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Configuration Control

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EIA CONFIGURATION MANAGEMENT BULLETIN NO. 6-4
CONFIGURATION CONTROL

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ACKNOWLEDGEMENT

This EIA Bulletin No. CMB6-4, "Textbook for Configuration Control," is presented by the Electronic Industries Association G-33 Data and Configuration Management Committee. It has been prepared to provide a textbook for use at the undergraduate level to teach the configuration control portion of the Configuration Management curriculum being developed by the Education and Training Task Group. Appreciation is extended to Ronald Van Buskirk, General Dynamics, Air Defense Systems Division, principal author and editor; William Dean, Air Force Institute of Technology; Alan Lager, Grumman Corporation; Elliott Whitten, Martin Marietta; Michael Daniels, VSE Corporation; Calvin Brown, Defense Systems Management College; for their valuable assistance. A special acknowledgement goes to Thomas Simon, McDonnell Douglas, for a very comprehensive Interface Control chapter.

The figures in this text are based on samples provided by a number of defense contractors and by the Department of Defense. The writers of this text wish to acknowledge the contributions of these sources; without their help it would have been difficult to generate the degree of detail provided. The samples provided have been modified in most cases to delete information elements peculiar to that company's system which could distract from the current illustration and/or to add data elements to improve the utility of the illustration. Therefore, there is no assurance by any of the companies, the EIA or by the authors that use of these exact forms will provide an adequate configuration control system.

FOREWORD

Configuration Management (CM) is the special name that has been coined to describe those specialized management practices used by industry and the Department of Defense (DOD) to define and control items (sometimes referred to as Configuration Items or CIs) in their inventories. The overall intent of configuration management is to support the establishment of a product service network for all items being developed and to assure the continued serviceability of the items as changes are made throughout their service life.

The configuration of an item is defined in both functional and physical terms. Functional requirements establish the performance the item is expected to achieve; the physical requirements define the specific design and appearance of the item to be built. In practice, an item being developed is described, and its development governed, primarily by its intended functional characteristics. Following development, however, an item being produced for customer use is primarily described and governed by its physical characteristics, although the functional characteristics continue to be controlled.

The practices we follow with configuration management are nothing startling or brand new. Basically, they are common sense management concepts that have been formalized into set practices to address the peculiarities of managing large inventories of units in multiple product lines. For convenience sake in describing the practices, CM is divided into four functional areas: identification, audits, control, and status accounting. Each of the four functions has a specific purpose and a specific area of emphasis.

- Common sense tells us to define what we want the product to do, or what it should look like, before we sign a contract to buy it. Through configuration identification, we obtain certain documentation that is used to define both the performance we desire from the design under development and the design of the interchangeable production items we want to buy. The documentation will also define the exact design for which a servicing capability must be established and maintained.
- If we are one of the contracting parties, common sense (and business law, too) tells us that the other party to the contract should not be allowed to change the contract without informing us of all the considerations and obtaining our agreement to the change. Through configuration control, we require that the full impact of a proposed change be determined before we make a decision on each change to the contractual (baseline) configuration identification. We are also constraining the design activity from making changes without the concurrence of the management activity.
- If we want to manufacture a consistent product and have the capability to service it, common sense tells us that we must have a means of recording and tracking the production definition (paper) used to manufacture the unit as well as the configuration of each unit our company produces. Through configuration status accounting, we follow up on the results of other configuration management activities to keep track of the current configuration identification documents, the current configuration of the delivered units, the status of changes being reviewed, and the status of the implementation of approved changes.

- If we have specified some requirements that the product must meet, common sense tells us that we must check at some point in time to be sure that those requirements are met. Through configuration audits, we verify that the design activity has proven that the items, as designed, meet or exceed the specified performance and that the design specified in the configuration documentation exactly matches the configuration of the (production) unit being audited and about to be delivered.
- This text will cover the details of the configuration control function. Identification, audits, and status accounting are covered in other textbooks. It is the intent of the authors that this configuration control text will serve a broad general population of personnel engaged in development, manufacturing, and distribution of both commercial and military items. The figures in this text provide illustrations of practices that might be required and sample formats that might be used in accomplishing configuration control. You will have to make the decisions about the exact content and practices appropriate for your project and/or facility based on the information contained in this text.
- The general concepts herein apply during the design and delivery of products to various types of customers and include policies and procedures which must be monitored for the continued support and service of your products. The Department of Defense (DOD) represents a major customer of such goods and services; consequently, a highly structured program utilizing configuration control along with the related configuration management disciplines exists in the environment of military item acquisition. The authors, however, have tried to avoid emphasis on DOD-related systems and requirements; where specific DOD requirements are discussed, we have attempted to indicate that such is the case.

OBJECTIVE OF THE COURSE

The objective of this course is to provide an in-depth understanding of the concepts and principles involved in the configuration control process. It is intended for an individual who has completed a basic introductory course in CM and who requires the deeper knowledge of a CM practitioner rather than a superficial overview.

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CHAPTER 1
INTRODUCTION1.1 OVERVIEW

The overall objective of configuration management is to guarantee the buyer that a given product is what it was intended to be, functionally and physically, as defined by contractual drawings and specifications, and to identify the configuration to the lowest level of assembly required to assure repeatable performance, quality, maintainability and reliability in all units of the same product.

With thousands of engineering changes a normal part of the development of a complex product, how can the customer and contractor be sure that the product initially described in a specification and contract is being delivered? Stripped to essentials, configuration control (and Configuration Status Accounting, CSA) directs itself at this need to know just what the hardware, software, and supporting data (drawings, design documents, operating manuals, repair instructions, etc.) consist of as the project evolves with changes that occur daily.

"Configuration" refers to a complete description of the physical and functional characteristics of a product; for example, its weight, shape, size, materials, processes, power consumption, and performance (measurement range, accuracy, stability, linearity, etc.). The term configuration also applies to technical descriptions required to build, test, operate, and repair a Configuration Item, (CI).

Configuration management implicitly accepts changes during the progress of a product as something normal - not something to be deplored, but something to be managed. This means that, by the baselining process, we progressively define the shape and form of the product or item we are managing. We must accept, as a necessary condition for the technological growth and cost effectiveness, the idea that change when properly managed is a vehicle for optimizing costs and other interface and project control considerations. In the absence of change control we have, in effect, technological anarchy.

The idea of progressive definition, integral to the product's life cycle, is a key concept in configuration management. As a product proceeds through conceptual studies, requirements analysis, preliminary and detail design, qualification, and first article, limited, and follow-on production, the identification of its configuration becomes progressively more definite and precise, and, coincidentally, more expensive to change.

Figure 1-1 illustrates the stages of a product's life. Regardless of the titles you choose to put on these stages, they always exist within good engineering and business practice in industry. Any product, be it an aircraft or a pencil, must have some reason for being, a function that has to be performed - a performance requirement. While this requirement and the general form of a product are being established, we are in the initial stages of concept and performance requirements analysis. When requirements have been defined and a limiting set of restrictions is placed on the product (such as size, weight, and durability) the third discernible stage, development, has been entered. Design requirements are defined and the physical characteristics of the product are determined in sufficient detail to enable it to be built and tested to see if it fulfills its intended functional (or performance) requirements. The next stage, production, operation and support represents the period in which it is

<u>STAGE 1</u>	<u>STAGE 2</u>	<u>STAGE 3</u>	<u>STAGE 4</u>
CONCEPT STUDIES	REQUIREMENTS ANALYSIS	DEVELOPMENT & DESIGN	PRODUCTION, OPERATION & SUPPORT
Define Basic Need For System Or Product	Define Performance Requirements To Satisfy Need	Design, Build And Test To Determine If Product Meets Performance Requirements	Production Delivery to User and Operational Use Of Product To Satisfy Basic Needs Defined in Phase 1

Figure 1-1. The Stages Of Any Product's Life.

produced, marketed, sold and operated and in which it must be maintained and repaired as required.

In a buyer-seller relationship, particularly in the aerospace marketplace where the buyer is usually purchasing not only the end product but its design and development as well, the point of departure or "baseline" between each of these stages has significance. Each represents a point of decision by the buyer or negotiation between the buyer and seller, or both. The buyer must have some measure of supervision and control over the seller's activities to assure that (a) he has sufficient information for making the basic critical decisions, such as continuation, cancellation or modification of a project; (b) he is getting the product contracted; and, (c) the product will be compatible with the other items in his complement of equipment and with associated project interfaces.

It has always been difficult to determine the optimum measure of control that should be applied. The cost and the degree of detail controlled increase considerably as the product's life cycle progresses. If the variation is to be in definable degrees, definitive baselines for each stage of the product's life cycle must be established.

The degree of technical control to configuration baselines will increase as each more detailed baseline is established. Therefore, the buyer must allow the seller's flexibility for maximum creativity and ingenuity during the early project stages where it will be most beneficial, whereas the buyer's control must become greater in later stages as the projected impacts and the cost of a change becomes greater.

1.2 CONTENT OF THE TEXT

One can see by the table of contents of this text that it covers the subject of configuration control in significant depth. This first chapter provides an overview of configuration control. This will give the reader the proper foundation and perspective with which to understand the specific details of configuration control in the remaining chapters of the text.

Chapter Two describes configuration control organizational concepts employed by corporations and government agencies and reviews the desired relationships between the organization responsible for configuration control and other organizations within the corporation, the customer and interfacing associate contractors.

Chapter Three introduces baseline theory which is the cornerstone upon which all the configuration management practice is based. It puts into perspective the various levels and layers of configuration control as they relate to evolving configuration identification documentation. It also establishes the basis for the Government/contractor, contractor/subcontractor and contractor/associate contractor interfaces.

Chapter Four traces the engineering change process through its entire cycle, describing the important functions to be performed, interactions which must take place, the documentation which is created at various stages of the process, the decisions that can be made and the ramifications of the various choices. It also delves into the processes necessary to establish and operate a controlled Software Development and Support Library, how to bond and release software and assure effective version, revision and patch control.

Chapter Five details roles and responsibilities of customer and design activity Configuration Control Boards (CCB) in support of the change process described in Chapter Four. It describes their composition and how they function to assure the orderly and controlled introduction of changes to baselined configuration.

Chapter Six describes the interface control process whereby an integrating agency or contractor maintains the integrity of the physical, functional and data interfaces between equipment and/or software produced by associate contractors under separate contracts to the Government. It also reflects the use of similar procedures to develop and control contractor to subcontractor interfaces.

Chapter Seven discusses the rationale for, and practices followed in passing down configuration control requirements from a prime contractor to subcontractors, and assuring the effective accomplishment of those requirements.

1.3 HISTORY OF CONFIGURATION CONTROL

A good part of the techniques and formalization of configuration management was based on existing business practices. However, regardless of the self-imposed discipline that was practiced by any individual company, the depth of procedures for the control and documentation of change, historically, was extremely shallow and there was no uniformity from company to company or from one Government agency to another.

