The configuration management requirements for aviation, space and defense organizations

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Abstract: *Certification of the quality management system for aviation, space and defense organizations, according to EN 9100: 2016 / AS 9100D standard requires compliance with the configuration management requirements. This article presents the implementation of Configuration management and documents control throughout the entire life cycle of product realization. Configuration management establishes a language of understanding between the client and the supplier both in predefined relationship (such as Built to Print) and those in which the supplier is given some freedom (such as Built to Spec), described in SR EN 16601-40: 2015 standard.*

Key Words: *configuration management, EN 9100: 2016/ AS 9100D, EN 16601-40: 2015, configuration management plan, configuration control, configuration status accounting, project life cycle, Built to Print, Built to Spec, IAQG*

1. INTRODUCTION

The Aerospace Standards (EN 9100D: 2015) require the implementation of configuration management and documents control throughout the entire life cycle of the product

What is "Configuration"? Functional and physical characteristics of existing or planned hardware, firmware, software or a combination there of as set forth in technical documentation and ultimately achieved in a product [8].

Why is it important to manage and control configuration in Aerospace & Defense?

Configuration management CM is a methodology which provides a technical and administrative framework for managing the development, manufacturing and maintenance of Configuration Items.

Configuration management is an integral part of the product life-cycle management. It is an activity required for establishing and maintaining consistent record of the performance parameters of a product and its functional and physical characteristics compared to the product design and operational requirements.

This discipline is applicable to hardware, software, processed materials, services, and related technical documentation throughout the entire lifecycle of the product (i.e. development, production, deployment, operation, maintenance and disposal) [3].

2. PRESENTATION OF CONFIGURATION MANAGEMENT PRINCIPLES [1]

2.1 Configuration and information documentation management are interrelated processes for managing projects

The main activities of these processes, depicted in fig. 1. Configuration management, are:

1. Management and planning;
2. Implementation of configuration management activities (configuration identification, control, status accounting, verification and audit);
3. Implementation of information documentation management activities (design, collection, review, delivery, storage and retrieval, archiving).

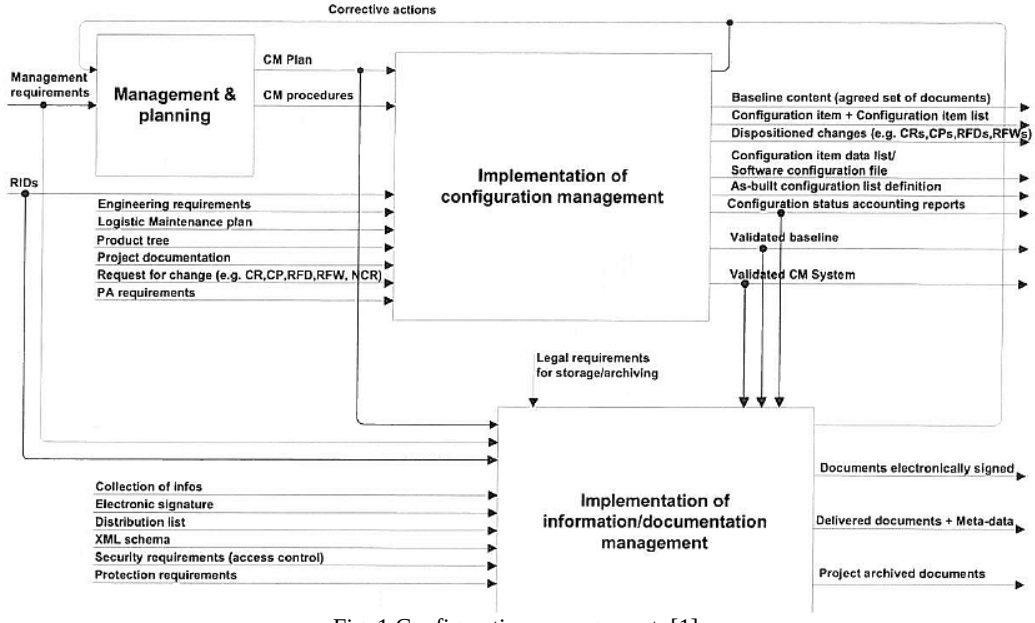

Fig. 1 Configuration management [1]

1) Management and planning

The client defines the configuration management requirements for a program or project. These requirements apply to all parties involved in the program or project as defined by the client at each level to his supplier/ suppliers. Each supplier produces a configuration management plan (CM plan) that responds to client requirements. The CM plan is provided to the client for approval. Upon its approval by the client, the supplier executes its new Configuration management plan. The purpose of configuration management plans is to define the processes and resources for product configuration management in a traceable and curved manner throughout the lifetime of the project or program. It also describes the means to effectively compare the predicted configurations (as designed) and the configurations conforming to the delivery of the delivered product. The Configuration management plan defines the relationship with the project management, engineering teams and the quality management process. Also, the configuration management plan provides all the elements necessary to ensure that the information/ documentation management meets all the requirements of the client and that it is in agreement with the project organization and its management structure. The client defines the phase of the project or program in which the

configuration management plan is prepared and approved. Each involved party designates a person responsable for configuration management implementation activities within its program or project team. Its role, responsibilities and associated authorities are described in the configuration management plan.

