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How is Configuration Management in Aircraft Industry implemented?

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RESUMEN

Apenas existe literatura sobre el empleo de Gestión de Configuración (CM) en la Industria Aeronáutica. Sin embargo, puede resultar muy útil en el momento actual, en que la complejidad para hacer aviones es creciente y la aplicación de CM resulta muy apropiada. Las piezas de la aeronave se fabrican en diferentes países, incluso se montan las mismas piezas en países y factorías distintas. Los diseños con materiales diversos y cada vez más ligeros, no hacen sino incrementar la complejidad, y además se une que los clientes solicitan versiones diferentes del mismo modelo, que son cambiantes con el transcurso de los años.

Los objetivos más importantes de la CM son: garantizar que existe conformidad entre productos y servicios que se han entregado al cliente, y apoyar el proceso de solicitud de certificado de aeronavegabilidad. El objetivo principal del trabajo es conocer cómo se implementa CM en el ámbito de la industria aeronáutica, con una aplicabilidad inmediata.

CM es una disciplina nacida de la necesidad de asegurar el control en complejos procesos de relaciones. CM está muy adaptada a la solución de problemas complejos, y permite la reducción e integración de períodos de diseño, de forma que disminuyen los plazos de entrega al cliente.

Palabras claves: Gestión de la Configuración, Industria Aeronáutica, Configuración de referencia

ABSTRACT

There is little literature on the use of Configuration Management (CM) in the Aviation Industry. However, it can be very useful today, where complexity to manufacture aircraft is increasing, and application of CM is very suitable. The pieces of the aircraft are produced in different countries, even the same parts are assembled in different countries and factories. Designs with different materials, and products increasingly lightweight, enhanced the complexity. In addition customers request very different versions of the same model, which are changing over years.

The two most important objectives of the CM are to guarantee that there is compliance between the products and services that have been delivered to the customer, and to support the process of application for individual certificate of airworthiness, while optimized business performances are taken into account.

The main objective of the study is how the CM is implemented in the aviation industry with an immediate applicability.

CM is a discipline that arises from the need to ensure control in the complex process of relationships. CM is well suited to solving complex problems, like in aircraft industry. Its application allows the reduction of periods of integration and design, so that reduce delivery time to customers.

Keywords: Configuration Management, Aircraft Industry, Configuration Baseline

1. INTRODUCTION

Configuration Management (CM) is the process of handling products, facilities and processes by managing the information about them, including changes, and ensuring they are what they are supposed to be in every case.

International Standard ISO 10007 gives guidance on the use of CM. Those configuration management rules are included into quality control.

Enterprise environment of CM: The aircraft industry has high technical investigation and development content. For each new aircraft project, various complex processes take place. In these processes many disciplines take part: aerodynamic, structures calculation, production, etc.

CM is a discipline that is born from the necessity to assure control in the complex processes relationships.

2. CONFIGURATION MANAGEMENT PROCESSES

Product design is generally concerned with form, fit, and function. How to manufacture a product and how much it will cost are questions not usually asked until the later stages of product development, at which point the design may have to be reworked in order to solve problems of quality or production.

Seven Configuration Management processes have been defined.

In the table below the processes are assigned to the business processes, the Configuration Management and the organization responsible for the leadership.

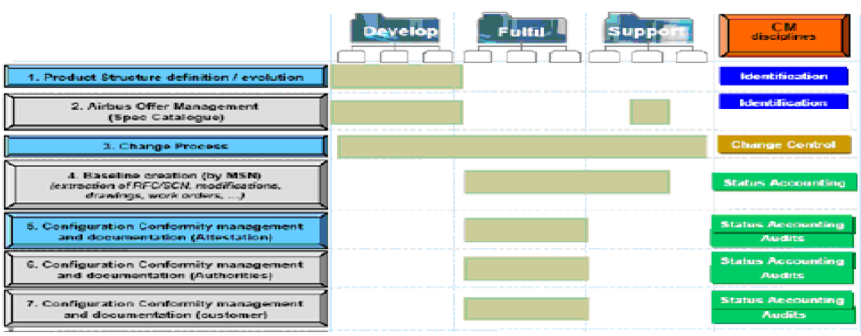

Figure 1: CM processes and disciplines

The 3 most important processes have been painted in blue.

