EDMS - Concepts, Motivations and Basic Requirements

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Abstract

The paper outlines the main concepts and motivations of the configuration management and the fundamental requirements of an engineering data management system (EDMS). The vendors of these systems have experienced a boosting demand from the industry practising product development and assembly based production. It is considered that better control of the documents related to company's mental processes provide competitive advantage in a business environment with continuous pressures to innovate, diminish costs, improve quality and maintain tight schedule constraints. The paper discuss the industrial motivations to exploit EDMSs and studies the content and properties of the information to be stored in such a system. Yet before the system could be fully exploited the engineering change procedures must be well established and obeyed. This is the task of configuration management which is also discussed before outlining the basic requirements of an EDMS. Finally, by relying on the product life-cycle approach the paper draws conclusions on the value-adding benefits and services provided by an EDMS.

Keywords: configuration management, new product development, project management, concurrent engineering, engineering data management system

1 Introduction

The data generated during a design and engineering process shares multiple features and structures. The more complex the product and the longer the project the more important is the control of the product configuration data. Apart from the traditional drawings and CAD models this data includes various technical notes, measurement results, material properties, key parameters of the system, manufacturing and assembly instructions, organizational relations (i.e. responsibilities) and chronological change history of each component of the product. The role of Engineering Data Management (EDM) is to store and provide a user-friendly access to this data during the product's life-cycle according to certain predefined control rules. These rules are defined by the configuration management of the project or company.

Means to control increasingly distributed product development and manufacturing processes play a crucial role in the near future industrial competition. The inevitable trend towards customised products, ever higher quality and faster deliveries have already trimmed in many cases the manufacturing processes into a level where improvements do not pay back the investment efforts efficiently enough. Better and faster productivity gains are being pursued from ever better operations management and especially from cutting non-value adding activities around document handling, generation and control. One clear evidence of this trend is the boosting engineering data management system (EDMS) markets. The annual markets around EDMSs are estimated to boom from 1994's $400 million with an average 30% annual growth to almost $1.2 billion in 1998 (CIMdata, 1994). This shows that the companies are complementing the traditional material and money management more and more with information and knowledge management.

Toffler (1990) has described how a shift in means of power has in general taken place in world economy and business environment. The colonialist mentality of subjugation was replaced by capital and wealth driven entrepreneurship, which is now changing rapidly towards knowledge based ruling and command. Similarly in industrial enterprises the management and exploitation of the in-house information and tacit knowledge is increasingly seen to be the next source of competence. Innovation and continuous small step upgrading are the necessary prerequisites for future survival (Porter, 1990). Advanced information technology will apparently have a vital role in this process of

capitalising the mental resources of the companies into better products. The following facts support this thesis:

- Most of the mental work related to product development within industrial companies is bound to documents and of managing, i.e. finding, retrieving, manipulating, mediating and storing them.
- Eventually each and every document produced by the advanced companies are in *digital* format.
- More and more of the development work is performed in a distributed fashion which implies the need for fluent and interactive communication over geographical and organisational boundaries. Information networks and services play crucial role in achieving true computer supported distributed collaboration.
- Paper based dissemination of information has become too slow and electronic networking and mode of collaboration is superseding the traditional way of working.
- Products have increased their technological complexity, which, in turn, increase the amount of technical documentation needed to describe the products.

These facts tend to emphasise the need to control geographically scattered product documentation. In addition to plain document creation, even more vital is the management of the whole process during which the documents are created, altered, fixed, distributed and used. It is clear that the prevailing world-wide acknowledgement to promote product data management together with networking stem from these basic facts. Against this facet the paper examines empirically following fundamental problems that the companies performing large-scale product development projects in geographically distributed design and manufacturing environment are confronting every day:

- how to control the product development process efficiently and on continuous basis;
- how to mediate, manage and access all project related administrative and technical documentation;
- how to improve human interaction and cross-functional interplay between diverse design and manufacturing teams;
- how modern information technology may support configuration management;
- how to guarantee the coherence and compliance of the product configuration with the customer needs.