a) Configuration management interfaces

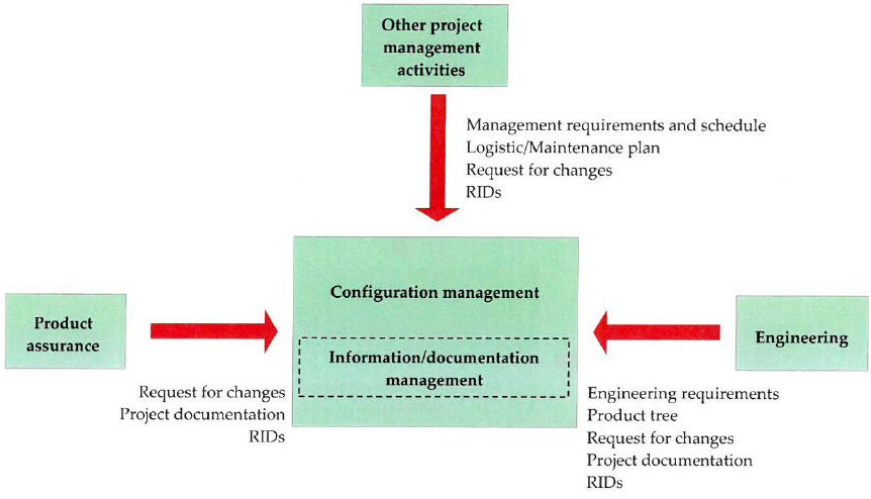

Fig. 2 Configuration management interfaces(inputs) [1]

Configuration management and information/ documentation are integral parts of the project management. Configuration management interfaces with engineering, product assurance, manufacturing, production and contributes to the organization of the program (or project) and to the planning of its execution by identifying all constraints related to the provisions of the contractual agreements. Configuration management also contributes to the project or program activities by providing all the necessary information through the information system. The information system is the main information repository where the project disciplines implement data and activate processes. It is also used to establish the configuration management process.

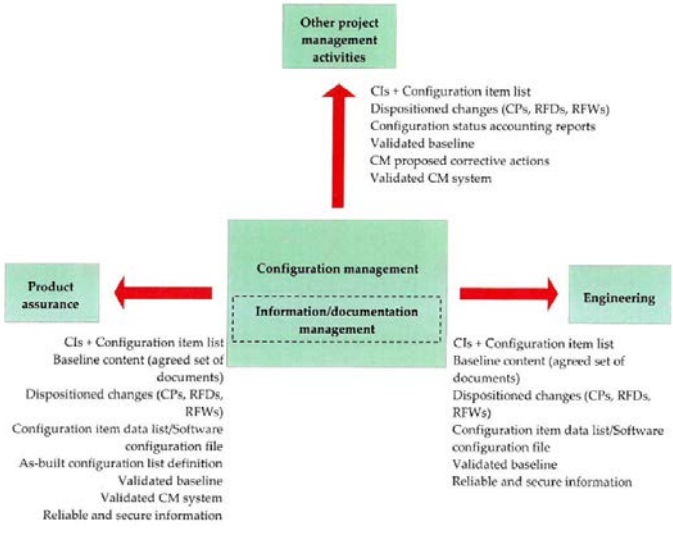

Fig. 3 Configuration management interfeces(outputs) [1]

2) Implementation of configuration Management

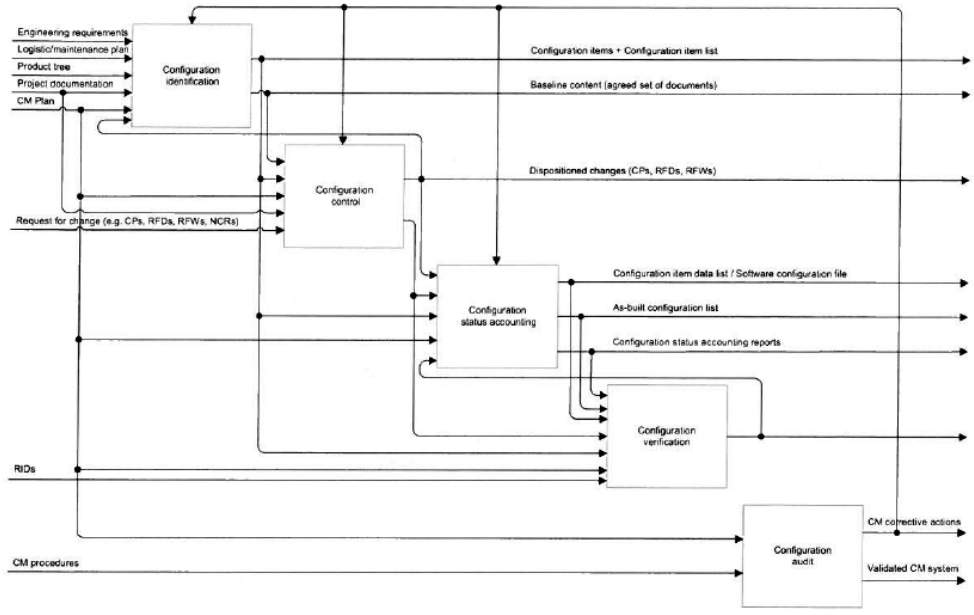

Fig. 4 Implementation of Configuration management [1]

The implementation of the configurations' management includes defining, organizing, executing and supervising the following activities, as shown in Figure 4:

A. Configuration identification is used to :
   a. identify the product architecture;
   b. select the configuration elements and define the associated configuration documents;
   c. define means of identifying products and documentation;
   d. define requirements for identifying software storage media;
   e. establish references' versions for the purpose of design requirements and management.