2.1 PRODUCT STRUCTURE DEFINITION/EVOLUTION

A product structure is the hierarchical breakdown of a product (aircraft) that is used to represent the product information in a database.

2.2 COMPANY OFFER MANAGEMENT (SPECIFIC CATALOGUE)

This CM process describes the following activities related to a company standard offer:

- Production of standard specifications and catalogues of options proposed to customers
- Management of a repository of customisation items
- Support to aircraft contractual definition: record and track customer requests and product evolutions.

The main users of the process are the airlines, and the company organizations programs, customer affairs, engineering and upgrade services.

The objective of this procedure is to guarantee that all actors and external parties have a common understanding of the processes and key concepts related to the company offer management.

Offer management process splits into 3 main activities. Each activity splits into different sub-processes, as shown hereafter on Figure 2.

• Manage standard offer data standard offer data is represented by the EPAC/TDU database, also called "As proposed" layer in product structure context.

• Produce deliverables production of the deliverables based on "As Proposed" layer: standard specifications and catalogues.

• Propose and record contractual A/C definition selection, for a given fleet and its aircraft, of an "As Contracted" definition in accordance with the customer choice and based on "As Proposed" data.

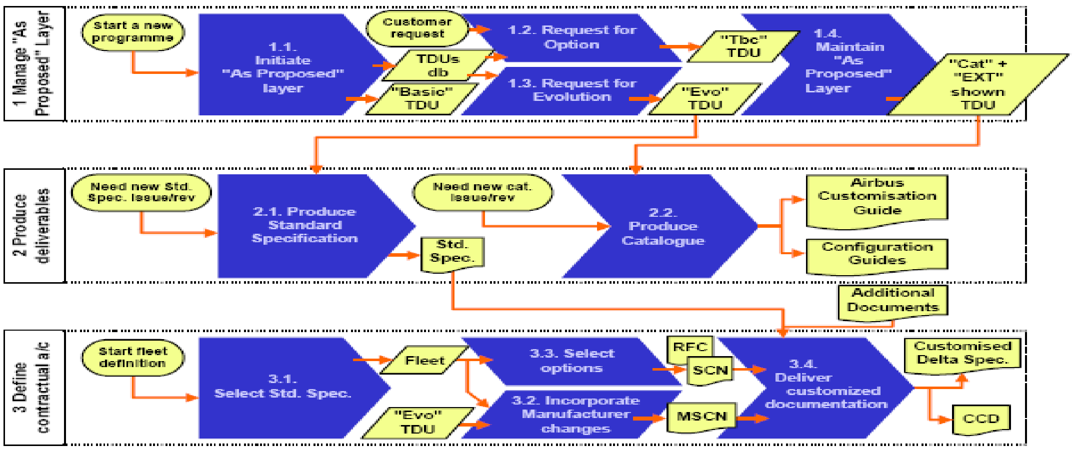

Figure 2: Offer management

Position within aircraft life cycle: offer management is used in different stages of aircraft lifecycle:

• During the development of a new aircraft the EPAC/TDU structure and the first standard specification and catalogues are first initiated. These deliverables are then maintained during the different phases of the Product development, reflecting the maturity evolutions.