The mad race for arms during World War II taught some bitter lessons. Engineering changes levied on increasingly sophisticated systems too often led to products that turned out to be a surprise. This deficiency also became apparent in the race for a successful missile launch in the 1950s. With time being critical, the promulgation of changes was accelerated to resolve incompatibilities among elements supplied by many associate and supporting contractors. When a successful flight was finally made and the buyer, in the euphoria of success, said, "Build me another one," industry found itself with the circumstances in Figure 1-2. The prototype was expended (launched into orbit) and there were inadequate records of part number identification, chronology of changes, and change accomplishment. Technical data did not reflect all the changes that had been made, and it was obvious that an identical article could not be produced, and a second success guaranteed.

This, of course, is gross oversimplification, but with the era of manned space flight approaching, the situation had to be improved.

Major General William B. Bunker of the U.S. Army Material Command described the situation in these terms: "Expensive and large systems were being delivered with no information as to how they were built and how to keep them running. Deficiencies and failures in tests started long sleuthing operations to determine what had failed and what design alternatives were available to solve the problem. Illustrated parts lists appeared months, sometimes even years, after the equipment (was delivered) and were usually inaccurate and incomplete. We qualified certain components and tests and then found, usually after they failed in service, that the production design had been altered, and we found that only the original manufacturer could supply the system or its component because we couldn't tell anyone else how it was made."

With the advent of the jet engine and the transistor, aircraft weapon systems were becoming quite complex. Military aircraft carried sophisticated electronic hardware which required on-line maintenance, and air bases and aircraft carriers now devoted great proportions of their space to electronic and avionic (electronic components used on aircraft) components and associated support facilities. Multiple configurations of items were often undiscovered until maintenance action was required and troubleshooting disclosed spares non-interchangeability and supporting documentation compatibility problems.

The first military regulation that formalized change activity was ANA (Army, Navy, and Air Force) Bulletin No. 390, which established the "Engineering

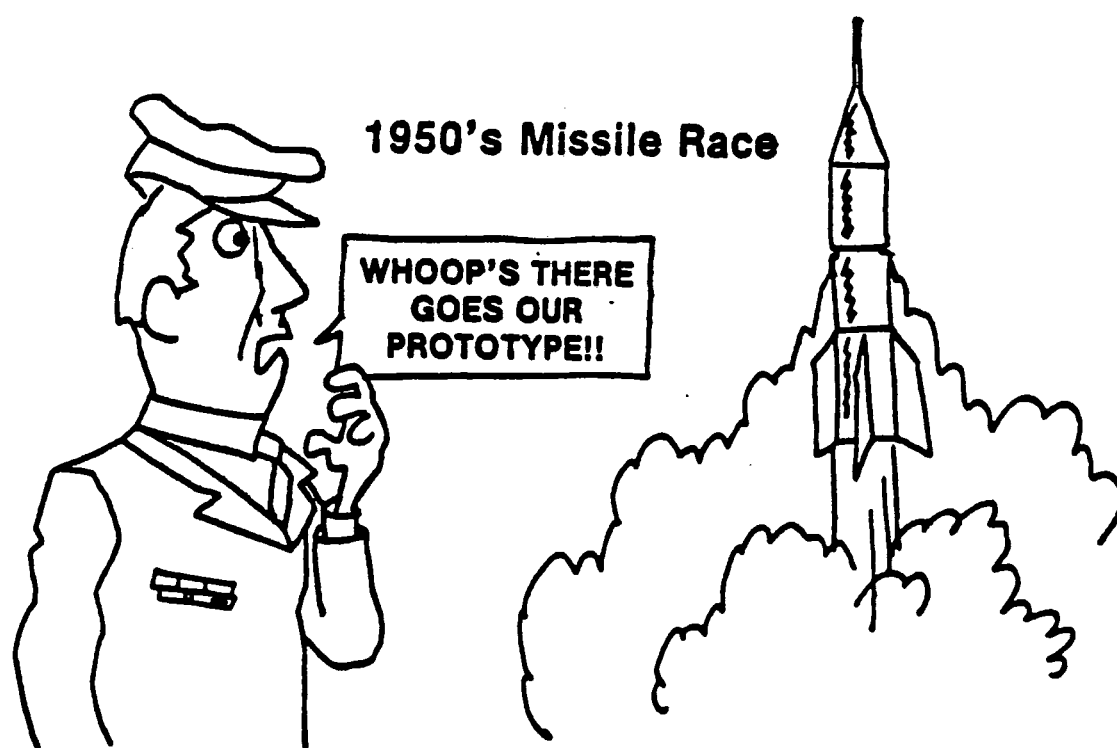


Figure 1-2. Lack of Configuration Control - An Embarrassing Consequence.

Change Proposal" (ECP) and gave industry uniform guidelines for proposing aircraft changes. ANA Bulletin No. 391a further broke down ECPs by classification of priority, and extended the discipline beyond the airframe industry into electronics and manufacturers of ground support equipment.

It was superseded in 1963 by Air Force-Navy design or Army-Navy design (ANA) Bulletin No. 445 which provided a uniform procedure for the submission of proposed engineering changes to the government for approval. ANA Bulletin No. 445 reiterated the necessity for including the technical, fiscal, and logistic supporting information required to define the impact of a proposed engineering change. Over and above the earlier bulletins, it added maintainability and reliability as elements requiring consideration as Class I changes.

ANA Bulletin No. 445 was subsequently superseded by Military Standard 480 (MIL-STD-480), which, in turn, has been replaced recently by MIL-STD-480B. MIL-STD-480B is today the universal standard governing configuration control on military programs.

Air Force Systems Command Manual, AFSCM 375-1, "Configuration Management During the Development and Acquisition Phases," was released for publication in June 1962. This document established a new concept of specification management and initiated the application of baseline concepts, configuration record requirements, seller-buyer interface responsibilities, and an elaboration on the change management requirements of ANA Bulletin 391A which was in place at the time.

In June 1964, AFSCM 375-1 was extensively revised and based primarily on three source documents: Defense Standardization Manual M-200A, Military Specification MIL-D-70327, "Drawings and Data Lists," and ANA Bulletin No. 445, "Engineering Changes." It superseded many other government specifications, bulletins, and standards. The Navy provided detailed instruction for processing of engineering change proposals in BuWeps Instructions 5200.20 and ANA Bulletin No. 445, Supplement No. 1.

In the mid-1970s, government and industry began to become aware of the increasing impact of software to the systems acquisition environment. In 1976, the Department of Defense (DOD), recognizing the significant impact of software on weapons system procurements, mandated in DOD Directive 5000.29 that:

"Defense system computer resources, including both hardware and computer software will be specified and treated as configuration items"

Previously, software has been treated contractually as items of data. Managing software as configuration items elevated it to the level of a prime hardware item, and put it under the close scrutiny of the procuring agency, theoretically assuring greater management attention.

In the ten years from 1976 to 1986, the software development process has begun to mature from what was once a "black art" to something approaching an engineering discipline. The stormy history of standards regulating the documentation of software and, therefore, providing a basis for its configuration control, parallels the early chaotic history of CM requirements documents. Figure 1-3 shows the chronology of these standards. A blow-by-blow description of the evolution is too lengthy to include here, and is not necessarily prerequisite to the subject of configuration control. These documents and their role in the configuration control process will be discussed in subsequent chapters, as necessary.

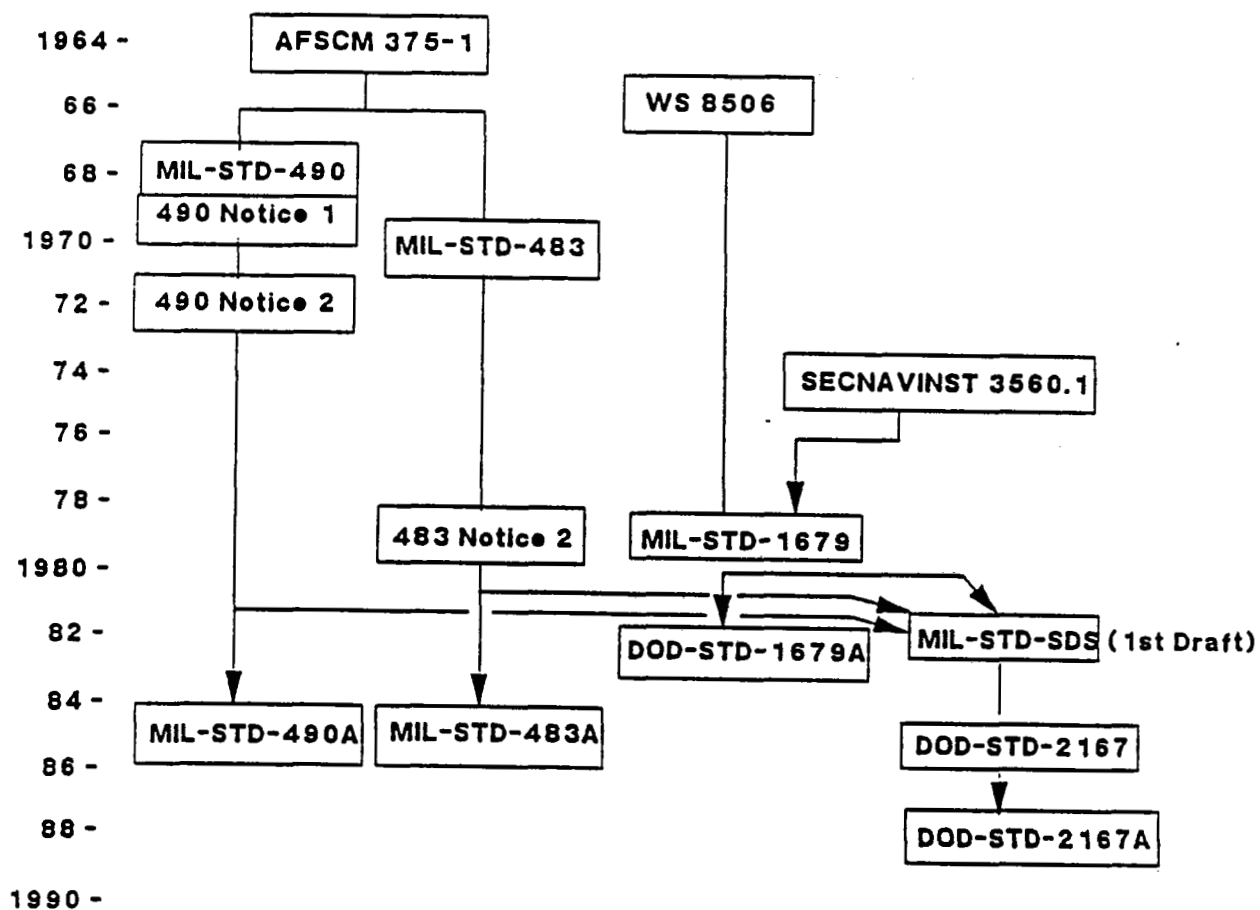


Figure 1-3. Software Documentation Standards Chronology.