B. Configuration control is used to :
   a. establish and implement the process of controlling changes to individual products and systems, and their internal and external interfaces;
   b. record and control the configuration of a product at any time of its evolution;
   c. register different configurations of a product;
   d. define and ensure the maintenance of software libraries or repositories where current and old versions of software are stored in a controled environment;
   e. store and maintaine software products and relevant recording media including backup copies in a controlled environment.

C. Configuration Status Accounting is used to :
   a. provide a product definition by reference to registered and approved states;
   b. establish access to software libraries in accordance with established privileges;
   c. Configuration Verification and Audit;
   d. verify and demonstrate that the product fulfills its functional, performance and physical characteristics in accordance with the documentation;

e. check that the configuration management system is efficient and meets the configuration management requirements of the program or project.

A. Configuration identification

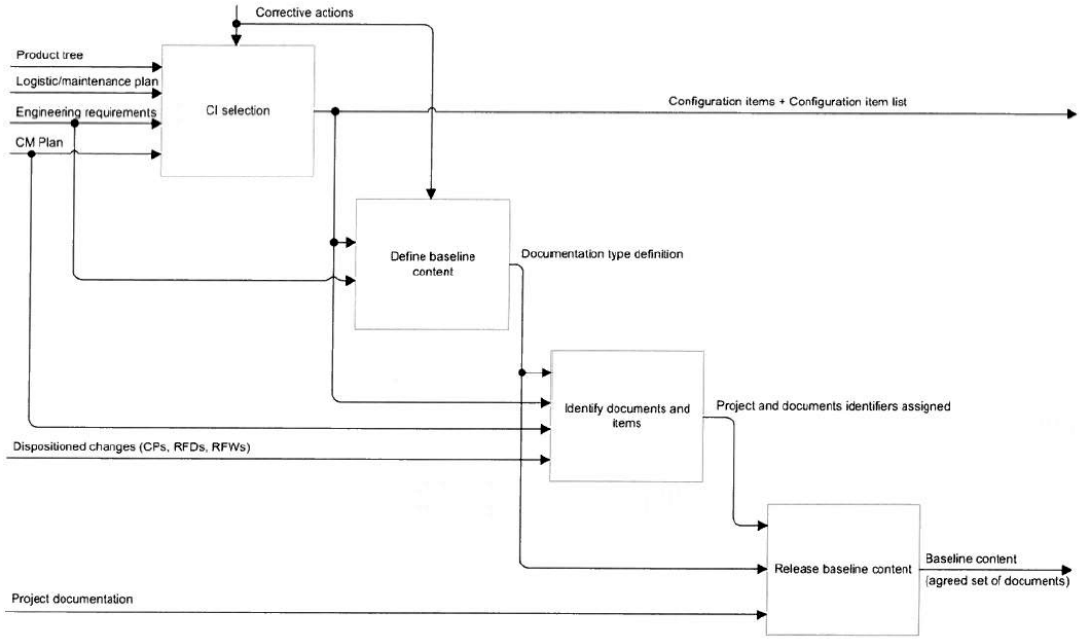

Fig. 5 Configuration identification [1]

Configuration identification, as shown in Figure 5, sets incrementally and releases controlled documentation for the purpose of identifying the characteristics of a product configuration until it is fully defined as intentions for physical, performance, and functional characteristics, ensuring the continued integrity of configuration of the product.

Configuration identification also provides a basis for evolution through controlled changes and product status monitoring over the entire life cycle of a product.

This ensures that all product or project disciplines have identical documentation for use. This allows traceability from the product to the definition documentation.

The product element identifier is represented by the element identification code set by the relevant documents defining that configurations.

The product element identifier can be:

a) The same code applied to identify the configuration definition document,
b) A code containing this code or,
c) A different code defined in the Configuration Definitions Document.

The individual identifier of a product may also include an additional identifier, eg a serial number (manufacturing) or batch number. Configuration elements, as defined in [5], in two categories, namely:

a. Developed configuration item.

This is a configuration item under development and partially or fully designed for a program or project.

Configuration management conforms to the program or project management requirements and is met by the developer responsible for its development.

b. Not developed Configuration item

This is a configuration element that is standardized or a off-the-shelf commercial product that was not specifically developed for the program or project.

It is subject to supplier definition and configuration management documentation.

This category also includes other products that have been developed and qualified for other programs or projects with comparable requirements and are used changed without modification.

c. Selection of configuration elements

The product tree, as defined in [2], is used to select the configuration elements and serves as basis for the work breakdown structure of the program or project.

Configuration elements are identified at various levels of the product tree, and defined at least by a technical specification.

The allocation of configuration elements provides the means for controlling product configurations. Each Configuration Item also becomes an element configured during its development.