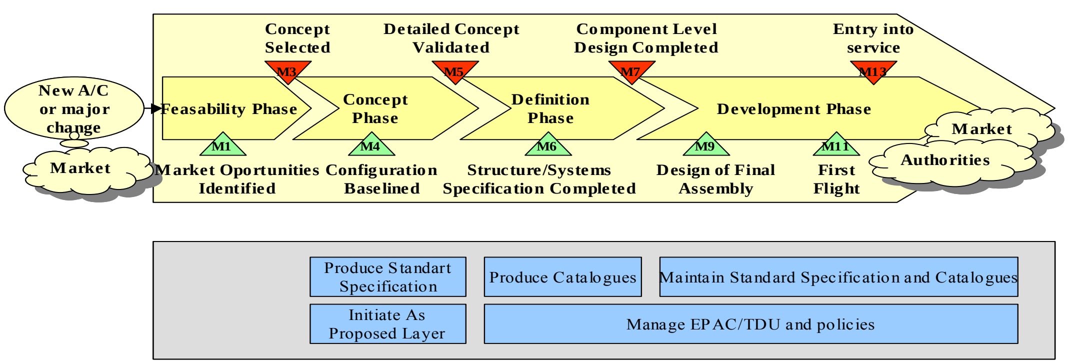

Figure 3: Development of a new aircraft

• For the production of an individual aircraft, company offer management process is used during the first step: contractual definition of the fleet and aircraft. The customized documentation delivered with each individual aircraft is based on offer management outputs.

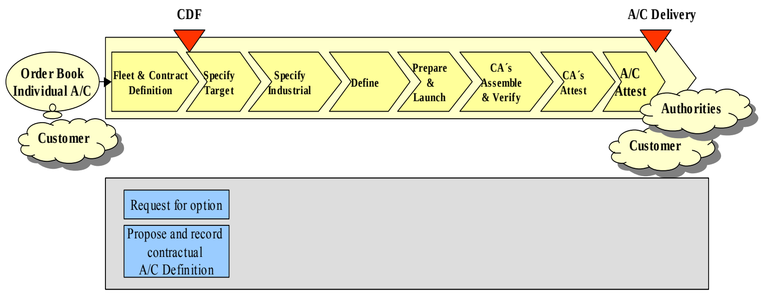

Figure 4: Specification and production of an individual aircraft

- After aircraft delivery, offer management is involved during upgrades regarding the management of upgrade options and the production of upgrade catalogue.

2.3 CHANGE PROCESS

The change process is a configuration management function, indicating all the steps that the change have to take, following them, their decisions and deliverables, and assuring that the process follows the protocol indicated.

2.4 BASELINE CREATION

This process manages for each A/C, the customer specification as frozen per contract.

A configuration baseline consists of all approved configuration documents that represent the configuration of an aircraft at a specified point in time. Configuration baselines shall be established by formal agreement between the relevant parties (e.g. customer, program, engineering, manufacturing and procurement) and used as starting points for the formal control of the configuration.

During the development of a new "standard" aircraft, configuration baselines shall be established that defines:

- Requirements baseline; It shall specify the configuration documents that define the physical and functional requirements that must be met in the design as result of the feasibility phase.
- Design release baseline; It shall specify the configuration documents for the design solution as the requirements are progressively implemented as result of the concept phase.
- Product configuration baseline; It shall specify the configuration documents that represent the manufactured product. The product configuration baseline shall provide the content of the aircraft definition dossier as result of the definition phase.

The establishment of these baselines relative to the phases of the lifecycle is shown in the following figure:

