approved major change. If the change review process was not comprehensive in its impact assessment and implementation, the program may never know if the program/project goals have been met. CM activities must include tracking of requirements genesis and closure (Figure 10.13).

This is where configuration change management pays for itself many times over. Both the technical and the contractual aspects of the program form functional baselines.

10.9 Configuration Audit

Configuration audit is an ongoing process that generally culminates at a formal audit event prior to a product being declared functionally compliant with requirements levied by either an internal or an external customer. Configuration audits are a precursor to a product design being designated as a product baseline.

10.9.1 In-Process Audits

Ongoing audits are generally referred to as “in-process audits.” In-process audits performed by CM or in conjunction with CM include audits of

- Allocated design against requirements
- Changes to design against requirements
- Internal approval of major changes against those authorized to approve prior to submittal

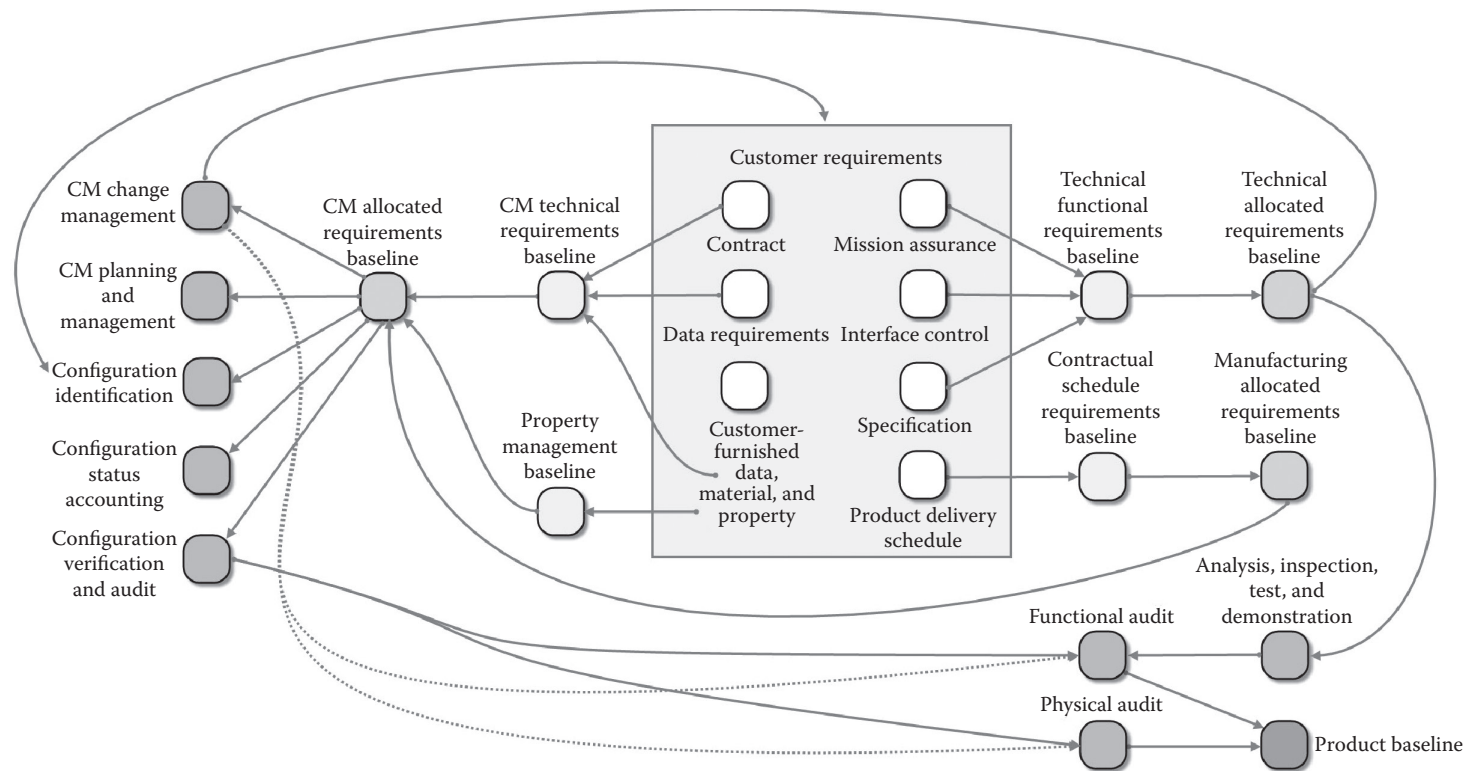


Figure 10.13 Requirements genesis and closure.

- Internal approval of minor changes against those authorized to approve prior to implementation
- Change incorporation against affected items
- Analysis, inspection, test, and demonstration results against expectations
- Data prepared for submission against data item descriptions
- Customer acceptance of data against data approval timelines
- Vendor data against vendor data requirements
- Vendor product against functional and physical requirements
- Contract changes authorized by the customer against what was proposed
- Changes were reviewed and approved by the proper contingent of people
- Changes were only released after a complete review was conducted
- Changes were released by someone having the authority to do so
- Associated metadata is complete for all fields in the PD/LM system prior to release

In-process audits assure that product meets expectation, the configuration is known and maintained and all supporting documentation is controlled and maintained.

10.9.2 Formal Audits

Formal audits can occur as a set of iterative events culminating in a functional summary meeting or it may be all inclusive. Product entering government inventory generally consists of two distinct audits, covering the areas of functional compliance (FCA) and conformance of the product to product documentation (PCA). MIL-STD-3046 (U.S. Army), Department of Defense (DOD) Interim Standard Practice: CM provides the best direction for the U.S. government procurements pertaining to formal audit requirements at the present time.

Generally, if an external customer is involved, the buying organization will

- Provide co-chairperson
- Review audit agenda
- Prior to audit, provide contractor with the name, organization, and security clearance of each government participant
- Participating in audit activities, identifying discrepancies, and determining their criticality
- Review daily minutes to ensure they reflect all significant government inputs
- Provide formal acknowledgments to the contractor of audit results; after receipt of audit minutes—approval, contingent approval, and disapproval

Generally, if an external customer is involved the selling organization will

- Provide co-chairperson
- Participation by subcontractors/suppliers as appropriate
- Establish a location
- Establish whether incremental audits will be conducted
- Audit plan
- Agenda
- Conference room(s)
- Applicable documents (specifications, drawings, etc.)
- Test results
- Minutes, including action item audit

- Tools and inspection equipment
- Access to facilities, security clearances
- Support personnel
- Isolation of item(s) to be audited

Audit key personnel are shown in Figure 10.14.

It is highly recommended that a pre-audit be performed for any formal audit. This will be addressed more fully in the discussions that follow.

10.9.2.1 Functional Configuration Audit

FCA or its equivalent functional product audit evaluates the allocated requirements against the functional requirements baseline. Each of the functional requirements is validated to assure that the right thing was built. MIL-STD-3046 defines FCA objective as:

The objective of the FCA is to verify the CI's performance against its approved functional and allocated configuration documentation. Test data for the FCA shall be from test of the configuration of the prototype or preproduction article. If a prototype or preproduction article is not produced, the test data shall be that collected from test of the first production article. Subject to prior acquiring activity approval, the FCA for complex items may be conducted in increments. In such cases, a final FCA may be conducted to ensure that all requirements of the FCA have been satisfied.

Putting this in nongovernmental terms, it is an audit of the proof presented by a company that the product functions in accordance with requirements. If the product contains components not previously qualified it also includes the qualification test results.

Perhaps one of the most extreme recent cases of functional requirements allocation and verification took place in the development of the Bugatti Veyron Super Sport 16/4. The vehicle pushed the envelope of what was possible in automotive design. It is possibly the most sophisticated automotive achievement to date, with attested top speed of 431.3 km/h at Volkswagen Group's test facility at Ehra-Lessien, exceeding the design goal of 425 km/h. This is faster than Formula

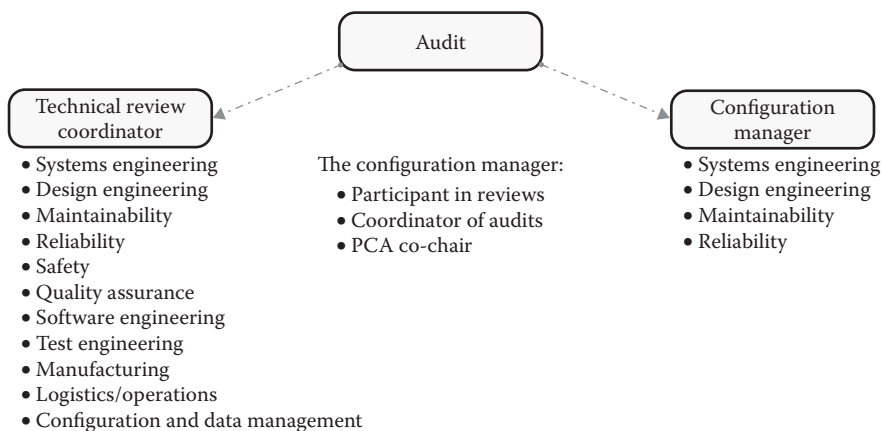


Figure 10.14 Audit key personnel.

One cars. The W16 engine produces 984.8 kW. The seven-gear manual transmission works with torques up to 1250 N m, allowing the car to go from zero to 100 km/h in 2.5 seconds. It is able to stop in 2.3 seconds from that speed. To maintain operational environments, the vehicle requires 12 radiators. All this sounds impressive and to put it into perspective, it must be remembered that the top speed of 431.3 km/h requires that a vehicle stays on the ground at that speed.

Below are the takeoff speeds for three aircraft by comparison:

- Boeing 747 and Airbus A340: 290 km/h
- Concorde: 360 km/h

The embodiment and synergy of the technology in the Super Sport version of Bugatti Veyron mandated tight configuration and data management control to standards higher than mandated on commercial imaging satellite programs. This is not unusual in market sectors not tied to preconceived definitions and limitations of CM based on U.S. government standards originally conceived in the 1960s. What it indicates is that CM while meeting the minimum guidelines of Electronic Industries Alliance, ISO, and the U.S. DOD has advanced to the enterprise level in the world market place. It has done this simply to survive in commercial environments not tied to one-off production (or limited production) and protected to maintain the industrial base such as U.S. government procurements.

The FCA may be combined with a functional systems audit previously known as a “formal qualification review” to ensure that system functional requirements not evaluated at the CI level have also been demonstrated. You may ask, “Wait a minute, where did that requirement come from? I thought all we had to manage in CM was those items designated as CIs.”

The simple truth is that the entire configuration and all the documentation associated with it are part of CM. It is an enterprise-wide activity and not simply relegated to a few items that someone decides to call a CI.

FCA pre-audit activities include the following:

- Identify CIs to be audited, audit participants, and facilities required
- Prepare agenda
- Prepare FCA checklist
- Provide verification cross-reference checklist
- Provide list of all deviations/waivers
- Collect test information

FCA post-audit activities include the following:

- Prepare and publish FCA minutes
- Record FCA results in CI status accounting reports
- Close out corrective actions

10.9.2.2 Physical Configuration Audit

PCA or its equivalent physical (*physical* includes such intangible items as models, software, and other representational engineering products used to produce the end product) product audit evaluates the end product against the engineering that defines it. Each of the design elements is verified

against the finished product to assure that the product was, in fact, built to that engineering. Turning again to MIL-STD-3046:

A Physical Configuration Audit shall be conducted for each CI and related component as required by the contract. The PCA shall verify the design documentation is a clear, complete and accurate representation of the product. Satisfactory completion of a PCA is required to establish the formal product baseline. The PCA shall include a detailed audit of engineering drawings, MBD datasets, specifications, technical data, design documentation, and associated listings which define each CI/component. The PCA shall also determine that the quality assurance testing and acceptance requirements of the product configuration documentation are adequate to ensure end item performance. The PCA shall not be started unless the FCA for the item has already been accomplished or is being accomplished concurrent with the PCA. Subject to prior acquiring activity approval, the PCA for complex items may be conducted in increments. After successful completion of the audit and the establishment of a product baseline, all subsequent changes to the product configuration documentation shall be done by formal change control only. Additional PCAs may be performed during subsequent production if required (e.g. if there has been a long gap in production or if a new manufacturer for the product is established). For software, the product specification, Interface Design Document, and Version Description Document (VDD) shall be a part of the PCA.

PCA, in some cases, can include complete disassembly of the product, inspection/measuring each manufactured part and subassembly against the released engineering and reassembly of the end product to the engineering. This is more likely in cases where a complete TDP has been prepared. TDP engineering is created at a high enough level of self-contained integrity, which does not rely on a single manufacturer's processes. A TDP can be provided to multiple suppliers each technically capable of manufacturing the product.

The FCA is generally co-chaired by the contractor's configuration manager and a representative from the customer. It is highly recommended that FCA ground rules be established prior to the review addressing the following areas:

- Time and place
- Definition of a finding versus an observation
 - Finding
 - Item does not match the engineering
 - No variance is in place
 - Approved changes are not incorporated
 - Observation
 - Engineering is not in error but could be clearer to facilitate reproducibility
- Finding resolution timeline
- Constitution of a successful review
 - Factors such as number of findings

PCA pre-audit activities include the following:

- Identify CIs to be audited and depth of drawing review
- Identify audit personnel, required facilities, scheduling of audit activities

- Provide list of all deviations/waivers
- Prepare PCA checklist
- Identify any difference between the physical configurations of the selected production unit and the developmental unit(s) used for the FCA
- Certify or demonstrate to the customer that these differences do not degrade the functional characteristics of the selected PCA units

PCA post-audit activities include the following:

- Receive customer notification of PCA approval, PCA contingent approval (requiring correction of specific discrepancies), or PCA rejection and requirements for re-accomplishment
- Prepare and publish PCA minutes
- Close out corrective actions

10.9.2.2.1 As Built versus As Designed

A critical component of the physical audit is an audit of the product against the engineering and production documentation. At the simplest level, this can be a comparison of the product structure against the items actually used. Substitute parts, minor hardware anomalies, and any other variances are identified to the lowest level of the product structure. Depending on the criticality of the product, the documentation supporting the as built versus as designed may go down to the level of receiving inspection reports, lot sampling, and MDSs from component as well as consumable items such as solvents and other cleaning agents.

10.9.2.2.2 Material Review Board

The material review board (MRB) is responsible for determining the disposition of nonconforming materials (e.g., material or manufactured items that fail inspection) and identifying corrective actions required to prevent future discrepancies. Customer-supplied production materials cannot be scrapped until the customer is first given the option to have the material returned. On the U.S. government contracts, this is tied to the “government property” clause in the contract and the material is identified on the government-furnished property/material and data listing (most often a contract attachment). Similar provisions and lists should be part of any contract, where the customer provides property, material, and data. It is important to remember that material includes items received from a vendor as well as items produced by the contractor. MRB activities are considered minor variances, also known as “minor deviations” or “waivers.”

The basic MRB dispositions are:

- Scrap the material or item
 - If a design change is required, the variance number is tied into the PD/LM system
- Rework completed assemblies
- Transfer MRB material to stock
- Return purchased items to the supplier (including customer-supplied production material)
- Re-grade material
 - Rework must performed and the item re-inspected before it can be placed in stock
 - Approved for “use as is” is moved directly to stock

MRB membership often consists of the following disciplines:

- Manufacturing engineering
- Materials
- Quality
- Purchasing

MRB dispositions are an element of the as built versus as designed documentation.