2 Motivations

Although it is difficult to get exact quantitative data on the net benefits and the investments on EDMS and configuration management, some facts, figures, results and management actions may be found publicly available:

- Several U.S. based companies have started to establish electronic archives for their technical documentation by scanning thousands of technical data items into a database (Puttre, 1992).
- A company producing large industrial production units indicated that on the average half of their design and engineering effort is related to searching for technical documentation (Nihtilä, 1995).
- One industrial facility producer estimated that they have 4 million technical drawings and when new order comes in they have 80% probability of having the needed drawings ready, yet the odds to find them is 4% (Sulonen, 1995).
- Global electronic company reduced change order cycle from 33 days to less than 10, halved the time needed to devise technical manuals and eliminated micro-fiche through the introduction of a product data management system with an objective of paperless documentation management (Frederick. 1995).
- Multinational computer and electronic company reduced its staff required to manage documentation load with 35%, plummeted storage cost/year/document from 50$ to 5$ and

improved significantly the document handling efficiency during a 5 year EDM project during which own EDMS was developed (McCrea and D'Agostino, 1995).

- A leading microprocessor manufacturer developed with the effort of 7 engineering years global, standard and PC based EDM procedures with vendor access; results mount in efficient document handling, paperless document process and up-to-date information (Hargrave, 1995).

The above examples illustrate well the potential hidden in efficient configuration management and in central storing of all information. Predominantly the results have been attained through the introduction of new managerial principles supported by an EDMS to maintain, control and archive all the design and specification changes. Sherpa Corporation (CIMdata, 1994) lists (Table 1.) the following results gained by its customers before and after implementing Sherpa's EDM system.

Category	Pre-PDM	Post-PDM	% Reduction
Engineering change cycle	61.5 days	10.25 days	83%
Cost per change	$4,200	$1,500	64%
Processing engineering change orders	60/month	<5/month	92%
Product development cycles	33 months	24 months	27%
Build-to-order cycles	9 weeks	3 weeks	67%
Average # of part lists	8	2	75%

Table 1: Average time and cost savings resulting from Sherpa's PDM system use (Data Supplied by Sherpa Corporation).

Multiple sources report that investments on EDM and supporting systems have pay-back times from one to three years. In addition the positive trend from the investment tends to continue even after three years when the full benefits of the system start rolling in. One may a bit sceptic against these positive pay back times as they are often reported by the system vendors. The experience says that shaping and gathering of the existing engineering information in such a format that it may be easily used by an EDMS takes a long time. The initial level of company's engineering processes strongly affects how long it takes to really benefit from such a system.

3 Concepts

Advanced and competitive manufacturing units organize their production facilities in such a manner that the product can be processed in the shortest production throughput time, with minimum capital invested and according to the quality specified. To succeed in this the companies tend to place the product itself, rather than the process, in the very core of the manufacturing. The traditional process-oriented thinking is ruled out (Burbidge, 1992) and the product focused approach is now prevailing. Product with its breakdown or *bill-of-material* is the fundamental data structure which affects to all operational activities within manufacturing and design operations in a company. Correspondingly, in a one-of-kind project the product and its structure forms the starting point for the other activities, i.e. project organization formation, resource allocation, work breakdown and planning (Bachy and Hameri, 1995). The control of the product data, including its change history during product's life-cycle is the task of configuration management.

Before going any further, some of the main concepts should be clarified. Product configuration displays at the time *t* a snap-shot of the design status of the product (components, equipment, parts, etc.). A version is a frozen configuration with complete technical documentation including its manufacturing instructions, specifications, technical notes, drawings, test results and responsible people. Subsequent versions are numbered and the control of their integrity is called version

handling. The overall status of a product configuration is compiled from specifications of its components, equipment and parts with their respective status. This status may have several values, depending on the adapted configuration management procedures. Basically the status of a certain specification could be closed/fixed/frozen, i.e. it has been accepted and can be used, but not changed, or it may be private, i.e. under development. Other values may be assigned also, depending on the situation (Hameri, 1995):

- *subject to changes*, meaning that the specification cannot be processed, issued or redeveloped at that moment and therefore the previous and verified version of the specification should be used;
- *recently changed*, indicates that the specification has undergone changes which have been accepted by the configuration team, yet the changes should be studied before the specification is used;
- *pending*, implies that the specification has been changed and waiting for verification, thus, the changes may be studied but not to be used;
- *verified*, the specification is approved and its functionality and compliancy with the overall product specification is verified, thus the specification is ready to be used.