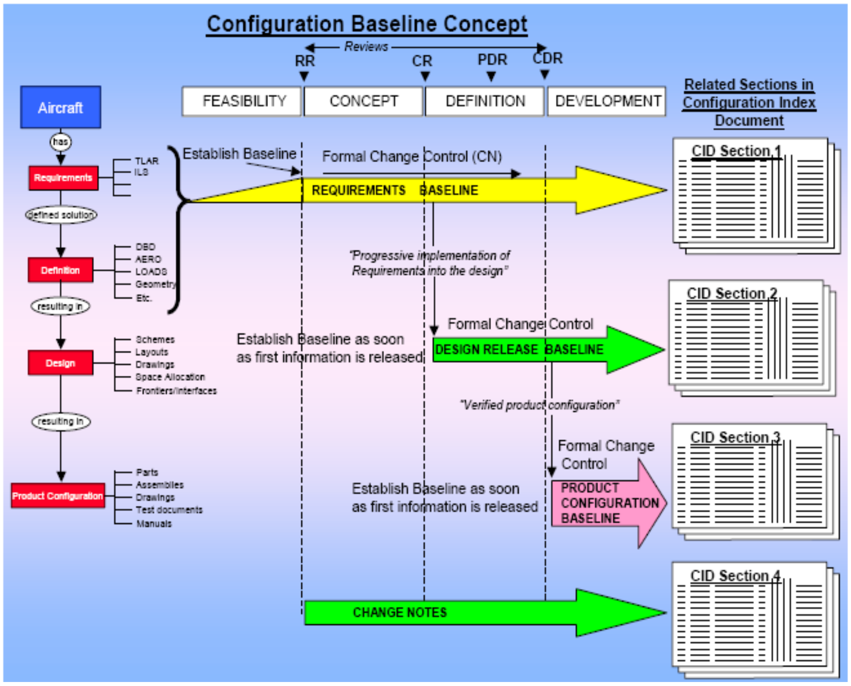

Figure 5: Configuration baseline concept

For a developed aircraft that offers to the market product derivates and option features a process of configuration allocation shall select a configuration that satisfies specific customer requirements thus establishing a contractual configuration baseline. This contractual baseline will be the basis on which the aircraft will be specified.

2.5 Configuration Conformity Management and Documentation (Attestation)

This process manages the conformity of the built product to its target definition that includes the conformity of the product's components.

2.6 Configuration Conformity Management and Documentation (Authorities)

This process manages the product definition compliance with an approved type design; each new change is subjected to an approval process and the final product design is subjected to a design declaration.

2.7 Configuration Conformity Management and Documentation (Customer)

This process manages the target definition compliance with the customer contractual specification and all applicable changes contractually agreed.

3. Configuration Management Disciplines

The activities, which are performed within the CM processes, are described below. It is essential that these activities be fully integrated with the business processes for the configuration management to be effective.

Traditionally configuration management develops five disciplines: status accounting, change, identification, control, and audits.

3.1 Planning and Management

This function tries to guarantee that the adequate CM processes, tools and activities are properly applied.

This function is the responsible to start working, indicating who is the responsible of each activity, what have to do, how and when they will take place. In other words, planning and management gives to Configuration Management internal structure and organizes its function's work.

For example, in a car design, planning and management indicate the responsible of identify the structure of the car (components, subcomponents and parts, in other words the car's breakdown) give to the change responsible the rules and the indications to proceed with the change processes (gives the protocol to follow-up by the change owner when somebody proposes a new change).

3.2 CONFIGURATION IDENTIFICATION

Configuration identification determines the product structure breakdown to allow its proper Configuration Management.

This function is the responsible to describe the product structure, configuration functions and its documentation interfaces and numbering.

It has to identify all the components and subcomponents within their associated documents to give an accessible way to see all information required for involved organizations.

In the development of a complex product like a car or an aircraft, configuration identification is the responsible of identify the car structure, understanding the car not only by its components and subcomponents, like chassis, tires, etc. It must take account all the information, documents and deliverables involved with them, like mock-ups, drawings, material treatments, etc.

In the next picture, we can see internal product structure:

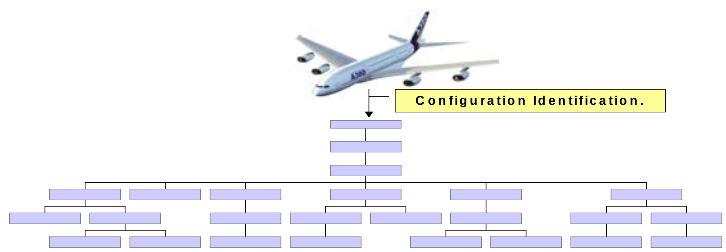

Figure 6: Aircraft/product breakdown

3.3 CHANGE MANAGEMENT

Change management enables change decisions to be based on accurate and complete change impact, limiting changes only to which are necessary or offer significant benefits.