10.10 Material Receipt and Inspection

Material receipt and inspection for incoming materials refers to the following.

10.10.1 Goods

Material with utility and/or intrinsic value purchased by, internally produced by, and/or supplied to a company.

10.10.2 Production Material

Material that becomes part of a shippable product.

10.10.3 Process Material

Materials that are required in the manufacturing process, but do not become part of the shippable product.

10.10.4 Customer-Furnished Material

Items consumed during the production process or items that become part of the final product.

Traditionally, the inspection process follows the following steps:

- First article inspection
 - Inspect inquiry for noninventory parts
 - If nonconforming, the item goes to the MRB for disposition
- Documentation verification
 - Drawings
 - Specifications
 - Vendor inspection and test records
 - Identification label accuracy
 - Material certification receipt accuracy
 - Markings and packaging
 - Supplier status
 - Receipt record accuracy

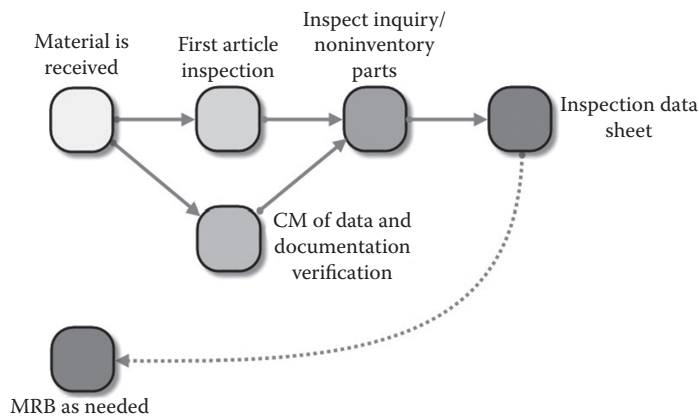


Figure 10.15 Material receiving and inspection flow.

- Expiration date
- Approved variances (deviations and/or waivers)
- Evaluation against any active alerts (GIDEP, or other)
- First article inspection data sheet

Each of these steps involves CM at the vendor with the resultant generation of configuration-controlled records by the customer. This flow is summarized in Figure 10.15.

WHEN THINGS GO WRONG

IV

Chapter 11

When Things Go Wrong!

11.1 Areas of Configuration Management Risk

The yearly sum of mechanical, interface, electronic, and other issues documented in the world press bear witness to areas where configuration management (CM) or the lack thereof has caused significant problems for the project, product, and a company. This chapter will relate examples of where lack of consistent enterprise CM has been part of the root cause. Larry Bowen* was instrumental in identifying areas that can be tied directly to CM disasters. His initial list has been expanded to include the following:

- Hardware and software integration
 - Software and hardware changes that are not coordinated among the communities creating problems in integration test
- Ineffective interface control working groups (ICWGs)
 - Dealing with external interfaces especially in concurrent development programs. This keys with poor Memorandum of Understanding, Memorandum of Agreement, and Associate Contractors Agreement that address the ICWG activity
- Milestone slips because metrics were not used to determine where a project was
 - Needed early enough to establish workarounds to fix the problems
- Inordinate change processing duration and number of changes
 - Resulting in greatly fluctuating functional baseline requirements and the inability to formulate a meaningful allocated baseline
- Lack of change implementation after approval
 - Resulting in mixed stock and/or items that do not conform to engineering in the inventory
- Lack of control of item identification
 - Resulting in poorly designed items having the same item identification as their replacement parts
- Undocumented changes or part substitution in final product
 - Resulting in life cycle management issues

* CM Manager at Ball Aerospace & Technologies Corporation.

- Lack of proper configuration control board (CCB) stakeholder review
 - During and after development
- High rate of scrap and repair
 - Root cause analysis not performed
- Maintaining software code and its associated design documentation
 - Baselines are out of sync and incomplete
- Lack of baseline control
 - Resulting in misunderstood requirements, analysis, and CM implementation
- Inadequate training to those performing CM functions
 - Result in a lack of CM control

We have collected examples of each of these areas through personal experience, one-on-one interviews, and online discussion groups and have presented them in the sections that follow.

11.2 Hardware and Software Integration

11.2.1 Commercial Titan—Intelsat 603

Commercial Titan (also known as 6F3) was developed as a leveraged design from Martin Marietta's successful Titan 3 line of boosters. It was designed to be capable of deploying one or two satellites into space utilizing a dual-dispenser control system. Commercial Titan first launched on January 1, 1990 carrying Skynet 4A for the U.K. Ministry of Defense and JCSAT 2 for the J SAT International.

The payload manifest for the second launch was for Intelsat 603, a single payload. The second launch occurred on March 14, 1990. Due to lack of coordination between the software and hardware development teams the dispenser control system was set as though two payloads were preset. The firing command was sent to the lower payload cable and the separation command was sent to the upper payload cable. The Commercial Titan launch vehicle failed to release the Intelsat 603 payload. The satellite was ordered to free itself from the Commercial Titan vehicle and its Orbus kick motor and to stabilize its low orbit using thrusters onboard the satellite. This reduced its operation life from 15 to 12 years. Intelsat 603 was rescued by the Endeavour shuttle on its maiden voyage on May 7, 1992, as STS-49. See Figure 11.1.

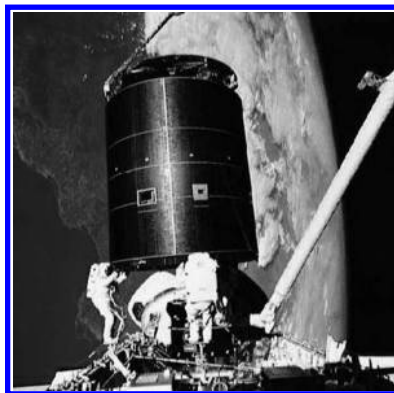


Figure 11.1 Intelsat 603 rescue.



Figure 11.2 QuickBird 1 Bolides over Argentina.

When Commercial Titan started, it was anticipated that the market existed to support five launches a year over a five-year period. Due to the losses sustained with the second Commercial Titan, the launch system was determined to be noncompetitive and the launch system was withdrawn from service after the fourth launch on September 25, 1992.

11.2.2 *Космос-3М—QuickBird 1*

November 20, 2000, a Космос-3М (also known as Cosmos 3М) was launched from Plesetsk Cosmodrome at 23:00 coordinated universal time (UTC). The second stage of the 3М shut down prematurely due to configuration errors and could not be restarted when the spacecraft reached Apogee to place it into the proper polar orbit. Payload retrograded in the atmosphere with reports of the bolides received from Montevideo, Uruguay; Argentina (Santa Fé and Buenos Aires); and our other territories (Mines and Paysandu). Figure 11.2 shows the QuickBird 1 bolides.

QuickBird 1 was lost. The satellite was built by Ball Aerospace for DigitalGlobe, LLC. DigitalGlobe had insured the launch for not only the cost of the development, build, and launch of the satellite but also for loss of anticipated profits. As a result of the Cosmos 3М failure and the insurance payout associated with it, launch insurance rates worldwide were increased.

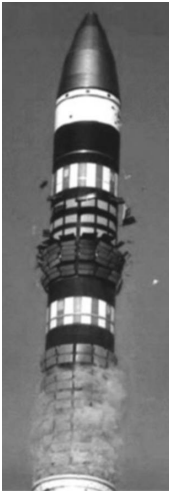
11.2.3 *Items Delivered of Unknown Configuration*

We have witnessed or heard this story so many times that this must be a common failure. In one case related to us via LinkedIn, prototype iterations are sent to the customer. The customer calls the supplier when the parts show up and do not work. No one at the supplying organization can say just what the constituent parts of the product the customer has. This is especially difficult or critical when it comes to the software portion of the product as there is no documentation or notation appearing to discern the functionality contained or even linkable part number in some case. Software that has considerable configuration possibilities becomes yet more difficult to identify.

11.3 Ineffective ICWGs

11.3.1 *Missile-X Interfaces*

The initial development of an advanced Intercontinental Ballistic Missile (ICBM), the LGM-118, to replace the aging U.S. Minuteman and Titan 2 series of ICBMs and keep pace with Soviet technologies was started in February 1972. It was designated “Missile X,” or simply “MX,” with initial operational capability scheduled for 1985. By 1977, it was decided that the MX would be comprised of three stages powered by solid-propellant rocket motors and a liquid-fueled post-boost vehicle that would carry 10 multiple independently targeted reentry vehicles.

**Propulsion:**

First stage—Thiokol solid-fuel rocket motor; 2225 kN thrust

Second stage—Aerojet solid-fuel rocket motor; 1225 kN thrust

Third stage—Hercules solid-fuel rocket motor; 290 kN thrust

Post-boost stage: Rocketdyne restartable liquid-fuel rocket motor

Diameter: 2.34 m

Length: 21.6 m

Weight: 87,300 kg (at launch)

Speed: 24,100 km/h

Range: 10,900 + km

Service ceiling (Apogee): 800–1000 km

Armament: 10 × Mk.21 MIRV

Cost: \$70,000,000

First launch: June 18, 1983

Initial operational capability: December 1986

Last launch: July 7, 2004

Retired in 2005



All figures are approximate.

Figure 11.3 Missile-X (also known as Peacekeeper).

Martin Marietta was awarded the systems integration and test contract as well as select components and development of the associated ground support equipment. MX was designed to use a cold launch system much like the submarine-based Polaris missile. When stored in its launching canister and launched by the high-pressure gas jet, the missile was separated from the canister walls by many small *adaptors* mounted to the side of the missile. When the canister was cleared, these adaptors fell away. Due to inconsistencies in ICWG activities, not all missile stages were the same diameter, resulting in one stage having a different pad configuration than the others (see Figure 11.3).

Six canisters were built by Hercules in Utah. These were the largest filament-wound graphite structures in the world at that time. The canister technology led to filament-wound boosters for the U.S. space transportation system (STS) shuttle boosters.

11.3.2 Mars Climate Orbiter

The Mars Climate Orbiter (see Figure 11.4) left Earth on December 11, 1998, to study the climate of Mars. On September 23, 1999, NASA lost contact.

**Figure 11.4** Mars Climate Orbiter.

The peer-review findings indicate that the ground-based computer software used English pound-seconds whereas the contract for spacecraft development specified metric newton-seconds. The Orbiter approached Mars from an altitude of 60 km instead of 150 km. The \$125 million-spacecraft was placed on a trajectory that brought it too close to the planet and was torn apart in the Martian atmosphere.

11.4 Milestone Slips because Metrics Were Not Used to Determine Where a Project Was

11.4.1 Throwing Decisions over the Fence

The development of a new product was being done on a very tight schedule in an integrated project team environment. The program had been aggressively bid with very low profit margins and it was critical that all changes be reviewed and approved in a less than a five work-day period. No metrics were put in place to track engineering change order (ECO) approvals due to the five work-day mandate. The development team was rapidly approaching a major review when it was discovered that the design of several key components were stalled in the program's change system due to lack of approvals.

Analysis of the changes showed that over 30 pieces of engineering had been in the approval cycle an average of 58 work days. One had been in the approval cycle for 118 work days. A closer analysis of each change was made and it was determined that there was a waterfall effect. The change that had been in review for 118 days was for a gasket and over the case of the ECO review the decision regarding what material it was to be made from have bounced between several departments on roughly two-month centers. Individuals would sign off "contingent" on further review by someone in another department. Eventually, over 48 people had reviewed the change and still no decision had been made. Some reviewers had contingently approved several times. The average number of reviewers on all changes was six.

The part's material characteristics drove its design and size. That size drove the next higher assemblies design and size. Without a decision the entire design could not move forward. Once metrics were developed and implemented multiple other assemblies were found to be at risk of meeting their design complete dates. These assemblies were not associated with a single design element such as mechanical or electrical but instead were found across all disciplines.

11.4.2 Company-Level Procedural Approval Holds Up Multiple Programs

To accommodate a wider level of customers a company decided to redefine its quality management processes to allow for multiple levels of reliability in its products based on customer needs. This was done to lower the bid costs on products with a shorter expected operational life rather than designing and manufacturing products with only the highest quality components.

A team of subject matter experts was assembled and all impacted policy and procedure changes were agreed to. A set of redlined documents was produced and engineering change requests (ECRs) were created. The generation of the ECOs was turned over to the owning department. The bid and proposal department was told to proceed with bidding new work against the policy and procedure redlines attached to the ECRs in anticipation of all changes being approved and implemented within 20 work days.

The company was awarded multiple new contracts three months later for products based on a lower level of quality and the use of materials with a shorter lifespan. The contracts were approved by the contractor's vice president based on his being told that all of the policy and procedure changes had been made. During an audit by the British Standards Institute for assessment of the company against the International Standards Organization implementation it was found that one department had taken no action to start the ECO approval. Resolution of the finding that work was being done other than as documented discovered that a transition from a retiring department manager to the successor had taken place at the time of the ECR generation. The new manager was not aware that any actions were needed.

Reviews on the new awards were delayed for a period of 40 work days while the department's ECO was approved and its people were trained. A fall out of the late implementation of the policy and procedure changes was the need to redo all of the documentation generated by the department on these programs and resubmittal of multiple documents to the customer for approval prior to the reviews taking place.

A policy and procedure corrective action and review board was established at the company. Metrics were tracked against expectations and multiple late to plan policy changes were discovered.

11.5 Inordinate Change Processing Duration and Number of Changes

11.5.1 Low Temperature Microgravity Physics Facility

The low temperature microgravity physics facility (LTMPF) was developed by NASA to provide a long-duration low temperature and microgravity environment on the International Space Station (ISS) for performing fundamental physics investigation.

LTMPF was a joint Jet Propulsion Laboratory (JPL), Ball Aerospace, and Design Net Engineering project funded by NASA that started in 1995. The system as conceived was for a system that provided two experiments with liquid helium cryogenic temperatures for up to five months at a time on the Japanese experiment module—exposed facility (JEM-EF) (see Figure 11.5).

During the summer of 2002, the initial flight of the LTMPF was delayed from late 2005 until early 2008 by a two years slip in the ISS manifest due to budget overruns. Further delays occurred because of the Columbia accident grounding the Shuttle fleet, but the LTMPF continued development for a launch readiness of early 2008.

Excessive change traffic and concept redefinition played a significant part in the costs associated with the program and eventual de-scope of the project portion assigned to Ball Aerospace & Technologies Corporation. While the obround (oblong) Dewar was completed much of the

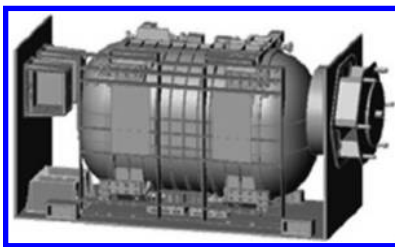


Figure 11.5 Low temperature microgravity physics facility.

activity was pulled back by JPL in an attempt to save cost and schedule. This in part was due to an experiment swap resulting in significant modifications to the facility design compared to the previous baseline design. On September 9, 1999, the LTMPF completed a successful requirements definition review.

Changes made included a redesign of the Dewar vent line to lower the on orbit temperature of the liquid helium bath from 1.6 K to 1.4 K, significant wiring modifications to accommodate the microwave drives needed for the superconducting microwave oscillator (SUMO), reconfigured electronics boxes, and a redesigned magnetic shield to meet SUMO's strict requirements. Additionally, work was being spent on defining how SUMO and the LTMPF will interface with the primary atomic reference clock in space experiment while both are on the JEM-EF to fully exploit the synergy of the two payloads. LTMPF was eventually canceled due to the remanifestation of the last STS payloads. The lack of a clear set of design criteria resulting in excessive changes and multiple iterations of the functional baseline drove the LTMPF costs and may have contributed to the decision.

