Implementation of manufacturing data management application in the scientific research project

CASE: CERN, the European Organization for Nuclear Research

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Abstract

IMPLEMENTATION OF MANUFACTURING DATA MANAGEMENT APPLICATION IN THE SCIENTIFIC RESEARCH PROJECT

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This Bachelor's thesis examined the implementation process of an MTF (Manufacturing and Test Folder) application in the CLIC (Compact Linear Collider) Radio Frequency Structure Development project for manufacturing data management purposes. The primary goal of the study was to investigate how MTF implementation and its integration with CERN EDMS (Engineering and Equipment Data Management System) system could facilitate product life cycle through the supply chain, and could affect on manufacturing operations performance in internal and external levels. The aim of the study was also to find out implementation differences within CERN (European Organization for Nuclear Research) projects.

The study is divided into two parts: a qualitative theory section and an empirical section. In the theory section differences of features between PDM (Product Data Management), EDM (Engineering Data Management) and PLM (Product Life Cycle Management) systems were studied. The thesis examined the benefits and managerial challenges of PLM implementation. The qualitative empirical study is based on data gathered during active participation in the implementation process of CLIC RF Structure Development project, as well as, from interviews in CERN projects having MTF implementation experience. Data gathered from MTF trainings and seminars dedicated to MTF implementation give additional details of the implementation process analysis.

The results of the study showed that MTF implementation was performed in different ways in various CERN projects. The purposes of implementation also varied. The ways how MTF implementation facilitates product life cycle and manufacturing operations differed from project to project. With a small serial production CLIC RF team has not yet implemented all advanced features of MTF application, including the system's inventory management capabilities. Therefore, different examined implementation solutions provided valuable information for further implementation phases of CLIC RF Structure Development project.

Key words: product life cycle, manufacturing, supply chain, system integration

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Tuotannon tiedonhallintasovelluksen käyttöönotto tieteellisessä tutkimusprojektissa

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Opinäytetyön tavoitteena oli tutkia MTF (Manufacturing and Test Folder) -sovelluksen kayttöönottoprosessi CLIC (Compact Linear Collider) Radio Frequency Structure Development -projektissa. Ensisijaisena tavoitteena oli tutkia, miten sovelluksen käyttöönotto ja sen integrointi CERN EDMS (Engineering and Equipment Data Management System) sovelluksen kanssa helpottaa tuotteen elikaaren hallintaa tilaus-toimitusketjussa, sekä miten se vaikuttaa valmistustoiminnan hallintaan sisäisellä ja ulkoisella tasolla. Tutkimuksella haluttiin myös tuoda esiin kayttöönoton erot muissa CERN (European Organization for Nuclear Research) -projekteissa.

Tutkimus koostui kvalitatiivisesti tutkitusta teoreettisesta ja empiirisestä osasta. Teoriaosuudessa tutkittiin PDM- (Product Data Management), EDM- (Engineering Data Management) ja PLM- (Product Life Cycle Management)-järjestelmien ominaisuuksien väliset erot. Pääpainona oli tutkia PLM -järjestelmän kayttöönoton etuudet ja haasteet. Empiirisen tutkimuksen analyysi perustui saatuihin tietoihin aktiivisesta käyttöönoton osallistumisesta CLIC RF -projektissa sekä haastatteluista, jotka toteutettiin kolmessa eri CERN -projektissa. MTF -sovelluksen koulutus ja seminaaritilaisuudet antoivat tutkimukselle syvällisempää lisätietoa käyttönottoprosessista.

Tutkimuksen tulokset osoittivat, että MTF -sovelluksen käyttöönotton toteuttaminen suoritetiin eri tavalla kussakin CERN -projektissa. Käyttöönoton tavoitteet myös vaihtelivat. Keinot ja tavat, jotka helpottavat tuotteen elikaaren ja valmistuken hallintaa vaihtelivat projektikohtaisesti. CLIC RF -projektin sarjatuotanto on vasta aluvaiheessa, joten kaikkia MTF –sovelluksen lisäominaisuuksia mukaan lukien varastonhallinan mahdollisuuksia ei olla vielä ehditty käyttöönottaa. Siksi tutkimuksessa esitetyt käyttööoton ratkaisuvaihtoehdot antoivat arvokasta tietoa käyttöönton jatkoa varten.

Asiasanat: tuotteen elinkaari, tuotanto, tilaus-toimitusketju, järjestelmäintegraatio

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Abbreviations

ABS	Assembly Breakdown Structure
BE	Beams Department
BLM	Beam Loss Monitor
BOM	Bill of Materials
BWS	Beam Wire Scanner
CAD	Computer-aided Design
CATIA	Computer Aided Three-dimensional Interactive Application
CDD	CERN Drawing Directory
CERN	European Organization for Nuclear Research (Conseil Européen pour la Recherche Nucléaire)
CLIC	Compact Linear Collider
CRG	Cryogenics Instrumentation Group
CTF	CLIC Test Facility
EAI	Enterprise Application Integration
EDM	Engineering Data Management System
EDMS	Engineering and Equipment Data Management System
ERP	Enterprise Resource Planning
ISRAM	Information System for Radioactive Materials
KEK	High Energy Accelerator Research Organization
LEP	Large Electron-Positron Collider
LHC	Large Hadron Collider
LINAC	Linear Particle Accelerator
MSC	Magnets, Superconductors and Cryostats Group
MTF	Manufacturing and Test Folder
PBS	Project Breakdown Structure
PETS	Power Extraction and Transfer Structures
PDM	Product Data Management
PLM	Product Life Cycle Management
R&D	Research and Development
RF	Radio Frequency
SAP	System Analysis and Program Development (Systeme, Anwendungen und Produkte in der Datenverarbeitung Aktiengesellschaft)
SLAC	National Accelerator Laboratory (Stanford Linear Accelerator Centre)
SR	Synchrotrons
TBM	Two-Beam Module
VSC	Vacuum, Surfaces and Coatings Group

1 Introduction

1.1 Research background

CLIC, Compact Linear Collider study is one of the future-oriented scientific research projects of the European Organization for Nuclear Research (CERN). As one of the most respected scientific research centers in the world CERN is aiming to build the world's largest and highest-energy particle linear accelerator, to explore possible discoveries of particle physics at the high-energy frontier. CLIC study is based in Switzerland and is a worldwide collaboration of 40 institutes from 19 countries and thousands of scientists working full and part-time. The R&D collaboration with scientific organizations KEK (Japanese High Energy Accelerator research organization) and SLAC (National Accelerator Laboratory) have played a significant role in engineering design, manufacturing and testing processes of the CLIC study. (Compact Linear Collider Study 2010.)

CLIC organization consists of several committees and subprojects, the main three subprojects are CLIC Design and Accelerators, CLIC Test Facility 3 (CTF) and Physics and Detectors studies. CLIC RF (Radio Frequency) Structure Development project is one of the projects of CLIC Design and Accelerators study. The main objective of CLIC RF Structure Development project is to develop in the international collaboration 100MV/m travelling-wave accelerating structures and other linear accelerator radio frequency technology for the collider, as well as testing them in scientific laboratories at CERN and at others worldwide scientific or industrial engineering organizations. (Compact Linear Collider Study 2010.)

The CLIC study is soon behind leaving the R&D (Research and development) conceptual design phase, which requires feasibility demonstration of the project. Approved conceptual design phase of the CLIC study will start the technical design phase, which will be more project-oriented. The technical design phase will include different processes of industrialization and mass production, and can probably lead to the construction of the collider. During the technical design phase will be very important in order to complete the equipment identification of RF accelerating structures and RF components. While the implementation of product data management tools will guarantee follow-up of manufacturing components through the whole product life cycle. (Ridonne 2009a.)

The CERN Engineering and Equipment Data Management System was launched at CERN in June 1997 and became the official CERN data management system in 2000. At the beginning it was dedicated to the machines and detectors of Large Hadron Collider (LHC) project. The quality assurance had a significant role in the acceptance of the system by collider participants. (Chemli 2000, 2450.) The system has become CERN-wide as it provides the service possibilities of engineering and equipment data management worldwide. EDMS provides access service worldwide 24 hours and 365 days a year also to other systems and applications like to CAD (Computer-aided design) systems and CDD (CERN Drawing Directory) application for drawings and technical document managements. EDMS is a Web interface which became CERN information system infrastructure, the EDMS Common Layer. (Boyer 2002, 2697- 2698.)

EDMS service provides project breakdown structures (PBS) for the project management, assembly breakdown structures (ABS) for item management and as-built structures for equipment manufacturing follow-up. Assembly breakdown and as-built structures are developed for managing engineering and equipment data for manufacturing and assembly processes. Those structures are associated with MTF (Manufacturing and Test Folder) application which is widely used by machine experiments' inventory, manufacturing, commissioning and maintenance purposes. (Boyer 2002, 2697- 2698.)

The MTF application is an integral part of EDMS and was as initially dedicated for the LHC project. MTF project was launched in 2000 and it became official service in 2001 (Chalard 2004, 596). The MTF service is now being extended to support other projects in the CERN domain. The objective of MTF is to provide tracking capabilities of large amounts of complex parts of components manufactured through the supply chain. An application provides the documentation follow-up of manufacturing and test procedures for both production data and delicate non-conformities issues. C. Delamare (2002) describes in his report how the MTF and EDMS, originally separated information systems joined together are now providing new features which did not exist in the original versions. (Chalard 2004; Delamare 2002.)

CLIC RF Structure Development project started the implementation process of EDMS in 2007, first by defining project breakdown structure and the documentation templates for different types of reports (Riddone 2009c, 3). Nowadays EDMS is widely used for project and engineering data management. In 2009 the management of CLIC RF Structure Development project initiated research of system for manufacturing follow-up and test procedures to complete product life cycle management for the RF structures and components. At some point the project management had in a plan to develop its own system, but in the end they have decided to use LHC project which already had wide experience of MTF application as an example.

1.2 Purpose of research

CLIC RF Structure Development team had a need for an integrated interface to make engineering data management easier. Collecting data from several databases and systems through different interfaces was not efficient. There was a demand for easier information access of RF accelerating structures, PETS (Power Extraction and Transfer Structures) and RF components throughout whole product lifecycle. They wanted to have BOM (Bill of Materials) of component assemblies, design drawings, quality control, test results and manufacturing documentation, as well as components tracking capabilities in one system. This included as well the definition of the quality assurance needs in collaboration with the engineers and physicists (Ridonne 2009a). The main requirement was user-friendly interface to archive all the related documents from the engineering design and to the testing processes. Initially they could not do it through one single system.

The MTF application which was already used by LHC project and its subprojects was a good alternative for the need they had. The implementation was initiated by the CLIC RF project supervisor and done in collaboration with CERN informatics group (EDMS support), EDMS local administrator in CLIC RF and with the person responsible for the MTF administration in CLIC RF group (the author of this thesis). The implementation was not only the deployment of MTF, but also its integration with the CERN EDMS system. CLIC project is a forerunner in the integration of those two databases through assembly breakdown feature of the EDMS system.

The theoretical part of the research introduces engineering and product life cycle data management systems that provide tracking capabilities of product data management. The key topics are benefits and managerial challenges of product life cycle management systems implementation. The integration of information systems is as well analysed as a part of product life cycle management. The theoretical part is however, focused more on enterprise solutions provided by vendors. CERN as an international scientific organization may not have same approach to product life cycle management, as enterprise organizations which will wait for example for quick return on investment when implementing a product life cycle system. Moreover, MTF application was developed at CERN for the mass production phase of a word-wide known project. During the research similar solutions have not been found on the market. Thus, it must be taken into account that research was done in the scientific organization and the implementation process may vary comparing to implementations performed at an enterprise field.

The objective of empirical research is to define how MTF implementation and its integration with other CERN systems affects on data management through the supply chain in the CLIC Radio Frequency Structure Development project by comparing the implementation results with other CERN projects. The empirical research answers two questions:

1. How MTF application implementation and its integration with other CERN systems facilitate product life cycle data management through the whole supply chain?
2. How MTF implementation affects on manufacturing operations management on internal and external level?

The main part of the empirical research is interviews performed at CERN, which helps to define MTF implementation's impact on operations and data management in different LHC subprojects. The comparison of experiences gives valuable knowledge of system usage, as it is used and integrated with systems in various ways by different CERN projects.

1.3 Research method

The research method of this thesis is empirical qualitative study. Qualitative analysis is defined by Suzan Burton and Peter Steane (2004) as a way to understand and interpret phenomena in different contexts. In order to get multiple perspectives of the subject under research it is important to use a variety of methods to understand the core idea. Observation, conversation, interviews, participation and archival research are the main methods, which helps the researcher to analyze the complexity, depth and richness of the research subject. These methods help to investigate and interpret processes and explain behavior of some practices. A qualitative researcher has a great opportunity to be involved in investigated situation and meet people with actual experience of practices being studied. (Burton & Steane 2004, 160-161.)

The researcher participation may vary, for example passive observation requires direct focus towards any sort of data which could provide insights into the subject's central research questions. Being a good listener is not just making keen observations or sensing what might be going on, it means being able to assimilate large amounts of new information even without having any background knowledge. (Burton, S. 2004, 162.) According to Robert K. Yin, good listening skills are not applying just on real-life situations, but on the analysis of documentation as well. The listener should sense if there is any important message between the lines. (Yin 2009, 70.) Active participation involvement allows access to covered and hidden sources of evidence. The researcher needs to develop abilities for achieve access to individuals and groups. Needed abilities are for example good communication and mutual trusting relationship skills. It's important to manage perceived role as researcher, organizational participant and, at the same time as a facilitator. (Burton, S. 2004, 161.)

The researcher of this thesis has been directly involved in the implementation process of the research subject, having opportunities to be an active participant and make observations. Even though, the researcher was an observer she had an impact on the project's progress by making development proposals and taking care of their accomplishment. Section, group and team meetings as well as, different seminars were the main information sources. Meetings with CERN informatics group gave base for the further research and situation analysis of the case project team's product life cycle needs. Moreover, the researcher had possibility to participate in the courses organized by CERN informatics group which have been dedicated to the EDMS and MTF databases. The purpose of those courses was to introduce the main principles of EDMS and MTF databases, and teach engineers or administrative personnel to use them as administrators. It was recommended to participate in several courses before starting to operate as a local administrator.

Being a local administrator means basically to be team's contact person for EDMS service support. The EDMS support is provides a service which is implemented in collaboration with the local administrators of the team. The courses gave valuable knowledge for the researcher which she could use for teaching the team members how to use those databases as users. Usually, there were only a few participants, but however courses provided a unique opportunity to gather information of other projects EDMS or MTF implementations.