Selection of configuration elements begins early in the program or project definition phase to build a manageable collection of hardware and software items.

Identifying an item as a Configuration Item falls on the client's responsibility if it is not delegated by the supplier. There are no fixed rules for selecting configuration elements.

Processes for selecting configuration elements are based on good judgment in system engineering, on configuration management experience, and supported by cost-quality-compromise considerations.

d. Configuration baseline

Configuration baseline represent the approved status of requirements and design in key stages of the program or project and provide the starting point for further development (see Figure 6).

These basic configurations are applicable to both hardware and software.

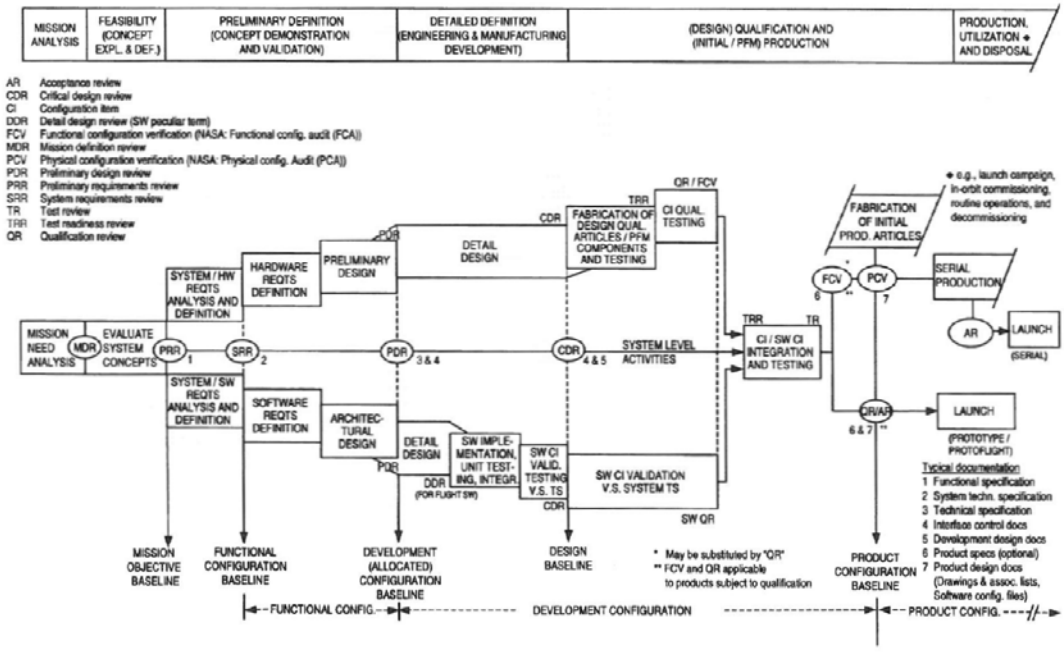

Fig. 6 Project phases and baseline definitions [1]

A basic configuration includes the documentation describing the characteristics of a product. This documentation is formally designated as the reference configuration at a primary key stage in the product life cycle corresponding to a major product definition event. Any subsequent change to some of the product features proposed for this documentation is subject to a formal change procedure involving all participants and subject areas before being incorporated.

During the life cycle of a product, the basic configurations are elaborated in the following order:

- Establishing the MOB (mission objective baseline) - the primary objective of the mission at the preliminary requirements rewiev (PRR) based on the approved functional specification.

This basic configuration establishes the purpose of the system, associated constraints and environments, operational capabilities and performance for each phase of the life cycle, and admissible flexibility.

- Establishing the basic functional configuration (FCB) at sistem requirements rewiev (SRR) based on the approved technical specification.

This basic configuration establishes the characteristics of the system in terms of technical requirements, as well as the appropriate criteria and levels of qualification and acceptability.

- Establishing the development reference configuration (DCB) is based on preliminary design rewiew (PDR) based on approved technical specifications (TS).

This basic configuration sets product characteristics in terms of technical requirements and design constraints, as well as the conditions for verifying them.

- The reference design, Design Baseline (DB) is established at the critical design review (CDR) based on the approved design documentation.

- Product Configuration Baseline PCB is established at Functional Configuration Verification (FCV/PCV) for serial production, or Qualification Review (QR)/ Acceptance And Review (AR) for prototypes based on an approved set of documents that contain all the functional and physical characteristics required for production, acceptability, operation, technical assistance, and destruction (disposal).

The journal, as specified in [4], is initiated at the successful completion of the revision for acceptability and is maintained in the use and destruction phases.

e. Identification marking

Each item, software and hardware is uniquely identified by a specific identification code.

The identification code is assigned to a product to distinguish it throughout its entire life. The rules for coding the identification system are stagnated in the CM plane.