11.6 Lack of Change Implementation after Approval

11.6.1 Apollo 13 Oxygen Tanks

Apollo Service module cryogenic oxygen tanks were well insulated and could hold several hundreds of pounds of liquid oxygen for breathing, electrical production, and water generation. The heater and protection thermostats were originally designed for the Command Module's 28 V DC bus. The specifications for the heater and thermostat were later changed to allow a 65 V ground supply, in order to pressurize the tanks more rapidly. The tank contractor did not upgrade all of the previously built units to handle the higher voltage.

The oxygen shelf carrying the oxygen tanks was originally installed in the Apollo 10 Service Module, but was removed to fix a potential electromagnetic interference problem. During removal, the shelf was accidentally dropped about 5 cm because a retaining bolt had not been removed. The tank appeared to be undamaged, but a loosely fitting filling tube was apparently damaged, and photographs suggested that the close-out cap on the top of the tank may have hit the fuel cell shelf. After the tank was filled for ground testing, it could not be emptied through the normal drain line. To avoid delaying the mission by replacing the tank, the heater was connected to a 65 V ground power to boil off the oxygen. Lovell signed off on this procedure. It should have taken a few days at the thermostatic opening temperature of 27°C. However, when the thermostat opened, the 65 V supply fused its contacts closed and the heater remained powered.

This raised the temperature of the heater to an estimated 540°C. A chart recorder on the heater current showed that the heater was not cycling on and off, as it should have been if the thermostat was functioning correctly, but no one noticed it at the time. Because the temperature sensor was not designed to read higher than the 27°C thermostat opening temperature, the monitoring equipment did not register the true temperature inside the tank. The gas evaporated in hours rather than days.

The sustained high temperatures melted the Teflon insulation on the fan power supply wires and left them exposed. When the tank was refilled with oxygen, it became a bomb waiting to go off. During the *cryo stir* procedure, fan power passed through the bare wires, which apparently shorted, producing sparks and igniting the Teflon. This in turn boiled liquid oxygen faster than the tank vent could remove it (see [Figure 11.6](#)).

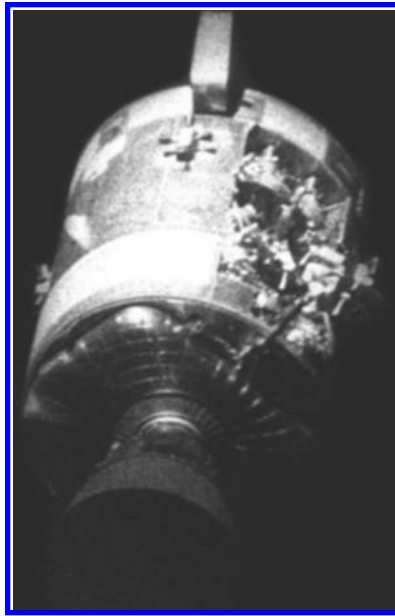


Figure 11.6 Apollo 13—Service module after separation.

The investigation board did recreate the oxygen tank failure; it did not report on any experiments that would show how effective the cryogenic malfunctions procedures were to prevent the system failure by de-energizing the electrical heater and fan circuits.

Oxygen tank 2 was not the only pressure vessel that failed during this mission. Prior to the accident, the crew had moved the scheduled entry into the lunar module forward by three hours. This was done to get an earlier look at the pressure reading of the supercritical helium tank in the lunar module (LM) descent stage, which had been a suspect since prelaunch. After the abort decision, the helium pressure continued to rise and the mission control predicted the time that the burst disc would rupture. The helium tank burst disc ruptured at 108:54, after the lunar flyby. The expulsion reversed the direction of the passive thermal control roll (nicknamed the “barbecue roll”).

11.7 Lack of Control of Item Identification

11.7.1 General Motors Corporation Switch Recall

On June 30, 2014, General Motors announced a massive recall for ignition switches due to detent plungers rotation issues in millions of vehicles worldwide manufactured back to 1999. The detent plunger issue can cause the key to rotate from the run to the accessory position. The key issue was known as early as 2001.

In this case, the switch in question is 10392423. The force exerted by the detent plunger was found to be insufficient at 9.24 n-cm for its intended purpose. A service advisory was issued in 2005 and a replacement detent plunger was designed in 2006 increasing the torque value to 17.57 n-cm and installed in the switch but the part number of the switch was not changed.

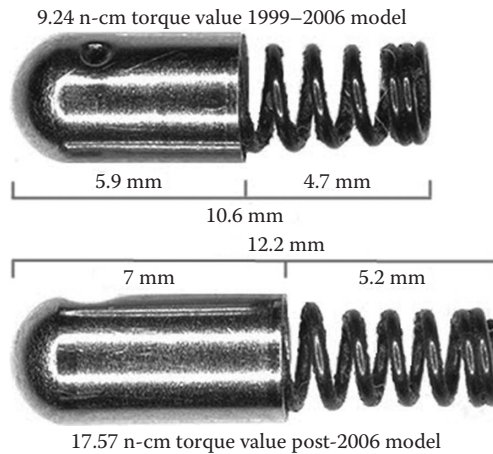


Figure 11.7 General Motor's detent plunger for switch 10392423.

Switches manufactured prior to 2006 took less torque to rotate than those manufactured previously. Unfortunately, as with the Apollo 13 oxygen tanks, no retrofit activity took place on the previously produced switches and as the switch part number did not change, there was no easy way to determine which vehicles had the longer detent plungers installed. Over a dozen people died as a result (see Figure 11.7).

The issue ties directly to a lack of proper part identification. No two parts should ever have the same item identification if they are different and differences in part identification roll up to the level of interchangeability.

11.8 Undocumented Changes or Part Substitution in Final Product

11.8.1 *Solar Maximum Mission*

In January 1981, three fuses in the solar maximum mission's (SMM) attitude-control system failed due to a voltage spike. This necessitated the SMM to rely on the magnetorquers in order to maintain attitude. Three of the seven instruments onboard were usable due to the lost capability to point the other at the sun. The use of the satellite's magnetorquers prevented the satellite from being used in a stable position and caused it to “wobble” in its orbit.

The April 6, 1984, STS-41-C mission successfully captured the SMM, replaced the entire attitude control system module and the electronics module for the coronagraph/polarimeter instrument and a gas cover was installed over the X-ray polychromator (see Figure 11.8).

It was not without issues. A special capture device called the “Trunion Pin Attachment Device” mounted between the hand controllers of the manned maneuvering unit (MMU) was built to mate with the Trunion pin on the spacecraft failed when its trigger could not be activated due to interference caused by an undocumented grommet put on the spacecraft prior to launch in February 14, 1980. This jeopardized astronaut safety as the spacecraft had to be manually captured as well as the STS-41-C mission timeline.



Figure 11.8 Solar Max and STS-41-C.

11.8.2 1978 BMW 320i w/Four Speed Getrag Gearbox Pilot Shaft Bearing

Thank you Chris Dickson for this story.

At 80,000 miles, I started hearing a squealing (actually more like screaming!) noise when I would push in the clutch pedal. After pulling out my service manual and consulting the service manager at a local shop, I decided to order a replacement throw out bearing, clutch disc and pressure plate. The manual also showed a pilot shaft bearing but the service manager told me he had never seen one fail and given the fact that they were out of stock, I decided NOT to order this bearing.

At this point in my life I was young, single, and an engineer so tearing into a project like this didn't scare me at all. Furthermore, my two roommates were both engineers and had strong backs so I had backup. Unfortunately, on Friday afternoon when I was ready to start my repair project, I found out that both of them had gone home to visit their parents. There would be NO help on this and would not be around to help over the weekend. No problem; I could handle the job by myself! I had no problem dropping the gearbox and replacing the clutch. Getting it back into place was another story but somehow I managed to get it done. I got back into the car and cranked it up to pull it off the stands, I pushed in the clutch and you guessed it—screammmmmmmmmmm! I am sure many of you can relate. Well, what to do? I drove my screamer (not Bimmer) to the foreign car parts store where the owner and I once again pulled up the print showing the clutch assembly. Nothing left to do but replace the pilot shaft bearing; it was the only thing left.

Fast forward to the next Friday night and with the new bearing in hand; I dropped the gearbox and pulled the clutch assembly. I had my bearing puller ready to yank out that #!@ bearing. Only problem was, there was NO bearing. Instead of a drawn cup needle bearing there was a bronze bushing. A #!@ bushing!!! Luckily, the parts store was still open so I called and had the owner take a second look at the print; NO

bushing was noted. Having worked in the automotive industry for many years I could guess what had happened: the assembly line had run out of bearings and someone came up the brilliant idea to cut a few bronze bushings to keep the line going. Mission accomplished right? Wrong! Failure to manage change or configuration is a risk that is avoidable. How many times have you heard about car companies recalling thousands of cars because change was not managed. It happens more than you know and costs car companies and their suppliers millions each year.

Well—back to my 320. I yanked out that #!\$@ bushing and replaced it with a bearing. Time for the big moment; crank the car and push in the clutch pedal. No scream; mission accomplished!

Here is the point. This was all avoidable. If this change had been managed correctly, the prints would have showed two possible configurations and I could have had both parts ready when I dropped the gearbox. More importantly, before BMW allowed this change, it should have confirmed the viability of the substitution via testing. The bushing should have been proven equivalent in terms of fit, form, and function (quality). Otherwise, NO BUSHING!

11.8.3 Drop-In Replacement Sometimes Not So

We both have witnessed instances where a presumed drop-in replacement part was in fact not so suitable, of course, found out well after the fact. Parts substitution has to be one of the often-trivialized areas that affect our product. The typical origin of the failure is insufficient configuration and change management controls. Form, fit, function, and the quality of any substitute part must be thoroughly vetted before making changes in the part. The more critical the subassembly or component part to the function of the entire product, the closer this scrutiny. We have many examples of a small change in material composition causing an issue with the product longevity. We have seen substituting parts from less competent manufacturers because their product specifications are seemingly comparable to our present supplier, only to find unique areas of our previous supplier actually yielded a more competent part. One way to resolve is through the use of production part approval process (PPAP). The PPAP is used in the automotive industry to successfully launch a product on the vehicle and to manage the changes to the product. The PPAP contains a list of 19 documents or activity areas. Specifically, those are

1. Design records
2. Engineering change notes
3. Engineering approval
4. Design failure mode effects analysis
5. Process flow
6. Process failure mode effects analysis
7. Control plan
8. Measurement systems analysis
9. Dimensional results
10. Material performance tests
11. Initial sample inspection
12. Process study
13. Laboratory certifications
14. Appearance approval report

15. Sample production parts
16. Master (golden) sample
17. Checking aids
18. Customer-specific demands
19. Part submission warrant

Not all of these will apply to every product change; however, we can see to it that to make a change, we undergo a comprehensive approach or measure of due diligence. In general, there are five response levels to product changes. These are five PPAP submission levels and the levels look like

Level 1: Warrant submission only.

Level 2: Warrant submission and physical parts with some supporting data—which associated with the change (e.g., product change or process change).

Level 3: Warrant submission physical parts and complete supporting data (all prescribed documentation).

Level 4: Warrant submission, physical parts, and any other customer-identified requirements deemed necessary to mitigate the risks associated with the change.

Level 5: Warrant submission, physical parts with complete supporting data reviewed at the supplier's manufacturing location (usually for process changes and implications).

Of course, the process will not work if we are not aware of the product changes and can theorize the possible problems generated by the drop-in part. The entire PPAP in the instances defined thus far, is predicated on the customer awareness of change and of the process. Experience suggests even in industries where the PPAP process is well established, the level of prowess by the front line engineers may be insufficient for success. We must understand that all of the parts of our organization are connected and we cannot have a cavalier approach to our product quality.

11.9 Lack of Proper Configuration Control Board Stakeholder Review

11.9.1 *Harness Support Bracket Redesign w/o Harness Team Input*

An automotive development project with a multinational product development team was recently working toward a common target, with periodic convergences to construct the system via prototypes. In many instances, the prototype parts did not merge well, indicating a loose change review system. In some cases, communication in the development of the subsystems appeared to be lacking. A review indicated that design engineers at each of the sites had little coordination of their efforts through any form of integrated change management system.

All of the teams understood the requirements at start of design with due processing of interface documentation. As the project moved forward, the team focus started to drift resulting in a bracket redesign with no stakeholder review of the entire team. One bracket existed solely to support the wiring harness. A bracket alteration by the structures team made it unsuitable to use for the harness mounting it was originally designed for.

11.9.2 Small ICBM Internal Shelf Design

The U.S. Small ICBM (Small Missile) project was originally conceived as a mobile ICBM to decrease U.S. vulnerability to attack in response to the Soviet development of the SS-24 Rail Mobile ICBM and the SS-25 Road Mobile ICBM. During the developmental stages, it was determined that a slight increase in the missile diameter would provide the necessary geometry to accommodate a different payload configuration. The change to the missile was negotiated with the U.S. government and the necessary redesign was started (see Figure 11.9).

Inherent to the missile design was a shelf attached to the interior of the missile. This shelf was used to hold guidance control and other components. A structural analysis was performed by the shelf design team that indicated the need to make the shelf more ridged by increasing the number of attachment points to the missile outer structure. This change was not coordinated with the vehicle structures team who continued to develop a larger diameter missile with the same number of mounting holes as the small diameter design.

The contracts manager noticed the design disconnect before hardware had been manufactured and the program CCB was expanded to include all of the design team and not just the individual design cells. The first successful test flight took place on April 18, 1991. The program was canceled in 1992. The Small ICBM graphite fiber-wound solid booster technology was leveraged forward on the side boosters of the Delta and the Orion stages of the Pegasus air launch missile.

11.9.3 Informal Change Management

Change management is inextricably linked to both CM and project management. Poor and unclear change management process will have influence on project and product success.

One project's scope was to create a new electronic architecture for heavy vehicles. This architecture change consisted of a multitude of electronic control units (ECUs). These ECUs are connected together via a data link sharing information in a network. The company employs a



Figure 11.9 Small ICBM.

stage gate method of project management with iterative prototype parts throughout the development of the product—both for software and for hardware. The problem arises when two entities delivering two components (subsystems). These entities have parts of the system that have direct interfaces, and these entities are responsible to deliver the hardware and the software (developed or managed) of these subsystems. In the course of the development entity, one needs to change messages. These two entities talk and arrive at a changes required for the system and set about making the change. They eventually generate their portion of the subsystem for the verification group to test.

The verification group begins testing to the specification and finds that the product (system) does not perform as expected or documented. Additionally, functions that worked in the previous iteration of the system now do not. The change to the message content was only shared by these two groups and other ECUs used that message for their respective portions of the functions. The change was not planned for by those ECU owners.

The issue went deeper than this one of four project team members also made a small change in design, neglecting to communicate that change to the other team members. The alteration to the subassembly or component appeared so trivial that there was no need to articulate this to other associated parts, as it was deemed a design improvement. The parts from the four teams come together, and nothing fit or worked as planned.

11.9.4 Open Loop and Stove Pipe Changes

During a new vehicle platform development issues were found during prototype fit checks and interoperability testing. These are eventually traced back to computer-aided design models not being checked out or back in as design changes are made. As a result, coordination between four different design departments breaks down.