The seminar of ongoing activities of CERN Vacuum, Surfaces and Coatings (VSC) group held in November 2010 gave valuable information for research as the seminar was dedicated to the Layout DB application and MTF implementation as well as, their integration. The seminar included presentations of MTF and Layout DB usage by their support. The electronics responsible of LHC Cryogenic Instrumentation & Controls group presented his experience of Layout DB and MTF from an equipment owner point of view.

The research subject's definition and framing was initiated by the project supervisor and Laurea-University of Applied Sciences logistics lecturer, and supplemented by observations analysis and preliminary data collecting performed by the researcher. Empirical data collection regarding MTF implementation process in CLIC RF Structure Development was carried out from August 2009 to August 2010. Interviews were done at the beginning of November 2010. Theoretical data collecting was done from June 2010 and until November 2010 with the help of Nelli-portal services, CERN document server, Indico CERN event management tool (Indico

2010) and EDMS database, as well as library services of CERN, Laurea-University of Applied Sciences and HelMet.

2 Managing engineering and product data through supply chain

2.1 Product Data Management systems

Manufacturing and engineering companies typically deal with difficult phases of product lifecycle because the effective supply chain management has a high importance. An increase of product variety and its quantities makes engineering and manufacturing processes more intensive which often leads to a lack of coordination and mistakes in different levels of the supply chain. (Hartiala, 2006, 121.) The product lifecycle information flow from designers to manufacturers is usually incomplete and slow. As a result of long product lifecycle designers are almost certain to have received new assignments before their designs pass through the whole supply chain and reach maturity. (National Materials Advisory Board 1991, 35-36.)

It is important to provide feedback to the designers on manufacturing problems of their current products in development. Furthermore, designers need to have complete information on the suitability of a product to ensure appropriate design for testing and manufacturing environment as well as, manufacturing techniques. The most reliable information comes from direct interaction between the designer and manufacturer but quite often it is limited by different reasons. To manage engineering design process better, decrease the complexities of data, and to provide information exchange between engineers, and manufactures the product data management (PDM) systems provide a unique technology, which integrates design applications data. PDM systems are not only for data management, they also facilitate collaborative design in globalised organizations. (Rouibah 2006, 1; Xu & Liu 2003, 315-317; National Materials Advisory Board 1991, 35-36.)

PDM systems manage large volumes of design data which facilitates faster development of complex products (Asklund, Crnkovic & Persson Dahlqvist 2003, 17). Product structure management is most important feature of the PDM system. The most known product structures are mechanical design-oriented hierarchical assembly structures that consist of subassemblies and components. In manufacturing industries these structures are described as the bill of materials (BOM). Figure 1 describes the structure hierarchy with each part quantified. PDM system manages also variations of parts, for example sizes like small, medium and large. (Asklund, 2003, 24-26.)

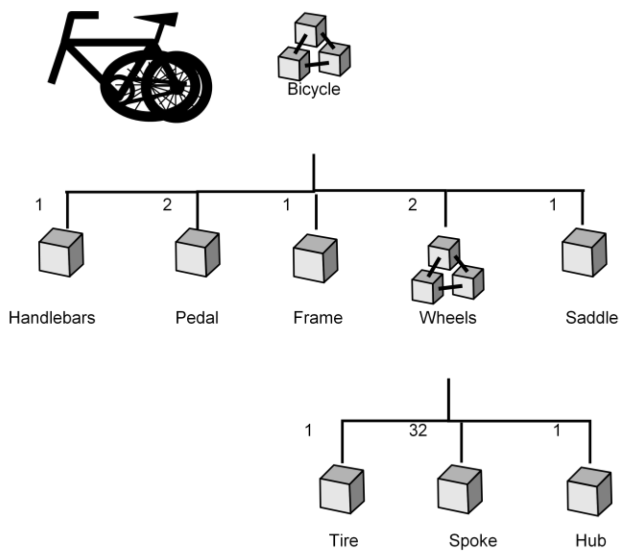

Figure 1: BOM of a bicycle (Asklund 2003, 26)

The central location of PDM system is data or database vault, in other words the repositories of product information (Figure 2). There is also control over externally generated data in terms of accessing and saving documents in other information systems or applications. In data vault are usually stored two types of data, the product data from computer-aided design (CAD) applications like CATIA (Computer Aided Three-dimensional Interactive Application) or AutoCAD and meta-data which controls PDM data. Product data can be design data, engineering drawings, technical specifications and bill of materials. PDM systems give also possibility for process management and design control in terms of modification of product configurations, part definitions, data relationships and versions control throughout product development life cycle. The meta-data in turn shows by whom and when this information was created, as well as its version changes. The user-directed functions of PDM system are storing, retrieving and managing data. Behind the user-directed functions are utility functions that are connected to the network infrastructure. Utility functions include design communication, data visualization, product or engineering data transport and distribution, as well as the system administration. (Asklund 2003, 22; Xu & Liu 2003, 315-316; Could.)

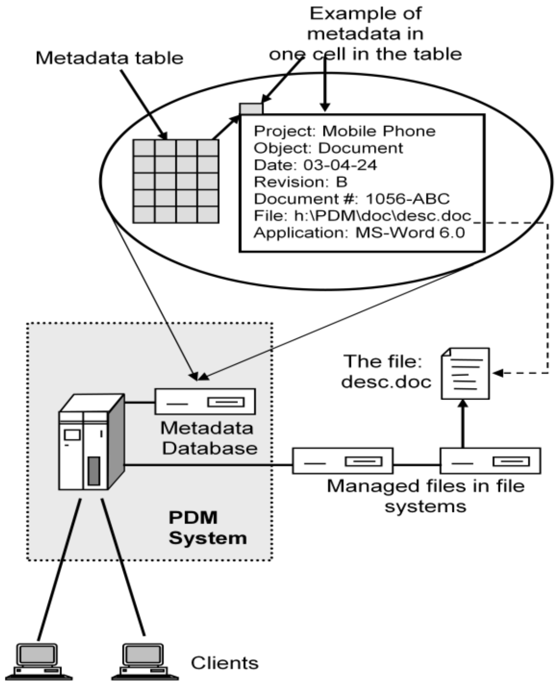

Figure 2: A PDM system with data vaults (Asklund 2003, 35)

2.2 Engineering data management systems' integration with PDM

The Engineering data management system (EDM) also known as Electronic Document Management System (EDMS) is widely used in the construction and process industries to cater product data of engineering and manufacture processes faster and at less cost. EDM systems are most useful when it is required to have additional information associated with the product, the information which describes the product itself. The information can be in terms of components' testing procedures results, mandatory for the production. The most important function of EDM system is the categorization of product groups and documents as well as, the possibility to link different document formats to several engineering applications. (Grieves 2006, 49; Hall 2000, 2.)

In PDM system design data is organized as bill of materials (BOM) hierarchy, in other words the product is on the top level which breaks down first into major components and continue breaking down until basic components. Defined product structure should be frozen until release of version, and can be used as a baseline for other same category products. The EDM system uses same product structure but in terms of folders which enables product grouping. The product grouping to different types, as Geoff Hall (2000) shows in his small, medium and large car example may not be so useful for mechanical engineer, while for the purchaser it can give valuable information for example of motors which have been used in different cars as well as, their cost and availability. (Hall 2000, 2.)

It is quite common that companies want to implement both systems to cover different department's needs. Nevertheless, if taken separately PDM systems are widely used among mechanical engineering industries, while EDM system is more often implemented in the chemical, transportation and utility industries and, as qualified vendors could be mentioned Intergraph and Cimage. Vendors like Altris, Centra 2000 and Metaphase have integrated PDM/EDM system into one more functional and developed system. (Hall 2000, 2.) Even though, EDM and PDM are becoming slowly one thing (Hall 2000, 2) the integration of systems is not beneficial for all users. They are two different types of systems and in some industries or organizations the integration may cause more work, or some functions will be just not used.

2.3 Product Life Cycle Management

Ulf Asklund, Ivica Crnkovic & Annita Persson Dahlqvist (2003) describes product life cycle as mechanism of product development and operations processes. Life cycle is always divided into multiple phases, which are characterized by inputs and activities performed by different people using different technologies or techniques (Figure 3). (Asklund 2003, 5.) The information produced during different phases has to be transformed between processes. The information life cycle, in other words the information integration between supply chain facilitates operations management. Moreover, information transparency helps to build trust and commitment while real-time accessibility improves early problem detection and faster response time. (Immonen & Saaksvuori 2005, 188; Lee & Whang 2001, 7.)

Figure 3: Product life cycle through supply chain (Asklund 2003, 20)

Product data management is part of the product life cycle management (PLM). According to Anselmi Immonen and Antti Saaksvuori (2005), PLM is considered as a wider data management approach, which enables product data management through the whole lifecycle by using different concepts, technologies and tools. In today's industrial production the life cycles of products and components are shortening as well as, their delivery times. PLM offers solution for quick and almost automatic product life cycle data distribution for the supply chain collaboration. However, PLM is not only implementing new tools and technologies as it often requires changes in product life cycle processes and their control. The existing processes have to be mature enough before PLM system utilization. (Immonen & Saaksvuori 2005, V-1.)

PLM system is an expanded version of PDM and EDM, which manages not only item documents and BOM's, but also data manufacturing procedures and tests, quality standards, change management, product performance, suppliers and transportation, inventory and even workflows. PLM systems features facilitate and enable user to standardize and speed up operations management. Web-based PLM systems provide facilities to data distribution globally, to external organizations such as to suppliers, and even to the customers. (Immonen & Saaksvuori 2005, 2.)

2.3.1.1 History of Product Life Cycle Management

The first users of PLM were automotive and aerospace industries because of complex manufactured products. The electronics sector, which product management issues focused more on software configuration than on complex product configurations, was also one of the PLM pioneers. The success of PLM in those three industries spread interest very quickly to other business areas such as to the pharmaceutical industry. (Grieves 2006, 1.)

Even though, the roots of PLM system are in engineering industry Jim Brown (2003) describes it as the official an enterprise application. However, PLM is not just another version of ERP (Enterprise Resource Planning) system. The main difference between systems is that PLM system takes care of engineering design and innovation side of the product life cycle, while ERP is concentrated on production. They are two different systems, and not to pollute ERP with design or manufacturing data or PLM with material costs it is an appropriate to have both systems. Major ERP vendors like SAP (System Analysis and Program Development), BAAN (ERP system, created by Jan Baan) and Oracle have recognized the consumer needs for the PLM functions and developed own additional PLM solutions, while others like PeopleSoft developed just partnerships. The integration of systems may give to some organizations extra value, but for real PLM needs there will still be demand for PLM products from specialised vendors like IBM/Dassault. (Brown 2003, 1-2.)

2.3.2 Differences between PDM and PLM systems

According to John J. McEleney (2007), engineering, manufacturing and product development companies often have difficulties to choose between PDM and PLM systems. Moreover, it's often thought that company can't have both systems at the same time. At the first sight, the difference between the systems may seem to be quite unclear. (McEleney 2007.) The main difference is that a product data management system is indented to manage mainly product design and development data. While, product life cycle management system has strategic approach to manage entire product life cycle by the principle of systems integration. PLM is focused especially on the product development and manufacturing processes which base the core of product life cycle. (Globalspec, the Engineering Search Engine 2010; McEleney 2007; SolidWorks 2008.)

When deciding which option should be implemented it is important to define first own current and future needs. PDM system is necessary for all 3D CAD engineering and manufacturing organizations to manage design data challenges. Design-focused technology of PDM helps to improve and facilitate product design and development data. PLM is more strategic an operations management-cantered approach which improves productivity through the whole supply chain. Even though, in the large globalized organizations PLM systems had huge success, for small and medium-sized manufacturers PLM may be not suitable. The size of the company, the number of employees, CAD-users and users who use that product design data are factors which have an impact on the implementation decisions. (SolidWorks 2008, 1-2.)

Before moving to PLM first it is important to learn how to manage efficiently product design data, discover functionalities which PDM provides. Some PDM system providers have created basic PLM functionalities in PDM systems. PLM in turn can have functionalities of PDM or even PDM software (Figure 4). However, every PLM system uses PDM data as a foundation for data operations (SolidWorks 2008, 1). The product structures can be defined without PDM, but PDM system's bill of materials automates data import and prevents human factor mistakes. The implementation costs of PLM are much higher comparing to PDM, which is also faster and easier to implement. PDM administration support and trainings are also simpler to provide. Nevertheless, when implementing PDM database manufactures often realize the benefits of PLM, and want to build later PLM system over PDM. Full-blown of PLM system is nevertheless more suitable for globalized, large organizations with multiple suppliers of the product life cycle. (SolidWorks 2008, 2-6.)

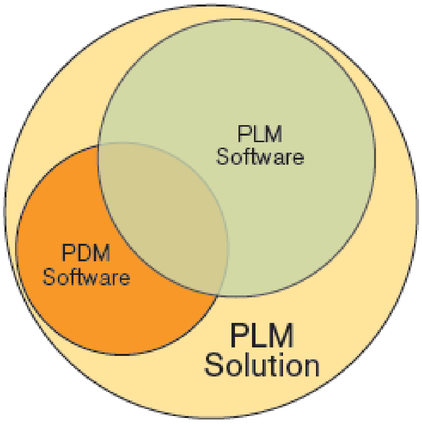

Figure 4 PLM Solution including PDM functionality (Solidworks 2008, 3)

2.3.3 Integration of the PLM system with other systems

In the industrial sector PLM system has a central part in the IT infrastructure. Usually implemented PLM system does not replace any old system on the contrary it brings new values to the infrastructure. The systems integration is usually considered as the most difficult part of implementation, as it is necessary to define which information should be updated to each system in use by organization and its suppliers. Moreover, in order not to pollute systems that information should be always updated to same place. The integration is not always necessary, but it is often worth it because of easier document utilization. The best known ways of integration are transfer file, database and middleware integration, of which transfer file is easiest way of the integration. In application manually or automatically created file can be exported to any other system as a transfer import file. (Immonen & Saaksvuori 2005, 57-59.)

EAI, the Enterprise Application Integration enables data interchange and distribution between applications, inside company's data network or even on the inter-organizational level.
The basic principle of EAI is to build an integration platform, a software layer (middleware) instead of integrating systems separately. The integration platform transmits and moves data between systems. EAI is not a tool which can be bought. It is a continuous process of development operations in the organization. Quite often EAI is implemented using some middleware product provided by vendor, who can even add additional operative applications for the platform. (Immonen & Saaksvuori 2005, 69-71.)