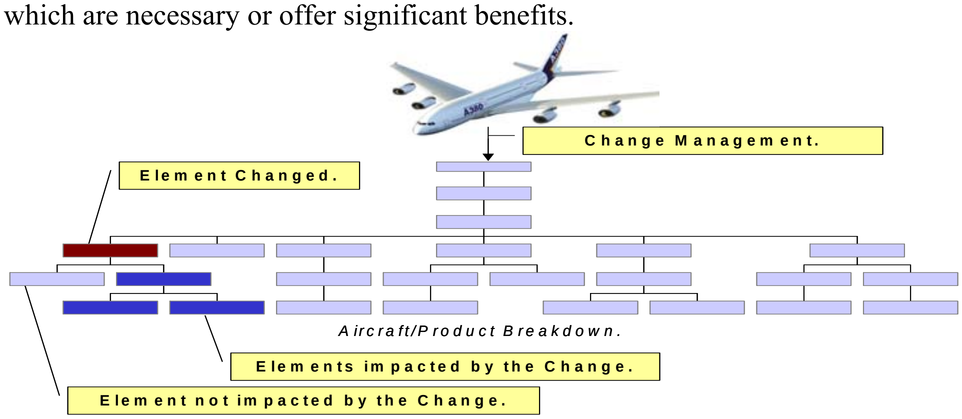

Figure 7: Change management

In ISO, it is included in configuration control that involves document and justifies the change, evaluates consequences of the change, approves or disapproves, implements and verifies the change and process deviations control.

Configuration Control has to manage the change processes, indicating all the steps that the change have to take, following them, their decisions and deliverables, and assuring that the process follows the protocol indicated.

In example, in the case of a car design if somebody wants to change the material of the spring valve, he has to initiate a change request justifying the change (i.e. weight decrease), and then the change request will go on or not, trough different phases, evaluation its viability (i.e. cost viability, manufacture viability, …the change can be rejected if it's too expensive, if it needs a very complex manufacture process, etc.).

After a deep investigation of the change impacts takes place (a complete study indicating the results, and all the possible impacts in another elements, in example: the bimetal corrosion between the valve and the spring valve) and finally if the change goes on successfully configuration management has to control the change implementation.

To investigate how this change management takes place in the company process, change process will be one of the central points of this document.

3.4 Configuration Status Accounting

The configuration status accounting records and reports the established configuration, the status of proposed changes and finally the status of the approved changes implementation.

The recording and reporting include:

- Record the relationship between configuration functions.
- Establish the configuration of each item at any time in terms of its requirements, design release and product configuration baselines and that any differences shall be identified and reconciled.
- Provide knowledge to users on the identity, status and location of all approved configuration documents.
- Record the relationship between configuration documents and changes.
- Establish the implementation status of approved changes.
- Permit full change traceability.

In resume the Configuration status accounting has to give the status of all items in the design process, they are used to indicate the development level and involved data precision.

In other words, and taking another time the car example, the configuration status indicates how near the car configuration is to the definitive one, with the car deliverable to the customer.

3.5 Verification and Audit

The verification and audit function examines that the configuration item is conformed to its configuration documents, or, in other words, ensures that the product design provides the agreed performance capabilities.

Moreover, it validates the integrity of the configuration documentation as well as the consistency between a product and its configuration documentation.

Normally we can distinguish two types of configuration audits:

1. Functional configuration audit: to verify that a configuration item has achieved the performance and functional characteristics specified in its configuration documents.

2. Physical configuration audit: an examination of the "as built" configuration of an item to verify that it is made conforms to its products configuration documents.

In resume, verification and audit function has to examine that all documents are associated with their respective element, due to every element have to link all their and only their required documents, giving an appropriate data-product structure.

Verification and audit has to check that everything is really as we suppose it should be.

The configuration conformity management and documentation is into this function. This is the responsible to attest and record the deviations between the works released and the complete finish and correct work that should be done.

The way to take control and report these deviations is with a delta concept.

In example, if somebody has to take some data (geometry and dimensions of one spring valve) it is necessary to guarantee that those data and documents are the correct and updated ones.