Suffice to say that a single tri-service Software Development Standard was achieved in June of 1985 with the issuance of DOD-STD-2167. It has, perhaps, been the most coordinated standard in history. This standard and its related data item descriptions are undergoing continuing evolution to address outstanding issues and to maintain them abreast of current technology.

Paragraph 5.7 of DOD-STD-2167 addresses the subject of configuration management. It represents, perhaps, the first time that industry comments to a section of a standard were accepted by the government and incorporated virtually verbatim. This section calls for software configuration management to be performed "within the framework of the system configuration management and... ensure that integrated procedures address the total system requirements, including such items as hardware, related CSCIs (Computer Software Configuration Items), support and training elements and facilities, and government furnished hardware and software, as applicable.

This, then, is the background for this text, to address configuration control from an integrated "system" viewpoint.

1.4 CONFIGURATION CONTROL

Configuration control means the control of the baseline documentation. Contrary to popular belief, particularly within the software community, configuration control procedures, including the use of formal engineering change proposals (ECPs), must be implemented once the functional baseline (system specification) has been established. As the allocated and product baselines are established, formal ECPs must usually be approved before changes can be made to the baselined documentation.. (Class II engineering changes to product baseline documentation are an exception to this approval requirement). But in all cases, government concurrence with the proposed changes is required before they may be implemented.

This is the "visible" portion of configuration control, as "seen" by both the contractor and the Government or other customer, such as a prime contractor. In addition, configuration control occurs at several levels internal to the contractors activities and at one or more levels within the Government/customer.

The bottom line of configuration control during production and operation is to ensure the continued logistics supportability of the system. Once production is complete, the contractor may disappear from the picture. However, there is still a requirement for the Government to control its own changes to the delivered items, whether they are the result of an approved modification program or an authorized maintenance action. Channels for official documentation and approval of all these changes must be established if configuration control is to be maintained for the delivered items. This theme will be repeated throughout the remaining chapters.

1.5 THE ROLE OF MILITARY STANDARDS

As one who applies configuration control, you should understand why there are requirements for certain events, documentation, and milestones in your program. The actual implementation of configuration control will be determined by the program type, phase, expected production, manning, etc. The key is to accomplish the intent of the configuration control activities as you proceed with the program even if you are unable to accomplish the complete scope of each of the activities. Care must be taken, however, in deviating from the basic requirements spelled out in the military standards.

The military standards that describe configuration control requirements for contractual application have been written and revised based on problems encountered and lessons learned in DOD programs. The requirements in the military standards may be tailored to delete unnecessary detail from the program, or they may be waived and entirely eliminated from the program. Indiscriminate tailoring or deletion, however, may lead to insufficient documentation and control of system design and may create communications problems in the understanding of contractual tasks.

The standards have established a common level of understanding of configuration control terms between the Government and most DOD contractors. If you speak of a critical design review, everyone understands the intent of the review and knows which document (in this example, MIL-STD-1521) should be used to find additional detail on the type of documentation that will be needed and the activities that will be accomplished. If you speak of a technical documentation review, however, you will need a detailed description of it and even then may not fully communicate its purpose. And there can be problems in assuring that all the necessary requirements are addressed if a "requirements specification" or "technical exhibit" is used to specify the performance requirements for a CI rather than, for example, a prime item development specification in accordance with MIL-STD-490.

The military standards provide for a common understanding of contractual tasks between the DOD contractors. The tasks associated with the standards are well defined and understood. If this is the first government contract for a contractor, the use of the military standards will give him a precise idea of the scope of effort required. The tailoring of these military standards for configuration management should be accomplished by a configuration manager who understands the needs of the program as well as the philosophy of configuration management. The same is also true for the selection of data items necessary to accomplish or document the tasks required by the military standards.

MIL-STD-480B (and MIL-STD-481B for some reprourement contracts) establishes the requirements for submittal of ECPs, deviations, and waivers. It also defines the amount and type of information that should be included with the documents.

CHAPTER 2 ORGANIZATION AND PLANNING

This chapter discusses the organizational considerations in the implementation of configuration management, including its placement in the corporate organizational structure and its relationship to other functions. It describes the configuration management functions to be performed.

The second half of the chapter describes the planning required to implement a CM program. It focuses on the CM plan, its purpose, preparation, tailoring of CM requirements to fit the program, and supporting CM procedures that must be applied for effective management. It is important to remember that much of what CM does is organization and planning. To implement "control" one needs to organize and plan.

2.1 ORGANIZATION CONSIDERATIONS

Given the variables, let's not assume that any given organization chart is the "only" one or the "right" one. For illustrative purposes only, a Program organization chart illustrating the relationship of the Configuration Manager to the Program Manager is shown in Figure 2-1. In this matrix organization, the Configuration Manager takes day-to-day direction from the Program Manager, provides guidance to other line managers on the program for configuration management functions, and serves as a direct interfacing point with the Customer for matters relating to configuration management. The Configuration Manager reports administratively to the Director of the Configuration Management Department, who provides guidance to the various programs, provides the important tasks of personnel recruiting and hiring, program staffing, salary administration, technology development and innovation, corporate oversight of program CM performance, development of common policies and procedures and other forms of support and administration which may be required.

2.2 FUNCTIONS TO BE PERFORMED

The techniques of Configuration Management have been developed in response to the requirements for a wide scope of information upon which to base management decisions. Its application begins with the definition of a weapons system in terms of CIs, selecting only those items that can and need to be separately defined and managed; continues with proper planning, coordination and change control activity; and culminates in judicious utilization of manual and automated status reporting and accounting systems designed to identify basic configuration, monitor change status, and verify change incorporation. It is the primary responsibility of the Configuration Manager to ensure that these goals are met without over-selection of configuration items, voluminous reports, and data inaccuracies. Excessive numbers of controlled (separate) items can overwhelm the most effective configuration management system.

Configuration Management has the responsibility to insure that the configuration of the deliverable product is adequately defined, that changes are controlled and accounted for, and that related data items are defined and delivered as specified by contract and Purchase Order requirements.

The basic tasks of a Configuration Manager are shown in Figure 2-2 and addressed below. Analysis of these tasks reveals that Configuration Management becomes involved with virtually every activity which directly or indirectly contributed to the contractual definition of the product. Accordingly, successful completion of these tasks assures proper configuration

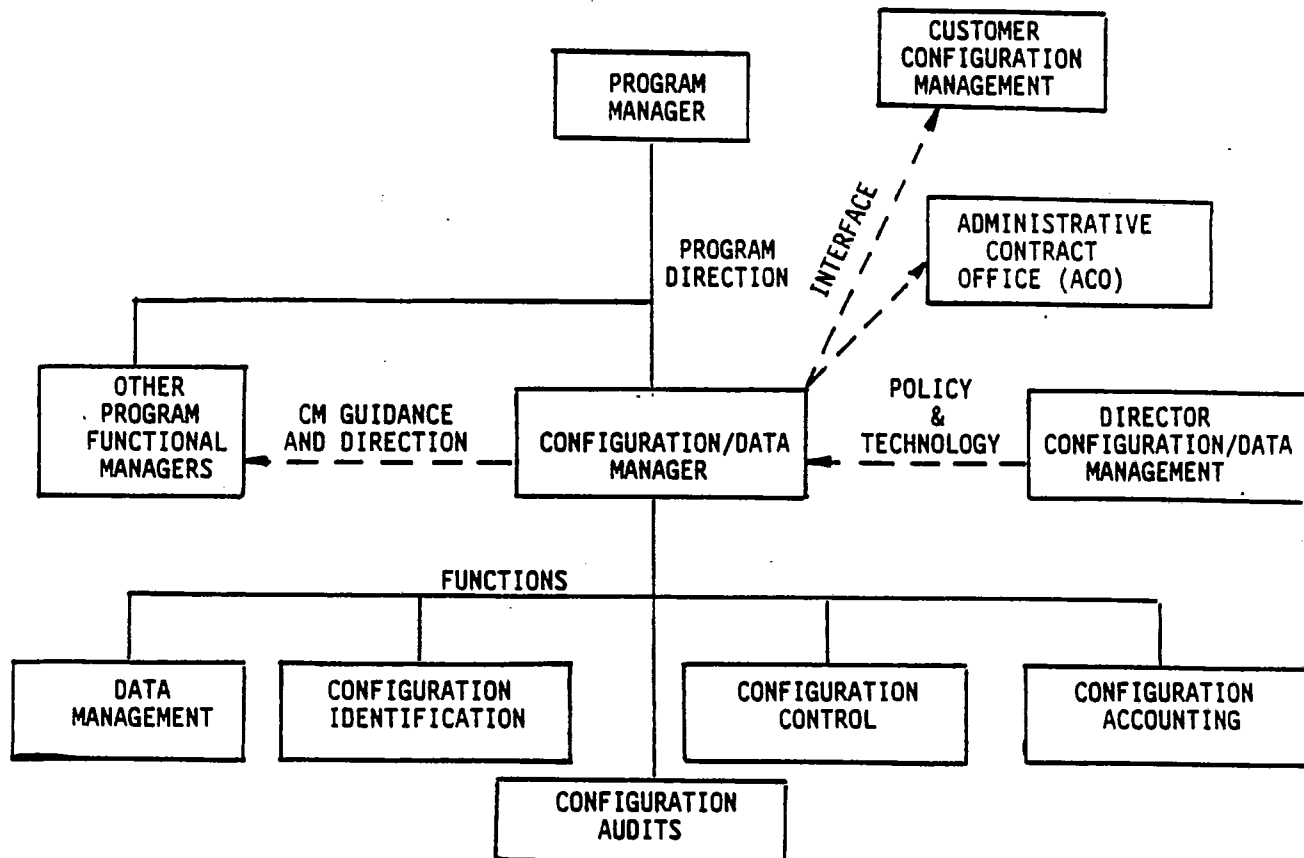


Figure 2-1. Program Configuration Management's Functional Relationships

1. Serve as a focal point for contact with procuring agency personnel for all matters pertaining to Program Configuration Management.
2. Coordinate the requirements of Configuration Management with other managers on the program to ensure meeting total system requirements.
3. Prepare the Configuration Management Plan(s) for the program.
4. Represent Configuration Management at all major design reviews.
5. Serve as member of the CCB, and subordinate change boards, i.e.,
 - Engineering Review Board (ERB)
 - Software Configuration Control Boards (SCCB)
 - Change Review Board (CRB)

CONTROL

1. Serve as a focal point for all change control activity.
2. Receive and assign control numbers to procuring agency and vendor change requests.
3. Prepare and distribute change recommendations and requests to change board members and promulgate records of the board's actions, including to the procuring agency, as required.
4. For Class I changes, prepare and submit the ECPs to the procuring agency.
5. Prepare and distribute subcontractor/vendor organizational and administrative procedures.
6. Establish Associate Contractor Agreements (ACAs) with interfacing contractors.
7. Perform interface control functions.
8. Prepare and submit deviations and waivers.
9. Operate Software Master Library (SML).