2.3.4 Benefits of the PLM system

According to Anselmi Immonen and Antti Saaksvuori (2005), the main factors leading to product life cycle management are globalization of business, company fusions, growing competition, tightening budgets, industry and quality regulations as well as, shortening delivery times and product life cycles. This pressure of continual changes requires competence to change own processes and to operate more efficiently. (Immonen & Saaksvuori, 2005, 99.)

The most important benefit of PLM systems is development of an internal and external communication. It improves as well transfer of different types of file formats, which brings quality, effectiveness and speed up the operations management. However, it's important to remember that PLM is only a tool which removes distances and improve effectiveness only when implemented and used properly. (Immonen & Saaksvuori, 2005, 102-103.)

Usually, PML implementation demands changes of current data management, and in the beginning may cause more work for the users. Nevertheless, in long haul it gives valuable advantages. As immediate advantages Anselmi Immonen & Antti Saaksvuori mention (2005) time saving for example in terms of faster product structure definition because of easier information utilization. Electronically performed approval and release of documents by respect of security access improve quality control. (Immonen & Saaksvuori, 2005, 104-105.) PLM can be used differently depending of organizations needs, but properly used it provides long term service of data management and archiving capabilities through the whole supply chain as well as simplifies product tracking.

2.3.5 Implementation of the PLM system

It is often assumed that companies jump at any chance to reap all the benefits from e-business to make data management in supply chain more efficient. Usually it is not the case, because the implementation of e-business and its products brings on different managerial challenges. First of all e-business implementation usually demands the use of considerable amount of resources, which cover the investment, hardware and software requirements, salaries of information systems specialists, the maintenance and the up-dating costs. (Andersen, Foroughi, Kocakulah & Lannert2002, 4.)

Integrating e-business with physically existing networks or databases is quite a demanding task (Chopra & Meindl 2004, 554). It is time consuming and causes difficulties to make systems available for the all supply chain members. (Andersen 2002, 4.) The most mentioned system implementation difficulty is lack of trust among the chain partners, as well as misinterpretation of feedback which leads to unwillingness to share information (Fawcett 2005, 3). Moreover, quite often the implementation of e-business requires physical changes in the facilities, as a good example Andersen (2002) mentions warehouses typical pallet-sized orders that makes it impossible to deal with the single-item or open-case shipping, which are provided by warehouse systems. Reorganization of warehouse picking methods causes additional costs. (Andersen, 2002, 4.)

Usually, the PLM implementation starts with the acceptance of need for change. This demand deep analysis of the subject supported by the PLM information gathered from seminars, conferences, consultations as well as, thorough reading of books and articles. The significance understanding of the PLM implementation will provide strong support through the implementation process. (Immonen and Saaksvuori 2005, 74-75.)

When choosing PLM system it is not easy to choose the right product for your needs, but there are several guidelines for managers to follow. The system should be reasonably-priced, easy to implement and use, and within minimum disruption to already standardized operations of organization or supply chain. The system should produce obvious benefits and quick return of investment, and implementation shouldn't overhaul of the company's infrastructure. (Andersen 2002, 5-6.)

According to Antti Saaksvuori (2007), the first step towards PLM utilization should be growth of the PLM maturity by building foundation of new management concept. This must be done by the management of organization with the help of experts who know the current practices, before definition of IT implementation program. Management concept has to describe information of the business framework and product life cycle phases, drivers, rules and requirements. It is simply a general plan for practical product life cycle management in the certain business or product level. Definition of the following areas is usually covered by product life cycle management concept (Saaksvuori 2007, 3- 4.):

- Product types and structures
- Parent/child relationships of components
- Identification of products
- Product related information
- Products and documents life cycles
- Product management related processes
- Product information management processes

Thus, it is important to understand that PLM implementation is not only information system project. However, in its technical character means the phases and features of the project are typical for IT implementation projects. The time for PLM deployment varies from several months to several years depending on the size and internationality of the organization as well as, on the scale of the system. Deployment can be performed in some project by a few persons, but in other it may need the involvement of several hundreds. (Immonen and Saaksvuori 2005, 74.)

The realization of project is usually performed with software suppliers and with systems integration consultants, who can help to plan and schedule the phases of the implementation. It is recommended to break the project in small parts that should be controlled by steering team. According to Anselmi Immonen and Antti Saaksvuori (2005), a PLM project can be divided in five different stages (Immonen and Saaksvuori 2005, 82.):

1. Start of the project
2. Preparation and planning of the project
3. Realization phase of the project
4. Start up phase of the system
5. Feedback and action

The transfer of existing documents from old systems or even from manual archives causes extra work for the project. However, there is always an alternative starting fresh with a new system. In the beginning trainings and seminars are compulsory to motivate and educate people to use a new system. Moreover, trainings have to educate employees to use the system the way company will want it to be used. It is worth to involve people outside the project to organize trainings, as often system providers may not understand how important basic information could be for the users. Final exam or PLM “driving license” may be also being attached to the course, adding more value for the users. (Immonen and Saaksvuori 2005, 84-86.)

To succeed in PLM implementation, a company has to understand the significance of the required new ways of working and sharing information. Cooperation between departments, collaboration partners and suppliers will increase and become more global. Thus, it is important to increase peoples motivation to share own information and make it available not only for the whole company but for all members involved in the product life cycle processes. (Immonen and Saaksvuori 2005, 93-96.)

Anselmi Immonen and Antti Saaksvuori (2005) highlight, that “the PLM system will never be entirely ready” because of constant information technology developments and changes. There might be as well changes in the organization’s internal operations, thus you have to be always prepared for quick and continual changes “in the world around you”. (Immonen and Saaksvuori 2005, 74.)

3 Case study environment

3.1 CERN

CERN, the European Organization for Nuclear Research founded in 1954 is one the most respected scientific research centers in the world. It is located by the Franco-Swiss border near Geneva. CERN's mission is to enable an international collaboration in the field of high-energy particle physics research, and to do this it designs, builds and operates particle accelerators and the associated experimental areas. The world most largest and complex scientific instruments are developed and used in CERN to learn more about fundamental particles. The main attention at CERN has been on the Large Hadron Collider (LHC) project, on the experiments of particles collisions to find Higgs boson particle, which is predicted to exist. (CERN 2010.)

CERN is an intergovernmental organization with 20 European Member States. It has also observer States and Non-Member States which membership is either not possible or not yet feasible, but those countries are involved in different experiment projects. The current Member States are: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom. (CERN 2010.)

Contribution of twenty European member states in year 2008 totalled approximately 1 billion Swiss francs, over than 650 million Euros. At present CERN have 2500 staff members and more than 9000 scientific users from 580 research institutes all over the world are using CERN's installations for their experiments. (CERN 2010.)

CERN's structure

The highest authority and responsibility over substantial decisions in scientific and administrative activities has CERN Council. It controls and approves different programs and budgets, and appoints the General-Director. The General-Director assisted by a Directorate manages CERN and is responsible for the CERN Laboratory. In Council every CERN European Member State has two official delegates responsible for the government administration and national scientific interests. The Council is assisted by the Scientific Policy Committee which takes care of scientific activities and by Finance Committee responsible for administration and financial matters. (CERN 2010.)

CERN has three different Directorate sectors, Administration and General Infrastructure, Research and Scientific Computing and Accelerating and Technology (Appendix 1). All three sectors have their own departments, which in turn have different groups and teams. For example Accelerating and Technology sectors has three departments Beams, Engineering and

Technology, which do close cooperation in projects dedicated to accelerating and technology research. (CERN 2010.)

3.2 CLIC

Compact Linear Collider (CLIC) study initiated at CERN, Switzerland aims to reach a nominal energy of 3TeV (teraelectronvolts-thousands of billions of electorvolts) with a future electron-positron collider. CLIC's unique capabilities of high energy and luminosity (10^{34}-10^{35} cm-^{2s} s $^{-1}$) will supplement the results of lower energy collider LHC, and make it possible to explore the future frontier of particle physics. Higgs boson is one of the first anticipated discoveries, the particle which will explain the origin of other particles' mass. (Braun, Delahaye, Geschonke & Roeck 2008, 15; Clements, 2005.)

So far, the highest centre-of-mass energy (209 GeV) in electron-positron collisions was reached at CERN's circular Large Electron-Positron Collider (LEP). The circular collider circulates particles which emit synchrotron radiation. Each turn in circle cause 3 % loss of beam energy and moreover, the energy loss caused by synchrotron radiation increases with the fourth power of the circulating beam's energy. Thus, Compact Linear Collider is the only option for electron-positron collisions without such a significant loss of energy. The basic principle of Compact Liner Collider is that two beams collide in the midpoint of two linear accelerators. Accelerators are facing each other, one accelerates electrons and the other positrons, which allow particles to collide head on (Figure 5). This scheme requires very high electric fields (100 MV/m) to enable 48 kilometre-long accelerator to accelerate particles in one single row and collide beams only once. (Braun 2008, 15; Ellis & Wilson 2001, 432.)

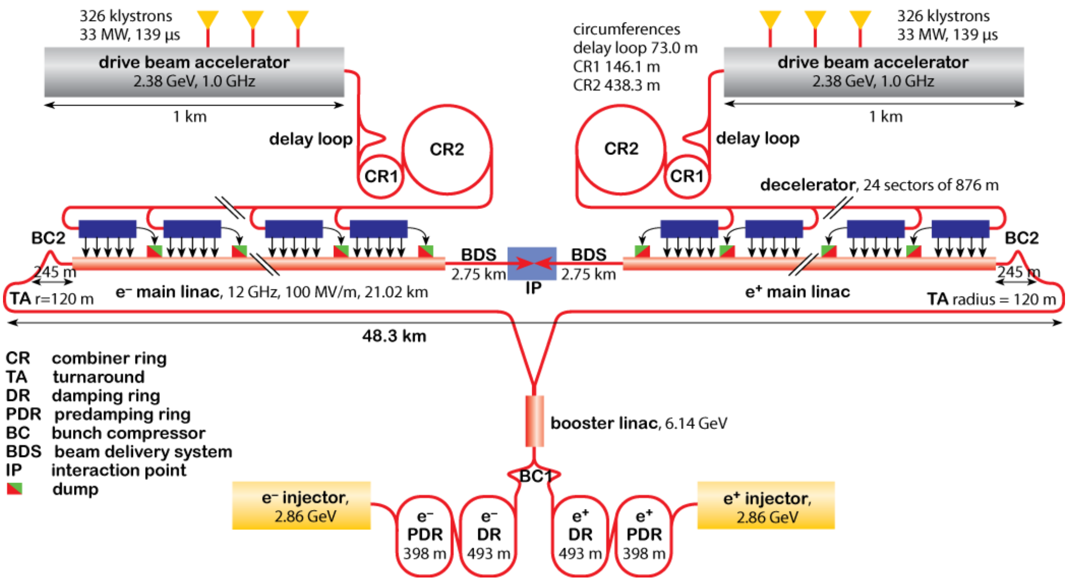

Figure 5: Overall Layout of CLIC 3 TeV (Compact Linear Collider Study website 2010)

The main design of CLIC is based on travelling-wave accelerating structures, power generating structures (PETS) and waveguide components which radio frequency operating performance ranges at 11.4 -30 GHz . To provide required high energy power for a 48 kilometer-long accelerator, a two-beam system will be used (Figure 6). The basic principle of the two-beam system is that a high-current (100 A peak) and low-energy (2.38 GeV) drive beam will provide energy to the main beam in form of high peak radio frequency power. (Braun 2008, 16.)

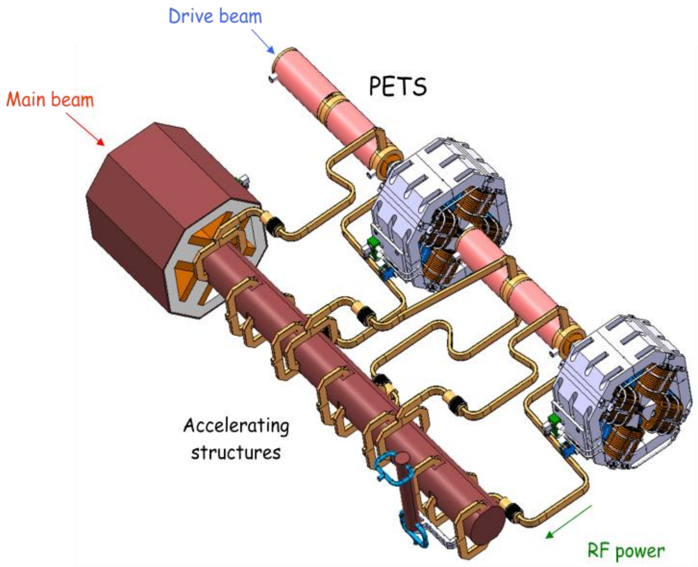

Figure 6: The CLIC two-beam scheme (Syratchev 2009, 2)

Beams will be running in parallel to each other about 65 cm apart, placed in a tunnel under the ceiling, at the end of linear particle accelerators (linacs). RF energy will be transferred through Extraction and Transfer Structures (PETS), which excite strong electromagnetic oscillations, in other words the drive beam loses its kinetic energy to electromagnetic energy. This electromagnetic energy is then sent through waveguides to the accelerating structures, running in parallel. (Braun 2008, 16.) PETS are travelling-wave, large aperture and high-group velocity structures. They comprises of eight octants separated by 2.2 mm wide damping slots (Figure 8). (Syratchev 2009, 4-5.)

In CLIC per one linear particle accelerator will be 10462 modules, 17406 accelerating structures and 35703 PETS. There will be several types of CLIC modules, in standard Module type 0 (Figure 7) will be eight accelerating structures and four PETS structures. In total per one linac will be 8374 standard modules. The integration of different technical systems if difficult and time consuming, the module integration design is going in parallel with technical system design. (Riddone 2009b.)