A configured harware article is identified by a landmark number and, if necessary, a batch number has batch so that each article has a unique identifier. In this context, raw material is treated as a landmark (part = piece, mark, ..). A software configuration item is identified by a unique code and version number. When the configured item is a configuration element, its code also includes a CI identifier. These different product identification data are applied to the product itself, or when it is not possible, are linked to the product.

f. Digital file and media identification

Configuration identification also provides the means for maintening traceability from a product to its design definition data resident in an electronic database. Such data are composed by a variety of subset data, which are merged in a controlled manner in order to represent the product design definition concerned in the intented configuration. Configuration management for these sets of data and their integration into a complete product design definition is dedicated application of software configuration management

precesses. Digital files defining the configuration characteristics of a product item are therefore subject to the same configuration management principles aplicable to configuration documentation. The application of configuration identification rules to digital data are applicable for:

1. Digital data identification,
2. Digital data storage,
3. Maintenance of digital data relating to the product,
4. Version control of digital data and the related change management process'
5. Controlled access to digital data,
6. Digital data transmittal

B. Configuration Control

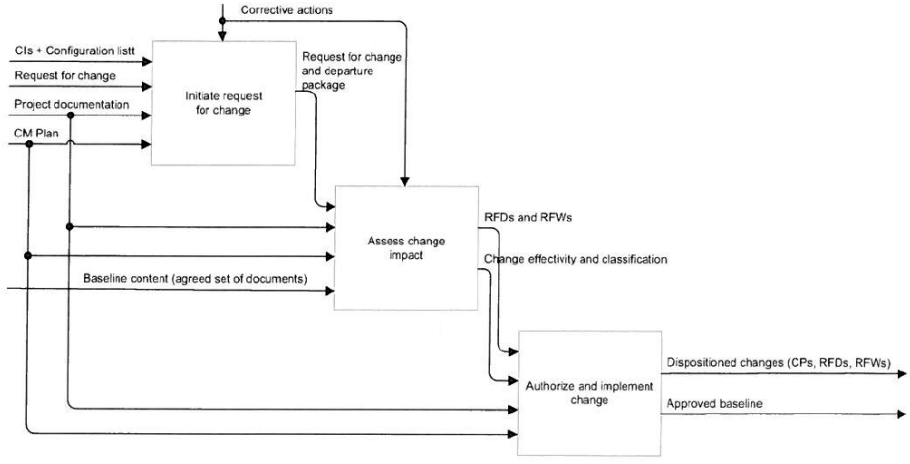

Fig. 7 Configuration control [1]

Configuration control, as shown in Figure 6, is the control process evolutions or deviations from the basic set configurations. This includes preparing, justifying, evaluating, arranging and implementing engineering and contractual changes, deviations and quits. Configuration control ensures that all changes, deviations, and quits from established base configurations, including their approved and issued documentation, are processed and controlled in a traceable manner.

The configuration control process ensures that the following activities are covered:

- preventing changes affecting product degradation,
- involving all parties in the analysis in question and decision-making on change,
- controlling the implementation of authorized changes or deviations, as well as checking their verification and registration,
- preventing the implementation of unauthorized changes or deviations.

The change control procedures are applied after the first basic option has been established. The basic documentation that has been issued is subject to configuration control procedures, including submission for approval to the client for approval by a higher unit or for revision as required. As such, no formal change can be generated without an approved basic version. A change can be:

- Client initiated (eg, the evolution of requirements) followed by a supplier response within a defined timeframe, or
- proposed by the vendor (eg an improvement of the design generated by it on its own initiative) followed by a client response.

Configuration Control Committees (CCBs) are set at each level of the project as the authority relevant to all changes. The CCB is chosen by agreement between the configuration manager and the project manager. The CCB consists of permanent representatives of all disciplines in the program or project needed to review and evaluate changes. CCB members are invested with decision-making authority. A change can only be implemented after reviewing and approving the supplier's response, for example a change request.

Classification of changes and deviations

The classification of a change or a deviation determines the type of approval and emission cycle required according to the cost criteria, planning, technical specifications and other technical or contractual issues.

Each change is categorized by CCB as a Category 1 or Category 2 change, and each deviation is major or minor. Change or deviation may be reclassified by hierarchically superior CCB. After the effects, a change proposal or a diversion request is processed at different levels within an organization. The appropriate decision-maker that can dispose of the measures in these proposals, NT is the level at which the effects of change or deviation have no repercussions on commitments made to the client. The layout is nevertheless sent to the client for information purposes.

Interface control

Interface control is part of configuration control activities and defines the processes necessary to fix and implement interface data, and control changes that affect interfaces. The interfacing control process is the responsibility of the systems engineering department supported by the configuration management. The CM activity provides the means to identify, track and report on the state of the approved interfaces. Control of interface is done through "Interface Control Documents" (ICDs) that are prepared to cover all aspects relevant to interfaces (for example, mechanical, electrical, thermal and software). Configuration management provides assistance and support to record the status of the interface data and to verify compliance with the requirements.

C. Configuration status accounting

Configuration status monitoring includes the creation and organization of a knowledge base required to perform configuration management activities. Configuration status monitoring is the source of configuration information for maintaining the entire program or disciplines in the program and their activities by establishing and maintaining the following:

- Recording of approved configuration documentation (eg data sets) and related identification numbers
- state of proposed changes and deviations required from the established configuration
- Implementing the status of approved changes and deviations
- the effective configuration of all configured items in the operational inventory.

Together they form a configuration status monitoring report.

a. As-designed and as-built data list

The configuration item data list CIDL document is generated for reporting the state of design of each product configuration element. This document is provided to PDR with the basic configuration configuration and maintained throughout the life of the product configuration element.