ECRs are not coordinated between departments prior to incorporation but retained in a closed-design team environment. Some of the designers keep copies on their individual machines and update the drawings and models only when the parts are ready for a prototype release, prohibiting other departments that are using these models by witnessing the changes in the design dynamically. That enables the viewers of the changes in the model to ask questions and bring concerns to the fore as well as adjust their portions of the design.

After check in, some of the model layers are not turned on to allow visibility of the other parts of the vehicle. When the parts come together that the electrical layer was not turned on and no electronics have been developed.

11.10 High Rate of Scrap and Repair

11.10.1 Untested Item Substitution

In early 2009, a major electronics firm producing environment-resistant printed wiring assembly (PWA) for a new product line suddenly started experiencing issues in its conformal coat processes. At an increasing rate that eventually reached 90% conformal coat was bubbling during the cure process and after cure would detach during vibration testing. At the time 10% of the board build and conformal coat had been offloaded to a subsidiary. All conformal coating was being done using the same processes and equipment yet only the boards conformal coated at the subsidiary passed inspection.

An evaluation of process records-associated conformal coat facilities showed that the processes had been adhered to, humidity levels were acceptable when the conformal coat was applied, bake temperatures and time were adhered to. Process engineering was stumped.

It was discovered that in an effort to save costs supply chain had found a second source for conformal coat material and issued it to the factory floor. The new material was administratively added to the database of authorized part substitutions without first being analyzed by parts materials and processes and validated against existing conformal coat procedures. The subsidiary still had stores of the older material in stock and had not yet started using the new material.

The estimated cost impact to rework the PWAs and tear down the conformal coat facility to remove all traces of the new material exceeded \$1.6 million.

11.11 Maintaining Software and Its Associated Design Documentation

11.11.1 Source Code and Compile

Another piece of the CM pie is the ability to move backward and forward from revision to revision. A developer writing in assembly language for a new product incrementally developed the features for the product. These features were reviewed at established milestones. He came to one of these milestones; he compiled the software and *burnt* the code into the microcontroller. After the code was in the target system, he conducted a series of tests to ascertain the level of functionality. The developer made note of the things that worked and those that did not and went back to the software. He filed away the compiled code in a secure area, guaranteeing that he would be able to go back to this level of functionality. However, he continued to work with the source file, correcting the known bugs and adding the next phase of new content.

At some point, he compiled the new source code and *burnt* the new code into another microcontroller. He then set about testing the prototype part and nothing worked. The system did absolutely nothing. He went back to retrace his footsteps to find out what went wrong; he *burnt* the microcontroller with the old compiled version and that level of software worked.

The developer had the compiled version of the working software; however, as he did not manage the source code, holding it constant to the same level as the *burned in* code for the microcontroller, he had to take the binary file and run a conversion program to turn the binary file into the original assembly language. Only when this was done was he able to compare the reconstructed source code to the current developed nonfunctioning code. This took considerable time to compare and find out what change caused the entire product to stop working.

Doing a disassembly analysis was probably a suitable self-punishment for the lack of CM. The source code should have been checked into the software CM system, where this developer would have been able to protect himself from himself.

11.11.2 Merge Failure

Another area in which we find problems can be when we merge products; this seems to be more of an issue for software products, but not exclusive to those products. Due to the multiple cases identified only a summary will be provided. When a merge is made, two or more products are combined making one platform from which we will secure both. To do this, the content of both of the products

and merge these under controlled conditions must be known and documented. Examples of missing configuration items—not identified to be in the new summary product, resulting in a miss build of one of the versions of the product are prevalent. A software parameter that is set to make the product perform in a specific way for a certain variant of the future product if not identified will not end up in the final version of the product. Product integration happens and the lack of functionality is discovered during testing, production, or when a customer states the product does not work as advertised or as they expected it to perform.

11.12 Lack of Baseline Control

11.12.1 *Subassembly of Switch*

A rocker switch consists of electrical parts—the electrical contacts, the switch body, the portion that mates into the wire harness, and the switching mechanism.

The supplier ships test parts to the customer for testing. The customer has a specially designed test fixture for the switches. The fixture exercises the switches under an electrical load. Exercising the switches consists of actuating the switch-rocker mechanism, on-off over time with spacing between the activations. Feeler gauges are used to ensure that the switch-activating mechanism does not overdrive or push the switch past the switch point. The entire fixture is inserted into a thermal chamber, which applies the temperature ranges the switches can expect to see in the vehicle.

According to the supplier testing, the part can withstand the specified thermal exposure and also withstand hundreds of thousands of activations. The test engineer and technician review the setup one last time before starting the rather lengthy test simulating the life expected for the switches. The next day, the test technician calls the engineer and reports that of the sample population a significant population has failed. The failure symptom has the stalk of the switch activation post snapping from the switch mechanism rendering the switching mechanism useless. This was not supposed to happen after less than 24 hours of testing. The rig is carefully removed from the thermal chamber to determine causal source of the failure.

Overdriving the switch is reviewed, along with thermal profile, nothing presents as obvious at first. However, after looking at the interface between the operator and the switching mechanism, it is noticed that there is an interference fit, which results in the banging of the post against the retaining or capture area for the rocker. This causes a minor deformation in the plastic each time the switch was activated as this postimpacted the surface near the capture area. In the course of a few hours, this collision snaps the post. Subsequently, it is found that the switch posts repeatedly impacts against the capture area on every switch cycle. The parts are sent back to the supplier for review, and ultimately confirmation.

The reason for the failure turns out to be a CM issue. One of the subassemblies used in the prototype parts was from an earlier soft tool. The shape of the switch interface capture area had a larger radius allowing the switch post to collide with the rocker stops rather than allow the switch to come to the rest position. This repeated collisions caused the plastic post to deform and over time snap. Had the switch been built with the appropriate subassemblies, there would have been no contact between the switch post and this bossed area. Finding this out meant the testing would have to start over again when the correct configuration of the parts was assembled and available.

11.12.2 Insufficient Development Baseline Definitions

Seldom is it a good idea to plan all of the product features in one delivery. Besides the fact that all of the product features likely do not have the same priority or focus, likewise not all of the requirements that are to be met have the same level of complexity. The more complex the product or system, the more important prioritization and coordination of the subsystems and function growth is required. We can improve our chances of success via sufficient planning of the product growth across the entire system and development life cycle. If we do not perform this planning of the development packages we will inevitably waste time and cause great frustration.

Consider the project that delivers a distributed system consisting of a multitude of embedded subsystems. A single function of the system is “splashed” across the entire system, for example, one part of the embedded system reads sensor data, then broadcasts that across a network, another receives this information and takes some action—either presents information to the user or takes some action based on this signal. A specific example from an automotive application would be the speedometer in the instrument cluster has that information provided by another unit on the vehicle. It is not possible to test or verify the systems capability without both (or all) parts of the system available that are required for the function. If the capabilities or requirements that are met in each package and component of the system are not identified the verification group will not be able to prioritize the testing.

We have seen this situation turn for the worse as our verification team steadily reports failures into the fault tracking system. The developers review the faults reported and are astonished that the test people are writing fault reports for features that have yet to be built. How is one to know, whether a feature is not built, or is not functioning due to failure or fault in software or hardware? Instead, define the iterative development packages as a map of the development work. Prioritize the feature content in some way, most profitable, most demanded, most complicated, or legal requirement. Then produce version description document often referred to as release notes, with the iteration. In this way, we describe the content and any known nonconformance (see Chapter 13).

11.12.3 Lack of a CM-Managed Functional and Allocated Baseline

An automotive project to create a new vehicle is underway. The vehicle will have considerable new content, while building on an existing platform. The changes for this new platform are largely on the interior, some exterior parts, and considerable portions of the electrical and electronic systems. The company develops all of these systems simultaneously. The changes to the cab interior are made at the same time as there are changes to the electrical and electronic system. The changes require the variety of disciplines that are available to the organizations, the cab group, the chassis group, and the electrical groups are principles in the work. Unfortunately, neither the project nor the line organizations have a good handle on managing the requirements that come with this new platform. There is no document or controlled allocated baseline due to the poorly defined functional baseline.

In the course of the project, there are instances where this lack of baseline management causes great harm to project schedule and cost and group morale as they first do, then redo the work. Subtle changes to mechanical portions of the system that cause interference fits with the electrical system—including the wire harness. These interferences are uncovered during the prototype builds when it is discovered that the vehicle cannot be built. A group then has to cut and modify the parts to make the system work causing considerable hours wasted in rework (unplanned in the schedule or the budget).

Four more incidents happen in the course of this project life. Some of the changes are found in the design reviews or design for manufacturing exercises. Most make it to the prototype vehicle and are solved there. All could have been avoided.

11.12.4 Design Baseline Updated from Wrong Revision

A modification is to be made to an existing set of hardware. The modification begins, post project activities with the updating of the functional schematic that defines the system. The typical resources for this update, the systems group is short on resources and not able to make the updates in the allocated time for the project to deliver in the project defined time.

To close the gap, another group agrees to make the drafting changes to the documentation and have the changes reviewed through the normal change approval process so that progress is made toward the desired product introduction date. The specific change being made is to part of the schematic and not to all of it.

Revision B of the design schematic is pulled from the archive file rather than the current revision C from active file and updated. Revision B version is updated and released as revision D undoing all of revision C changes. The use of the wrong revision causes a two-week slip in the program's already tight schedule.

11.13 Inadequate Training of Those Performing CM Functions

Every function or department within a company performs some aspect of CM. The entirety of enterprise CM does not rest on a single department, nor does the entirety of CM rest on the shoulders of a single project individual or a single team of individuals. There is a symbiosis between all functional elements that collectively accomplishes CM as defined in guidance and requirements documents. It is a collective effort. The product life cycle demands this. As products become more complicated and the boundaries between hardware, firmware, software, and biomechanical interfaces blur, CM will continue to increase in difficulty. CM professionals will take on an increasingly important role in orchestrating CM across the industry infrastructure as well as defining boundaries/trigger points associated with product planning and management, configuration identification, configuration change management, configuration status accounting and configuration verification, and audit.

Regardless how well trained the staff of any department called "configuration management" maybe it is incumbent on company management to train everyone at the firm in what CM activities are and how their department or function relates to the larger sense of CM. All of the errors identified in this chapter when viewed by those involved retrospectively stem from a general lack of understanding of the interrelationship of how and what they were doing related to the ultimate goal rather than any deliberate action. This is born out in over 1200 audits of program performance across hundreds of companies worldwide.

11.13.1 What Is the Point of Processing an Engineering Order

A company manufacturing a series of assemblies with unique system architecture was making a more robust block update to the design of the power distribution system. The power distribution system was tested using a specialized test set and with an operating system at version 5.1 prior to the electronics design update.

The engineer responsible for the software design (Fred) was being transitioned into another roll at a sister facility, and the development of the new operating system was transitioned to a highly skilled associate (George). Three years later George was let go due to a reduction in staffing caused by market conditions. His computer hard drive was removed in accordance with company procedures and reformatted for use by another person.

One year after George was let go a second update to the power distribution system was in development and the operating system on the test set required another update. Software released in the product data/life cycle management (PD/LM) system was still at version 5.1. Software resident in the test equipment was at version 10.5. No documentation existed for any of the versions between 5.1 and 10.5. A set of compact disks were found in a box next to the test set containing the operating system versions 6.0 through 10.4. The company processed ECOs for each version and *administratively* changed the release dates to match the file date in the PD/LM system. Working with the software CM function version 10.5 was downloaded from the test set and converted, so that it could be edited using the software development tools. The research and backtracking cost the company 300 hours. During the investigation, one engineer sitting nearby remembered that George had an engineering notebook. This was eventually found and the entry days after George was assigned the task read, “What’s the point of processing an EO for software used on any test set. Test software shouldn’t be put under configuration change control.”

11.13.2 Where Is That Written Down?

All design activities had been finished and the first set of final assemblies built and turned over to a newly qualified set of test conductors to perform a 100,000 cycle life testing of the unit. Results were encouraging and general status was provided to the design and other program team members on a nightly basis via e-mail. They generally simply stated, “All is nominal.” No specifics were ever included. 1000 cycles could be run in 6 hours. At that point test was halted, the units were disassembled, inspected, and reassembled. This was the daily shift routine during the three-shift 34-day test cycle.

At the end of the test activities, the test conductors were asked to prepare a plot of test results against expectations.

Do what?

The expected test results and parts wear had been projected for the major assemblies with articulated interfaces based on design and stress analyses and that the tables were in exhibits to the test procedures.

Yeah ...

We would like to see the actuals graphed against the predictions so we can adjust our models and have the data available to support FCA activities.

Where is that written down that we have to do that? When the units passed the life test we shredded the test logs!

With no documented substantiation, the entire life test had to be redone requiring the fabrication of a new set of final assemblies and another 23-day test cycle. The impact was over \$285K.

11.13.3 No Records to Combat Environmental Violation Allegations

In 1999, a major manufacturing facility was being sued by a small community located downstream who claimed that factory pollution of the groundwater was the cause of the high degree of a rare disease in their community when compared to surrounding communities. The facility had

been in operation for over 50 years and had been on the environmental watchlist by several proactive environmental organizations.

Prior to the enactment of country, state, or local environmental regulations the company's stance on environmental issues had been rather lax. In 1960, it drilled test wells along the perimeter of its holdings and ran an extensive testing for all chemicals and materials used at the plant. These tests proved to be negative. Not being sufficiently satisfied with the due diligence, wells were also drilled along the perimeter of each building that either housed or used chemicals for manufacturing. Results proved positive for contaminants associated with electroplating, anodizing, and beryllium milling and machining activities. Contamination was also found in its wastewater processing facility as well as in the sewage pipes that tied into the municipal wastewater disposal system. The wells also showed trace contaminants from an upslope source but as these were not from anything used by the company no mitigation efforts were put in place associated with those pollutants. No one at the company in 1960 who were involved in was still employed there in 1999.

Extensive mitigation efforts were put into place that included discontinuing all on-site manufacturing of items from beryllium and changing over its electroplating and anodizing processes to what was then considered state-of-the-art eco-friendly methods and materials. Wastewater processing facility upgrades and new piping connecting the facility to the municipal wastewater disposal system were installed. Testing continued until the date of the lawsuit and no other contamination from materials used at the plant were found from 1960 to 1999.

As the lawsuit proceeded, all environmental records were subpoenaed by the prosecution and only the records from the last five years were able to be located. Local medical authorities were informed and environmental organizations raised a cry of obstructionist against the company. As it turned out, all of the company's records over five years had been destroyed in an uncoordinated cost-cutting effort by the facilities department. Eventually, the company that performed the testing and mitigation activities was identified. Luckily they were able to locate the records for use by both the defense and the prosecution. The records proved that the contamination source was not the company in question but came from an old factory located 20 km higher in the terrain, which had been acquired by the city years earlier.

The government was satisfied that the company was a good environmental citizen and started extensive contamination mitigation at the old factory, which used to produce enriched radioactive materials for the country's nuclear efforts. Had there not been a sound tie between supply chain management and CM, the company who performed the mitigation could not have been contacted. CM had the records of the report numbers and a copy of the contract in its PD/LM database.

After the lawsuit, CM was tasked with assuring that all records associated with environmental activities be located, scanned, and attached to the CM records associated with the vendor in the PD/LM system.

11.13.4 Quotations

What follows are a list of quotations related by individuals from many companies worldwide. They were purportedly made by managers, directors, and vice presidents to help in illustrating some basic misunderstandings regarding the worth of CM.

CM? Why do we need to fund training for release clerks ... We should do away with CM in its entirety and turn release over to the designers.