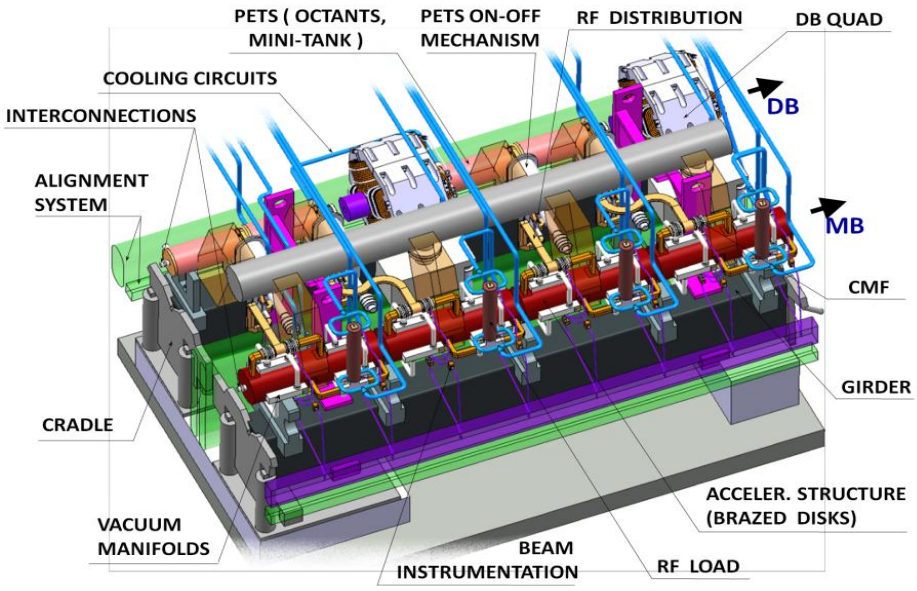

Figure 7: CLIC Module type 0 (Riddone 2009b, 4)

The CLIC study is living a transition phase from R&D to project-oriented, the conceptual design phase is as well near to the end. It is still required to demonstrate feasibility of CLIC project and its technology. (Tomas 2010, 1.) To demonstrate and test major CLIC technologies have been built at CERN CLIC Test Facility 3 (CTF3) in the worldwide collaboration with 40 institutes from 19 countries (Corsini 2010). So far CTF have been used to test mainly accelerating structures and CLIC critical components (CLIC Test Facility 2010). CLIC Test modules will be built in CLEX in the coming years 2010-2013 (Riddone 2009b, 41). Currently, in CLEX experimental area through the international collaborations has been made important progress in experiments with high-gradient accelerating structures and beam (Tomas 2010, 1).

3.2.1 CLIC Radio Frequency Structure Development project

As one of the projects of CLIC Design and Accelerator study, CLIC Radio Frequency Structure Development project is in charge of for developing the high-power X-band system for the main linear particle accelerator (Linac) as well as, to the drive beam system. This includes designing, developing and manufacturing PETS (Power Extraction and Transfer Structures), transfer network and accelerating structures. The main objectives of the project are to investigate high-power radio frequency phenomenon and to develop different manufacturing techniques, as well as, design and test structures experimentally. (Uusimäki 2009, 58.)

The project consists of nearly fifty team members, the permanent staff, and scientists from long term and temporary collaboration institutes. Team members are mainly engineers and physicists. The project is managed by two project leaders and assisted by few additional managers of the project. All significant decisions are always made in CLIC RF structure development meeting kept once a week. The meeting gives possibility for formal project monitoring as otherwise, communication between project managers and team members happens in informal small meetings. (Uusimäki 2009, 59.)

CLIC Structure Production

The MTF implementation project was initiated by CLIC Structure Production team. The CLIC RF Structure Development project's CLIC structure production team is responsible for accelerating structures, PETS and RF components development and production. The team takes care of mechanical design control, quality control, manufacturing, test and measurement processes in a collaboration with international scientific and manufacturing organizations. Its main tasks include testing different manufacturing techniques and definition of manufacturing workflows as well as, their follow-up.

The team has several dedicated programs of the components testing procedures which are performed in different testing facilities. The CLIC Structure Production team consists of nearly thirty members who are mainly engineers, physicists, technicians and data maintaining systems administrators, who gather together once a week. The main objective of the team activities is to prepare high-quality components for future industrialization and the mass production phase of the CLIC project. However, it is important to underline that CLIC is not at that wide production level as LHC project. CLIC is having at the moment small serial production, but the earlier it will set up product life cycle management system, the easier it will be to face the mass production phase.

3.2.2 Data Management in CLIC RF Structure Development

The mechanical design of RF components, accelerating structures and PETS in CLIC RF Structure Development project is carried out using the CERN wide 3D CAD (Computer-Aided Design) system CATIA (Computer Aided Three-dimensional Interactive Application) by Dassault Systems, integrated with commercial system SmarTeam PDM system. All the drawings are then archived in CDD (CERN Drawing Directory) database for approval, and can be seen for users without CATIA/Smarteam access with the help of CERN HP-GL viewer. SmarTeam as a product data management system helps to manage and store complex data of CATIA. The SmarTeam identify equipments and defines BOMs (Bill of Materials), the list of components.

EDMS is CERN's integrated Product Life Cycle Management (PLM) platform, which consists of multiple integrated applications and several commercial systems. CERN's long product life cycles of the installations demands reliable data archiving system for changes follow-up during long period of time, as one generation designs and builds accelerators and next one operates and maintains them. In addition, regulations demands strict traceability control over CERN equipments as such LHC is defined as a nuclear installation and documentation of procedures is compulsory. EDMS has at the moment (June 2010) approximately 1 100 000 uploaded documents as well as, 6 400 active users, and every month it has 6 300 new documents and 4 500 new equipments. (Garcia Carnero 2010.)

The Engineering and Equipment Data Management System (EDMS) has been in use by CLIC since 2007, in the beginning for technical data management, and information flow between team and project members, collaboration organizations and suppliers. The implementation started when the CLIC project was in the transaction phase from R&D towards project-oriented. CLIC structures have been implemented to the system at one go, as there has not been before any similar data management system, and they didn't asked EDMS support for any radical modifications of the system. (Ridonne 2010.)

The project structure definition was done in 2008 by respect of the EDMS quality assurance, examples of previous projects, existing CLIC structures and organization charts. The implementations started by importing the existing data to the system, and for efficient data management standard templates for reports and parameters of technical specifications were created. The implementation of EDMS was not performed at the same time by all CLIC projects, but when the CLIC RF Structure Development project started the implementation of EDMS it was already in use in several CLIC projects. (Riddone 2009c.)

The implementation of EDMS in the CLIC project started the process of systems and applications integration to enable the whole product life cycle management of equipments and components. In 2009 the implementation of MTF (Manufacturing and Test Folder) web application was started for manufacturing and test follow-up of RF structures and components. The same year systems for inventory and financial management were implemented. In Figure 8 shows PLM platform at CERN, initially developed for LHC installations' data management. As this PLM platform has been already used by the worldwide known project and results have been rather successful, it gives more confidence for the other CERN projects to choose something already tested at CERN, than to start to develop something own or get some products from the large market of a different type's information systems, which probably can't be integrated with the CERN systems.

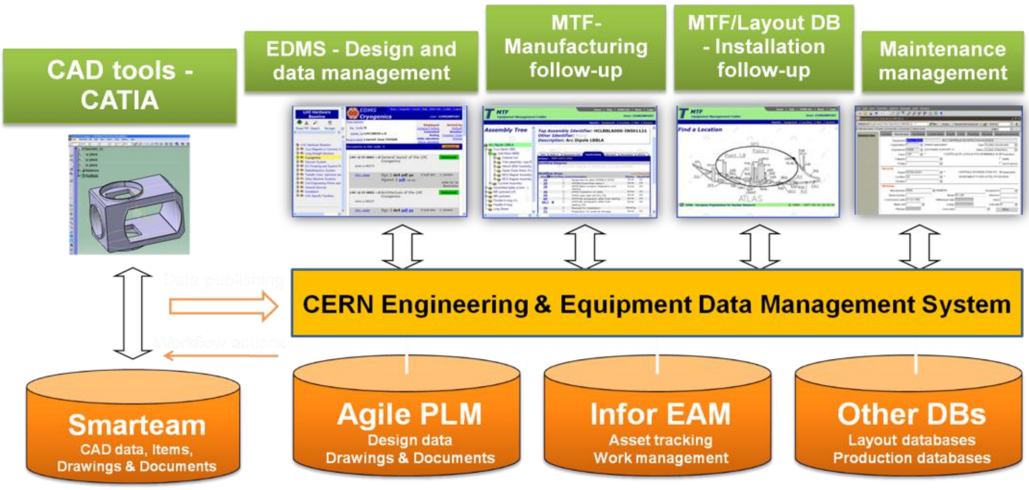

Figure 8: PLM platform in CERN (Garcia Carnero 2010, 17)

As the EDMS common layer provides a unique service of systems' and applications' integrations, well performed trainings and support as well as, development of systems based on the consumer's needs and requirements, it is widely used in CERN even though sometimes just partially. CERN doesn't have its own department of a quality assurance, which will approve the quality of performed manufacturing procedures, and the documentation related to them. However, there is a group of quality assurance which defines quality assurance standards for LHC, and on which both EDMS and MTF systems have been based. CLIC is also following the same quality assurance regulations.

The CLIC project is in the transaction phase from conceptual design and R&D to the project-oriented mass industrialization and, now is the best time to set up the product life cycle management tools, as different data management needs are defined. LHC project's PLM experience is a great example for CLIC and so far it has been following the product life cycle data management standards of LHC even though, some independent systems in use have not been yet integrated with the PLM platform as, they have been decided to keep separately.

Data distribution in the supply chain

CLIC RF Structure Development project has two main supplier types. The first one is material providers, who are also taking care of transportation. Manufacturers who build structures or components with the help of drawings produced at CERN are the main suppliers, selected with the highest criteria. Quality standards, equipments, price and experience of manufacturer are the key factors when choosing the right supplier. Some steps of the manufacturing workflow like the cleaning procedures can be done using CERN services. The collaboration partners have a significant role in the equipment development thus shipments of components or whole structures to both directions are very common.

As CLIC RF Structure Development project has huge amount of suppliers in the globally distributed environment, the web-based product life cycle system is compulsory for information integration and tracking capabilities. Before the MTF implementation all the production documentation was stored in EDMS which was the main data distribution tool. The created external CERN account gives automatically EDMS access for the suppliers and collaboration partners. Some folders or documents can be strictly controlled with context access. The context can be restricted by department, group or specific team for example budget documents have usually sensitive data which can't be available for everyone. As MTF is for more advanced users, access has to be asked from EDMS support, but usually there is no problem to get one. The main principle of EDMS platform is however, open access for all users. Too strict access control will make it too heavy and complicated, and can possibly lead to the user's unwillingness to use the system. E-mailing by using step file methods is also one of the basic data distribution ways of CLIC RF Structure Development group.

4 Implementation of Manufacturing and Test Folder (MTF)

4.1 Research interviews

The comparison analysis of MTF implementation experiences of different CERN projects is based on interviews performed at CERN during November 2010. Analysis includes also the implementation experience of CLIC RF Structure Development project. The purpose of the interviews was to define how the implementation of MTF and its integration with other systems affects on the manufacturing operations management in the internal and external level as well as, how it facilitates product life cycle data management throughout the whole supply chain. Overall, to see what kind of MTF implementation process experience other CERN projects had, which will help to define the usefulness of the application. For reliable results were interviewed three current key users of MTF recommended by EDMS support, and the project manager of MTF implementation in CLIC RF Structure Development project. It has been decided that interviewees will be kept anonymous.

The content of the structured open questions interview had been regarding the MTF application implementation as well as, its integration with EDMS database or other applications. The key questions were about inventory management, product life cycle management, equipment tracking, and the technical features of application and experience of implementation process (Appendix 3). During some interviews additional questions were asked which helped the interviewees give more detailed answers.

Questions had been defined in advance and tested with the help of the system manager working for Version Control Systems team in CERN IT department. Furthermore, questions were sent in advance for approval, to ensure that everyone accepts them as they are, and see them to be important for the research. None of the questions were modified or asked to be removed. The length of interviews varies from one hour to two hours. All the interviews were recorded, but only for the personal use, to facilitate analysis of interviews.

The interviewee 1 is working in the Beams department in the Beam Instrumentation group for LHC Beam Loss project. He couldn't do face to face interview but kindly sent on 25th November 2010 a small presentation about his group's MTF experience based on interview's questions. Their implementation started in 2006, the same year when the BLM (Beam Loss Monitor) project was launched. The main reasons for the implementation were manufacturing and testing data management, but later reasons have been expanded.

The second interview was done on 4th November 2010. The interviewee 2 was one of the first clients of MTF application. He is currently working in the technology department for magnets, superconductors and cryostats (MSC) group. He is following LHC activities as a magnet expert, and taking part in R&D of CLIC magnets. Previously he was working in same department but as a technical coordinator of LHC dipole and quadrupole procurements, and for this activity he became an active user of EDMS and MTF. Having almost ten years experience of MTF he saw the development of the system, and was even an active participant of the development.

The interviewee 3 is working as an electronics engineer in the technology department for LHC cryogenics instrumentation group (CRG) which is responsible for design, manufacturing, installation, operations, commissioning and maintenance of the cryogenic systems in LHC and its detectors. He is working with electronics for cryogenics instrumentation, with the system of 10 000 electronic cards and 10 different models of them installed in crates all around LHC machine. The initial aim to implement MTF in 2007 was to provide stable data to the manufacturer through a database. Moreover, they wanted to archive the manufacturer's test results in some database to be able to compare results over time because equipments will be subjected to the radiation. For them product life cycle follow-up is important, as when the test results start to drift and the equipment fails the replacement and maintenance are compulsory. Later they started to use MTF also for the inventory management. The interview with interviewee 3 was done on 5th November 2010.

The fourth interview performed on 11th November 2010 was with the CLIC RF Structure Development MTF implementation project manager. The interviewee 4 is working in the BE (Beams) department in RF (Radio Frequency) group and SR (Synchrotrons) section as a leader of the CLIC X-band RF structure production and Two-Beam Module (TBM) project. The main aim of MTF implementation for CLIC RF Structure Development was the manufacturing and test procedures follow-up.

4.2 Determination of need and objectives of implementation

CLIC structure production collaboration has been well documented since the beginning of the project. All manufacturing and test procedures have been documented and stored in the EDMS database, but with the continuously growing amount of structures the archiving of production data in EDMS became complicated and inadequate. The manufacturing follow-up in EDMS is possible, but for this need LHC project used MTF (Manufacturing and Test Folder) web application which is fully integrated with the EDMS database. MTF is lighter system specified in the manufacturing phase of the product life cycle. However, the purpose of the application usage varies, depending on the users' needs. Since the beginning of MTF usage at CERN the application version has not been frozen. Continual development expanded MTF service to inventory management, installations follow-up and the maintenance control.