4. MILESTONE MODEL

To understand the Configuration Management mission and its impact in an aircraft project, it is necessary to know how a generic project is developed, and their phases and how configuration management acts in each one. For example, a change process is different in a definition from a development phase.

An aircraft project development is structured mainly in four phases. This phases can be divided in 14 milestones, this model of aircraft project development is called Milestone model. A milestone is a significant event that corresponds with the end of an activity, usually the completion of a major deliverable.

Highlighting the milestones in the process has the following objectives:

- Reduce risk by improving transparency of the process: existing risks can be better estimated and monitored by the FCO Manager, especially when slight changes in planning are necessary.
- Implement and conduct process checkpoints by positioning the MIR reviews versus the milestones.
- Support the repair project decision process and enable an effective management of repairs through points of decision and target dates, with alerts towards the Heads so that they are able to foresee problems and to work out solutions to keep the repair on target.

Those milestones divide the project in four main phases. Those are feasibility, conception, definition and development. They can be seen in the next figure:

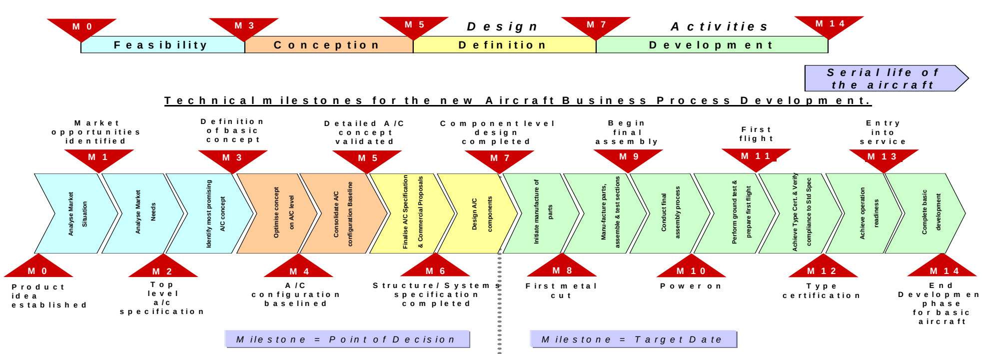

Figure 8: Project phases (milestone model)

4.1 FEASIBILITY PHASE (M0 TO M3)

This phase involves from the establishment of product or the A/C idea until the basic concept definition. During this phase, the market situation and its needs are studied in order to identify an aircraft (A/C) concept capable to satisfy specific market needs. It is necessary to do a potential market study, taking account several global variables like prices, units, necessary infrastructure, production rhythm and distribution.

If after this study is considered that there is a market that our enterprise can satisfy, the project goes on to the conception phase.

4.2 CONCEPTION PHASE (M3 to M5)

Where the A/C basic concept definition is optimized and consolidated. This phase ends when the detailed A/C concept is validated. In this phase the project must be concreted, defining in general lines the product, in the above example, the caravan-car has to give a general idea of its dimensions, seats, weight, motorizations, etc. It may be understood like a correct conceptual product, but it hasn't a complete detail, only the relevant items that define the product. In several products like cars, a real concept-car can be produce, to see it physically and to use it in marketing process, but in aircraft market, normally it isn't available by costs.

4.3 DEFINITION PHASE (M5 TO M7)

During this phase, the specification and the commercial proposals have to be finalized. Moreover, performance and cost guarantees from major suppliers should be made available. On the other hand, the physical definition and functional simulation of the A/C has to be completed down to detailed component level, the development and production funding should be ensured and the industrial launch conditions fulfilled. Finally, the sale contracts with launch customers should be signed. In this phase all the design details must be specified, and it has to assure that all parts fit and are compatibles, only after that the production develop can start to work.