At contract award for an operational system after a very successful proof of concept Engineering Development model had been demonstrated the Program Manager said,

"I don't give a Tinker's D___what the contract says, the processes or procedures say or you say. This is my program, I've worked with these guys for years on this thing and know exactly what the customer wants and C&DM isn't part of it!" 28 months later and 3 weeks before first article acceptance I received a late night phone call ... "OMG, you know that program that I fired your department from ... I ran it like the proof of concept lab ... why didn't anyone tell me we had to do FCA/PCA!"

You should be doing the new CM it costs less.

You should be doing the old CM it costs less.

We shouldn't do C&DM it costs less.

Configuration Management is a subset of Data Management. Give up the budget for one or the other I don't need both.

CM and DM add no value. With a good programmer and the PD/LM code I could eliminate the need for both functions in 6 weeks!

That's not how we did it at _____.

That's not how we did it on program X.

First month of the program, "The software is 90 percent done." 3 weeks before delivery, "The software is 90 percent done."

We got rid of the checkers and CD&M is next!

You are nothing but a bunch of people who couldn't make it as librarians.

Intellectual Property and ITAR legends are worthless. Nobody wants to steal this stuff, our design is really old school and if some foreign government did steal it what could we do about it anyway?

During negotiations: "We added 100 more CDRLs to the follow-on contract, just apply a learning curve and you'll see that C&DM costs less now. You already collect the data. Just format it the way the DIDs say and get over it."

You guys are living in the past. Nobody needs C&DM anymore. My admin can do the deliveries and the engineers can release their own stuff.

On my programs contracts does C&DM. Your department charges direct to my programs and Contracts charges G&A. I don't have to pay for them and I can show a greater profit.

This is a FOUO program, everything we produce has to be marked and controlled like we were in a Skiff.

Actually for a contractor it only applies to stuff not covered by the FOIA or FAR—i.e. Program financials and schedules.

Shall, Will, May ... don't they all just mean best efforts on the part of the contractor?

So we built this thing five years ago on a top secret program I worked on and I want to sell an exact copy to South Korea. You're telling me I can't do that because of ITAR?

I just don't get why hardware design, development and fab costs so much. Why can't you do as efficiently as Software?

Aren't you part of Document Operations?

All I need CM for is to release engineering. I want that done as efficiently as possible. No review or coordination of ECOs. Just release whatever engineering gives you. Another thing, I don't care if they want you to release a document that has no content in it. We need to keep our releases consistent with the release curves. I want no negative metric reports on the project. We'll do an updated release later where we add in the content.

TIEMPO, RELATED CM STANDARDS, AND REFERENCE DATA

V

Chapter 12

Test, Inspection, and Evaluation Master Plan Organized

Ensuring product quality is not accomplished solely through testing and verification activities. Testing is but a fraction of the techniques that are at an organization's disposal to improve their development quality. Good planning of the product incarnations, that is, a phased and incremental delivery of the feature content, makes it possible for an organization to employ test, inspections, and evaluation as tools for competitive advantage. To really improve (and prove product quality), a more comprehensive approach is required.

The Test, Inspection & Evaluation Master Plan Organized (TIEMPO) adds an extra method to the Test and Evaluation Master Plan (TEMP—specified in IEEE 1220 and MIL-STD-499B [Draft]) to support product quality. TIEMPO expands the concept of a TEMP by focusing on staged deliveries with each product/process release a superset of the previous release. We can consider these iterations our development baselines closely linked to our configuration management (CM) activities. Each package is well defined; likewise the test, inspection, and evaluation demands are well defined for all iterations. Ultimately, the planned product releases are coordinated with evaluation methods for each delivery. Under TIEMPO inspections are

- Iterative software package contents
- Iterative hardware packages
- Software reviews
- Design reviews
 - Mechanical
 - Embedded product
 - Design failure mode and effects analysis (DFMEA)
 - Process failure mode and effects analysis (PFMEA)
 - Schematic reviews
 - Software requirements specification reviews

- Systems requirements reviews
- Functional requirements reviews
- Prototype part inspections
- Production line process (designed)
- Production line reviews
- Project documentation
 - Schedule plans
 - Budget plans
 - Risk management plans

12.1 Philosophy of the Master Plan

At its core, TIEMPO assists in coordinating our product functional growth. Each package has a defined set of contents, to which our entire battery of quality safeguarding techniques will be deployed. This approach—defined builds of moderate size and constant critique—has a very agile character, allowing for readily available reviews of the product. In addition, TIEMPO reduces risk by developing superset releases wherein each subset remains relatively untouched. Most defects will reside in the new portion (the previously developed part of the product or process is now a subset and proven defect free). Should the previous iteration contain unresolved defects, we will have had the opportunity between these iterations to correct these defects. Frequent critical reviews are utilized to guide design and to find faults. The frequent testing facilitates quality growth and reliability growth and gives us data from which we can assess the product readiness level (should we launch the product).

12.2 Benefits of the Master Plan

Experience suggests the following benefits arise:

- Well-planned functional growth in iterative software and hardware packages
- Ability to prepare for test (known build content), inspection, and evaluation activities based on clearly identified packages
- Linking test, inspection, and evaluations to design iterations (eliminate testing or inspecting items that are not there)
- Reduced risk
- Identification of all activities to safeguard the quality—even before material availability and testing can take place
- Ease of stakeholder assessment, including customer access for review of product evolution and appraisal activities
- Experience also indicates that at least 15% of the time associated with downstream trouble shooting is wasted in unsuccessful searches for data simply due to lack of meaningful information associations with the developmental process baselines. The TIEMPO approach eliminates this waste ferreting out issues earlier in the process and allowing more dollars for upfront product refinement.

12.3 An Overview of One Approach

How each of these pieces fit together is shown below. TIEMPO need not be a restricted only phase-oriented product development, but any incremental and iterative approach will be the beneficiary of a constant critique including entrepreneurial activities.

12.4 System Definition

The TIEMPO document and processes begin with the system definition. Linked to the CM plan, it will describe the iterative product development baselines that build up to our final product function entirety. In other words, we describe each of our incarnations of the products in each package delivery. We are essentially describing our function growth as we move from little content to the final product. Each package will have incremental feature content and bug fixes from the previous iteration. By defining this upfront, we are able to specifically link the testing, inspection, and evaluation activities to not only make an iteration, but specific attributes of that iteration and capture it in an associative data map in our CM system. In the example of testing, we know the specific test cases we will conduct by mapping the product instantiation with the specifications and ultimately to test cases. We do this through our CM activities. We end up with a planned road map of the product development that our team can follow. Of course, as things change we will again update the TIEMPO document through our CM actions.

12.4.1 Test (Verification)

Test or verification consists of those activities typically associated with determining whether the product meets the specification or original design criterion. If an incremental and iterative approach is applied, prototype parts are constantly compared against specifications. The parts will not be made from entirely production processes but will increase in level of production content as the project progresses and we approach our production intent. Though prototype parts may not represent production in terms of durability, they should represent some reasonable facsimile of the shape and feature content congruent with the final product. We use these parts to reduce the risk by not jumping from idea to final product without learning along the way. We should learn something from this testing to use to weigh the future quality of the resultant product. It is obvious how testing fits into TIEMPO. However, there are some nonobvious opportunities to apply TIEMPO. We could use inspection as a form of test plan. Did we get the testing scope correct? We can also use this inspection technique on our test cases, analyzing if we will indeed stress the product in a way valuable to our organization and project, not to mention that we can inspect software long before it is even executable. The feedback from this inspection process will allow us to refine the testing scope, test cases, or any proposed nonspecification or exploratory-based testing. The testing relationships in a typical software–hardware release plan are shown in [Figure 12.1](#).

12.5 Reliability Testing

In the case of reliability testing, we assess the probable quality behavior of the product or process over some duration. Finding failures in the field is a costly proposition, with returned parts often costing the producer to absorb from profit five to ten times the sales price, not to mention the intangible cost of customer dissatisfaction. For reliability testing, small sample sizes are used when a baseline exists (and we combine Weibull and Bayesian analytical techniques) or larger sample sizes without a baseline. Physical models are used for accelerated testing in order to compute probable product life. Inferior models will hamper our progress, especially when a baseline does not exist. Our approach is specified in the TIEMPO document; along with what specific packages (hardware/software) used to perform this activity. Thus, our development and reliability testing are linked together via our CM work.

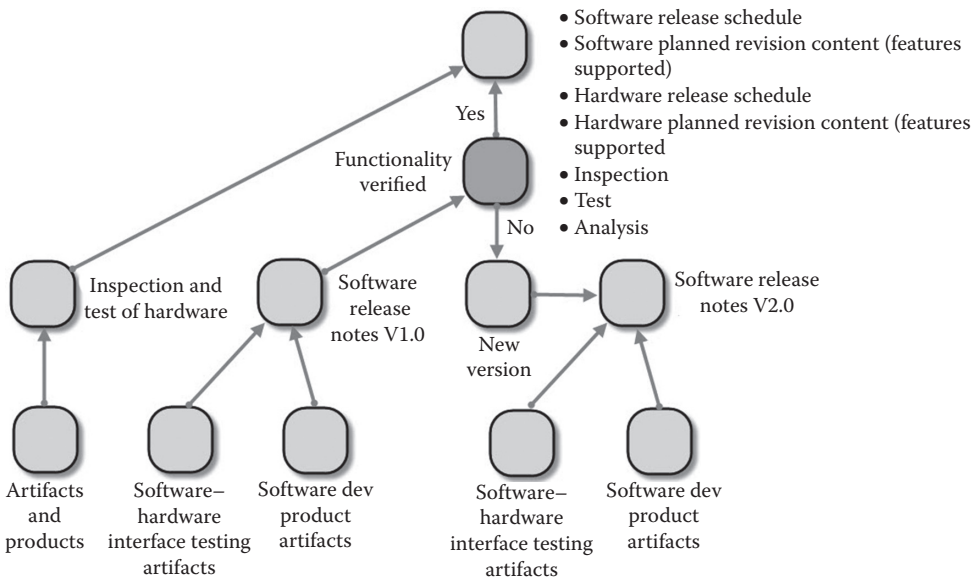


Figure 12.1 Testing relationships in a typical software-hardware release plan.

12.6 So, When Do We Start Testing?

Many may believe that it is not possible to test a product without some measure of hardware or software samples available. It is possible to test if we have developed simulators to allow us to explore the product possibilities in advance of the material or software. This requires accurate models as well as simulation capability. To ensure accurate models we will run tests between our model results and real-world results to determine the gap and make necessary adjustments to the models. We may even use these tools to develop our requirements if sophisticated enough. These activities reduce the risk and cost of the end design because we have already performed some evaluation of the design proposal. As prototype parts become available, testing on these parts is done alone or in concert with our simulators. If we have staged or planned our function packages delivered via TIEMPO, we will test an incrementally improving product.

12.6.1 Types of Tests during Development

When we get into the heavy lifting of the product or service testing, we have a variety of methods in our arsenal. At this stage, we are trying to uncover any product maladies which impact neither us nor our customer. We will use approaches such as

- Compliance testing (testing to specifications)
- Extreme testing (what does it take to destroy and how does the product fail?)
- Multi-stimuli or combinatorial testing
- Stochastic (randomized exploratory)

12.7 Inspections

Reviews are analogous to inspections. The goal of reviews is to find problems in our effort as early as we can. There may be plenty of assumptions that are not documented or voiced in the creation of these products. The act of reviewing can ferret out the erroneous deleterious ones allowing us to adjust. We can employ a variety of review techniques on our project and product such as

- Concept reviews
- Product requirements reviews
- Specification reviews
- System design reviews
- Software design reviews
- Hardware design reviews
- Bill of Materials
- Project and product pricing
- Test plan reviews
- Test case reviews
- Prototype inspections
- Technical and users Manuals
- Failure mode effects analysis (discussed further)

DFMEA and the PFMEA employed by the automotive industry can be applied to any industry. These tools represent a formal and well-structured review of the product and the production processes. The method forces to consider the failure mechanism and the impact. If we have a historical record, we can take advantage of that record or even previous failure modes effects analysis (FMEA) exercises. There are two advantages; the first of which is the prioritization of severity. The severity is a calculated number known as the “risk priority number” (RPN) and is the result of the product of:

- Severity (ranked 1–10)
- Probability (ranked 1–10)
- Detectability (ranked 1–10)

The larger the resulting RPN, the higher the severity; we then prioritize our addressing of these concerns first. The second advantage fits with the testing portion of the TIEMPO. The FMEA approach links testing to those identified areas of risk as well. We may alter our approach or we may choose to explore via testing as an assessment to our prediction. For example, let us say we have a design that we believe may allow water intrusion into a critical area. We may then elect to perform some sort of moisture exposure test to see if we are right about this event and the subsequent failure we predict.

12.8 Evaluation (Validation)

Evaluation can be associated with validation. With these activities we are determining suitability of our product to meet the customers need. We are using the product (likely a prototype) as our customer would. If the prototype part is of sufficient durability and risk or severity due to malfunction low, we may supply some of our closest customers with the product for evaluation.

Their feedback is used to guide the remaining design elements. This facilitates our analysis of the proposed end product. There are other ways to employ evaluation. Consider the supplier or manufacturer of a product to a customer for subsequent resale. We may perform a run-at-rate assessment on the manufacturing line to measure probable production performance under nearly realistic conditions. Now, we are evaluating the line under the stresses that would be there during production. We may use the pieces produced during the run-at-rate assessment to perform our testing. This approach is reasonable, as the resulting parts will be off the manufacturing line and built under comparable stresses to those in full production. In fact, we may choose to use these parts in the mentioned early customer evaluations.

12.9 Inspection Caveats

By definition, an inspection is a form of quality containment, which means trapping potential escapes of defective products or processes. The function of inspection, then, is to capture standard material and to stimulate meaningful remediation. Inspection for such items as specification fiascoes prevents the defects from rippling through impending development activities where the correction is much more costly. The containment consists of updating the specification and incrementing the revision number while capturing a “lesson learned.” Reviews take time, attention to detail, and an analytical assessment of whatever is under critique, anything less will likely result in a waste of time and resources.

12.10 Product Development Phases

Usually there are industry-specific product development processes. One hypothetical, generic model for such a launch process might look like the following:

- Concept
- System level
- Preliminary design
- Critical design
- Test readiness
- Production readiness
- Product launch

For the aforementioned processes, we could expect to see a test, inspection, and evaluation per phase, as indicated in [Figure 12.2](#).

The design aspects will apply to process design just as much as to product or service design.