CLIC RF Structure Development was first CLIC project which decided to implement MTF for the structure production data purposes, to trace all manufacturing steps from engineering design to the testing. The main objective of the implementation was to provide for own employees, collaboration partners and suppliers easier way of manufacturing data distribution. EDMS database was too heavy, and didn't provide tracking capabilities of physically existing equipments. The tight integration of systems was done to make operations management and product life cycle management more effective.

LHC is defined as radioactive installation, consequently the equipment's product life cycle documentation and manufacturing procedures' as well as, tests results' long term archiving is compulsory for all LHC subprojects. Regulations demand strict follow-up of changes in equipments for the further replacements, maintenance and disposal. The approaching phase of magnets mass production determined need of equipment tracking tool in the case of interviewee 2. They have been facing different procurement phases which demanded a tool for the production follow-up, including test reports archiving. The old way to track manufacturing operations, with the help of paper document called "traveler" filled by manufacturer after every procedure, has been found not future-oriented, as the number of pieces of paper made impractical if not impossible to find one specific document.

In the case of interviewee 3, the MTF implementation culture has been already established in the group, as there has been done before implementations by other teams. The team of interviewee 3 knew that they will need a tool for tracking manufacturing procedures. Since, the team is quite small, but has a lot of equipments they wanted to have a tool which will help to manage manufacturing operations.

The reasons for MTF implementation in the case of interviewee 1 were in the beginning as also manufacturing and test data management. However, later their reasons have been expanded for systems integration. They integrated MTF with Layout database for installations follow-up and with BLM (Beam Loss Monitor) system which is intended to detect beam losses at the LHC machine. Recently they started to use MTF for LHC BWS (beam wire scanner) project.

4.3 Implementation steps

According to the experience of Gonzalo Penacoba Fernandez (2010), implementation of MTF can be done in three steps. Logistics usage he defines as a first phase of MTF implementation. Performance and operations usage he recommends for more advanced users. (Penacoba Fernandez 2010.)

4.3.1 Logistics usage

Inventory management always demands the equipment identification which should be based for all LHC projects on LHC naming convention for the hardware commissioning. The LHC naming convention guidelines should be adopted to own equipments identification standards. Next steps for inventory management will be own inventory performance and preparation of serial numbers for bar-code system. MTF provides capabilities to track equipments by their status, operational state, physical location and maintenance job. Moreover, easy data import and automatic notification system of the MTF facilitates communication. (Penacoba Fernandez 2010.)

However, in the case of CLIC RF Structure Development project the primary object on MTF usage was not inventory management. The preliminary equipment identification has been done before MTF implementation, and MTF implementation was indented in first place for manufacturing operations results tracking and archiving purposes. MTF system’s inventory management capabilities have been understood much later, and they are still not fully in use. However, according to interviews it is possible to have only one system for inventory management, which as well combines manufacturing operations, test results tracking and archiving services.

4.3.2 Performance usage

The MTF provides unique service of property values' drifts tracking, to see how equipment has degraded during the years. Penacoba Fernandez (2010) mentions, to have possibility to follow parameters changes, the definition of parameters have to be done before the manufacturing phase. Thus, the implementation of MTF has to start before the manufacturing operations. For LHC project follow-up of parameters' is important for each equipment type, as systematic evaluation is compulsory after repairs and shutdowns of the machine. (Penacoba Fernandez 2010.)

In the case of CLIC RF Structure Development project property values have not been yet defined, but this is because project is still in the conceptual design phase and installations have been performed only in test facilities thus, most of the equipments do not have any environmental impact. However as most of the equipments are tested will be advisable to define temporary property values. Property values show detailed information of equipment including summary of all test results.

4.3.3 Operations usage

Operations usage in Pencoba Fernandez (2010) point of view is the last step of MTF implementation. Operations usage is for more advanced users, whose project has gone already long way. Operations usage demands MTF integration with other systems, for the automatic generation of data. The operation usage phase is focused more on equipment's functions performance. There is even a possibility to integrate MTF with the LHC control application PVSS (Prozessvisualisierungs- und Steuerungs-System) through Layout DB. (Penacoba Fernandez 2010.)

4.4 Features and functions of MTF

According to interviews, the main two strength features of the application are manufacturing and test data management, and the secondary features have been defined as the inventory management, traceability of equipment, workflow management and maintenance follow-up. Interviewee 3 describes, that besides the manufacturing follow-up and test results archiving they started to use MTF as the main tool for intensive inventory management. MTF locates physically all equipments, shows status of the equipment which can be for example installed, under maintenance in workshop or in the storage area. Moreover, MTF gives tracking capabilities by showing the current location of equipment as well as the history of previous locations. For maintenance and quality assurance the status history feature provides data of environment impact on the equipment. Furthermore, track of repairs gives indication of failure expectations. All these inventory management features have not been seen by the team in the beginning, but they became fundamental requirements over time. From interviewee 3 point of view, the key advantages of the MTF application are that it is web application, accessible for all members involved in the different product life cycle phases, and it is one single source of information for the whole team. MTF is considered by them as a tool on which they can completely rely on, as it is always up to date.

In the case of interviewee 3, the MTF is used as a product life cycle management system, by principle of CERN EDMS common layer's systems integration. All the data of equipment is managed through MTF, which is integrated with several other systems, including main engineering data management system, EDMS. In Figure 9 is shown CERN EDMS product life cycle, which consist of several systems and applications provided for CERN users to manage different phases of product life cycle. It is an interface through which is easy to navigate to any phase of equipment's product life cycle. However, EDMS PLM platform is a set of integrated systems, and not one single system.

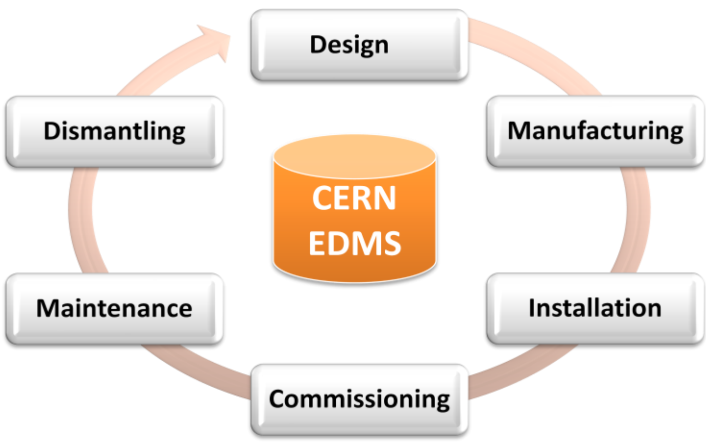

Figure 9: Product life cycle at CERN (Widegren 2009, 2)

According to interviewee 4, for CLIC EDMS PLM platform implementation gives the possibility to integrate applications towards more efficient product life cycle management. The EDMS integration with the SmarTeam PDM system made possible for CLIC RF Structure Development to follow product life cycle already from the engineering design phase, and workflow function of the MTF system gives possibility to follow life cycle of the manufacturing processes.

However, during the MTF implementation process in the CLIC RF Structure Development project it has been noticed that the equipment tracking and inventory management is possible only until certain level of equipments. Small components which are produced in batches like screws is difficult to identify and define which one corresponds equipment created at MTF, as CLIC RF Structure is not yet using bar-code system. For the inventory management of smaller components CLIC RF Structure Development project decided to create its own system based on Microsoft Access. However, interviewee 2 and 3 mentioned that they are also tracking equipments in MTF until certain level, too small components they group in batches which can be easily tracked in MTF.

Another difficulty noticed by the CLIC RF Structure Development project was concerning assembly trees in MTF. Accelerating structures designed by CLIC RF Structure Development project have usually several levels of parent-child relationships thus, a lot of subassemblies and components. Manufacturing reports concerning the whole accelerating structure are always attached to the main top assembly. However, sometimes some measurement can be performed specifically to one component belonging to the structure. In MTF there is no possibility to see from the assembly tree if any documents have been attached to the components, and this makes data tracking of smaller components difficult.

4.4.1 Workflow steps

In MTF the list of manufacturing operations performed by supplier or as in the case of CLIC Structure Development project, partially at CERN is named as a list workflow steps. By all interviewees workflow steps function has been found useful for efficient manufacturing operations management. In the case of the CLIC RF Structure Development project workflows have been defined with the help of existing manufacturing and assembly procedures. For MTF have been defined three different workflow types for accelerating structures (Appendix 4), PETS (Appendix 5) and RF components.

The MTF is also providing function of workflow diagram which shows the whole manufacturing process in diagram. A workflow diagram is as a description of manufacturing process which helps to analyze done operations. Step reports of performed manufacturing operations attached to the workflow steps facilitate tracking necessities. Extra step function which allows adding steps between any workflow steps is useful when having additional operations which are not defined as standard workflow steps. Interviewee 2 describes, it as easy way to repeat a step, to be more flexible, and not to contact EDMS support every time you have unexpected operations. This as well prevents continual changes of the standardized workflow template.

According to interviewee 1, the definition of workflow steps can be difficult if the team did not have in advance any work breakdown structures or existing procedures, because the definition of workflow has to start then from zero. Interviewee 2 also says that MTF is seen as an archiving system, than database because it is impossible to search and retrieve results from the attached documents in manufacturing workflow steps. System is having limitations for searching measurement results which are inside the documents, as it provides only list of test result files. For this need they decided to create their own lighter system dedicated for sensitive data of the test results.

In the case of interviewee 3, the workflow steps of manufacturing procedures have been defined during the MTF implementation based on tracking needs. The first step of manufacturing workflow is accepting manufacturing test results. If electronic cards don't pass the manufacturing results they will not be registered in to the system. The two following steps contain information of shipping and arrival inspection performed at CERN during which engineers submit that equipment did not get any damages during the transportation. Next steps contain information of measurements performed at CERN, not accepted equipments can be sent back to the manufacturer. The accepted equipments will be installed in to the machine or kept as spares. Installed equipments will be connected to the system which will record their performance.

Since, now equipments have received radiation from particles during the period when LHC machine has been on, interviewee 3 mentions that removed equipments that are going for commissioning procedures has to pass the radiation protection control. Technicians can't just remove equipment from the tunnel and bring it to the laboratory. Thus, the rule for them is that removed equipment by technician has to be dropped to the special zone at each surface point of the tunnel, and inform radiation protection team about it. In the beginning only one call to radiation protection team was enough to make them come and measure radiation of equipment. However, a huge amount of equipments forced interviewee 3's team to change the way of communication.

They made an agreement with radiation protection people to use MTF for radiation control follow-up. In addition to predefined workflow steps, MTF provides operations tab through which can be created so called "jobs". Job can be defined each time when there is a need for unexpected work. The team of interviewee 3 started to use operations function for radiation control. Every time when equipment has been removed from the tunnel and placed to the so called "buffer zone", technicians created a job in MTF which automatically sent a notification letter for radiation protection people. The results of radiation measurement are then uploaded to the system by the person who performed the control. Moreover, uploaded results of measurement create notification which contains information of the equipment's radiation condition. The radiation classification statement shown in MTF is also useful in cases when equipments are given to measurements which are performed by other teams at CERN. They can get independently through MTF, a statement of radiation measurement which shows if it is safe to handle equipment. In the case of interviewee 3, operations function is also used for repair operations follow-up. Every time there is a need for repair of certain equipment, the information will be given for the technicians through MTF system.

4.4.2 Notification letter

The notification letter system is widely used by EDMS users, as it makes data distribution more efficient. CLIC RF Structure Development group uses it for receiving data of newly created documents. The team receives once a day an automatic letter from EDMS showing the list of new documents in the system with details of owner and type of document. MTF application has same notification system which updates every hour. CLIC RF Structure Development group has been planning to implement MTF notification letter under same requirements as in EDMS. New documents attached to workflow steps in MTF will be listed in notification letter and sent to CLIC Structure Production team members once a day. It is as well recommended to implement notification letter for closing workflow step purposes, as then people can better follow equipments' progress of manufacturing operations. Not to overload people's mailboxes, notification letter can be sent once a week.

Team of interviewee 3 uses MTF notification letter for non-conformity cases, for example when equipment fails and is diagnosed as a broken, to inform others about repair procedure, technicians write in EDMS non-conformity report with all details of broken equipment. The generated non-conformity notification letter for team members is written in a document which is then attached to the MTF.

4.4.3 BAR-code system

In the experience of interviewee 1, 2 and 3 the bar-code system is essential part of efficient inventory management. Interviewee 3 mentions, that all their electronic cards are labeled with 2D bar-code sticker on the top, to be able to scan information when equipment is already installed in the tunnel, and with 1D dimensional bar-code sticker on the side. Both bar-codes have same serial number. Since, in the tunnel light is not always good, there is a lot of noise, as well as human factor can affect negatively on notes taking. Bar-code system allows data scanning with the help of small bar-code reader, which can be easily carried in the pocket. Thus, bar-code system reduces effectively number of mistakes, as 19 digits code can be easily written incorrectly.

In the experience of interviewee 2, the MTF bar-code system has been used in context of inventory management only for final assemblies, and big components. Bar-codes facilitated work of transportation and installation of equipments in to the tunnel, as during the installation phase people worked under pressure and could make mistakes for example when loading equipments in to the truck for transportation.

4.5 MTF integration with other systems

There is a strict balance between the data recovered at CERN. In the case of CLIC, drawing data produced at CATIA system is stored at Smarteam PDM and CDD (CERN Drawing Directory) databases. The main engineering data and additional information associated with equipment is stored in EDMS. Project breakdown structures, seen in EDMS as a folder structures are used by CLIC for general engineering documentation including technical specifications, test results, drawings and physical parameters of equipment as well as, for quality assurance, project managerial and collaboration purposes (Figure 10). EDMS is fully accessible for CLIC suppliers and at the moment it is the main engineering data management system. However, team of interviewee 3 use EDMS more for internal technical documentation purposes. EDMS has been implemented by them in 2004 and since then it is their main data sharing tool. Interviewee 3 emphasizes, that released document in EDMS is “like the Bible, everybody has to follow it.”

PBS (Project breakdown) in EDMS	ABS (Assembly breakdown) in EDMS	AS-built(MTF)
Engineering documentation	Assembly structure	Documentation of manufacturing processes
Technical documentation	Physical parameters	“Where installed” information
Drawing of RF structures and components	Assemly drawings	Production reports
Physical parameters		Test results
Management reports (collaborations)		Reports of manufacturing procedures
Quality assurance documentation		Inventory management
Test and measurement reports		
Technical specifications		

Figure 10: CLIC documentation in breakdown structures

Assembly breakdown structures in EDMS are intended especially for items. They facilitate equipment data management by providing easier data retrieving method. As example, drawing of structure components can be stored in project breakdown file called “drawings” where will be list of attached drawing documents. While in assembly breakdown structure as shows Figure 11, drawings can be attached to the corresponding components. Documents related to the certain components or whole structure can be attached straight to the assembly structure. Consequently, when opening assembly breakdown of certain structure it shows all document related to it, and you don’t have to go separately to folders of different procedures.