The configuration item data list CIDL itself and the data included serve as a starting point for controlling future changes in performance, design and construction. When software

configuration (CI) elements are involved, a software configuration file is also prepared to provide additional information relevant to the installation and use of the product descries.

The configuration item data list CIDL is the source for preparing the ABCL (Building Configuration Data List), which is the document used to report the state of the building and conform to the configuration it was tested for each product configuration element identified by a serial number.

b. Configuration Verification

Configuration verification is the process of verifying the state of the current configuration of the product being analyzed and results in the establishment of the basic configuration as defined in clause *Identification Marking*.

This activity is undertaken during program or project revisions, which are defined in [2] together with their objectives.

At the end of each revision, the documents and data sets identifying the current version of the current configuration are updated to comply with revisions and then submitted to the client for approval.

c. Configuration management Process Audit

The effectiveness of the configuration management system is measured by the audit to verify the correct application of the configuration management requirements over the product lifecycle as specified by the client. Audit operations are conducted in accordance with the requirements defined in [2]. Configuration management approach for the operational phase. Configuration management activities during the operational phase (E and F phases of a project) are required by the [2] stability review kit.

If necessary, you can prepare a dedicated CM (Configuration Management) plan to describe the process that must meet the objectives of the operational phase. During this phase, CM functions are continued from earlier phases of the project.

3) Implementation of information/ documentation management

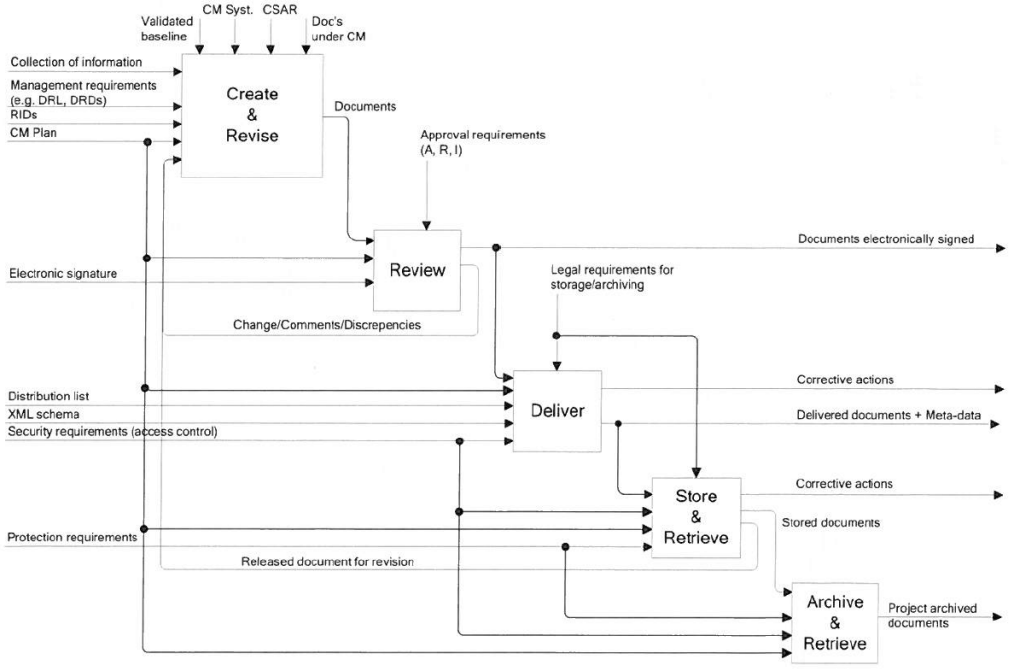

Fig. 8 Implementation of information/ documentation management [1]

The implementation of information/ documentation management includes the activities described in the following sub-clauses:

A. Creation and revision

During this phase the content of the documents is established and the reference documentation is assigned.

The activity is conducted under the responsibility of the organization designated in the DRL (document requirements list). Additional attributes for documentation references may be included as needed (for example, DRL/ DRD references, CI identifiers, authorities involved in the revision process).

For Configuration Control Documents, the Configuration Control process defined in this Standard applies.

At this stage the document bears the status "in preparation". It is considered preliminary and as such is not used for contractual agreements that create obligations between parties. The same logic applies to a new version of a document in preparation.

B. Revisions

a. Revision activity

When the document is complete, it is subject to revision and approval as required. The revision process is then initiated as specified in the CM plan.

At this stage, the document has the status "in revision". The same restrictions apply to its use as in the creation/ revision phase so it should not be used for contractual agreements.

The reviewing authority can confirm compliance with the applicable requirements or identify and report the discrepancies together with the proposed solutions.

In the latter case, the document is returned to the creation/ revision phase for incorporating comments and solutions to observed discrepancies.

During a revision process, a document may be "retired" (if it has not passed the revision cycle and is maintained or tracked for historical purposes only), or it may receive the status of "depraved" or "replaced" by when it was issued but has been replaced by a newer document.

b. Approvals and emissions

Approval may be given by electronics signature or by a process defined by the CM plan (configuration management). The electronic signature or process approval ensures the following:

i. The document has not been modified after approval (integrity) and
ii. The author can not disclaim responsibility for the content of the document (non-repudiation).