12.11 Conclusion

There is no one silver bullet. Test, inspection, and evaluation are instrumental to the successful launch of a new product. This is also true for a major modification of a previously released product or service. We need not limit these to the product but can also employ the techniques on a new process or even a developing a service. Both testing and inspection provide for verification and

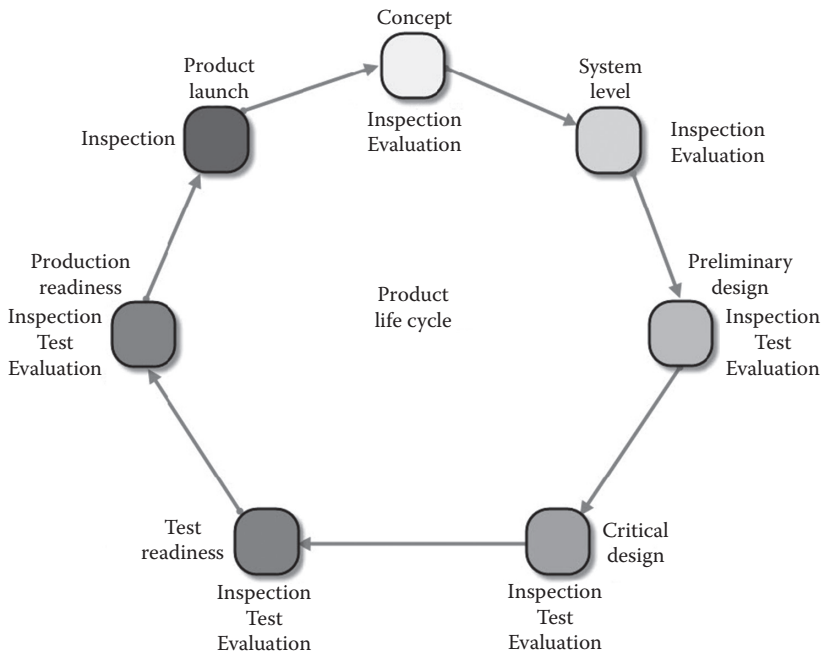


Figure 12.2 Test, inspection, and evaluation by phase.

validation that the product and the process are functioning as desired. We learn as we progress through the development. If all goes well, we can expect a successful launch. The automotive approach has been modified and used in the food and drug industry as the hazard analysis and critical control point system. Critical control points are often inspections for temperature, cleanliness, and other industry-specific requirements.

The following is an outline for a TIEMPO document*:

1. Systems Introduction
 - 1.1. Mission Description
 - 1.2. System Threat Assessment
 - 1.3. Minimum Acceptable Operational Performance Requirements
 - 1.4. System Description
 - 1.5. Inspection Objectives
 - 1.6. Critical Technical Parameters
2. Integrated Test, Inspection, and Evaluation Program Summary
 - 2.1. Inspection Schedule
 - 2.2. Integrated Test Program Schedule
 - 2.3. System Evaluation Schedule
 - 2.4. Management

* Pries, K.J., and Quigley, J.M. (2012). *Total Quality Management for Project Management*. Auerbach Publications Taylor & Francis Group, Boca Raton, FL. Reprinted with permission from the Publisher.

3. Developmental Test and Evaluation Outline
 - 3.1. Simulation
 - 3.2. Developmental Test and Evaluation Overview
 - 3.3. Component Test and Evaluation
 - 3.4. Subsystem Test and Evaluation
 - 3.5. Developmental Test and Evaluation to Dates
 - 3.6. Future Developmental Test and Evaluation
 - 3.7. Live Fire Test and Evaluation
4. Inspection
 - 4.1. Inspection Philosophy
 - 4.2. Inspection Areas (documents, code, models, physical parts, material)
 - 4.3. Inspection of Models (model characteristics, model vs. real world)
 - 4.4. Inspection Material (physical) parts
 - 4.5. Appearance Criteria
 - 4.6. Prototype Inspections
 - 4.7. Post Development Test Part Inspections
 - 4.8. Inspection Documentation
 - 4.9. Inspections Software
 - 4.10. Design Reviews
5. Operational Test and Evaluation Outline
 - 5.1. Operational Test and Evaluation Overview
 - 5.2. Operational Test and Evaluation to Date
 - 5.3. Features/Function Delivery
 - 5.4. Future Operational Test and Evaluation
6. Test and Evaluation Resource Summary
 - 6.1. Test Articles
 - 6.2. Test Sites and Instrumentation
 - 6.3. Test Support
 - 6.4. Inspection (Requirements and Design Documentation) Resource Requirements
 - 6.5. Inspection (source code) Resource Requirements
 - 6.6. Inspection Prototype Resource Requirements
 - 6.7. Threat Systems/Simulators
 - 6.8. Test Targets and Expendables
 - 6.9. Operational Force Test Support
 - 6.10. Simulations, Models, and Test Beds
 - 6.11. Special Requirements
 - 6.12. T&E Funding Requirements
 - 6.13. Manpower/Personnel Training

Appendix: Related Configuration Management Standards

Aerospace

- AS9100C, Advanced Quality System
- DO 178B, Software Considerations in Airborne Systems and Equipment

Alliance for Telecommunications Industry Solutions (ATIS)

- ATIS 0300250, Operations, Administration, Management & Provisioning (OAM&P)—Extension to Generic Network Model for Interfaces between Operations Systems and Network Elements to Support Configuration Management—Analog and Narrowband ISDN Customer Service Provisioning

American National Standards Institute (ANSI)

- ANSI INCITS TR-47, Information Technology—Fiber Channel-Simplified Configuration and Management Specification (FC-SCM)

American Nuclear Society (ANS)

- ANSI/ANS-3.2-1982, Administrative Controls & Quality Assurance for the Operational Phase of Nuclear Power Plants

American Society of Mechanical Engineers (ASME)

- ASME/NQA-1, Quality Assurance Program Requirements for Nuclear Facilities
- ASME/NQA-1B-2011, Quality Assurance Requirements for Nuclear Facilities Applications
- ASME/NQA-2A-1990, addenda to ASME NQA-2-1989 Edition, Quality Assurance Requirements for Nuclear Facility Applications

- ANSI/N45.2.11, Quality Assurance Requirements for the Design of Nuclear Power Plants
- ANSI/N18.7, Administrative Controls & Quality Assurance for the Operational Phase of Nuclear Power Plants
- ANSI/N45.2.9-1974, Requirements for the Collection, Storage, & Maintenance of Quality Assurance Records for Nuclear Power Plants
- ANSI/N45.2.13, Quality Assurance Requirements for the Control of Procurement of Items & Services for Nuclear Power Plants
- ASME Y14.100, Government/Industry Drawing Practices
- ASME Y14.24M Types & Applications of Engineering Drawings
- ASME Y14.34M, Parts Lists, Data Lists & Index Lists
- ASME Y14.35M, Revision of Engineering Drawings & Associated Documents
- ASME NQA Committee, Task Group—CM Draft, January 1991

Australia

- AS/NZS 3907:1996, Quality Management—Guidelines for Configuration Management
- Australian Army Configuration Management Manual (CMMAN) Army CM Manual; version 3.0
- DI(G) LOG 08-4, Configuration Management of Systems and Equipment
- DI(A) SUP 24-2, Configuration Management Policy within Army [currently being updated for issue as DI(A) LOG XX-X, Configuration Management Policy for Capabilities in the Land Environment]
- DI(A) LOG 1-33, Integrated Logistic Support and the Army Material Process (currently being updated)
- The Army Specification Manual (SPECMAN)
- EMEI Workshop A 850, Modifications, Trial Modifications, and Local Modifications to Equipment
- MINE WARFARE-STD-499B, Systems Engineering

Automotive Industry Action Group (AIAG) (North America Automotive Industry)

- QS9000, Quality System Requirements (replaced by ISO/TS16949)
- ISO/TS 16949 “Quality management systems particular requirements for the application of ISO 9001:2000 for automotive production and relevant service part organizations.”

American Society for Quality (ASQ)

- ANSI/ASQ Q9004-2009, Quality Management Standards—Guidelines for CM Draft Standard for Facilities, 5/8/93; never finished?

Bell Communications Research (BELLCORE)

- TR/OPT/000209, Guidelines for Product Change Notice Was Superseded (see Telcordia)

Bell Canada

- Trillium, Model for Telecom Product Development & Support Process Capability

British Standards Institute (BSI)

- BS 6488, CM of Computer-Based Systems
- BSI PD ISO/IEC TR 18018, Information Technology—Systems and Software Engineering—guide for configuration management tool capabilities
- BS EN 46001, Application of EN 29001 (BS5750: Part 1) to manufacture medical devices
- BS5515:1984, British Code of Practice for Documentation of Computer-Based Systems
- BS 7799, Information Security Management
- BS 15000-1 IT Service Management defines the requirements for an organization to deliver managed services of an acceptable quality for its customers. *Note:* replaced by ISO 20000-1
- BS 15000-2 IT Service Management best practices for Service Management processes. *Note:* replaced by ISO 20000-2
- BSI PAS 55:2008 “Asset Management”
- BS EN 13290-5:2001, Space Project Management. General requirements configuration management

Canada—Department of National Defense (DND) Standards

- C-05-002-001/AG-00, Aerospace Engineering Change Proposal Procedures
- D-01-000-200/SF-001, Joint Electronics Type Designation System (JETS)
- D-01-002-007/SG-001, Requirements for the Preparation of CM Plans
- D-01-002-007/SG-002, Requirements for Configuration Identification
- D-01-002-007/SG-004, Requirements for Configuration Status Accounting
- D-01-002-007/SG-006, Requirements for the Selection of Configuration Items
- D-01-100-215/SF-000, Specification for Preparation of Material Change Notices
- D-01-400-001/SG-000, Engineering Drawing Practices
- D-01-400-002/SF-000, Drawings, Engineering, & Associated Lists
- D-02-002-001/SG-001, Identification Marking of Canadian Military Property
- D-02-006-008/SG-001, The Design Change, Deviation, & Waiver Procedure

Chrysler/Ford/General Motors

- QS-9000, Quality System Requirements

CMII (Institute of Configuration Management)

- CMII-100E CMII Standard for Enterprise Configuration Management

Code of Federal Regulations (CFR)—U.S. and Other Governments

- Clinger–Cohen Act (IT)
- Sarbanes–Oxley—“Define and establish controls . . .” is the heart of the Sarbanes–Oxley Act
- Title 21 CFR Part 820, Quality System Medical Devices FDA
- Title 10 CFR Part 830 122, Quality Assurance Criteria DOE
- Title 14 CFR Chapter I (FAA), Part 21 Certification Procedures for Products and Parts

- Title 48 CFR, Federal Acquisition Regulations
- Title 48 CFR 2210 Specifications, Standards, and Other Purchase Descriptions
- Title 48 CFR 1 Part 46 Quality Assurance

Commercial U.S. Airlines Air Transportation Association (ATA)

- ATA 100*
- ATA 200
- ATA 2100*
- ATA 2200

Department of Defense (DOD) (U.S.)

DOD Superseded/Canceled

- AMCR 11-12, Total Decision-Making Process
- AMCR 11-26, CM (Army, 1965)
- ANA Bulletin NO. 390, Engineering Change Proposal (Army, Navy, and Air Force)
- ANA Bulletin 391, Engineering Change Proposal
- ANA Bulletin 445, Engineering Changes to Weapons, Systems, Equipments, & Facilities (1963)
- AR 70-37, Joint DOD Service Agency Regulation Configuration Management
- AFSCM 375-1, CM During the Development & Acquisition Phases (Air Force Systems Command, 1962)
- AFSCM 375-3, System Management (1964)
- AFSCM 375-4, System Program Management Procedures (1966)
- AFSCM 375-5, Systems Engineering Management Procedures (1966)
- AFSCM 375-7, Configuration Management for Systems, Equipment, Munitions, and Computer Programs (1971)
- AFWAMAN33-2 Air Force Weather Agency Consolidated Network Configuration Management Plan (2003)
- AMC Instruction 33-105 Enterprise Configuration Management
- ASWSPO 5200.4 (Navy, 1965)
- Army Regulation 25-6, Configuration Management for Automated Information Systems
- BuWeps Instruction 5200.20, Processing Engineering Change Proposals (NAVY)
- CMI, CM Instructions, Air Force Systems Command, Space Systems Division (1963):
 - CMI No. 1, Facility Engineering Change Proposal procedures (1964)
 - CMI No. 2, Engineering Change Proposal Procedures (1964)
 - CMI No. 3, Specification Maintenance (1964)
 - CMI No. 4, Configuration Change Implementation (1964)
 - CMI No. 5, Configuration Accounting Procedures (1964)
 - CMI No. 7, Configuration Control Board (1964)
 - CMI No. 9, First Article Configuration Inspection (1964)

* In 2000, ATA Spec 100 and ATA Spec 2100 were incorporated into ATA iSpec 2200: Information Standards for Aviation Maintenance. ATA Spec 100 and Spec 2100 will not be updated beyond the 1999 revision level.

- DOD 5000.2-M, Defense Manual—Defense Acquisition Management Documents & Reports
- DOD 5000.19, Policies for the Management & Control of Information Requirements
- DOD 5010.12, Management of Technical Data
- DOD 5010.19, DOD CM Program
- DOD 5010.21, CM Implementation Guidance
- DOD 8000 Series, Policies & Procedures for Automated Information Systems
- DOD-D-1000, Drawing, Engineering, & Associated Lists
- DOD-STD-2167, Defense System Software Development
- DOD-STD-7935, DOD Automated Information System Documentation Standards
- M200 (1962), Standardization Policies, Procedures, & Instructions, Defense Standardization Manual, then replaced by 4120.3-M in 1966
- DOD-HDBK-287, A Tailoring Guide for DOD-STD-2167A
- MIL-STD-12, Abbreviations for Use on Drawings, Specs, Standards, & Technical Documents, will eventually be replaced by ANSI Y14.38
- MIL-STD-100, Engineering Drawing Practices
- MIL-STD-454, Standard General Requirements for Electronic Equipment
- MIL-STD-480B, Configuration Control—Engineering Changes, Deviations, & Waivers
- MIL-STD-481, Configuration Control—Short Form
- MIL-STD-482, Configuration Status Accounting Data Elements & Related Features
- MIL-STD-483, CM Practices for Systems, Equipment, Munitions, & Computer Programs
- MIL-STD-490, Specification Practices
- MIL-STD-498, Software Design & Development (replaces DOD-STD-2167, DOD-STD-7935, & DOD-STD-1703)
- MIL-STD-499, Systems Engineering
- MIL-STD-999, Certification of CM/DM Process (DRAFT)
- MIL-STD-1456, CM Plan
- MIL-STD-1521, Technical Reviews & Audits for Systems, Equipments, & Computer Software (Appendixes G, H, & I were superseded by MIL-STD-973)
- MIL-STD-1679, Software Development (1978)
- MIL-STD-2549, Configuration Status Accounting (canceled 9/30/2000). However, Army is using AMC-STD-2549A until EIA 836 is published
- MIL-STD-3046, DOD Interim Standard Practice Configuration Management (Army, 2013)
- MIL-D-70327, Drawings & Data Lists
- MIL-Q-9858, Quality Program Requirements
- MIL-S-52779, Software Quality Program Requirements (1974)
- MIL-T-47500/1-6, Technical Data Package, General Specification for
- MIL-T-31000, Technical Data Packages, General Specification for
- NAVAIRINST 4000.15, Management of Technical Data & Information
- NAVMAT INSTR 4130.1 (Navy, 1967)
- COMDTINST 4130.6A, Coast Guard Configuration Management Policy
- COMDTINST M4130.8, Coast Guard Configuration Management for Acquisitions and Major Modifications
- COMDTINST M4130.9, Coast Guard Configuration Management for Sustainment
- NAVMATINSTR 4131.1, Configuration Management (Navy, 1967)

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- NAVMATINSTR 5000.6, Configuration Management (Navy, 1966)
- NAVSEA 0900-LP-080-2010, Software Configuration Control Procedures Manual (Navy, 1975)
- (U)-E-759/ESD, Software Quality Assurance Plan (Air Force, 1980)
- OPNAVINST 4130.1, Configuration Management of Software in Surface Ship Combat Systems (Navy, 1975)

DOD Active or canceled but still specified in existing contracts

- US COE EC 11-2-173, USCCE Manpower Civil Program Civilian Air Force Configuration and Management
- US COE ER 15-1-33, Automation Configuration Management Boards
- AFDPD 21-4, Engineering Data
- AFI 21-401, Engineering Data Storage, Distribution, & Control
- AFI 21-402, Engineering Drawing System
- AFI 21-403, Acquiring Engineering Data
- AFMCPAM 63-104, IWSM Configuration Management Implementation Guide (2000)
- AFWAMAN 33-2, Air Force Weather Agency Consolidated Network Configuration Management Plan (2003)
- AMCI33-105 Configuration Management October 15, 2000
- DID Guide, HQ AFMC/EN DID Guide
- DOD 5000.1, Defense Acquisition
- DOD 5000.2, Defense Acquisition Management Policies & Procedures
- DOD 5010.12-M, Procedure for the Acquisition and Management of Technical Data
- DOD 5010.12-L, Acquisition Management System & Data Requirement List (AMSDL)
- DOD Cataloging Handbook H6, Federal Item Identification Guides for Supply Cataloging
- DOD Cataloging Handbook H7, Manufacturers Part & Drawing Numbering Systems for Use in the Federal Cataloging System
- DODISS, Department of Defense Index of Specifications & Standards
- MIL-HDBK-59, Computer Aided Acquisition & Logistics Support (CALS) Program Implementation Guide (CALS is now known as “Continuous Acquisition & Life-Cycle Support”)
- MIL-HDBK-61, Configuration Management
- MIL-STD-109, Quality Assurance Terms & Definitions
- MIL-STD-1168, Lot Numbering of Ammunition
- MIL-STD-130, Identification Marking of U.S. Military Property
- MIL-HDBK-245, Preparation of Statement of Work
- MIL-STD-280, Definition of Item levels, Item Exchangeability, Models, & Related Terms
- MIL-HDBK-454, Standard General Requirements for Electronic Equipment
- MIL-STD-881, Work Breakdown Structure for Defense Material Items
- MIL-STD-961, Military Specifications & Associated Documents, Preparation of
- MIL-STD-969, Specifications
- MIL-STD-973, CM Notice 3 (canceled 9/30/2000)
- MIL-STD-974, CITIS (Contractor Integrated Technical Information Service, which is being transitioned to a nongovernmental standard).