As David Widegren (2009) describes, the once created item “becomes the carrier of information and point of navigation throughout all the different project phases and different information systems used at CERN” (Widegren 2009, 4). Data providing only inventory, manufacturing and test workflow information is stored at MTF. However, MTF should be used only for physically existing equipments. Thus, while equipment is under design phase, data associated with equipment should be stored only at EDMS.

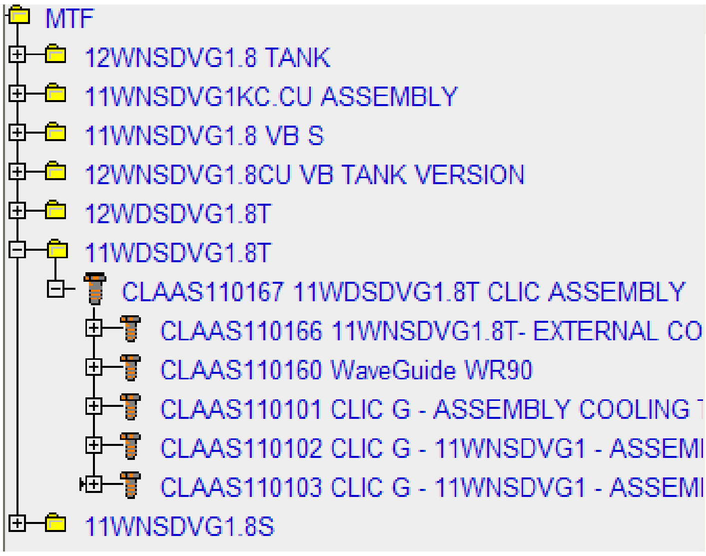

Figure 11: Assembly breakdown structure of CLIC RF Structure Development (Saifoulina 2009, 23)

4.5.1 EDMS assembly breakdown

To facilitate equipment tracking EDMS support created new integration function between EDMS and MTF which was dedicated especially for manufacturing purposes. There is possibility in MTF to attach file to the manufacturing workflow steps from EDMS database or create new file through EDMS which then attach to MTF. Both systems have links to each other but, links transfer always to the main page. This is unpractical from equipment searching point of view. When searching assemblies through MTF you need to remember identifiers or at least machine and equipment code. The MTF assembly identifiers are based on quality assurance definition of LHC part identification (Figure 12). Standard 19 digits of assembly identifiers are creating problems for CLIC equipments, as only standard part numbers are having eleven or twelve digits (Figure 13).

The most problematic are the external codes provided by the collaboration partners. Their codes are usually very long and the context of digits is unknown. In this kind of situations the equipment codes are changed using equipment identification standards of CLIC. Most of the created items codes in EDMS/MTF are based on drawings equipment identification. Those codes also have twelve digits, and cause the same problems. EDMS and MTF can't handle over eleven digits part number codes, which cause codes modifications during the data import performed by local administrators and EDMS support. Every time a third digit is removed from machine code and in non-standard codes always the same third digit. Based on the systems limitations the current equipment identification was found inadequate. However, interviewee 2 mentioned having the same difficulties with too long codes, which they solved as well by removing one digit form the machine code. Thus, the problem is in system itself not in the naming convention defined by LHC project.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
MACHINE CODE		EQUIPMENT CODE					SEQ. NUMBER			SEPARATOR	PRODUCTION SITE		SEQUENTIAL NUMBER					
PREFIX CONTROLLED BY CERN							CONTROLLED BY SUPPLIER OR CERN			-	CONTROLLED BY CERN		CONTROLLED BY SUPPLIER					
PART NUMBER										-	SERIAL NUMBER							
H	C	M	C	S	M	E	0	0	1	-	A	A	0	0	0	0	0	1

Figure 12: LHC part identifiers (Costa 2008, 35)

C	S	T	3	0	H	D	S	1	1	L	_	T	i	-	I	M	0	0	1

Figure 13: CLIC equipment identifier (CLIC project - EDMS/MTF 2007)

The integration function created especially for CLIC RF Structure Development makes it possible that MTF users do not have to remember equipment identifiers by heart, as well as all the codes modifications. The EDMS assembly breakdown structure created through lower level system, Agile PLM by local administrator as well as, link between EDMS and MTF created by EDMS support integrates systems more effectively. The link between EDMS and MTF is in terms of equipment versions created for cases of mass production of the same equipment (Appendix 6).

The assembly breakdown in EDMS looks visually similar to the equipment structure in MTF (Figure 14). However, the CLIC RF Structure Development project has in EDMS assembly breakdown at the moment only 2D drawings of every component. Reports of manufacturing procedures are stored in the top assembly of MTF equipment structure. It is recommendable to attach any documents related to the equipment life cycle in to the EDMS assembly breakdown structure, not of course including reports of manufacturing phase that should belong only to MTF.

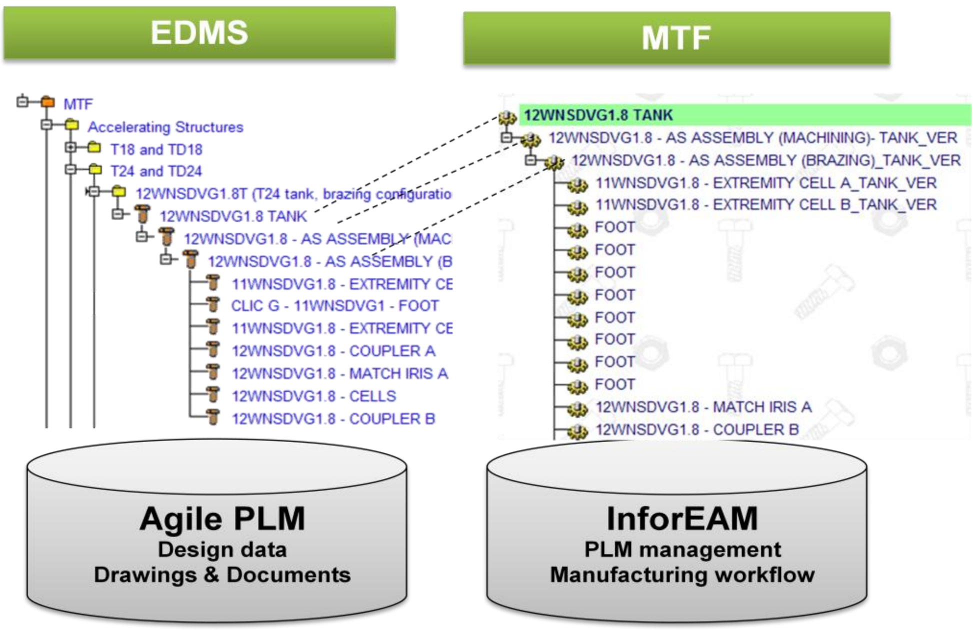

Figure 14: EDMS and MTF integration (Filippova & Saifoulina 2010, 4)

4.5.2 Layout Database

The MTF features provide support for the installation procedures of LHC machine. The MTF records the information provided by the Layout database of installed equipments, and equipments that will be installed in a given slot. At the given slot are also seen executed procedures. Originally, the procedure of non-conformities tracking in the installation context was elaborated from the manufacturing context. Since, there is no fast network connection in the LHC tunnel, the EDMS service is preparing offline MTF, which will allow data collecting of executed operations by packaging all measurement results into a single file. Collected data at the end of the day will be compressed and sent for EDMS Import procedure. The next day the data will be already available for monitoring the progress of installation. (Mallon Amerigo & Manola-Poggioli 2004, 4.)

According to interviewee 3, the MTF integration with Layout DB contributes product life cycle management. The functional position defined for equipment is shown in MTF by link to Layout DB, which showing the role of equipment in other words, the mission of equipment's life cycle. Layout DB is showing position of equipment and measurements it is doing. Furthermore, there are equipments marked as a redundant or spare in case the main equipment breaks. When the machine is on, equipments can't be removed, that is why there are always spare pieces installed in the machine.

4.5.3 MTF identity card

The MTF application has been developed so, that it can extract data in terms of non-conformities and ID card reports. ID card system extracts different types of measurement reports from several systems by compressing and summarizing data in one single file which can be seen through MTF.

Interviewee 2 mentions, that the MTF identity card was created by EDMS support for their magnet evaluation board committee which is responsible for magnet performance quality. In MTF the last step of the magnet's manufacturing workflow is dedicated to the magnet quality evaluation. Especially for this case created MTF ID card, extracts data of major assemblies and subcomponents from several databases, including data from MTF. The file which is part of MTF helps committee to have data of magnet performance in one single file which generated data automatically.

4.5.4 Information System for Radioactive Materials

According to the Swiss radioactive waste regulatory authorities, decommissioning wastes from large nuclear research facilities like CERN should be characterized by application with sophisticated identifier codes which will help to calculate inventories after activation of materials. Waste documentation has to contain waste package type specification, which describes waste procedures like manufacturing procedures and the quality control program. To support waste control has been developed network-enabled Information System for Radioactive Materials (ISRAM), which has been implemented at CERN in the early 90's. The system has been supplemented by tracking capabilities of waste, from its production to the final storage. (Kolbe, Maxeiner & Schweingruber 2002, 175-182.)

According to David Widegren (2010), the CERN EDMS service provides a complete product life cycle follow- up (Figure 15). All the data related to manufacturing of equipment is physically stored and managed in the lower level system InforEAM. Registered equipments at InforEAM can get benefits of the maintenance and dismantling functionalities. Widegren (2010) as well mentioned in a seminar of ongoing activities in the CERN Vacuum, Surfaces and Coatings (VSC) group kept in 12th of November 2010 that integration between MTF and ISRAM is possible. (Widegren 2010, 11.) However, none of the interviewees mentioned that they are using ISRAM when asked about other systems integration with MTF.

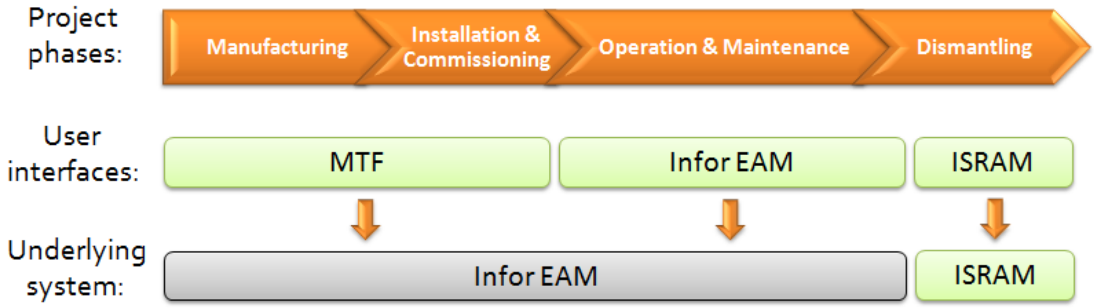

Figure 15: A complete equipment lifecycle follow-up (Widegren 2010, 11)

4.6 Import process

In the case of interviewee 3, a database engineer inside the section defines and creates data in MTF and Layout DB in collaboration with EDMS as well as, with the Layout people. Created equipment, which is linked to the Layout DB, is then fully in use by technicians and engineers of the team. To do import of manufacturing results provided by manufacturer they are using import template in other words transfer file provided by EDMS support. Transfer file helps to do data exchange between manufacturer and CERN.

In the case of interviewee 2, the plans of mass production forced them to automate as fast as possible their own data import procedures including the format standardization of the technical specification and transfer files. They didn't want to have any manual operations to avoid making any human factor mistakes. Test bench machine which extracts test results was designed and manufactured with the objective that it will import data to the MTF. Machine generates one Microsoft Excel file per card, after Excel files of all cards are converted to the one single file and sent to MTF for import. The development of automated procedures was a parallel effort; on one side there was a database engineer developing macro compressing system for transfer file as well as, doing database definition in other words the layout and preparing information for the manufacturing, and another person was meanwhile integrating the test bench machine with the MTF system. One of the test benches has been also sent to the manufacturer, them to do tests of electronic cards under the manufacturing preparation, and then send results to CERN for MTF importing.

However, according to interviewee 3, the transfer file technique is not always efficient and flexible. For them small error can cause failing of the whole import, for example when importing data of 2 000 electronic cards the error in one of the compressed files can crash the whole import, which consequently has to be repeated. The another problematic issues was with the measurements listed in transfer file, as at the one point they noticed that one measurement property is missing from the list, and they created the second version of the template file with the help of EDMS support. However, it didn't solve all problems on the contrary it caused more difficulties, as they had from time to time contradictions to choose the right file. Moreover, one of the engineers decided that he will need additional information of one measurement and asked document version one to be modified, thus the new step which was in version two was missing from version three. Even though, the problem was that EDMS support did not expect them to change requirements of transfer file, interviewee 3 describes this case as their own mistake.

In the case of CLIC RF Structure Development project, the import process should be done with the help of SmarTeam system. Based on CAD structure SmarTeam system should create Bill of Material (BOM), the Microsoft Excel transfer file, which shows assembly structure and quantities of components. With the help of the BOM file, EDMS assembly breakdown structure should be created through lower level system Agile PLM system, and after when BOM file will be imported to the InforEAM, to the lower level system of MTF (Figure 16). However, according to engineers of the CLIC RF Structure Development project, BOM file created by Smarteam is not showing all parent/child relationships of components thus, it can't be used for data import.