ACCOUNTING

1. Serve as a focal point for all manual, mechanized status reporting and accounting.
2. Establish procedures necessary to ensure accurate and effective reporting of "as designed" and "as built" configurations, differences therein, parts location, spares status, documentation release, and change status.
3. Relate and define the status of all elements that affect the configuration of CIs, such as inspection deficiencies, deviations, waivers, engineering and specification change proposals, unincorporated engineering orders, authorized design substitutions, contract changes and flight test instrumentation.
4. Maintain these data available for customer inspection in a consolidated document to facilitate transfer or delivery of equipment to the procuring agency by means of a DD250.

AUDITS

1. Chair or co-chair audit.
2. Coordinates formation of technical support team.
3. Obtains necessary technical documentation.
4. Provides various status accounting records.
5. Obtains agreement with buyer on action items.
6. Prepares audit minutes.
7. Takes follow-up action for close-out.

Figure 2-2. Generic Tasks of a Program Configuration Manager.

identification, control and accounting in a formal manner for contractor and procuring agency management.

2.3 DESCRIPTIONS OF CM RESPONSIBILITIES

The following description of CM responsibilities is typical of a large aerospace program:

2.3.1 Configuration Identification. The identification of Configuration Items for both hardware and software, and the selection of the optimum points in time for the establishment of baselines for their configuration control, will be accomplished by CM in consultation with, and based on concurrence of, appropriate engineering and software managers.

Engineering will implement hardware, software and documentation numbering and revision systems based on consultation with CM. CM will assure that the systems meet contractually specified standards, provide clearly delineated configuration versions, and are consistent with other corporate systems. CM and Engineering will agree on the procedures and approvals required for the release of the baseline configuration since such procedures and approvals are dependent on the baseline status and configuration control ground rules for a given program.

2.3.2 Configuration Control. CM is responsible for the management of the Configuration Control System and will implement procedures for the preparation, processing, review and implementation of authorized changes to baselines, including internal development baselines.

These procedures include Engineering responsibilities and authority for change documentation preparation, participation in change review, and change implementation.

Depending upon the contract requirements and in accordance with the Configuration Management Plan, change approval and implementation authority may be granted to the Engineering or Software Manager, for changes that are within the scope of the contract, up to an appropriate time (such as satisfactory completion of initial software development testing of each major software segment.) After test completion, the segment of software is considered baselined and change approval/implementation authority is vested in the CCB chairman.

At the appropriate point in the software life cycle, the use of the Contractor Change Directive (CCD) will be introduced to provide a vehicle for Program Management review, direction and authorization of changes including those proposed by Sellers/Subcontractors. Engineering will prepare the initial CCD. CM will be responsible for management of the CCD system, assignment of CCD numbers and evaluation of CCDs for adequacy and completeness. CM will continue to be responsible for management of the ECP process including numbering, preparation, and submittal of all ECPs to the customer. Engineering will provide technical, schedule, and fiscal inputs to the proposals in accordance with the ECP preparation instructions.

The primary change board on all programs is the Configuration Control Board (CCB), chaired by the Program Director or his designee. CM acts as Secretary of the CCB, establishes the agendas, publishes minutes and issues revised CCDs as appropriate to disseminate direction. On programs where software is a factor, Software Engineering (SE) will be a member of the CCB. Subsidiary to the CCB are the Change Review Board (CRB) and the Engineering Review Board (ERB) or its software equivalent, the Software Configuration Control Board (SCCB). The purpose of the CRB, chaired by CM, is to coordinate

ECP preparation. Software Engineering, when involved in an ECP, will be a member of the CRB. The ERB, chaired by Engineering or ILS, depending on the change, screens potential changes for technical adequacy and desirability. Both CM and SE shall be members of the ERB. For software changes only, SE will chair a SCCB that will function as the software equivalent of the ERB. CM will participate in SCCB meetings.

Also, part of the Configuration Control system will be the generation and control of Request for Deviation (RFD) and Request for Waiver (RFW). Unlike the ECP that implements permanent engineering changes, the RFD/RFW allows for a temporary departure from the mandatory requirements of the Technical Data Package (TDP) e.g. specifications, drawings, etc.

In most cases, the RFD/RFWs will be processed in a similar manner as the ECP and will be discussed in detail in Chapter 5.

NOTE: These boards are typical of internal CCBs as well as customer conducted CCBs and may vary dependent on individual company and customer requirements. Further description of Configuration Control Boards is contained in Chapter 5.

2.3.3 Configuration Status Accounting. Reporting to the customer on the current configuration status and the status of changes is the responsibility of CM. Engineering will support the reporting requirements by furnishing information available from the development activity and such automated development tools/systems as are in use on the program. The departments agree on the content and source of information required to satisfy customer reporting requirements with minimum duplication of effort.

CM's responsibility is to assure that approved changes are incorporated into the deliverable product. Change incorporation is verified, based on inspections and tests, by Quality Assurance. Documentation update corresponding to changed computer programs must be certified at the time of test.

At the completion of integrated testing of a given equipment or software module, Engineering will provide CM with a Software Quality Assurance certified record of the as-tested configuration of the computer program and its associated documentation. CM will review the certified record against the change authorization documents (ECPs, etc.), update baseline records, as necessary, and authorize bonding of the software and documentation as appropriate.

Engineering, CM and Quality Assurance will agree on the software media bonding and documentation release procedures appropriate to a given project, consistent with contractual requirements and Configuration Management, Software Development, and Quality Assurance Plans.

2.3.4 Reviews and Audits. CM will be a participant, sometimes only in an administrative function, in all Design Reviews (e.g., SRR, SDR, PDR, CDR, etc.). Specific responsibilities will be as assigned by the Program Manager or Review chairperson.

Engineering and QA will participate in and fully support the following formal Configuration Audits and reviews mandated by the customer. In most instances CM will co-chair formal configuration audits with the customer.

A Functional Configuration Audit (FCA) will be chaired by CM to verify that the configuration item's actual performance complies with its performance specification. CM will conduct a Physical Configuration Audit (PCA) to verify that the as-built configuration of the CI conforms to the Technical Documentation which defines it.

2.4 THE CM PLAN

A configuration management plan is a road map to the application of configuration management on a specific program or project. It describes:

- How the company or Government agency is organized to conduct configuration management.
- What the configuration items are that CM will be applied to.
- What documents will form the various configuration baseline; when they will be established.
- What control ground rules apply for changes to each baseline.
- What procedures and tools will be employed for configuration identification, control, status accounting and audit.
- Interfaces with other disciplines.
- Level of automation.

There are many levels at which CM planning is accomplished. These include Government procuring activities, contractors and subcontractors. There are unique configuration management plans created at each of these levels to establish the ground rules for joint ventures, partnerships and other contractor teaming arrangements. Finally there are configuration management plans that are prepared as part of a contractor or subcontractor proposal in response to an RFP as well as plans prepared after contract/subcontract award to detail the application and procedures to be followed in performance of the contract/subcontract.

Regardless of the Data Item Description (DID) used, the plan must address the functional, allocated, and product baselines and the identification and control of the documents which comprise them.

The contractual aspects of configuration control must be addressed, including, specifically, the requirements to classify changes and submit ECPs, deviations, and waivers for approval of concurrence in classification. ECPs and SCNs are not "reporting documentation", such as test reports or trade-off studies, which connotes after the fact documents, but are the media for Government approval of changes which affect their interests.

Provisions for management and change control of subcontracted and GFP software must be addressed.

2.4.1 CM Plan Content. The content of the CM Plan is provided in Figure 2-3. This content can be tailored by the Plan preparer to meet almost any situation or product calling for a CM Plan whether the product is hardware or software or, as is most frequent, a combination of both.

DATA ITEM DESCRIPTION	2. IDENTIFICATION NOES.	
1. TITLE	AGENCY	NUMBER
CONFIGURATION MANAGEMENT PLAN	DoD	DI-E-7XXX
3. DESCRIPTION/PURPOSE The Configuration Management Plan (CMP) describes the contractor's organization, policies, and procedures for accomplishing Configuration Management (CM), to include configuration identification, configuration control, configuration status accounting, and configuration audits for hardware, software and firmware.	4. APPROVAL DATE	
	5. OFFICE OF PRIMARY RESPONSIBILITY	
	6. DOE REQUIRED	
	7. APPROVAL LIMITATION	
7. APPLICATION/INTERRELATIONSHIP 7.1 This data item description applies to all contracts requiring delivery of a Configuration Management Plan. This plan is intended to provide the Government with an understanding of the contractor's Configuration Management System. 7.2 The CMP prepared in accordance with this DID is for information only even though it is submitted for government approval unless contract explicitly states that upon approval the CMP becomes a contractual requirement. 7.3 The terms "contract" and "contractor" include <u>intragovernment orders and activities.</u> (Con't on page 2)	8. REFERENCES (Summary of cited in block 10) DOD-STD-100 DOD-STD-480 DOD-STD-481 DOD-STD-482 MIL-STD-483 (USAF) MIL-STD-490 DOD-D-1000 MIL-STD-1521 (USAF)	
	9. REFERENCES (Continued on page 2) (Continued on page 2)	
10. PREPARATION INSTRUCTIONS 10.1 The plan shall describe how the contractor intends to assure proper configuration identification, configuration control (including the control of approved Engineering Change Proposals (ECP)), configuration status accounting, and configuration audits. Applicable Military Standards and Specifications, listed in Block 9, shall be used in accordance with the contract requirements to develop the plan's details. 10.2 The plan shall include, but need not be limited to, the following sections to encompass hardware, software, and firmware: 1. Introduction 2. Applicable Documents 3. Configuration Management Organization 4. Interface Management 5. Configuration Management Phasing and Milestones 6. Configuration Identification 7. Configuration Control 8. Configuration Status Accounting		

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PAGE 1 OF 2 PAGES

Figure 2-3. CM Plan Data Item Description (Page 1 of 6).

DI-E-7XXX

BLOCK 7. APPLICATION/INTERRELATIONSHIP (Continued)

7.4 This DID satisfies the requirement of MIL-STD-483, Appendix 1; MIL-STD-1456; and DOD-STD-2167.

7.5 This DID supersedes DI-E-1100, DI-E-2035, DI-E-3108, DI-E-5391, DI-E-5528 and DI-MCCR-80009.

BLOCK 9. References (Continued)

DOD-STD-2167
MIL-S-83490

BLOCK 10. Preparation Instructions (Continued)

9. Configuration Audits

10. Subcontractor/Vendor Control

10.3 Content Instructions. The CMP shall be prepared in accordance with the following content instructions:

Section 1 - Introduction.