At the crash stage, once all necessary approvals have been obtained, the document reaches the status of "Released".

Once issued, the document is valid for use and therefore ready for distribution. Once the document has been released, any changes to it will imply a new version.

c. Delivery

Documents are billed in accordance with procedures defined by the CM Plan, taking into account the level of confidentiality applicable to each document. The document status can not be changed during delivery.

Documents are delivered using TDP format ('Technical Data Package') which defines how to deal with related content and metadata files and their structure in directories.

A TDP is a ZIP file containing document files and metadata describing these documents. Metadata used in TDP are a subset of [6] metadata that are added by specific metadata defined in Appendix L of [1].

Metadata are stored in the datapackage.xml file, see Figure 8.

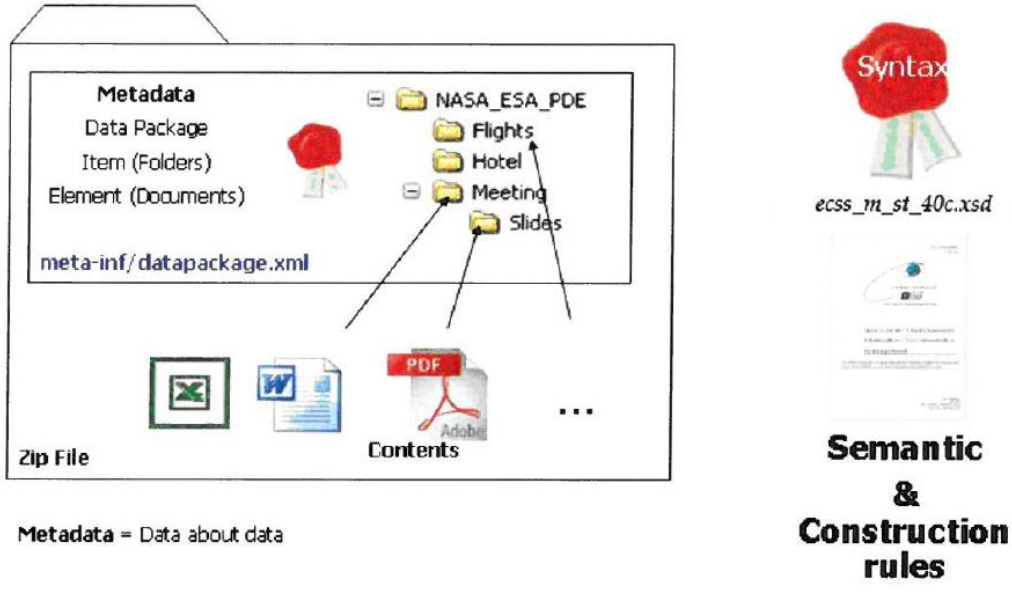

Fig. 9 TPD contents [1]

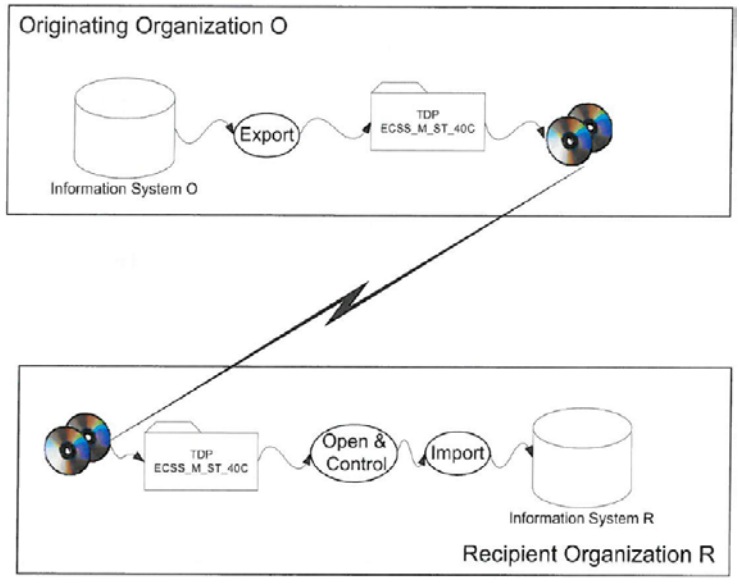

Fig. 10 Delivery process for TPD [1]

d. Storage and recovery

Storage and recovery overlap with the other phases defined above. The status of a document is not changed during storage and recovery.

The information system is designed to manipulate static and dynamic metadata and content. The reproducibility and integrity of stored information is ensured over the life cycle of the program/ project.

e. Archiving and recovery

Archiving is the final phase of information processing. It aims to ensure:

- keeping the data in order not to be lost or corrupted
- Their accessibility and recoverability for use
- controlled access by authorized persons.