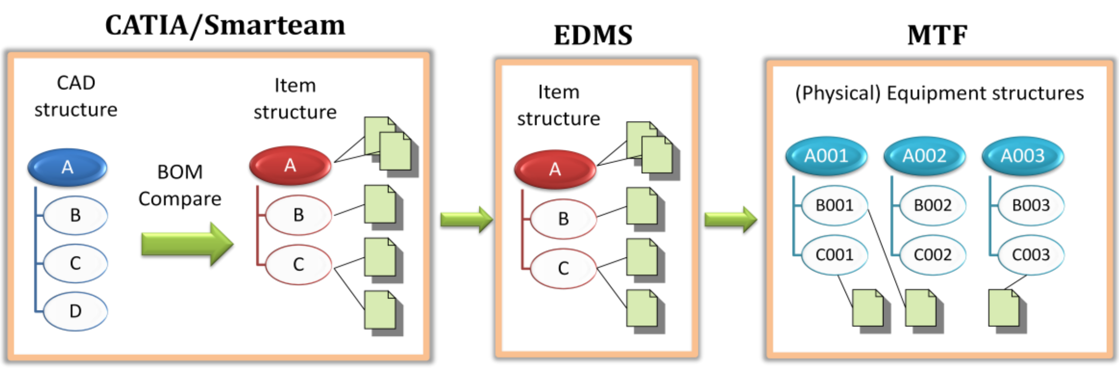

Figure 16: Import process in CLIC RF Structure Development (Widegren 2009, 8)

Consequently data import is done manually by filling the Microsoft Excel transfer file with the help of assemblies' project structures and drawings. The whole import process is seen in Figure 17. The manual import has been found inadequate and the main source of mistakes occurred during the import process. Moreover, manual template filling takes a lot of time. Interviewee 4 mentions, that this process has to be finalized, as at the moment data import is not efficient. It is just not working as it should be, but once it starts working it will standardize the import process.

	Workflow steps of import process
1.	Item structure - BOM Microsoft Excel worksheet creation for import
2.	Item creation in EDMS through lower level system Agile PLM or straight in EDMS
3.	Creation of equipment in MTF through lower level system InforEAM
3.1	Creation of assembly identifiers in InforEAM
3.2	Creation categories and parent-child relationships of equipments in InforEAM
3.3	Creation of workflow steps in InforEAM
4.	Attaching assembly drawings to structure in EDMS, extracted from Smarteam PDM system
5.	Data management in MTF

Figure 17: Workflow steps of import process

4.7 Users and local administrators

Local administrators, database engineers have responsibility to represent their project when collaborating with EDMS support. Local administrators have wider access to the database and they also instructed how to manage lower level systems of EDMS and MTF. They create breakdown structures and take care of document management which includes control over different release processes of documents. The CLIC project has five local administrators and its subproject CLIC RF Structure Development only two, one is taking care of project breakdown structures and documentation management, and another only of assembly breakdown structures linked to the MTF application. Person who is taking care of assembly breakdown is as well local administrator of MTF application.

End-users of EDMS in CLIC RF Structure Development are project managers, mechanical engineers, technicians and physicists who use the database for information exchange and distribution as well as, for archiving purposes. Access of every user is strictly controlled, and document creation and modification rights are depending on the user's project context properties. Before any document is released it has to pass through different approval stages and has to be signed by different specialists. This method provides security and quality assurance of the engineering data management.

Interviewee 4 mentions, as one of the MTF implementation's difficulties was to motivate people using the system on their daily basis, as implementation requires changes in their work. Manufacturing operations follow-up demands from all participating entities well prepared reports as well as, their uploading to the system. People saw it in the beginning as an extra work, which takes a lot of time. However, it took a while for them to understand that as they are going towards the project-oriented phase the implementation is compulsory, and at the end it will facilitate their work.

The implementation of MTF demands to convince people to use the system. To motivate people, project management has to introduce system step by step. According to interviews, in the beginning of implementation process it is important to provide for team members seminars which introduce how to use system. People are also interested to know who already used the system and how. Interviewee 3 describes, that everybody knew that MTF implementation will give them a lot of work, but they understood that the implementation will be compulsory. The most difficult was to convince technicians who have been installing manufactured cards in to the tunnel, to use MTF after every operation in the tunnel. Consequently, in the beginning tracking of operations in the tunnel was performed poorly. Equipments have been indentified and they knew where equipments are at certain time, but to get information if they are already installed in the tunnel was more difficult. The pressure of the installation phase complicated the technicians work, but once it was over they understood how important it is to have a database up to date, and how much it helps them to do their work. During the operating and commissioning phases the tracking of operations improved significantly.

4.8 Support and trainings

In the beginning of MTF implementation in CLIC RF Structure Development group small meetings have been provided by EDMS support. Trainings have been organized only for local administrators, who later presented for the group how to use MTF as an end-user. CLIC RF Structure Development group had in total three seminars regarding MTF usage, the last one was more about progress of MTF implementation. There has been continual development of MTF administration during whole implementation process. Data import, workflow steps and identifier modifications have been always supported by the EDMS team. However, as interviewee 4 mentions, user-friendliness of systems makes system easy to use and trainings are not always compulsory. Additionally, EDMS support provides user instructions which are easy to find in EDMS database.

In the case of interviewee 3, they had seminars for engineers provided my EDMS support. Once they started the MTF implementation process, EDMS support has been providing support every time when needed. For the electrical technicians they didn’t provide any seminars, but as a good alternative they wrote very detailed document which demonstrated how to update information in the MTF after performed operations in the field.

In the case of interviewee 2, the technicians have been travelling to the industry for educating suppliers how to use the system. As team of interviewee 2 was one of the first users of MTF the official training program have not been yet developed thus, the main trainings happened in the field. However, when it was needed they organized seminars at CERN.

4.9 Data exchange with suppliers

In the case of interviewee 3, technical specifications of equipments have been provided to the manufacturer through EDMS database. LHC machine’s circle tunnel is divided by eight sectors, and according to the plan of LHC they needed to install certain sector in the particular month, not in sequential order. Thus, manufacturer has been asked to manufacture specific cards to the certain sector in the certain time. For manufacturing procedures have been created special folder for distribution in EDMS, where all technical specifications for the manufacturer has been stored. The released technical specifications in EDMS allows manufacturer to retrieve data and start manufacturing processes. The manufacturer in turn provides manufacturing reports by storing them in the manufacturing folder in EDMS, after when data is imported to the MTF by the responsible person at CERN. However, manufacturer does not have access to the MTF system, as have been decided that it will be safer if management of import will be done at CERN.

Thus, EDMS database was for them a tool of communication, as all the data including fixed dates have been notified through EDMS without any e-mailing or calling procedures. EDMS is as well providing data assurance for both sides, which can’t be achieved for example by phone orders. Any file modifications can be seen at EDMS easily, as there is strict document release procedure. The technical problems during manufacturing process of course demands closer cooperation. However, in the experience of interviewee 3, the equipment tracking through supply chain during the installation phase of LHC machine did not work well. During the installation phase all the entities of supply chain have been working under pressure and being constantly out of the schedule. Once the installation phase was over, and the machine started to operate normally, the importance of regular documentation in the system was quickly understood. Interviewee 3 says that if they had more time for preparation before the installation phase, the results would have been much better.

In interviewee 2 point of view, when facing suppliers it is recommended to provide system at already frozen level which was not possible with MTF, at least in the beginning. When introducing system, suppliers wanted to know all small details of implementation including how much time for them will take to upload all existing test results. In the experience of interviewee 2, every time they introduced new version of MTF to the suppliers, they have been protesting about the time they needed to spend on employee’s trainings. Moreover, suppliers wanted to standardize all the manufacturing operations as soon as possible, and new versions of MTF slowed down the automation.

In the beginning of MTF development any changes of the system have not been welcomed by suppliers, as they required changes of their existing procedures. Interviewee 2 mentioned also one case, when supplier didn’t sign the contract for using MTF as system of their manufacturing follow-up. The supplier refused to negotiate because of unwillingness to share own data, and modify own production operations. In the experience of interviewee 2, they had different cases of data exchange with suppliers. Some suppliers agreed to upload test results to the CERN MTF system, in parallel with their internal archiving managing system for data acquisition. Others simply refused to do data management in cooperation. In the interviewee 2 point of view, MTF provides for CERN special feature of the quality assurance cross-check. In industry, suppliers have their own quality standards, and according to his experience it is impossible to oblige supplier to change or modify standards to look more similar to the quality assurance of CERN. The interaction between both sides seemed to be the best solution.

In the case of CLIC RF Structure Development project supplier are informed of MTF implementation and they can get access to the system, once EDMS account has been created. However, suppliers are not yet using system as users. All test results provided by suppliers are uploaded to the system at CERN, by project members. Collaboration partners are using MTF to retrieve data of manufacturing operations. However, according to interviews it is recommended to introduce system in terms of seminars and trainings for permanent supplier as soon as, MTF usage will be standardized and automated at CLIC RF Structure Development project.

5 Results and decisions

5.1 Accomplished success of research

The primary objective of this thesis was first of all, to research how MTF implementation and its integration with other CERN systems in CLIC RF Structure Production Development project facilitate product life cycle data management through the whole supply chain. The second objective was to analyze how implementation affects on manufacturing operations management in internal and external levels. The comparison of the MTF implementation experiences of other CERN projects helped to get deeper perspective of research by discovering how MTF application is used by the other projects, as due to the research interviewees, MTF can be used in different ways and for various purposes. However, all users expected from MTF implementation that system will fulfill its primary promises of manufacturing and test operations tracking capabilities as well as, the maintenance follow-up.

CLIC RF Structure Development project had huge advantage of MTF implementation, as application was already used by the LHC project. Comparing to experience of LHC project, CLIC is still in the R&D phase consequently, technical requirements are still under definition and finalization. As a result, manufacturing workflow has been changed several times during the implementation. MTF application was originally developed for the mass production of LHC project, when their manufacturing procedures have been already well defined. Thus, for EDMS service CLIC project may give valuable experience of a case when project is only planning own mass production and is still defining technical requirements and equipment identification. The most challenging for CLIC RF Structure Development was the preparation for the implementation, as it was difficult to see possible difficulties in advance, the issues that can go wrong to prepare solutions in advance. Experience of LHC project gives valuable example, but as CLIC is not subproject of LHC, not all guidelines can be used.

Convincing people to use the system has been found challenging, especially in the beginning of MTF implementation, when users did not have full access to the system. Local administrators are still in collaboration with the EDMS support developing and standardizing system towards more efficient use. Based on interviews it can be said that in the beginning of implementation the advantages of the system are often underestimated, especially by suppliers as it requires changes of operations and demand extra work. However, once the system is in full use it facilitates and boosts manufacturing operations management in on the internal and external levels. However, as the CLIC RF Structure Development project has just recently started MTF implementation it has not yet discovered all the advantages the MTF could provide for the data distribution through the supply chain.

The CERN EDMS common layer provides unique service of product life cycle management. Systems integration makes data management efficient, not only inside the CERN but as well, in external level. Suppliers can get easy access, and follow as well product life cycle of equipment. Manufacturing and Test Folder application integration with EDMS common layer makes possible to track manufacturing phase operations of product life cycle. The implementation of MTF and its integration with EDMS platform can be considered as a future-oriented large-scale project, which requires an investment of time and effort but as an experience of LHC showed it is compulsory part of the project quality management.

The research produced useful information of experiences for later MTF implementations in CERN and especially in the CLIC projects. Moreover, made research analysis may help the new and current implementations to avoid the same pitfalls as were faced during implementations presented in the research. The thesis provides a comprehensive set of basic theoretical information about PDM, EDM and PLM systems' features and functions as well as a compact description of PLM system's implementation benefits. Above all, the research increased general awareness of MTF application among the team members of CLIC RF Structure Development project, and provided information of different implementation solutions.

5.2 Reliability and Validity

The results of the research rely on analysis based on documentation, observations during the implementation process in the case project and on several interviews performed in the different CERN projects. EDMS/MTF training courses as well as, the seminar of ongoing activities of VSC group kept in November 2010 gave for research additional information on which as well has been relied on. The weaknesses of research methods have been understood, but to rely on observations the researcher kept often small informal discussion with people who had knowledge of the research subject. Some interview questions were found to be not clear enough for the interviewees, but more detailed descriptions provided by the researcher helped to get answers of the desired subject. However, because the research describes the research environment profoundly, results may be tested by performing interviews and their analysis in similar ways. Furthermore, detailed analysis of documentation which supports observations, and clear decisions making can state work to be rather reliable.

The results of the research are based first of all, on theoretical research. Gathered information from previous researches and solutions provided by vendors has been analyzed profoundly. The researcher tried to construct a relationship between information presented in the theoretical part and the empirical framework. Secondly, the implementation process in the case project and performed structured open questions interviews provided all the answers on research questions. Information presented in training courses and in seminars dedicated to the research subject has been analyzed for additional information. The research plan was performed in the exact way as it was planned, despite the fact that one of the interviews was not performed face to face. Conclusions made in research are based on the arguments from observations, and supported when it was possible by the facts of the documentation. Thus, all the decisions have been based on evidences, but they can't be measured be the only correct ones. Moreover, the results of CLIC RF Structure Development project's MTF implementation can't be generalized fully to results gotten from LHC subprojects, as CLIC started MTF implementation before technical requirements were finalized. In the case of LHC project, when MTF development started all technical requirements have been already defined. Moreover, MTF development was actually based on LHC technical requirements. Furthermore, the CLIC project is having at the moment small serial production, while LHC project had upcoming mass production when starting MTF implementation. Thus, results of research can't be stated to be fully valid. However, research results provide valuable information of different implementation solutions for further implementations not only in CLIC, but as well in the other projects CERN domain. In addition, the advantage of study can be used partially for similar PLM implementation projects performed outside the CERN.

6 Conclusion and recommendations

6.1 Recommendations

Based on interviews it can be said that equipment identification is the most important action in the beginning phase of implementation. The earlier it's done the more efficient will be the implementation. Not properly defined identifiers may slow the import process of data, and cause problems for users to identify equipments. Standardized identification will make engineering design process as well as, the equipment traceability through whole product life cycle more efficient. The equipment identification of CLIC RF is still not complete, the equipment identification document originally prepared for EDMS/MTF implementation in 2007 needs to be expanded. EDMS support is asking for document which should be created by respect of CERN quality assurance requirements. The defined standards will do import data process easier and more efficient for both parts as well as, will facilitate tracking of equipment through supply chain. For determined need have been created project proposal by thesis writer about possible equipment identification project with an outcome of official equipment identification document for the CLIC RF components, accelerating structures and PETS (Appendix 7). The project proposal have been already approved by CLIC Structure Production leader and put in action.

The research showed that implementation of MTF should be performed as soon as project has been approved, as it is difficult to start to deploy all existing data. Based on gathered observations and interviews has been defined different implementation solutions to facilitate product life cycle management and manufacturing operations through the supply chain. The inventory management feature of MTF has been in use by LHC project many years with success. However, the research clearly showed that it is not obvious that every project will explore same benefits from MTF implementation. Thus, it is very important when planning implementation to set clear objectives. Even though some requirements will not be possible to implement exactly as wanted, they still can be modified to fulfil needs of the user.