This section shall include:

- a. The purpose, scope, and specific contractual applicability of the CMP.
- b. Reference to applicable directives or glossaries containing definitions of terminology and acronyms used in the CMP.
- c. A description of the plan's major features and objectives, and a concise summary of the contractor's approach to Configuration Management for hardware, software and firmware.

Section 2 - Applicable Documents.

This section shall begin with the following paragraph: "The following documents of the exact issue shown form a part of this plan to the extent specified herein. Documents referenced in the following documents are for guidance only unless they are otherwise cited in the contract requirements."

It shall list those specifications, standards, manuals, and other documents referenced in the CMP. Each document shall be completely identified by title, document number, issuing authority, revision status, and when applicable, change notice/ amendment number, and date of issue.

Figure 2-3. CM Plan Data Item Description (Page 2 of 6).

DI-E-7XXX

BLOCK 10. Preparation Instructions (Continued)**Section 3 - Configuration Management Organization.**

This section shall describe and graphically portray the contractor's organization for CM which shall include the:

- a. Relationships between the contractor's project organization and functional organizations.
- b. Responsibilities and authority for CM of all participating groups and organizations.
- c. Identification of the contractor's CM organization including configuration control boards and the relationship of responsibilities for hardware, software, and firmware CM.
- d. Policies and directives relating to CM.

Section 4 - Interface Management.

This section shall describe the contractor's plans and procedures for coordination of interfacing design with associate contractors (i.e., two or more contractors working under separate Government contracts) or government agencies; and for processing companion/related changes. It shall describe, as applicable:

- a. Associate contractor agreements.
- b. Responsibilities of each party to the interface.
- c. Interface working group procedures.
- d. Interface control documentation.
- e. Interface change procedures, forms, communication media, and documents.

Section 5 - Configuration Management Phasing and Milestones.

This section shall be specific in:

- a. Defining the sequence of events and major milestones for implementation of CM.
- b. Establishing contractual baselines and internal configurations.
- c. Interrelating events critical to CM.

Figure 2-3. CM Plan Data Item Description (Page 3 of 6).

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BLOCK 10. Preparation Instructions (Continued)

Section 6 - Configuration Identification.

This section shall present the contractor's plans for:

- a. Recommending and identifying configuration items as required by the contract, and additional items considered necessary by the contractor to ensure proper configuration identification.
- b. Developing, numbering, changing, and maintaining specifications; and illustrating their relationships by means of specification trees.
- c. Preparing, identifying, and revising engineering drawings and associated lists.
- d. Establishing baselines as appropriate (functional, allocated, and product).
- e. Preparing and processing of software specifications during development, and their identification and relationship to higher level specifications.
- f. Establishing a software support library (when applicable).
- g. Assigning nomenclature, serial numbers, and part numbers to hardware, and titling, labeling, numbering, and cataloging software.
- h. Releasing engineering documentation.

Section 7 - Configuration Control.

This section shall describe the contractor's procedures for configuration control, including:

- a. Specific application of contractual configuration control requirements.
- b. Classification of Class I and Class II changes (in accordance with DOD-STD-480) to established configuration identifications and the level of authority for change approval/concurrence.
- c. Configuration control between the contractor's internal organizations, between the contractor and the procuring activity, and between the contractor and subcontractors. Include function, responsibility, and authority of each control board, working group, etc.

Figure 2-3. CM Plan Data Item Description (Page 4 of 6).

DI-E-7XXX

BLOCK 10. Preparation Instructions (Continued)

- d. Format, processing requirements, and submittal to the Procuring Agency, or Procuring Agency's Representative, of documents used in the conduct of configuration control (e.g., Engineering Change Proposals, Specification Change Notices, Notices of Revision, Class II Changes, Requests for Deviation/Waiver, Software Trouble Reports, and when applicable, specific internal control and authorizing documents).
- e. Control of, access to, and security of libraries, data bases, release files, etc., involved in configuration control.
- f. Procedures for ensuring that all items are appropriately reidentified to reflect the change.

Section 8 - Configuration Status Accounting.

This section shall present:

- a. The contractor's procedures for collecting, recording, processing, and maintaining data necessary to produce contractual status accounting information via reports and/or data base access.
- b. Description of report/data base content related to (as applicable):
 - (1) Configuration identification (baseline) status.
 - (2) Change Proposal status and history.
 - (3) As-Designed versus As-Built configuration.
 - (4) Other change implementation status.
- c. Methods of access to information in status accounting data bases and/or frequency of reporting and distribution.

Section 9 - Configuration Audits.

This section shall describe:

- a. Plans, procedures, documentation, and schedules for functional configuration audits and physical configuration audits in accordance with MIL-STD-1521.
- b. Format and reporting results of in-process configuration audits.

Figure 2-3. CM Plan Data Item Description (Page 5 of 6).

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BLOCK 10. Preparation Instructions (Continued)

Section 10 - Subcontractor/Vendor Control.

The contractor shall describe the methods used in providing and assuring subcontractor/vendor compliance with configuration management requirements.

10.4 Format. Any format which satisfies the requirements of this DID may be used for the Configuration Management Plan, provided:

- a. There is a cover page with the plan title, system/item name and designation, contract number, CDRL number, date, revision identifier (when applicable), and contractor name and address. A revision status record may be included.
- b. There is a table of contents when the plan is longer than 10 pages.

Figure 2-3. CM Plan Data Item Description (Page 6 of 6).

CHAPTER 3 BASELINE MANAGEMENT

The whole concept of progressive definition (maturity) of product configuration and the gradual application of increasing levels of control are the essence of configuration management and can be summed up in the phrase "Baseline Management". Baseline Management is synonymous with configuration control.

This chapter will describe the use of the formal baselines in controlling configuration changes, introduce the "non-formal" or "internal" baselines used by contractors, illustrate the multiple layers of interrelated baselines that may exist in a complex project, and discuss the application of control authority to the structure. In effect, this chapter examines the theory of configuration control with the remaining chapters of the text focusing on the practices and tools used to perform it.

3.1 ESTABLISHMENT AND DEFINITION OF FORMAL BASELINES

The baseline concept is an essential cornerstone to the Configuration Management process. A baseline connotes an agreed-to or approved departure point for the definition and control of changes. Baselines consist of established (contractually set or approved) configuration identification which provide the reference points for change management.

The names given to the baselines are a convenient way of indicating, in one word, which set of control rules applies to a given identification document and hence tell us the level of approval that is required to effect a change. The formal Functional, Allocated and Product Baselines are, therefore, a series of gates defining in three progressive steps, the configuration of the product that the Seller is producing for the Buyer; they reflect the increasing stake the Buyer has in the product as it progresses from a "paper" product to a "real" one. As the cost of making a change increases, so does the level of scrutiny and approval.

Establishing a formal baseline does not mean that changes are stopped - only that formal approval must occur before the change can be implemented. As shown in Figure 3-1, changes which impact an established baseline must be examined closely and approved by the customer. As a by-product, unnecessary changes, including "nice-to-have" but costly gold-plating, are eliminated. The entire Configuration Management program can cover its own costs if it succeeds in screening out a single "mega-buck" change that is unnecessary.

But before a Configuration Manager can hope to achieve such successes, he or she must first determine the practical and economical level at which to apply the baseline principles. He must define the "Configuration Items"; those things (be they hardware, software or firmware) to which configuration management is to be applied.

3.2 SELECTION AND IDENTIFICATION OF CONFIGURATION ITEMS (CI)

Sometimes, selection of a CI is patently obvious and is simply a matter of looking at what the contract calls for as the deliverable end product. In fact, the early terminology for configuration items was "Contract End Item", as described in Chapter 1.

BASELINING CONFIGURATIONS

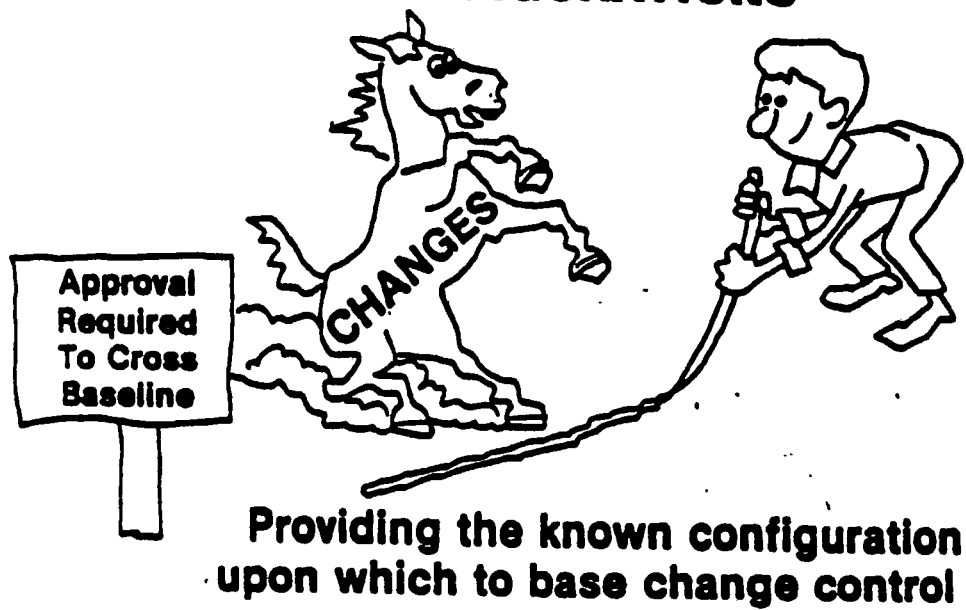


Figure 3-1. The Function of Baselines is Not to Stop Changes.

But because, in complex programs such as Aircraft and Major Electronic Systems, there is a need to manage at lower than the "system" level, the terminology was revised to Configuration Item (CI) which may be further delineated as HWCi (or just CI alone) for hardware items and CSCi (formerly CPCi) for computer software configuration items. In this section we are using the term CI generically to reflect either hardware or software.

CIs are usually selected in the Demonstration and Validation Phase of the program life cycle or early in Full Scale Development as an output of the system engineering process. They represent the levels of technical interface with the procuring agency (Customer) and with Subcontractors.

As the development of the CI progresses, specifications or specification-type documents (depending on customer requirements) are generated by the contractor/subcontractor and reviewed and approved by the customer. The approval and authentication of designated documents establishes baselines for configuration control. Management of baselines, both external (Customer) and internal (Program Management) as described, involves evaluating each change for its impact on the configuration identification of related hardware/software configuration items.