- MIL-STD-1309, Definitions of Terms for Test, Measurement, & Diagnostic Equipment
- MIL-STD-1465, CM of Armaments, Munitions, & Chemical Production Modernization
- MIL-STD-1520, Corrective Action & Disposition System for Nonconforming Material
- DOD-STD-1700, Data Management Program
- MIL-STD-1767, Procedures for Quality Assurance & Configuration Control of ICBM Weapon System Technical Publications & Data
- MIL-STD-1840, Automated Interchange of Technical Information
- MIL-STD-2084, General Requirements for Maintainability of Avionics & Electronic Systems & Equipment
- DOD-STD-2168, Defense System Software Quality Program
- MIL-I-8500, Interchangeability & Replaceability of Component Parts for Aerospace Vehicles
- MIL-S-83490, Specification, Types, & Forms
- SMC-S-002, Configuration Management (Space and Missile Command)
- USAFAI33-114 Managing Software Configuration and Controlling Data in the Cadet Administrative Management Information System (CAMIS)

DOD, Draft Documents

- MIL-STD-CNI, Coding, Numbering, & Identification
- SD-15, Performance Specification Guide

DOD Initiatives

- AD-A278-102, Blueprint for Change (regarding the use on commercial standards, obtain through NTIS)

Department of Energy (DOE) (U.S.)

Note: Check for recent status, as standards are being canceled and replaced on a regular basis.

Also see www.ac-incorp.com/CM_Standards.html.

- DOE Order 430.1, Life Cycle Asset Management
- DOE Guide G-830-120, Implementation Guide for 10CFR Part 830.120, Quality Assurance
- DOE Order 4330.4A, Maintenance Management Program
- DOE Order 4700.1, Project Management System (will be phased out)
- DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities
- DOE Order 5700.6C, Quality Assurance
- DOE Order 6430.1A, General Design Criteria
- DOE-STD-1073-93 Parts 1 & 2, Guide for Operational CM Program
- NPO 006-100, DOE Office of New Production Reactors CM Plan
- DOE 5480.CM, Operational CM Program (see DOE-STD-1073)
- DOE Draft, No Number, CM for Non-Nuclear Facilities

Department of Transportation, Federal Highway Administration (DOT/FHA) (U.S.)

- Configuration Management for Transportation Management Systems Handbook, FHWA-OP-04-013. <http://ops.fhwa.dot.gov/freewaymgmt/publications/cm/handbook/index.htm>
- Configuration Management Fact Sheet. <http://ops.fhwa.dot.gov/freewaymgmt/publications/cm/factsheet/>
- Configuration Management Primer. <http://ops.fhwa.dot.gov/freewaymgmt/publications/cm/primer/>
- Configuration Management Tri-Fold Brochure. <http://ops.fhwa.dot.gov/freewaymgmt/publications/cm/brochure/>
- Configuration Management Technical Presentation. <http://ops.fhwa.dot.gov/freewaymgmt/publications/cm/presentation/index.htm>

Electronic Industries Alliance (EIA)

- ANSI/EIA-632-1, Draft Process for Engineering a System—Part 1: Process Characteristics
- ANSI/EIA-632-2, Draft Process for Engineering a System—Part 2: Implementation Guidance
- ANSI/EIA-649B, Configuration Management (now written by TechAmerica)
- CMB 3, Recommendations Concerning CM Audits
- CMB 4-1, CM Definitions for Digital Computer Programs
- CMB 4-2, Configuration Identification for Digital Computer Programs
- CMB 4-3, Computer Software Libraries
- CMB 4-4, Configuration Change Control for Digital Computer Programs
- CMB 5, CM Requirements for Subcontractors/Vendors
- CMB 6-1, Configuration & Data Management References
- CMB 6-2, Configuration & Data Management In-House Training Plan
- CMB 6-3, Configuration Identification
- CMB 6-4, Configuration Control
- CMB 6-5, Textbook for Configuration Status Accounting
- CMB 6-6, Reviews & Configuration Audits
- CMB 6-7, Data Management
- CMB 6-8, Data Management In-House Training Course
- CMB 6-9, Configuration & Data Management Training Course
- CMB 6-10, Education in Configuration & Data management
- CMB 7-1, Electronic Interchange of CM Data
- CMB 7-2, Guideline for Transitioning CM to an Automated Environment
- CMB7-3, CALS CM SOW & CDRL Guidance
- EGSA 107, Glossary of DOD CM Terminology & Definitions
- EIA/IS 632, System Engineering
- EIA-748, Earned Value Management Systems
- EIA-927, Common Data Schema for Complex Systems
- EIA SP 3537, Processes for Engineering a System
- EIA SP 4202, Online Digital Information Service (ODIS)
- EIA SSP 3764, Standard for Information Technology—Software Life Cycle Processes
Software Development Acquirer/Supplier Agreement

- IEEE/EIA 12207.0, Industry Implementation of ISO/IEC 12207 (Standard for Information Technology)
- IEEE/EIA 12207.1, Guide for Information Technology—Software Life Cycle Processes Life Cycle Data
- IEEE/EIA 12207.2, Guide for Information Technology—Software Life Cycle Processes Implementations Considerations
- J-Std-016 (EIA/IEEE Interim Standard), Standard for Information Technology; Software Life Cycle Processes; Software Development; Acquirer/Supplier Agreement
- Systems Engineering EIA-632
- Systems Engineering Capability Model SECM EIA-732

Electric Power Research Institute (EPRI)

- EPRI TR-103586, Guidelines for Optimizing the Engineering Change Process for Nuclear Power Plants, prepared by Cygna Energy Services, Oakland, CA
- EPRI NP-5640, Nuclear Plant Modifications & Design Control: Guidelines for Generic Problem Prevention
- EPRI NP-6295, Guidelines for Quality Records in Electronic Media for Nuclear Facilities
- EPRI NP-3434, Value-Impact Analysis of Selected Safety Modifications to Nuclear Power Plants
- EPRI NP-5618, Enhancing Plant Effectiveness Through Improved Organizational Communication
- EPRI NSAC-121, Guidelines for Performing Safety System Functional Inspections

European Cooperation for Space Standardization (ECSS)

- <http://www.ecss.nl/>
- ECSS-M-ST-10, Space Project Management—Project Planning and Implementation
- ECSS-M-ST-40C, Space Project Management—Configuration and Information Management
- ECSS-Q-ST-10-09, Space Product Assurance—Nonconformance Control System
- ECSS-Q-ST-20, Space Product Assurance—Quality Assurance

European Committee for Standardization (ECS)

- CEN EN 13290-5, Space Project Management—General Requirements—Part 5: Configuration Management
- EN 13290-6, Space Project Management—General Requirements—Part 6: Information/Documentation Management
- EN14160, Space Engineering—Software
- EN 9200, Programme Management—Guidelines for Project Management Specification

European Computer Manufacturers Institute (ECMI)

- ECMA-TR 47, CM Service Definition

European Community

- JAR-21, Certification Procedures for Aircraft & Related Products & Parts (Draft)

European Defense Standards Reference System (EDSTAR)

- CEN Workshop 10, European Handbook for Defense Procurement Expert Group 13 Life Cycle (Project) Management Final Report
- ECSS-M-40A, Configuration Management
- ECSS-E-10, System Engineering
- ECSS-M-50, Information/Documentation Management
- ECSS-E-40, Space System Software Engineering. <http://www.eda.europa.eu/EDSTAR/home.aspx>

European Space Agency (ESA)

- PSS-05-01, ESA Software Engineering Standards
- PSS-05-09, Guide to Software Configuration Management
- PSS-05-10, Guide to Software Verification and Validation
- PSS-05-11, Guide to Software Quality Assurance

European Telecommunications Standards Institute (ETSI)—Too Many to List

- <http://www.etsi.org/standards>

Federal Aviation Administration (FAA) (U.S.)

- Title 14 Code of Federal Regulations, Parts 1–59
- FAA-STD-002, Facilities Engineering Drawing Practices
- FAA-STD-005, Preparation of Specification Documents
- FAA-STD-018, Computer Software Quality Program (1977)
- FAA-STD-021, Configuration Management Contractor Requirements
- FAA-STD-058, Standard Practice Facility Configuration Management
- FAA Order 1800.8, National Airspace Systems Configuration Management
- FAA Order 6030.28, National Airspace Systems Configuration Management
- FAA 1100.57, National Engineering Field Support Division Maintenance Program Procedures, Operational Support (AOS)
- FAA 1800.63, National Airspace System (NAS) Deployment Readiness Review (DRR) Program
- FAA 1800.66, National Policy Configuration Management Requirements
- FAA 6032.1, Modifications to Ground Facilities, Systems, and Equipment in the NAS

Food and Drug Administration (FDA) (U.S.)

- FDA 8541-79, Good Manufacturing Practices, Food & Drug Administration (superseded by QSR)
- QSR Quality System Regulation for the Medical Device Industry (QSR) (based on ISO 9001)

Federal Highway Administration (FHA) (U.S.)

- Configuration Management for Transportation Management Systems Handbook (FHWA Publication Number: FHWA-OP-04-013) (EDL Document Number: 13885)
- A Guide to Configuration Management for Intelligent Transportation Systems (FHWA Publication Number: FHWA-OP-02-048) (EDL Document Number: 13622)
- Configuration Management for Transportation Management Systems Primer (FHWA Publication Number: FHWA-OP-04-014) (EDL Document Number: 13886)
- Configuration Management for Transportation Management Systems Brochure (FHWA Publication Number: FHWA-OP-04-016) (EDL Document Number: 13888)
- Configuration Management for Transportation Management Systems Fact Sheet (FHWA Publication Number: FHWA-OP-04-017) (EDL Document Number: 13889)
- Configuration Management for Transportation Management Systems Technical Presentation

France

- NF EN 13290-5 January 2002, Management of Space Projects—General Requirements—Part 5: Configuration Management
- AFNOR NF EN 300291-1, Telecommunications Management Network (TMN)—Functional Specification of Customer Administration (CA) on the Operations System/Network Element (OS/NE) Interface—Part 1: Single Line Configurations (V1.2.1)
- AFNOR NF ETS 300617, Digital Cellular Telecommunications System (Phase 2)—GSM Network Configuration Management

Germany Deutsches Institut für Normung (DIN)

- DIN EN 13290-5, Aerospace—Space Project Management—General Requirements—Part 5: Configuration Management, German and English versions
- DIN EN 300291-1, Telecommunications Management Network (TMN)—Functional Specification of Customer Administration (CA) on the Operations System/Network Element (OS/NE) Interface—Part 1: Single Line Configurations [Endorsement of the English version EN 300291-1 V 1.2.1 (1999–02) as the German standard]
- DIN EN 300291-2, Telecommunications Management Network (TMN)—Functional Specification of Customer Administration (CA) on the Operations System/Network Element (OS/NE) Interface—Part 2: Multiline Configurations [Endorsement of the English version EN 300291-2 V 1.1.1 (2002–03) as the German standard]
- DIN EN 300376-1, Telecommunications Management Network (TMN)—Q3 Interface at the Access Network (AN) for Configuration Management of V5 Interfaces and Associated User Ports—Part 1: Q3 Interface Specification [Endorsement of the English version EN 300376-1 V 1.2.1 (1999–10) as German standard]
- DIN ETS 300617, Digital cellular telecommunications system (Phase 2)—GSM Network Configuration Management; English version ETS 300617
- DIN EN 300377-1, Telecommunications Management Network (TMN)—Q3 Interface at the Local Exchange (LE) for Configuration Management of V5 Interfaces and Associated Customer Profiles—Part 1: Q3 Interface Specification [Endorsement of the English version EN 300377-1 V 1.2.1 (1999–10) as the German standard]

- DIN ETS 300377-2, Signaling Protocols and Switching (SPS)—Q3 Interface at the Local Exchange (LE) for Configuration Management of V5 Interfaces and Associated Customer Profiles—Part 2: Managed Object Conformance Statement (MOCS) Performance Specification; English version ETS 300377-2:1995
- DIN EN 300820-1, Telecommunications Management Network (TMN)—Asynchronous Transfer Mode (ATM) Management Information Model for the X Interface Between Operation Systems (OSs) of a Virtual Path (VP)/Virtual Channel (VC) Cross-Connected Network—Part 1: Configuration Management [Endorsement of the English version EN 300820-1 V 1.2.1 (2000-11) as the German standard]
- DIN EN 301268, Telecommunications Management Network (TMN)—Linear Multiplex Section Protection Configuration Information Model for the Network Element (NE) View [Endorsement of the English version EN 301268 V 1.1.1 (1999-05) as the German standard]
- VG 95031-1, Modification of Products—Part 1: Procedure According to CPM
- VG 95031-2, Drawing Set—Part 3: Parts List
- VG 95031-3, Drawing Set—Part 3: Changes on Drawings

Institute of Electrical & Electronic Engineers (IEEE)

- IEEE 323, Qualifying Class IE Equipment for Nuclear Power Generating Stations
- IEEE 344, Recommended Practices for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations
- IEEE 352, Guide for the General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems
- IEEE Std 610 (ANSI), Computer Dictionary
- IEEE Std 730-1989 (ANSI), Software QA Plans
- IEEE Std 828-90 (ANSI), Standard for Software CM Plans
- IEEE Std 830-84 (ANSI), Guide for Software Requirements Specifications
- IEEE Std 1028 (ANSI), Standard for Software Reviews & Audits
- IEEE Std 1042 (ANSI), Guide for Software CM
- IEEE Std 1063 (ANSI), Standard for User Documentation
- IEEE Std P1220 (ANSI), Systems Engineering
- IEEE Std 803-1983, Recommended Practice for Unique Identification in Power Plants & Related Facilities—Principles & Definitions
- IEEE Std 803.1-1992, Recommended Practice for Unique Identification in Power Plants & Related Facilities—Component Function Identifiers
- IEEE Std 804-1983, Recommended Practice for Implementation of Unique Identification System in Power Plants & Related Facilities
- IEEE Std 805-1984, Recommended Practice for System Identification in Nuclear Power Plants & Related Facilities
- IEEE Std 806-1986, Recommended Practice for System Identification in Fossil-Fueled Power Plants & Related Facilities
- IEEE Std 828-2012, IEEE Standard for Configuration Management in Systems and Software Engineering
- IEEE/EIA 12207.0 Industry Implementation of ISO/IEC 12207 (Standard for Information Technology)
- IEEE/EIA 12207.1 Guide for Information technology—Software Life Cycle Processes Life Cycle Data

- IEEE/EIA 12207.2 Guide for Information Technology—Software Life Cycle Processes Implementations Considerations
- J-Std-016 (EIA/IEEE Interim Standard) Standard for Information Technology; Software Life Cycle Processes; Software Development; Acquirer/Supplier Agreement
- IEEE 828-2012-IEEE Standard for Configuration Management in Systems and Software Engineering; Institute of Electrical and Electronics Engineers/16-Mar-2012/71 pages

Institute of Nuclear Power Operations (INPO) (U.S.)