What are the motivations for configuration management? Essentially, the task of the configuration management is in the control of the flow of engineering work/information/data and to provide the project with configuration related services. The development process forms a kind of cycle during which the previous version is refined to the next version or generation of the product. In a completely one-of-a-kind product delivery the development cycle starts from the functional specifications and ends to the final assembly. Yet this process may share various versions of the final design. The following picture (Fig. 1) displays schematically the process of the design and engineering work from product's configuration point of view.

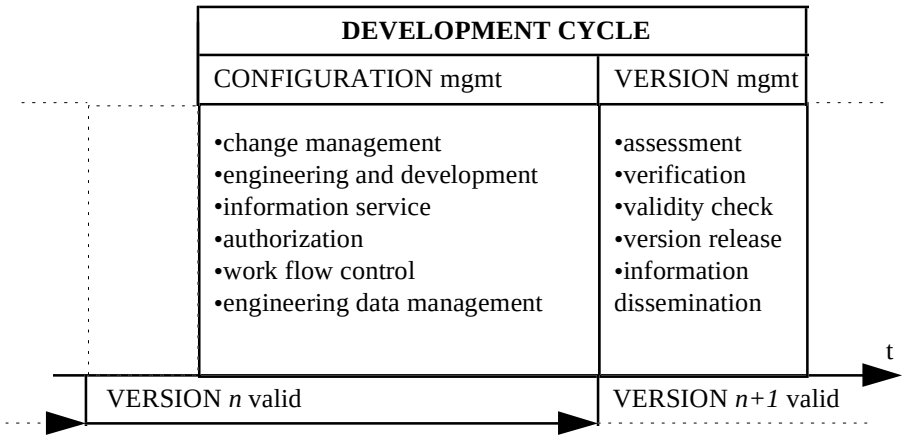

Figure 1: The evolutionary process of the development of the product configuration.

To summarize, in an environment with multiple projects aiming to produce a complex product the need for configuration management with a supporting EDM tool is justified along with the following statements:

- Several empirical studies (e.g. (Luhtala et al., 1994) in project oriented manufacturing industries indicate that most, even up to 90%, of the specification changes originate in-house. Processing these changes is the cause of most of the problems, which tend to emerge during manufacturing, assembly and delivery phases, or even as late as the operational phase of the product. The costs of correcting the mistakes will increase exponentially the later in the process they are fixed. The very essence of configuration management is to control the specification changes in such a manner that the overall configuration maintains its functionality and correspondence with the needs.
- The underlying spirit of engineering work is to continuously develop new and advanced solutions both to old and new technical problems. This appreciated activity establishes the

very core of innovations. Without control, the situation may lead to continuous engineering syndrome, when individual whims overtake the original objectives. Apart from controlling the specification changes, configuration management must control also the correspondence with the original plan. In addition configuration management is in charge to provide the organization with a flexible communication and information retrieval interface between system versions *n* to *n+1*.

- The project organization must share a common understanding of the main parameters and design principles of the product. In order to achieve this, configuration management must provide all project collaborators with an easily accessible source of information containing the current understanding of the system configuration (key parameters, measures and standards of the system, status of the various component configurations, quality requirements, responsible people, etc.).
- The documentation of product's change history is vital in long term projects, where the organization is subject to changes. Configuration management is responsible for systematically recording and archiving all the changes, in order to provide the necessary information for the later steps of the project (commissioning, operation, maintenance). This is vital especially, when the age composition of the organisation indicates accelerating retirement rate, which, in turn, necessitates detailed archiving of all engineering related data and information.

In general terms configuration management, when properly implemented and focused on the control of configuration data, will shorten time to market, lower design costs, provide better quality, reduce manufacturing costs and provide means for lifelong product maintenance.