At any time in the life of a Configuration Item, its current configuration identification is defined by the previously established baselines and approved changes.

Choosing Configuration Items (CSCIs or HWCIs) is a management decision based on both technical and administrative factors. The CI is the level to which the system requirements, usually expressed in a System Specification (or equivalent), are allocated for individual assignment of development responsibility or separate procurement. In many cases the need to prepare a separate specification is obvious and coincides with the rationale for CI selection.

Thus, the selection of CIs is not a simple matter. It can have a significant influence on the cost of applying configuration management over the full life cycle of the product. Excessive CI selection can not only make the configuration management activity a cost driver but, by overburdening the resources with administrative tasks, can obviate the cost-saving benefits of an efficient CM program. Taxed with too much "paper pushing", a configuration manager's cognitive processes may be dulled to the point where change review becomes a formula process rather than the careful individual examination of each change to discern the hidden "show stoppers" and "budget wasters." An optimum selection of CIs is the first step in developing a cost-effective configuration management program.

3.3 FORMAL BASELINES

In the hardware world, the DOD agencies and industry standardized on the definition of three baselines: Functional, Allocated and Product - after a number of years of individual designations for more or less the same thing. These baseline titles are equally applicable to software. The distinction is more in the subtleties of their use than in basic definition.

The three formal baselines are conceptually the same for all DOD services but are defined by different software documentation depending

upon the documentation standard that is contractually specified. Although DOD-STD-2167 is now the universal standard for software development and documentation, the others (DOD-STD-1679A and the MIL-STD-483/490 [basic versions]) live on in the form of (a) previously developed software which is being modified to a limited degree (probably less than 30%) and for which cost prohibits rewrite of existing documentation, and (b) follow-on contracts under which the prevailing development and support environment is that of the earlier standards. Life is not simple in the real world.

Figure 3-2 illustrates the definition and content of the formal configuration baselines.

3.3.1 Functional Baseline. The Functional Baseline represents the documented and agreed-to system level requirements embodied in a System Specification or equivalent systems requirements document. It is usually established prior to the Full-Scale Development Phase (contract) as a result of the effort completed during the Demonstration and Validation Phase (contract). The Functional Baseline is usually contractually applied as a configuration control tool no later than the establishment of the Full-Scale Development contract. Where applicable, the Functional Baseline concerns both hardware and software. The system specification allocates functions to the hardware/software elements comprising the system.

3.3.2 Allocated Baseline. The Allocated Baseline results from the further allocation of system level requirements via "Development Specifications" to the individual hardware and software configuration items comprising the system. This baseline is established during development, usually prior to the Preliminary Design Review (PDR) when the customer approves the allocated requirements and the planned functional approach to development. This, however, in no way relieves the contractor from meeting the system-level, Functional Baseline requirements. But while the Functional Baseline always takes precedence over the Allocated, the Allocated Baseline remains the primary technical basis for change control with the customer throughout the development process.

3.3.3 Product Baseline. The Product Baseline for hardware consists of the documentation necessary to build, test and accept the product in production and is a primary technical basis for change control during the Production Phase (contract). At this point, the product baseline represents the physical embodiment of the functional baseline requirements. All three baselines are in place with the order of precedence being functional, allocated and product.

Since software literally does not have a production phase, there is a subtle difference in the significance of the product baseline. In the case of software, the Product Baseline is the validated documentation of the tested and accepted software rather than the basis for production. It is thus primarily a baseline for software maintenance which encompasses continuing change control. Most changes to Allocated Baseline (performance) requirements will have an impact on the source code and documentation comprising the Product Baseline. Likewise, any change to the Product Baseline must be examined for impact on the allocated and functional.

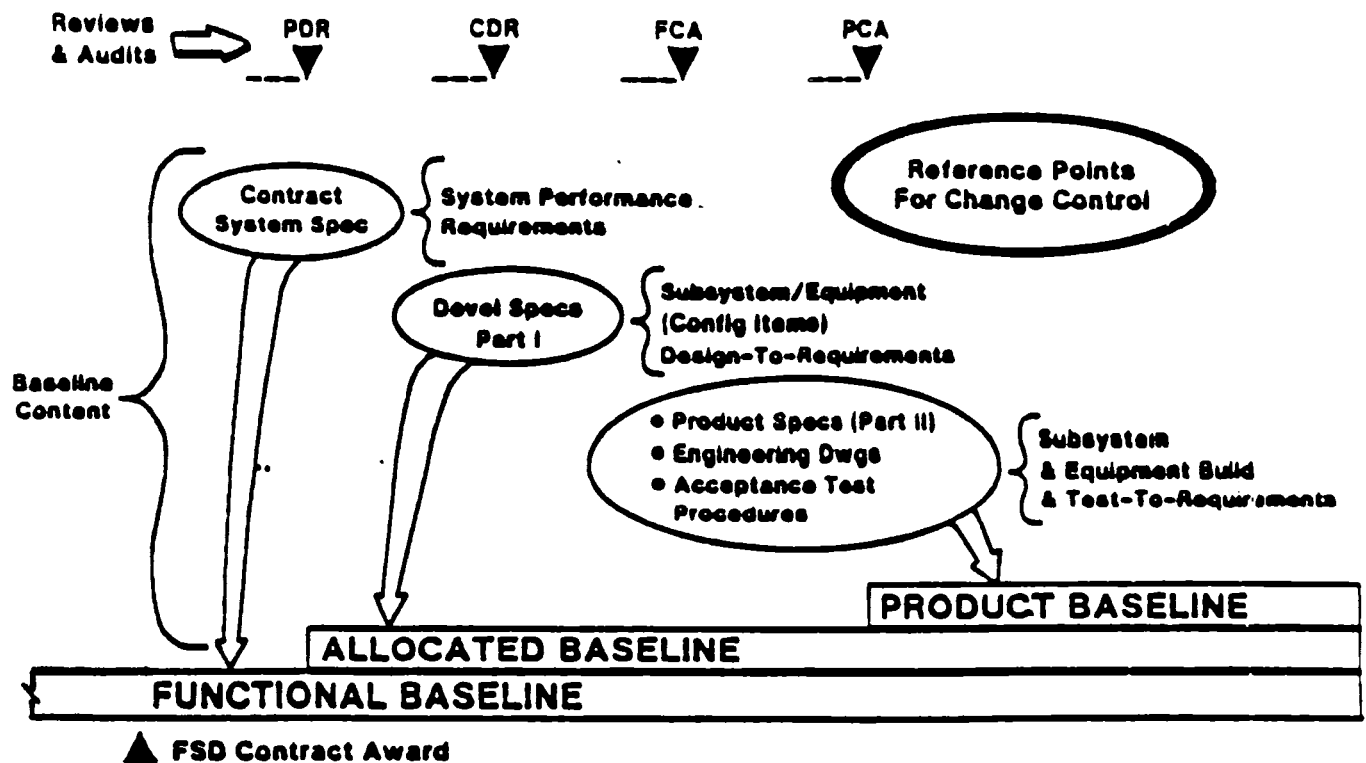


Figure 3-2. Formal Baseline Theory.

3.4 INTERNAL DEVELOPMENTAL BASELINES

Internal baselines, and the internal configuration management practices we apply to them are really the basic good management practice upon which initial CM concepts were based when the discipline was first defined in the early sixties. Once the topic is understood, the feeling is that, "Hey, this is what we really have been doing all along - when we take the trouble to do things right!! And when we don't, the result is chaos!!"

3.4.1 Defining Internal Baselines. As widely accepted as the formal baseline terminology has become, it is a bit surprising that until recently one could not use a universally understood term to describe internal configuration baselines.

When Draft MIL-STD-1679 introduced the term "Developmental Baseline" to the software community, it was rejected by some Government and industry users of the document, because it could be incorrectly interpreted as another baseline subject to Government control rather than an internal practice of the contractor.

The true character of this baseline began to be understood, strangely enough, when the term "baseline" was removed and the term "configuration" substituted by the authors of DOD-STD-2167. They reasoned, after receiving comments to their first two drafts, that deleting the term "baseline" alleviated the concern about Government control of the software documentation at too low a level and too early.

The development configuration for software is analogous to the internal release control and release records for hardware drawings. In fact, many in the industry prefer to include both hardware and software under the umbrella of the developmental configuration terminology. Any change to released engineering drawings requires internal approvals. Government approval or formal approval is required only when the established Functional or Allocated baselines are impacted by the proposed change.

Once documentation or code has been entered into the Developmental Configuration, each proposed design change, though internally controlled, must be examined for its impact on program costs, since a released engineering drawing immediately can cause additional work to be performed. This work includes such activities as manufacturing planning, tool design and fabrication and manufacture of parts. If uncontrolled, change, though not impacting the customer's baseline, could defeat much or all of the baselining and control effort. Thus, rigorous internal configuration control to the documents in the Developmental Configuration engineering release record is a necessity.

When the engineering development of the hardware is completed and proven by the completion of the FCA and PCA, the engineering drawings (which are the top level and detailed level design documents for hardware) are, along with the Product Specification, formally baselined as the Product baseline. Any change must be treated as Class I or II and submitted to the customer in accordance with MIL-STD-480B.

Thus, the analogy is completed and we can clearly see that, conceptually, at least, there is no difference between the internal or formal configuration control of hardware and software. As practiced by some companies, the Developmental Configuration is subdivided into a series of internal sub-baselines with increasing levels of change approval authority required as each successive baseline is established.

For example, in the development of a missile, there may be a number of internal baselines that reflect the stages of the design. A Launch Test Vehicle (LTV) baseline may be established in the evaluation of the propulsion system. Any changes would require some sort of change documentation.

The LTV could be followed by a Control Test Vehicle (CTV) baseline. This baseline would "build upon" the propulsion by including the control mechanisms. This would evaluate the control of the airframe during the various propulsion stages.

Finally the CTV test configuration could add guidance to create a Guidance Test Vehicle (GTV) for verification of total system performance e.g., propulsion, control and guidance.

As you can see, it is necessary to apply more formal change controls as the configuration approaches the production or tactical configuration.

3.4.2 Management of Computer Programs and Documentation. Configuration management of computer media (magnetic tapes, cassettes, etc.) and documentation encompasses library controls which secure and bond code and documentation at the appropriate point in the development cycle to prevent the inclusion of unauthorized changes. Specifically, the library controls assure that computer software items retained in a computer software library are identified, controlled and accounted for and that material is recorded, filed, maintained and safeguarded in a manner that will provide proper identification, storage, protection and authorized release, revision, reproduction, distribution, and removal. The release control requirements described in the previous section are administered via the software library.

3.4.3 Internal Baseline Control. Configuration Control is applied to both internal and external baselines incrementally as the development progresses. The depth and timing of this control is critical to program success. Applied too soon, configuration controls can be a cost driver to the program and an impediment to efficient development. Applied too late, they cannot be effective in minimizing program cost and preventing schedule slippage.