Note: GP—Good Practice Document.

- GP MA-304, Control of Vendor Manuals
- GP TS-402, Plant Modification Control Program
- GP TS-407, Computer Software Modification Controls
- GP TS-412, Temporary Modification Control
- GP TS-415, Technical Reviews of Design Changes
- GP TS-411, Temporary Lead Shielding
- INPO 85-016, Temporary Modification Control
- INPO 85-031, Guidelines for the Conduct of Technical Support Activities at Nuclear Power Stations
- INPO 86-006, Report on Configuration Management in the Nuclear Utility Industry
- INPO 87-006, Report on Configuration Management in the Nuclear Utility Industry
- INPO 88-009, System & Component labeling
- INPO 88-016, Guidelines for the Conduct of Design Engineering
- INPO 90-009 REV. 1 Guidelines for The Conduct of Design Engineering
- INPO 94-003, A Review of Commercial Nuclear Power Industry Standardization Experience

International Organization for Standardization (ISO)

Note: Standards can be searched at <http://www.iso.org/iso/home.html>.

- ISO 9000:2000 Series
- ISO 9000:2000, Quality Management Systems—Fundamentals and Vocabulary
- *Note:* This replaces ISO 9001, ISO 9002, and ISO 9003
- ISO 9001:2000, Quality Management Systems—Requirements
- ISO 9004:2000, Quality Management Systems—Guidelines for Performance Improvements
- ISO 19011, Guidelines on Quality and/or Environmental Management Systems Auditing (under development)
- ISO 10005:1995, Quality Management—Guidelines for Quality Plans
- ISO 10006:2003, Quality Management Systems—Guidelines for Quality Management in Projects
- ISO 10007:2003 Guidelines for Configuration Management
- ISO/DIS 10012, Parts 1 and 2, Quality Assurance Requirements for Measuring Equipment
- ISO/DIS 10303-239 Industrial Automation Systems and Integration—Product Data Representation and Exchange—Part 239: Application Protocol: Product Life Cycle Support
- ISO 10013:1995, Guidelines for Developing Quality Manuals

- ISO/TR 10014:1998, Guidelines for Managing the Economics of Quality
- ISO 10015:1999, Quality Management—Guidelines for Training
- ISO/TS 16949:1999, Quality Management Systems Particular Requirements for the Application of ISO 9001:2000 for Automotive Production and Relevant Service Part Organizations. Joint Effort IAOB (International Automotive Oversight Bureau) and ISO
- ISO/IEC 17025, General Requirements for the Competence of Testing and Calibration Laboratories
- ISO 8402, Quality Management & Quality Assurance Vocabulary
- ISO 9000-1, Guidelines for Use of the ISO 9000 Series (replaced by ISO 9000:2000)
- ISO 9000-2, Guidelines for Applying ISO 9000 to Services (replaced by ISO 9000:2000)
- ISO 9000-3, Guidelines for Applying ISO 9000 to Software (replaced by ISO 9000:2000)
Note: TickIT is an ISO 9000 accreditation scheme for software developers and supporters
- ISO 9001 Model for Quality Assurance in Design/Development, Production, Installation, & Servicing. (replaced by ISO 9001:2000)
- ISO 9001:2008, Quality Management Systems—Requirements
- ISO/DIS 10303-239, Industrial Automation Systems and Integration—Product Data Representation and Exchange—Part 239: Application Protocol: Product Life Cycle Support
- ISO 9002 Model for Quality Assurance in Production & Installation. *Note:* Replaced by ISO 9001:2000 (replaced by ISO 9001:2000)
- ISO 9003 Model for Quality Assurance in Final Inspection & Test. *Note:* Replaced by ISO 9001:2000 (replaced by ISO 9001:2000)
- ISO 9004, Quality Management & Quality System Elements—Guidelines (replaced by ISO 9004:2000)
- ISO 9004-7, Guidelines for CM (Draft) never released under this number. It was released as ISO 10007
- ISO 10011-1, -2, and -3: Guidelines for Auditing Quality Systems
- ISO 10303-1 and on 1994 Industrial Automation Systems and Integration—Product Data Representation and Exchange. This standard had too many parts to list here. *Note:* Check ISO for corrections and revisions in this 10303 series. The collection appears to be subject to many changes. What follows are all the parts to this standard
- ISO 12207, Information Technology—Software Life Cycle Processes
- ISO 13485, Quality Systems—Medical Devices—Particular Requirements for the Application of ISO 9001
- ISO 14001, Environmental Management Systems—Specification with Guidance for Use
- ISO 14004, Environmental Management Systems—General Guidelines on Principles, Systems, and Supporting Techniques
- ISO/IEC TR 15504-1 to -8:1998, Information Technology—Software Process Assessment—Parts 1 through 8
- BSI BS ISO/IEC TR 15846, Information Technology—Software Life Cycle Processes—Configuration Management
- ISO 20000-1: 2005, IT Service Management
- ISO 20000-2: 2005, IT Service Management Code of Practice, describing specific best practices for the processes within ISO 20000-1. Also, there are industry specific variations of ISO 9000: see canceled QS9000 (automotive), TL9000 (Telecommunications), QSRs (FDA), and AS9000 (Aerospace) elsewhere in this guide

International Versions

- AENOR UNE-EN ISO 10007, Quality Management Systems—Guidelines for Configuration Management (Spanish)
- AFNOR FD ISO 10007, Quality Management Systems—Guidelines for Configuration Management (French)
- AENOR UNE-ISO 10007, Quality Management Systems—Guidelines for Configuration Management (Spanish)
- UNI ISO 10007, Quality Management Systems—Guidelines for Configuration Management (Italian)
- CSA CAN/CSA-ISO 10007:03, Quality Management Systems—Guidelines for Configuration Management (Canadian)
- TSE TS EN ISO 10007, Quality Management Systems—Guidelines for Configuration Management (Turkish)
- SNV SN EN ISO 10007, Quality Management Systems—Guidelines for Configuration Management (ISO 10007:1995); Trilingual version (English, German, and French)

Information Technology Infrastructure Library (ITIL)

- ITIL Framework—best practice in the provision of IT service. See <http://www.ogc.gov.uk/index.asp?id=1000364>

International Telecommunications Union (ITU)

- ITU-T Q.824.5, Stage 2 and Stage 3 Description for the Q3 Interface—Customer Administration: Configuration Management of V5 Interface Environment and Associated Customer Profiles—Series Q: Switching and Signaling Specifications of Signaling System
- ITU-R S.1252, Network Management—Payload Configuration Object Class Definitions for Satellite System Network Elements Forming Part of SDG Transport Networks in the Fixed-Satellite Service
- ITU-T J.705, IPTV Client Provisioning, Activation, Configuration and Management Interface Definition
- ITU-T X.792, Configuration Audit Support Function for ITU-T Applications—Series X: Data Networks and Open System Communications OSI Management—Management Functions and ODMA Functions

National Aeronautics and Space Administration (NASA) (U.S.)

Note: Check for recent status, as standards are being canceled and replaced on a regular basis.

NASA-Superseded.

- NPC 500-1 (or NHB 8040.2), Apollo CM Manual (released 1964) & MSC Supplement #1 (1965)
- PC-093, Maintenance & Configuration Control Requirements, NASA Pioneer Program (1965)

NASA Active

- NASA GPR 1410.2, Configuration Management (GSFC)
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Acronyms

Acronym	Definition
3D	Three dimensional
AC	Actual cost
ACD	Allocated configuration documentation
ACWP	Actual cost of work performed
AECA	Arms Export Control Act (U.S.)
AFE	Authorization for expenditure
B&P	Bid and proposal
BAC	Budget at completion
BCP	Bridging control protocol
BCWP	Budgeted cost of work performed
BCWS	Budgeted cost of work scheduled
BGP	Border gateway protocol
BI	Business intelligence
BOD	Bill of documents
BOM	Bill of materials
CA	Contract award
CaC ₂	Calcium carbide
CAD	Computer-aided design
Ca(OH) ₂	Calcium hydroxide
CCB	Configuration control board
C&DM	Configuration and data management
CER	Cost estimating relationship
CFE	Customer-furnished equipment
CFO	Chief financial officer
CI	Configuration item or configured item
CII	Configuration item identifier or configured item identifier
CLM	Contract life cycle management
CM	Configuration management
COC	Certificate of conformance
COGS	Cost of goods sold
CORE	Controlled requirements expression
COTS	Commercial off-the-shelf
CPU	Central processing unit

CSA	Configuration status accounting
CSCI	Computer software configuration item
CV	Cost variance
DCAA	Defense Contract Audit Agency (U.S.)
DDTC	Directorate of Defense Trade and Controls
DFMEA	Design failure mode and effects analysis
DM	Data management
DND	Department of National Defense (Canada)
DOD	Department of Defense (U.S.)
DOE	Department of Energy (U.S.)
DOORS	Dynamic object oriented requirements system
dpi	Dots per inch
DR	Disaster recovery
DRL	Data requirements listing/data requirements list
DRP	Disaster Recovery Plan
<i>E. coli</i>	<i>Escherichia coli</i>
EAC	Estimate at completion
EAO	Everything-at-once
EAR	Export Administration Regulations
EBIT	Earnings before interest and taxes
ECO	Engineering change order
ECR	Engineering change request
ECU	Electronic control unit
EIA	Electronic industries alliance
ETC	Estimate to complete
FAR	Federal Acquisition Regulations (U.S.)
FCA	Functional configuration audit
FCD	Functional configuration documentation
FDA	Food and Drug Administration (U.S.)
FIFO	First-in first-out
FMEA	Failure modes effects analysis
FOIA	Freedom of Information Act (U.S.)
FOUO	For Official Use Only (U.S.)
FQR	Formal qualification review
FSA	Functional systems audit
FSIS	Food Safety and Inspection Service
FSLIC	Federal Savings and Loan Insurance Corporation (U.S.)
FSRD	Functional service request disposition
FTC	Federal Trade Commission (U.S.)
G&A	General and administrative
GIDEP	Government and industry data exchange program
GSFC	Goddard Space Flight Center (U.S. NASA)
HQI	Hardware quality instruction
IBIS	Issue-based information system
IBM	International Business Machines
ICD	Interface control drawing; International Classification of Diseases
ICT	Information and communication technologies

ICWG	Interface Control Working Group
ID	Identification
IEEE	Institute of Electrical & Electronic Engineers
IP	Intellectual property
IR&D	Independent research and development
IS-IS	Intermediate system-to-intermediate system
ISO	International Organization for Standardization; International Standards Organization
ISP	Internet service provider
I&T	Integration and test
IT	Information technologies
ITAR	International Traffic in Arms Regulations (U.S.)
ITIL	Information technology infrastructure library
JAD	Joint application design
JEM-EF	Japanese experiment module—exposed facility
JPL	Jet propulsion laboratory
JSD	Jackson system development
LAN	Local area network
LLC	Limited liability corporation
LSA	Link state advertisements
LTMPIF	Low temperature microgravity physics facility
MAR	Mission assurance requirements
MIRR	Material Inspection and Receiving Report
MRB	Material review board
MTBF	Mean time between failure
MX	Missile X
NANOG	North American Network Operators Group
NOAA	National Oceanic and Atmospheric Administration (U.S.)
OEM	Original equipment manufacturer
OH	Overhead
OS	Operating system
OSPF	Open shortest path first
PCA	Physical configuration audit
PDF	Portable data format
PD/LM	Product data/life cycle management
PDM	Product data management
PDR	Preliminary design review
PFMEA	Process failure mode and effects analysis
PLM	Product life cycle management
PPAP	Production part approval process
PROM	Programmable read-only memory
PRR	Production readiness review
PWA	Printed wiring assembly
QFD	Quality function deployment
QR	Quick response
REE	Requirements engineering environment
RFID	Radio frequency identification

Rh	Rhesus
RIP	Routing information protocol
RTC	Resolution Trust Corporation (U.S.)
SBRE	Scenario-based requirements elicitation
SFR	System functional review
SME	Subject matter expert
SMM	Solar maximum mission
SOW	Statement of work
SpaceX	Space Exploration Technologies
SQI	Software quality instruction
SRR	System requirements review
SSC	Single-string approach based on criticality
SSM	Soft systems methodology
STS	Space Transportation System (U.S.)
SUMO	Superconducting microwave oscillator
SV	Schedule variance
SVA	Systems verification audit
TAA	Technical assistance agreement
TBD	To be determined
TBN	To be negotiated
TBR	To be reviewed
TBS	To be specified
TDP	Technical data package
TEMP	Test and Evaluation Master Plan (U.S. DOD)
TIEMPO	Test, Inspection & Evaluation Master Plan Organized
TO	Task order
TPAD	Trunnion pin acquisition device
TRR	Test readiness review
TTCP	Technology transfer control plan
TTR	Tabletop review
UART	Universal asynchronous receiver/transmitter
UCC	Uniform commercial code (U.S.)
USML	U.S. Munitions List
USTM	User skills task match
VHS	Video home system
VP	Vice president
VTC	Value to the company
VW	Volkswagen
WAN	Wide area network
WAWF RR	Wide Area Workflow Receiving Report

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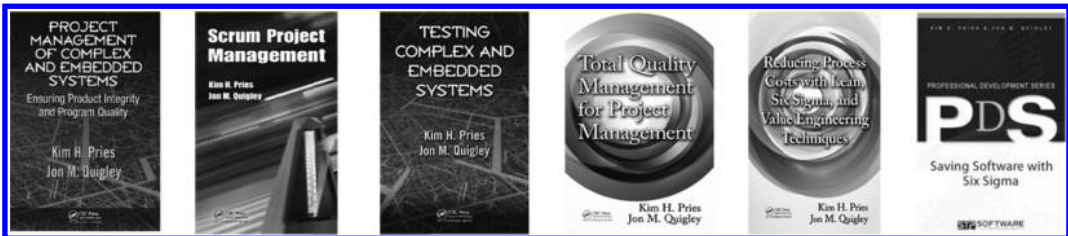
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