4 Configuration management - principles

Configuration management differs from traditional project, product and production management in its focus and scope. The essential difference is in the status of the configuration management team in the organization. The team provides the organization with *services* concerning the product data management, control and distribution. They mediate between various groups responsible for various systems by collecting, analyzing and keeping them informed of all changes concerning specifications, key parameters and other related modifications related to the product information. With respect to the motivations for better product data management the following practical configuration management principles can be stated to achieve high performance technical coordination in the project:

- Configuration management is a service unit within the project, whose customers are all the other departments that deal with product data.
- The main task of configuration management is to control, archive, structure and disseminate product data in such fashion that the information is verified, consistent and up-to-date.
- Configuration management acts as an interface between engineers and the product itself by providing the structured communication means to disseminate and interact around the product configuration.
- From manufacturing point of view the configuration management team ensures that each specification entering production is in accordance with the overall configuration of the project; by doing this the ground is prepared for faster production throughput times with fewer interruptions.
- For product development the configuration management team provides the latest information concerning the project and also interactively records design changes and their influence on the other sub-projects.

In practice these principles transfer into the following actions when considering a large-scale project with long duration:

1. Collect the product expertise and experience of the organization into a configuration team, i.e. assign responsible *configurator* for each major system/product of the project.
2. Provide the team with the relevant means to perform its task.

3. Define protocols, preferably simple and visual ones, to process changes in product specifications.
4. Establish frequent meetings with the configurators to study each and every product specification change emerging during the development cycle.
5. Build an information network.
6. Provide the organization and other collaborators of the project with an easy-to-use media to transfer configuration related information.
7. Define, identify, gather and manage configuration related information into a logically centralized repository.
8. Document every change, with a reference to the original problem, responsible people and implications to the configuration.
9. Store, verify, release and disseminate product versions and maintain their integrity with customer needs.

In this respect the configuration management maintains the coherence of the product, which comprises all product related data, including whenever possible the product related tacit knowledge. Configuration management acts with the objective of preserving the project from contradictions and inconsistencies, yet, to adjust to changed circumstances.

5 Engineering Data Management Systems

In recent years, there has been a growing awareness that although computer-aided design technology and the widespread use of computer applications to prepare engineering documents were accomplishing their objective of improving the productivity of individual engineers and designers, they were not doing much to improve the productivity of the overall enterprise. To accomplish this latter objective better methods were needed to share information between members of the design teams and other groups involved in the product life cycle (Scott Tsao, 1993).

Engineering Data Management (EDM) is a set of techniques and tools to organize, control and distribute all product related data during a product's life cycle (Fig. 2). They have been developed to reduce the development cycle of new products while maintaining control of the data and distributing it automatically to the people who need it when they need it.