The external control of formal baselines inhibits the development process by restricting the work to that which is contractually authorized and funded. It requires the customer to technically approve changes that impact his interests, and provides a means for providing authorization for "out-of-scope" effort and equitable adjustment in contract price and/or schedule where justified. Therefore, formal external control must be applied only where it is truly required.

This formal control essentially remains at the requirements level throughout development. It is applied initially as a general statement of the entire system performance requirements (Functional Baseline) and then to more detailed requirements for each CI or CSCI (Allocated Baselines). What this means is that the contractor has the freedom to change, subject only to his own internal controls, any product design or code so long as it is judged within the technical and fiscal scope of the then currently established baselines. If the baseline specifications or other contractual parameters, as delineated in MIL-STD-480B, are impacted, appropriate change classification must occur and customer approval must be obtained.

Once a CI or CSCI is delivered and is under the control of the Product Baseline, all changes to the design of the product, or its code in the case of software, whether for correction of error or enhancement, impact the customer operations, and, therefore, more stringent procedures are applied. However, if the contract calls for the contractor to provide software support and maintenance subsequent to software delivery, strict control to the product baseline might be deferred until customer takeover. However, this is the exception and is highly dependent upon contractual considerations.

Throughout the life cycle of the CI/CSCI, it is essential that each request for change be reviewed for possible contract change implications. Many projects, particularly in the software area, have been unwisely escalated in cost by a contractor responding to customer requests and suggestions without documenting them as changes and seeking additional funding.

No amount of discipline or control at the formal contractual level, however, can save a project that does not rest on the firm foundation of good, basic, common sense, internal discipline and control. Internal control is the foundation level for configuration management.

Good basic software design and development management insists on "as-you-go" documentation by analysts and programmers, the maintenance of notebooks and/or unit development folders and the coordination with others on interfacing requirements. The analysis and design of the system hierarchy and the allocation of work into organized work packages, or units, sets the basis for all levels of control. This "revelation" that has come rather lately to the software community is really an adaptation of the basic design discipline practiced by hardware designers - under the banner of good basic engineering practice since the turn of the century.

As a project progresses, with each unit of software moving from analysis to design, and then on to the coding and test stages of the development process (which parallels the simultaneous progression of hardware through preliminary and detail design, fabrication, and test), higher levels of internal configuration control are employed, such as development libraries, release controls, and test controls.

When tests are complete for identifiable units of code or hardware components and they enter integration testing with other hardware/software elements, higher authority is needed to effect change and correct errors. At this point, others besides the individuals in the group responsible for the given unit or component are involved and may be impacted by the contemplated change or correction.

This internal baseline control can be thought of as the management of an "informal contract" that the development (engineering) team has with the Program Manager. In this context, the "informal contract" encompasses milestones which apply in staggered (waterfall) fashion to CIs and/or CSCIs and at a lower level to its assemblies and hardware parts or computer software components and units. These milestones or "internal baseline" points, each signal a greater degree of management control.

This management control, i.e., the requirement for change approval, is natural and should inhibit the development effort only to the extent that one is restricted from taking action which impacts other affected areas of responsibility and of incurring unnecessary costs to the

project by redoing completed tasks without having to justify why the change is necessary and prudent.

The only other area of internal control which regulates the design process is the design review and configuration audit process, which is a quality assurance as well as configuration management function. The internal configuration control concept is essential regardless of such customer-related elements as CIs and formal specification approvals. It can and must be practiced, for a project to be successful, whether or not formal configuration management is contractually stipulated. Simply put, a project without inherent internal configuration control cannot produce an effective product that is maintainable and supportable and meets all the requirements of the customer.

3.5 CONTRACTOR HIERARCHY

There are a number of contractor relationships that can influence the planning for configuration management and the definition of baselines for configuration control. As in the Government hierarchy, there are a wide variety of scenarios in different defense contracting environments. Far from the "one contractor/one government office" relationship one would infer from the simplistic approach in the MIL-STDs, regulations and handbooks, we may have one or more of the following:

- A prime contractor or two or more interfacing prime contractors
- Contractors teams in the forms of:
 - Equal partnerships
 - Principal subcontractors
 - Major subcontractors
- Dual source development and manufacturing
- Leader/follower type of contractor relationships
- Multi-company, multi-national consortia

These, and other similar arrangements constitute only the first and possibly the second tier of contractor hierarchy. Below that tier there may be from one to four or five or more levels of subcontractors and vendors, depending on the complexity of the contract, the product, and the services required.

3.6 BASELINE RELATIONSHIPS

These multiple levels of baseline controls on both the Government and Industry sides provide an interrelated set of baselines which define the contractual requirements. Those interfacing contractual requirements are subjected to configuration control from one level to the next higher level.

Rather than try to diagram the entire fifteen or so levels which would only be confusing, Figure 3-3 shows the interface between two adjoining levels, those of a prime contractor and of a first tier contractor. This example is typical. It illustrates the relationship between the functional and the allocated baselines as viewed from both sides of the interface.

This diagram illustrates that the Prime Contractor's Functional Baseline is derived from the Prime Contractor's contract with the Government. From the Functional Baseline, the Prime allocates requirements to CIs and establishes an Allocated Baseline. Part or all

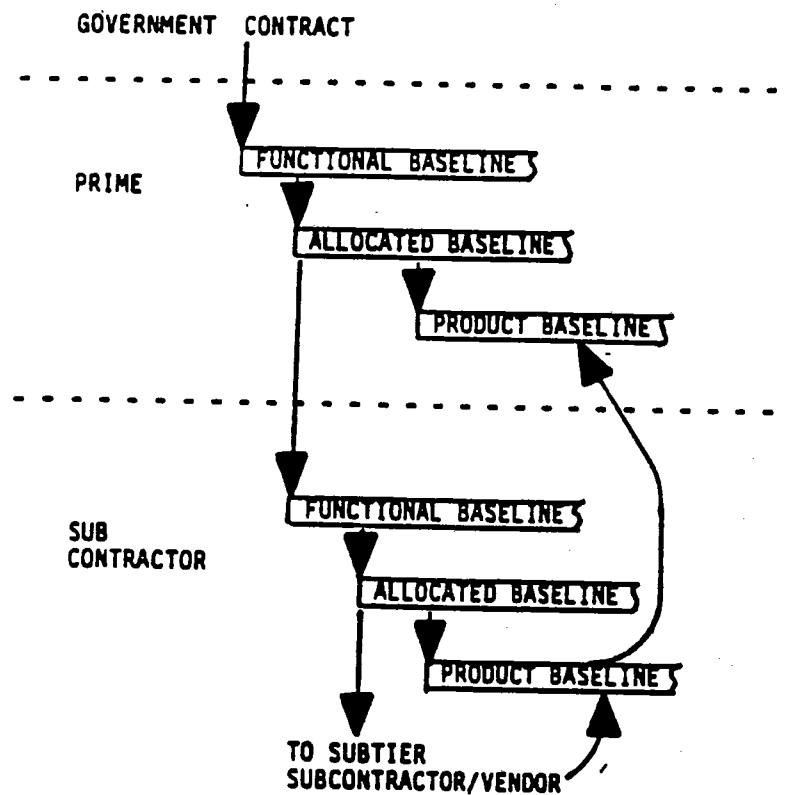


Figure 3-3. Baseline Relationships at Intersecting Levels of Contractor Hierarchy.

of the Prime's Allocated Baseline establishes the requirements established in a subcontract with a subcontractor, who in turn may allocate requirements to lower levels and acquire items from subtier suppliers. The subcontractor's Functional Baseline thus derives from the Prime's allocated baseline. The Prime's Product Baseline, which is the physical manifestation of his allocated baseline, includes the Product Baseline representing the subcontract portion of the Prime's Product. One can carry this analogy down through subsequent levels of subcontractors. The lower one goes, the less precise the relationships become.

The classic baseline relationship is often distorted by the contracting and subcontracting process leading to such terminology as Functional/Allocated baselines or Functional and Product with no Allocated. These distortions may result from too limited a view of the entire process or the desire to simplify references. Regardless of the terminology used, however, any of these established baselines are similarly treated from a Configuration Control point of view; so it is wasted effort in debating the semantics.

Each layer of the Baseline structure requires Configuration Control to be exercised by the next lower level. Thus a change to a component by a subtier supplier can and often does bubble up through successively higher levels until it reaches the point at which it does not impact an established baseline.



CHAPTER 4 THE CHANGE PROCESS

While chapter 3 described the concepts associated with the establishment of configuration baselines, this chapter addresses how changes from the established baselines are managed. It traces the engineering change process through its entire life cycle and examines the functions to be performed, the requirements for documents and data files to be created, the role of configuration control (change) boards, the rationale involved in each of the decision processes and the procedures typically employed. In the process, unique considerations of the change process relating to different product types such as aircraft, ships, armament, software, microprocessor firmware, etc., are highlighted.

4.1 OVERVIEW OF THE CHANGE PROCESS

The change process is the principal by-product of change management. It is the mechanism by which changes to a product are managed. Change management, or the control of a program's constantly changing configuration, must utilize this process to follow configuration's development as the design evolves. This process provides a disciplined methodology to handle change management activities from initiation to definitized changes, which includes tracking and status reporting for both internal (company) and external (customer) use. This mechanism for controlling change includes a series of organized steps to initiate, review, approve, and implement changes to established documentation (programmatic and contractual) for all programs within a company. These steps must be progressive and as follows:

1. Requesting and assessing the impacts of the change.
2. Classifying the change.
3. Proposing the change.
4. Approving and authorizing the change.
5. Implementing the change.
6. Verifying and accounting for accomplishment of the change.

Managing change is a multi-faceted process. The details of specific change management procedures can be confusing and rather overwhelming when viewed in their entirety. However, by breaking the process down into the series of discrete steps, illustrated in Figure 4-1, we are able to examine the process in detail. This overview flow chart of the configuration change process provides the roadmap for the remaining sections of this chapter.

Section 4.2 examines the Change Request Process. It discusses the sources of, and reasons for, change initiation and explores the activity in this part of the change cycle. The change begins at the time the need for the change is identified and continues through the initial assessment of the potential change impacts.

Section 4.3, Change Classification, describes the next logical step, which is to determine which of the several change processing paths is most applicable to the specific change, depending on the nature of the change and the extent of its impact. The term classification is used in this context to delineate the level of approval authority that

**Documents**

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is necessary for the given change and, therefore, the documentation, routing, signatures, change board approvals or contractual authorizing and funding actions it requires.

Section 4.4, Change Proposal Preparation, describes how each class of change is scheduled, documented, evaluated and approved, including submittal for customer approval.