4.4 Development Phase (M7 to M14)

This is initiated when the A/C components level design have been completed, involves the A/C manufacturing, the final assembly, ground and flight test, the "type certificate" achievement, etc. This phase ends with the A/C entries into service and the "target service reliability" is reached. In other words, in this phase starts the physical work, starts production, firstly to essays and certificates in ground and later in flight, and finally the deliverables aircraft production. The Configuration Management must to manage the relations and control the deliverables between the involved phases.

5. CONCLUSIONS

CM is well suited to solving complex problems and allows the reduction of periods of integration and design, so that reduces delivery time to customers. This discipline is essential in complex projects like aircraft design, but also recommended for integrating other projects or programs that manages products built by components, with many activities or processes.

One of the aircraft industry problems is the long design periods (around seven years). This situation leads to loss of competitive advantage of the product (aircraft).

The reduction and integration of the design periods results in several processes taking place at the same time. This situation is called concurrent engineering. CM was born to manage processes, relationships and deliverables between the different organizations. CM resolves problems during the life cycle, and that shortens the time the changes to the versions, and good management avoids errors.

Recent failures in development processes, in the major aircraft manufacturers, have led to significant delays in deliveries to customers. At present, using CM correctly would have been avoided.

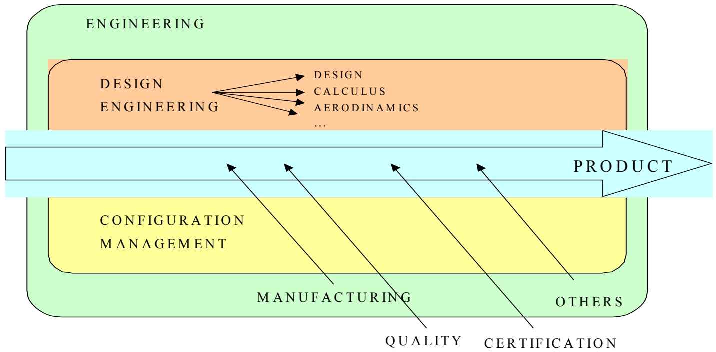

Figure 9: Configuration Management inside design engineering

In this picture, we can see conceptually concurrent engineering and configuration management as integrator element.

In resume, CM shift emphasis in:

1. Accommodate the change.
2. Accommodate the reuse of standards and best practices.
3. Ensure that all the requirements (all the released information) remain clear, concise and valid.
4. Communicate (1), (2) and (3) to each user promptly and precisely.
5. Ensure that the results conform to the requirements in each case.

To understand the Configuration Management mission and its impact in an aircraft project, it is necessary to know how a generic project is developed, and their phases and how configuration management acts in each one.

This study demonstrates how the CM is implemented in the aviation industry with an immediate applicability.

REFERENCIAS

Berczuk, S.P.; Appleton, B.; Brown, K. (2003). "Software Configuration Management Patterns". Addison-Wesley Professional, Pearson Education. NJ, USA.

Blanchard, B.S. (2008). System Engineering Management", Fourth Edition. Wiley Series in Systems Engineering and Management. John Wiley & Sons, Inc. NJ, USA.

Collins-Sussman, B; Fitzpatrick, B.W.; and Pilato, C.M. (2002). "Version Control with Subversion: For Subversion 1.6". svn-book.pdf.

Forsberg, K.; Mooz, H.; Cotterman, H. (2005). "Visualizing Project Management", Third Edition. John Wiley & Sons, Inc. NJ, USA.

Hass, A..M..J. (2003). "Configuration Management. Principles and Practice". Cockburn-Highsmith Series Editors. Pearson Education. NJ, USA.

St. Charles, D. P. (1990). "Simultaneous Engineering. Integrating Manufacturing and Design", 1st edition, pp. 160-164. Society of Manufacturing Engineers. Dearborn, Michigan, USA.

Stoll, H. W. (1990). "Simultaneous Engineering. Integrating Manufacturing and Design", 1st edition, pp. 165-171. Society of Manufacturing Engineers. Dearborn, Michigan, USA.

SWEBOK. (2001). "Guide to the Software Engineering Body of Knowledge", trial version. IEEE Computer Society. Los Alamitos, CA, USA.

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