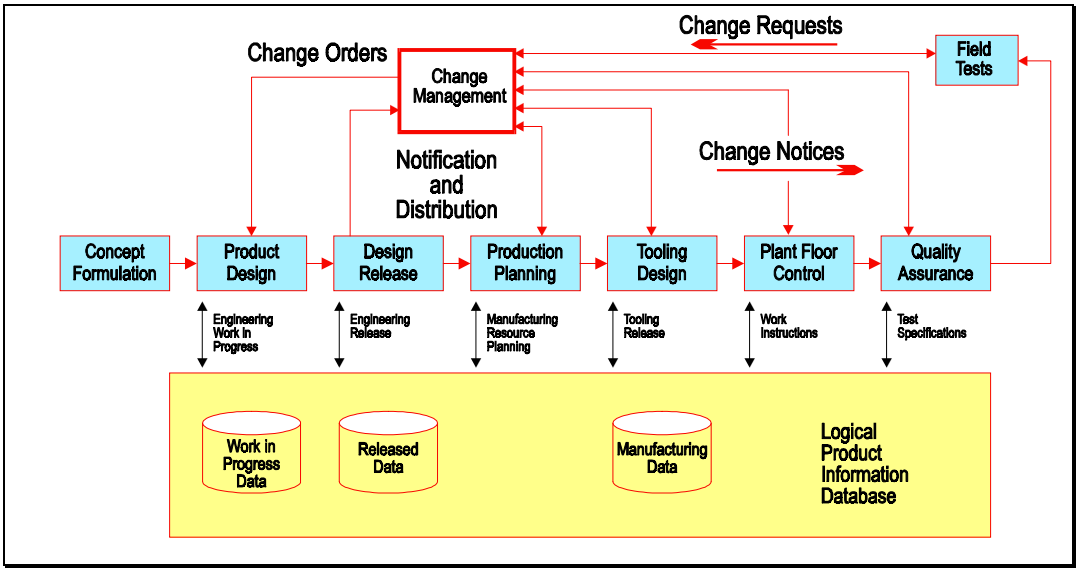

Figure 2: EDM's Role in the Product Life Cycle (Scott Tsao, 1993).

One of the prime motivation for EDM is the sheer volume and diversity of engineering data (Stark, 1992). An exhaustive description of a part or an assembly requires a huge amount of documentation.

The more complex the item, the more diverse is the documentation. The following information topics could easily be listed under the heading of the complete set of the engineering documentation of a part or an assembly:

- drawings,
- CAD models,
- part lists,
- structural analysis models,
- spread sheets,
- technical notes,
- measurements results,
- manufacturing instructions,
- assembly instructions,
- organizational relations,
- material properties,
- schematics,
- applicable standards,
- photos and shaded images.

In the near future multimedia documents, e.g. audio and video sequences, will be added to the list.

5.1 The Role of Engineering Data Management

As multiple systems are used to design, analyze and manufacture a product throughout the product life cycle, the different pieces of product data are created by a variety of tools and stored in files or databases which reside on multiple electronic media. This means that the full description of a part or assembly includes a large number of computer files. The very essence of EDM is to manipulate this data in a coherent way by establishing and maintaining links between the documents, including their various versions, and the parts and assemblies to which they are related to. As this data is constantly being modified and accessed by various users, the basic functions required of EDM must include (Bachy et al., 1995):

Release Management: provides a set of functions similar to a library card catalog:

- allowing users to register a set of data (files) as a single dataset, enter pertinent metadata (attribute data) about the dataset,
- check it out for modification,
- prevent other users from checking out the same dataset, and check it in after modification is complete,
- automatically creating a new version of the dataset after each check-in,
- allowing authorised users to review the dataset for approval before release according to a pre-defined release procedure.

Change Management: provides a set of function to control the change of a registered dataset:

- defining the release procedures for various types of data,
- allowing users to initiate change request against certain datasets, issue change orders in response to change request, and automatically generate change notices after the change is complete.

Notification and Distribution: provides a set of function to send messages and/or datasets to users upon the occurence of defined events:

- creating distribution lists,

- defining events,
- automatically notifying the sender when the messages and/or datasets are received.

Administration: provides a set of functions similar to database administration functions provided by a conventionnal database management system:

- assigning user access privileges,
- providing archiving/restoration facilities,
- allowing automatic back-up/recovery.

Product Breakdown and Configuration Management: provides a set of functions to maintain various configurations of the product definition data:

- creating and editing the product breakdown,
- associating datasets to parts and sub-assemblies of a given assembly,
- navigating the product breakdown and associated datasets.

The basic concept of EDM to manage datasets created by the various tools is to create a metadata layer, i.e. a layer containing pointers and summary information for the datasets being managed. The metadata itself is usually maintained in a database and managed by a DBMS. This is similar to the use of library card catalogs.

5.2 Other important issues

5.2.1 User Interface

The undisputed number one hurdle to a successful use of EDM in an organization is “Cultural Change” (Williams and Cleveland, 1995). Cultural Change is caused by the introduction of new ways of doing things. Implementation of such a change may face some resistance from the end users’ side. The EDM team can greatly reduce the impact of cultural change by presenting tasks and the process to complete the task to the user in a familiar manner. Newly required tasks and processes should be easy to perform.