Section 4.5, Customer Approval and Authorization of the Change, outlines, for each classification of change for which the customer is involved, the specific actions that must be taken to approve the change, direct its implementation and provide the funding for the various elements of the change. It also delineates the type of scheduling and tracking that is required by both the contractor and the customer depending on the classification of the change.

Section 4.6, Contractor Change Implementation, takes us from receipt of the change authorization from the customer through the steps necessary to direct and control the incorporation of the change in all areas that are impacted. It includes the processes necessary to re-evaluate the change, as authorized, provide budgets and job charges, and authorize work.

Section 4.7, Change Implementation focuses on the execution of the change. It discusses the activities required to perform final implementation planning, and release of all the information that is necessary for functional activities to complete their responsibilities with respect to the authorized change. It also addresses the procedures for verifying the change incorporation and the requirements for status accounting associated with the configuration control process.

It should be noted that the processes and detail forms specified in this chapter as well as other chapters in this text are examples used in industry today but are not to be considered best in all cases. Similar practices exist in all companies and are to be implemented according to the company, the product, and the phase of the product life cycle.

4.2 CHANGE REQUEST (CR) AND ASSESSMENT PROCESS

The request for a change to a product is a necessary step that organizations must utilize to initiate the dynamics of the overall change mechanism. The specific Change Request form (see Figure 4-2 for a sample) should be available for use by anyone in the organization to request product changes. Consequently, anyone in the organization working on the development and/or production of the product can initiate a change request by providing the information required by the form and attaching to the form whatever supporting documentation is required. It is important to remember that everyone should have access to change request forms, including people in manufacturing, quality assurance, testing, procurement, and product support.

4.2.1 Types of Change Request Sources.

4.2.1.1 Government (Customer) Initiated CR. The customer can initiate a change request either by a direct letter, contract modification, or more frequently by using an Advance Change Study Notice (ACSN). The ACSN can be prepared by the contracting agency to request information about a change, or an approved ACSN is used to authorize the contractor

CHANGE REQUEST (CR)

PAGE ____ OF ____

REASON FOR CHANGE				1. CCB RECEIPT DATE		2. CR NO.	
3. WE NEED A ☐ CHANGE ☐ DEVIATION ☐ WAIVER. ON PART/DOC NO. _____ TITLE _____ USED IN NEXT ASSY. _____ ON PROGRAM _____ BECAUSE: ☐ TECHNICAL: _____ WON'T FIT: _____ WON'T FUNCTION: _____ WON'T MEET TECH. REQ'T. ☐ COST OR ☐ SCHEDULE PERFORMANCE IS UNACCEPTABLE ☐ CUSTOMER WRITTEN DIRECTIVE ☐ SUPPLIER PROPRIETARY CHANGE IF THE PART NO. IS PURCHASED MATERIAL, ENTER THE SUPPLIERS NAME: _____							
4. STATE THE TECHNICAL, COST, SCHEDULE OR CUSTOMER REQUIREMENT THAT CANNOT BE MET. REFERENCE AND ATTACH A COPY OF THE DOCUMENT THAT CONTAINS THE REQUIREMENT.							
ATTACH ADDITIONAL SHEETS, IF NECESSARY.							
5. ORIGINATOR (PRINT & SIGN)				6. DATE		7. DEPT/SECT NO. _____ MAIL ZONE _____	
9. THE FOREGOING IS ACCURATE & COMPLETE (SUPERVISOR PRINT & SIGN)				10. DATE		11. DEPT/SECT NO. _____ MAIL ZONE _____	
WHERE USED							
13. NEXT ASSY		14. CONTRACT NUMBER		15. PROGRAM NAME		16. R	
19. ASSIGNED PRIME SECTION		20. PRIME SECTION RESPONSE DUE ON OR BEFORE:				21. TARGET EFFECTIVITY	
22. DISPOSITION: ☐ REJECTED ☐ APPROVED ☐ CHANGE ☐ WAIVER ☐ DEVIATION DATE _____							
ATTACH ADDITIONAL SHEETS, IF NECESSARY.				23. CHANGE CONTROLLER (PRINT & SIGN)		24. DATE	
PURCHASED MATERIAL INFORMATION AND APPROVAL(S)							
25. ☐ APPROVED: BUYER'S CONTROLLING DOCUMENT NOT AFFECTED ☐ APPROVED: MINOR WAIVER-SEE WAIVER SHEET FOR MRS APPROVAL SIGNATURES ☐ APPROVED: BUYER'S CONTROLLING DOCUMENT CHANGE IN PROGRESS							
SEE DOCUMENT NUMBER(S)				26. CHANGE CONTROLLER (PRINT & SIGN)		27. DATE	

Figure 4-2. Change Request Form.

to prepare a proposal based on its content. This ACSN will authorize the contractor to be paid for performing engineering effort necessary to prepare a formal ECP.

4.2.1.2 Subcontractor/Vendor Initiated CR. Subcontractors can initiate change requests either by using a form similar to the buyer Change Request form or by submitting a Request for Deviation (RFD) to the buyer. Since an RFD should not be used for the total contract quantity it will usually initiate a review by the buyer to determine if the deviation can be accepted in the design of a limited number of production units. Rejection of the RFD could lead to a Change Request to change all units.

4.2.1.3 Manufacturing Initiated CRs. Once production has begun, manufacturing will initiate the majority of the CRs on a program. Most CRs will be proposed to improve production yields, implement improved processes or change assembly techniques.

4.2.1.4 Software Problem Reports (SPR). Software Problem Reports are used to report all Software problems which occur after any software element or document has been placed under formal change control. Generally these SPRs will be submitted to the SCCB for evaluation prior to submittal to the CCB.

4.2.2 Change Process Initiation. Once a change request form is filled out and approved by immediate supervision, it is submitted to the configuration control administrative function of the company's configuration management organization. That function reviews the change request, adds a change request number to the form, records the number and title, and submits the change request to the Configuration Control Board (CCB) for change analysis. The CCB Chairman, often the Project Manager or Configuration Manager, reviews and preliminarily approves the Change Request (CR). Upon preliminary approval by the Chairman, the CCB organization, made up of representatives from the program's functional disciplines, conducts/monitors an assessment of the change the following change impact areas:

- a. Product's Form, Fit, or Function
- b. Cost/Schedule
- c. Manufacturing Operations
- d. Tooling
- e. Purchasing/Materials
- f. Facilities
- g. Test Equipment
- h. Impact on Government Furnished Equipment (GFE)
- i. Spares/MOD Kits/Manuals/Reliability/Maintainability
- j. Support Equipment
- k. Associate Contractors
- l. Other functional disciplines such as Contracts, Legal, Finance may be added for a particular change where their assessment is necessary
- m. Data Requirements

4.2.2.1 Preliminary Technical Evaluation. Some companies require a preliminary engineering review to be accomplished prior to the generation and processing of the change request to the CCB for action. Its purpose is to review proposed changes to the design, problems and errors detected during testing and integration, and reports coming from the operational/maintenance facilities. It includes technical evaluation of these changes, assures their coordination among the affected technical disciplines and recommends further action on their correction or implementation. If the design has not been released (or baselined) no further action may be required if the change request is approved by the head of the engineering team. Where the change affects established baselines, a change request should be prepared after completion of the technical evaluation and the change is passed on for formal change processing.

4.2.2.2 Initial Evaluation. As discussed in Chapter 5 there are other organizations associated with the change control process which must evaluate proposed changes. These groups evaluate the totality of the impact of the change including technical, cost and schedule considerations.

4.3 CHANGE CLASSIFICATIONS

In order to effectively manage changes to Configuration Items (CIs), it is important that the changes be classified properly. The two most common classifications are nonbaseline changes, sometimes referred to as Class II internal developmental changes, and Baseline (or Class I) changes. In addition, there are deviations and waivers, both of which represent temporary departures from contractual requirements.

4.3.1 Internal Development and Class II Engineering Changes. These nonbaseline changes provide a cost-effective tool for change control in a development environment. During the development and testing phase of the product's design, once the performance requirements document or Development Specification has been approved and baselined, a change which does not impact requirements is a nonbaseline change. Even after the customer has baselined the released design documentation, numerous minor changes to the design may be accomplished without affecting the baselines. However, unless positive controls are established over their generation and implementation, these nonbaseline changes can seriously impact profitability because the project managers and the associated configuration management function are not aware of their cost impact on the program. Nonbaseline changes are not normally paid for by the customer. Therefore, the company's bid package must include funds to cover the normal amount of non-baseline engineering changes. The number of changes can be quite large and can only be estimated using the company's past experience with similar contracts. Without this experience, and without controls for nonbaselined changes, the company can suffer severe loss of profits due to runaway change activity.

These baselines are generally under full contractor control but without customer involvement. As such Class I Engineering Change Proposals (ECPs) and the associated formal change documentation e.g. (Notice of Revision, Specification Change Notice), do not apply. This allows the contractor more latitude in working design changes in a



timely manner while allowing the customer control of the formally released Baselines. Internal change documentation such as (similar to the Change Order (CO) shown in Figure 4-3) must be required for each nonbaselined change and a specific evaluation/decision process completed before they are implemented.

This latitude does not mean that the documentation is not being controlled, it just means that a different control process is being used. This less formal change process provides basically the same information to the company's decision making but it does not require formal documentation to be provided to, and decisions to be made by the customer.

4.3.2 Class I Engineering Change. A proposed engineering change is normally considered Class I (i.e., to be approved by the customer) if approved baselines are impacted. The Government usually invokes the following factors to be used to determine the change shall be Class I.

- a. The Functional Configuration Identification (FCI) or Allocated Configuration Identification (ACI), 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 and survivability;
 - (3) weight, balance, moment of inertia;
 - (4) interface characteristics;
 - (5) electromagnetic characteristics; or
 - (6) other technical requirements specified in the FCI or ACI.

NOTE: Minor clarifications and corrections to FCI and ACI shall be made only as an incidental part of the next Class I ECP and accompanying SCN, unless otherwise directed by the procuring activity.

- b. A change to the Product Configuration Identification (PCI), once established, will affect the FCI or ACI as described in a. above, or impacts one or more of the following.
 - (1) Government Furnished Equipment (GFE)
 - (2) safety;
 - (3) deliverable operational, test, or maintenance computer software associated with the CI and CSCI being changed;
 - (4) compatibility or specified interoperability with interfacing CIs or CSCIs, support equipment/software, spares, trainers or training devices/equipment/software;
 - (5) configuration to the extent that retrofit action is required;
 - (6) delivered operation and maintenance manuals for which adequate change/revision funding is not provided in existing contracts;
 - (7) preset adjustments or schedules affecting operating limits or performance to such extent as to require assignment of a new identification number;
 - (8) interchangeability, substitutability, or replaceability as applied to CIs, and to all subassemblies and parts except the pieces and parts of non-reparable subassemblies; or as applied to CSCIs and to all CSCs and CSUs;