2.2 The configutation continuum

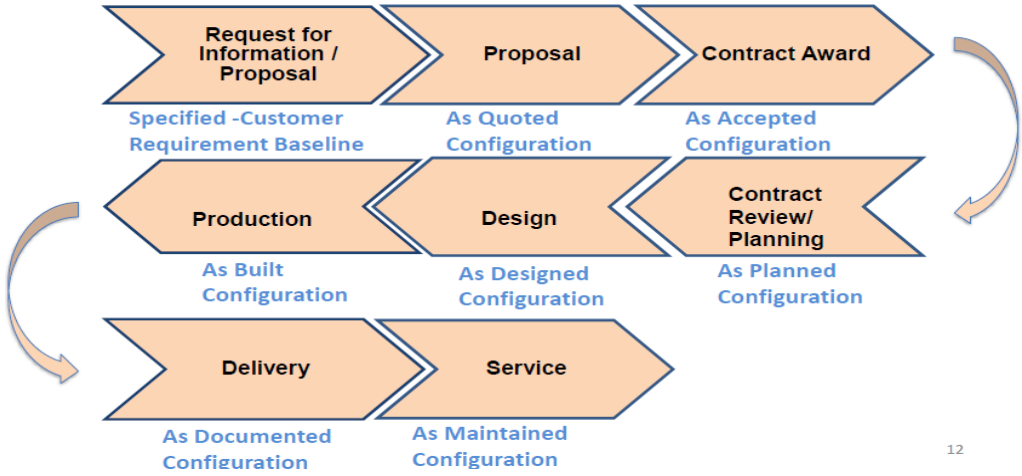

Fig. 11 – Program Life Cycle Configuration Progress [4]

Request for Information/Proposal –RFI/RFP

As Specified/Requirement Baseline is the client baseline. It is specified in the RFI/RFP and includes any allocated requirements, specifications, structure, configuration management requirements, etc.

The client expects to receive information/ proposal from the supplier including supplier attitude to the Requirement Baseline.

As Quoted Configuration (by the supplier)

Following the RFI/RFP from the client, the supplier prepares his response. In the response the supplier presents his attitude toward the implementation of client requirements.

The supplier proposes a configuration management plan in response to the client's configuration management requirements.

In some cases the proposed/quoted configuration differs from the As Specified configuration and thus it is the As Quoted baseline.

As Accepted Configuration (Configuration at Contract Award)

This configuration includes the system requirements specification & the system interface specification as finally agreed by the client and the supplier.

The method to manage configuration baselines and changes is established at this stage. The As Accepted configuration serves as a basis for the next (planning/review) phase.

Proper management and control of client documents is a condition essential to the maintenance of a well regulated production process.

The management and control of the client's documents and drawings should be done as specified by the contract.

The client defines the configuration management requirements for the project. These requirements are applicable to all the actors of the project. The purpose of the CM plan is to define the process & resources for managing the configuration of the product in a controlled & traceable manner throughout the project life cycle.

As Planned Configuration (Contract/Review Planning)

The As Accepted configuration is reviewed during initial stages of contract implementation. Mutually acceptable revisions to the configuration are included.

As part of the allocated baseline the sub-systems' requirements & interface specifications are frozen towards the Preliminary Design Review phase (As Planned).

As Designed (By Engineering)

The As Designed configuration may be accomplished in a few stages (as applicable to the contracted product):

System Requirements Review and System Design Review (SRR & SDR),

Preliminary Design Review (PDR),

Critical Design Review (CDR).

The configuration at each stage should include block drawings, schematic drawings, design documents, design interfaces documents and Validation & Verification V&V documents.

At each stage the configuration should be frozen and change control implemented. At As Designed configuration (after CDR) those documents are frozen.

As Built (By Production)

The manufacturer must allow the traceability from the finished product to the components and materials comprising it, in accordance with the type of the product and the contract requirements.

During procurement, storage, production, assembly, and test, details & identification marking will enable the follow-up of the history of the item in all its stages. The level of traceability shall be specified and updated in accordance with contractual requirements.

As Built (By Production)-(cont'd)

The traceability process shall allow, when required, the identification of all products manufactured from the same batch of raw material or from the same production batch as well as the delivery destination of all products from that batch.

In addition, the process shall allow identification of all parts and components of products/assemblies defined as requiring tracking.

As Documented (in Delivery Documentation)

An individual file will be issued for each item for which all the conditions specified below have been met, unless otherwise specified by contractual requirements:

Item have been tested according to their individual test procedures,

Item have been identified by individual serial numbers,

Item have been awarded a Serviceable tag upon completion of test.

As Maintained (Service Documentation)

The maintenance contract should define the maintenance levels, and the infrastructure to be prepared. Involvement in product maintenance is set according to client demands, which are decided upon receiving the client's order.

In certain cases, the demand will be to apply a specific maintenance policy in manufacturing and the design of the product, including the definition of needs in training, accompanying technical documentation, maintenance contract with the client and suggestion of spare parts for initial provisioning.

3. CONCLUSIONS

What does Configuration management do for the supplier? [8]

- Prevents technical anarchy;
- Avoids trial and error engineering and program management;
- Avoids embarrassment of client dissatisfaction and complaint
- Captures information needed to make later decisions
- Avoids cost and catastrophe.

What does Configuration management do for the user? [8]

- Provides client choice on changes affecting client interests;
- Guarantees continued support of a product, or at least notice of obsolescence;
- Assures consistency between the product and the information about the product;
- Enables user and service person to distinguish between product versions and correlate to related instructions.

The author's contribution is to present the configuration and information / documentation requirements for spatial projects.

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