5.2.2 Communication

Complex products are often engineered and manufactured in a distributed manner. This fact emphasizes the system’s capability to provide certain communication services to the organization. From configuration management point of view these services should include:

- basic means for technical communication between various engineering teams;
- access to the communication network, e.g. Internet and the file transfer protocols. From CERN’s point of view access to the World-Wide Web is of course essential;
- communication follow-up services to provide information for the project management, i.e. capability to study how the communication frequencies have evolved and how individual collaborators have utilized the system.

5.2.3 Standards

While describing Product Data Management we have focused on configuration management aspects. That is only part of the story. An organization’s engineering data represents its collective know-how. As such it is a major asset and should be protected and secured for its entire useful life. Over such a long period it is impossible to guess what will become of the tools we use today to create engineering documents. Consequently engineering data should be stored as far as possible in recognized standard formats, rather than in the proprietary formats of the creation tools. Standards are also essential to enable electronic communication of data and documents inside and outside the organization with other Document Management System.

Standard formats exists for some documents types at least, ISO STEP, SGML, HTML, CCITT to name but a few. In some cases the use of de-facto standards, e.g. Postscript, is another possibility. It will be the role of EDM to promote the use of selected standards thereby insuring the perennity of engineering information.

5.3 Summary

All of the above listed requirements promote the role of an EDM as a multiple linking system between people, documents, products and time together with the capability to assign various status indicators on various items and to establish rules on how they are controlled.

Introducing an Engineering Data Management solution can be done in a number of ways: selecting and buying a ready-made EDM System from a vendor, selecting and adapting a vendor's system to the specific needs of the organization, or developing an in-house solution. Whatever the choice, the successful introduction of EDM in an enterprise is a complex task involving people and technology. Key issues and preparatory activities are well documented (Stark, 1992):

- secure the support of top management,
- create a cross-functionnal team of configurators from all groups involved to define requirements and select a solution,
- identify a short-list of possible EDM systems vendors, evaluate the products, suppliers and references,
- plan for short-term, mid-term and long term,
- test the chosen solution in a pilot project,
- implement EDM in stages, starting with areas where benefits will appear quickly.

The active participation of end-users, mainly "configurators", at all stages of the EDM selection and introduction process is essential.

6 Conclusions

The use of EDM is essentially an issue concerning the project's own capability to control specification changes and the work/information/data flow during engineering and manufacturing processes. EDM provides tools to the existing management, i.e. it does not provide the management. Thus, a successful implementation of EDM requires first the organization's agreement on the managerial issues concerning the processes around the product configuration and its evolution. The overall success in configuration management stems from administrative skills and routines supported with a sophisticated EDM system. Table 2. summarises the main value-adding functions of configuration management and an EDMS in different phases of the product life-cycle.

The supportive actions of configuration management and EDMS			
	Conceptualisation	***Execution***	***Exploitation***
Configuration management	• translates customer requirements into technical language • manages version handling • maintains product coherence • controls specification and design changes	• ensures product's manufacturability • disseminates technical information between vendors and project teams • controls specification and design changes	• supports operational and maintenance activities of the system • provides a base of learning for future • summarises specification and design changes
Engineering data management system	• archives design history • provides user interface to all product data • maintains design process status • supports dissemination of technical information	• provides continuous source of up-to-date product information • supports technical communication between project collaborators from bids to project closure	• provides data for an aftermath and learning from the design process • helps tracing solutions to maintenance and operational problems
Main contribution of EDMS	⇒ *support and co-ordination of engineering work/ information/data flow* ⇒ *quality of design*	⇒ *mediation between customer, production and design* ⇒ *quality of manufacturing*	⇒ *maintain operational period and establishes learning process* ⇒ *lifetime support*

Table 2: The value-adding functions and services of configuration management and EDMS during the whole project/product life-cycle.

Configuration management is not a hindrance for the normal product development or project activity. It is merely a previously non-existent addendum to the project organisation, and its role should be seen more as a service provider to the rest of the project organisation. Verified and organisation-wide coherent understanding of the product configuration provides the best results with fewer mistakes. At its best an EDMS provides the organisation with an easy access to a coherent and well structured data that specifies the current status of the product configuration with links to design history and responsible people.

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