6.2 Need for further research

The research achieved all its set objectives, and as an income of analysis has been provided new information of different implementation solutions. However, to improve usefulness of the system and to make manufacturing operations and product life cycle management more efficient the further research may provide more detailed solutions. Furthermore, as it was not possible to state the research fully reliable and valid due to the applied research solutions, the further empirical research may find out if there are some other implementation issues in other CERN projects, which has not been noticed or on which has not paid right attention in the research.

To improve the usefulness of the MTF application in CLIC RF Structure Development project, and to increase success of its implementation, better research will be needed in areas of inventory management, systems integration and equipment identification. It is also important to research different methods of data exchange with the suppliers, solutions in non scientific organizations can be as well applied.

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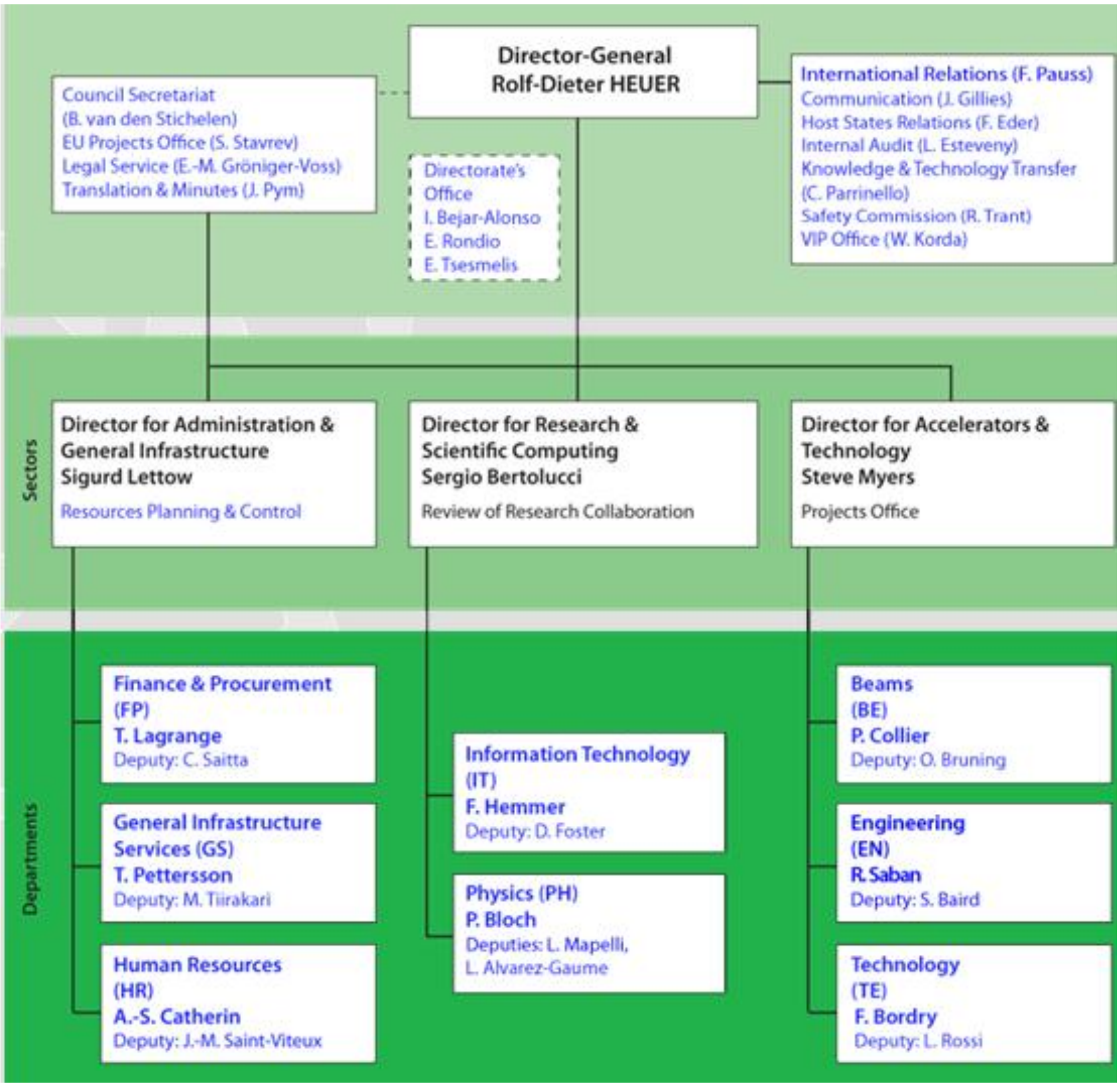
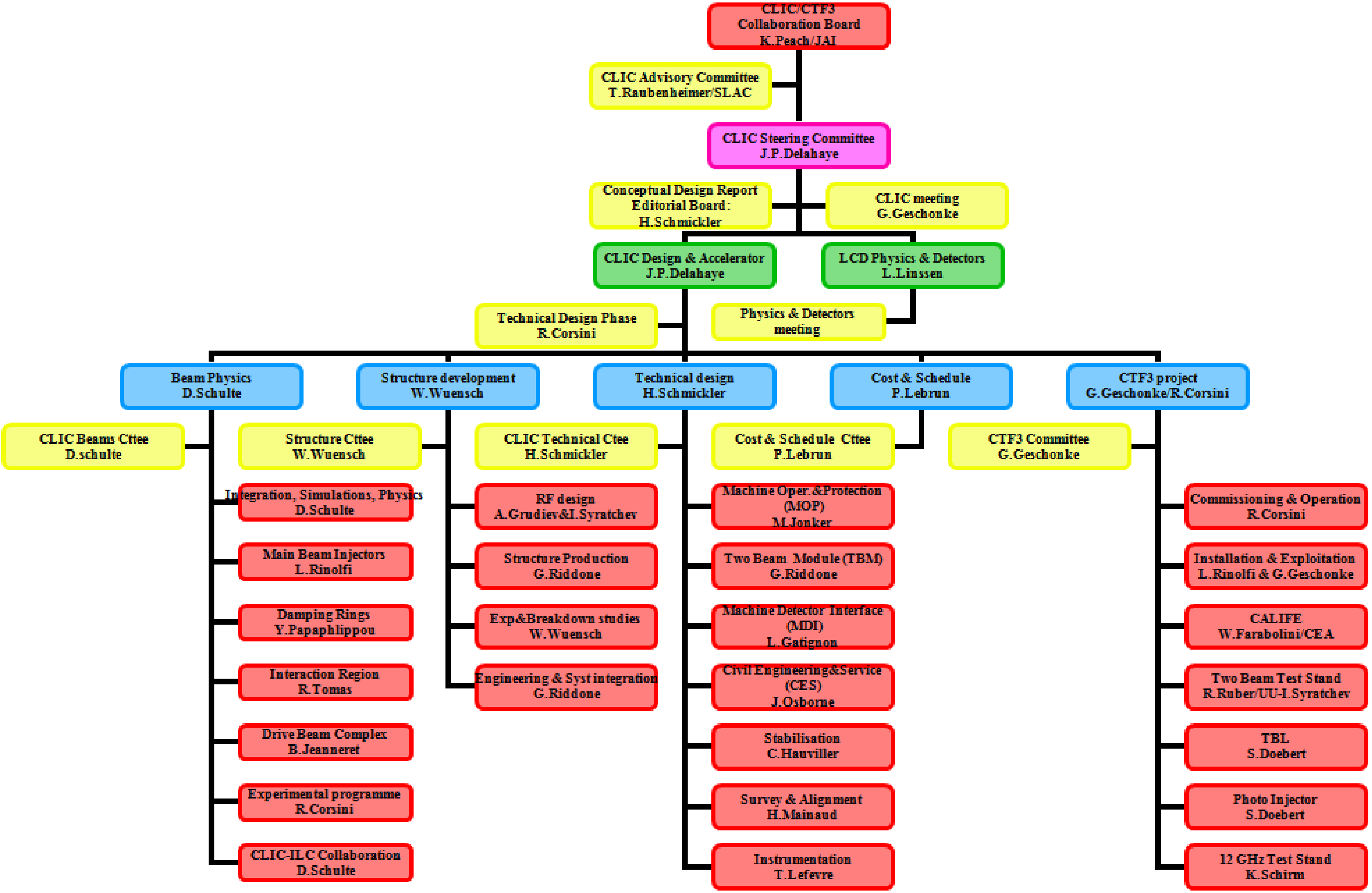
Appendices

Appendix 1: CERN structure



Appendix 2: CLIC structure



Appendix 3: Interview questions

The research of MTF (Manufacturing and Testing Folder) implementation

The information provided by you will be used to define how MTF implementation and its integration with the other CERN systems affects on the inventory, manufacturing and testing operations management on internal and external levels as well as, how it facilitates the product life cycle data management throughout the whole supply chain. Please read the following questions before the interview. Thank you for participation.

1. What is your work position and for which department/section/group/team and project/projects are you working for?
2. When did your project implement the EDMS system and what were your main reasons for that?
3. When did the implementation of MTF application start and is it still in the process?
4. What were your project's main reasons and expectations for implementing MTF application and integrating it with the EDMS database?
5. How did the project members react on the implementation initiation, and has the reaction changed during or after the implementation process?
6. How was performed project members preparation for the implementation process?
7. Were the supply chain members involved to the system's implementation?
8. Did the implementation include MTF integration with the other systems? If there was such integration with other databases, what kind of value did it give to the project?
9. How do you think MTF implementation and its integration with EDMS affected on:
    a. Manufacturing and testing data management?
    b. Inventory management?
    c. Product life cycle data management?
    d. Equipment tracking throughout supply chain?
    e. Quality assurance?
10. Which issues were taken under consideration:
    a. When defining a workflow for MTF application?
    b. When defining which data should be entered straight into the MTF and which should be linked to the original location?
11. Did the implementation require definition of the equipment identification standards? If yes, how it was done?
12. What kind of data import process was used, and were there any changes of it? Do you consider data import process to be efficient?
13. Has the MTF bar code system been implemented? If yes:
    a. When has it been implemented, during the MTF implementation process or later?
    b. How does it assist the inventory management?

c. How does it assist the product life cycle management?

14. Has the MTF notification letter been implemented? If yes, do you think that it facilitates data management? Is it sent to the external users as well?
15. How trainings of MTF use for the end-users and local administrators have been organized? Has use instructions been provided to the external users as well?
16. Do you consider the design of MTF application user-friendly?
17. What were the key challenges of the implementation process?
18. Did the implementation change the objectives of your project?
19. What can you recommend for the others planning to go through the implementation process of MTF application?
20. Do you want to add something in addition to the questions above?

Appendix 4: Manufacturing workflow of accelerating structure in MTF

Assembly Folder: Manufacturing Workflow

Assembly Identifier: **CLCVG10100-CR000001**
Other Identifier: None
Description: **CLIC 11WNSDVG1 ASSEMBLY**

Main | Made of | Equipment data | **Manufacturing** | Operation | Documents | History | Map

Actions : Add extra step

Workflow Diagram

No workflow diagram is defined for this assembly

Workflow Steps

Last Repeated

Step	R/E	Other name	Description	Status	Result	NC
1		()	RF design and parameters (*)	Done	Ok	
2		()	Technical specification (*)	Done	Ok	
3		()	Machining	Pending		
4		()	Quality control at factory	Pending		
5		()	Inlet reception at CERN	Pending		
6		()	Video inspections	Pending		
7		()	Dimensional control	Pending		
8		()	SEM (*)	Done	Ok	
9		()	Cleaning	Pending		
10		()	Brazing of couplers (H2 , 1045 °C)	Pending		
11		()	Coupler machining	Pending		
12		()	RF check before bonding	Pending		
12.1	E	()	Brazing of flanges (*)	Pending		
12.2	E	()	Brazing before and after thermal treatment (*)	Pending		
13		()	Diffusion bonding of disk stacks (H2, 1040°C) (*)	Done	Ok	
14		()	Brazing of disk stacks with couplers and tuning studs (H2, 1035°C) (*)	Pending		
15		()	Brazing of cooling circuits (H2, 1020°C)	Pending		
16		()	Welding of flanges	Pending		
17		()	Leak tightness test (*)	Done	Ok	
18		()	RF check and tuning (*)	Done	Ok	
19		()	Baking structure (vacuum, 650°C > 10h) (*)	Done	Ok	
20		()	Packaging and shipping	Pending		
25		()	Traveller	Pending		

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Appendix 5: Manufacturing workflow of PETS in MTF

Assembly Folder: Manufacturing Workflow

Assembly Identifier: CLAP11_0045-CR000001
Other Identifier: None
Description: 11.424 GHZ WITH DAMPING MATERIAL - GENERAL ASSEMBLY

Main | Made of | Equipment data | **Manufacturing** | Operation | Documents | History | Map

Actions :

Workflow Diagram

No workflow diagram is defined for this assembly

Workflow Steps

Step	R/E	Other name	Description	Status	Result	NC
				Last Repeated		
0	E	()	RF design (*)	Done	Ok	
1		()	PETS couplers - Quality control (*)	Done	Ok	
2		()	PETS couplers - Cleaning (NGL+ chromic acid) (*)	Done	Ok	
3		()	PETS couplers - 1st brazing (body), vacuum, 800 °C (*)	Done	Ok	
3.1	E	()	Brazing of PETS Coupler Cooling System Assem. (*)	Done	Ok	
4		()	PETS couplers - 2nd brazing (flanges, cooling), vacuum, 800 °C (*)	Done	Ok	
5		()	PETS couplers - RF check (*)	Done	Ok	
6		()	PETS bars - Quality control (*)	Done	Ok	
6.1	E	()	Dimensional control (*)	Done	Ok	
6.2	E	()	Dimensional control of PETS bar surface (*)	Done	Ok	
7		()	PETS bars - Cleaning (NGL+ solvent) (*)	Done	Ok	
8		()	PETS bars - EB welding of the bars (*)	Done	Ok	
9		()	PETS bars - Baking (vacuum, 200 °C, 2h) (*)	Done	Ok	
10		()	Tank - Quality control (*)	Done	Ok	
11		()	Tank - Cleaning (degreasing only) (*)	Done	Ok	
12		()	Tank - Baking (vacuum 650 °C, 1-2 days) (*)	Done	Ok	
13		()	SiC - Quality control (*)	Done	Ok	
14		()	SiC - Cleaning (degreasing only) (*)	Done	Ok	
15		()	SiC - Pre-fire (vacuum, 1000 °C) (*)	Done	Ok	
16		()	Assembly - Assembly of the 8 bars (*)	Done	Ok	
17		()	Assembly - EB welding of the bars (*)	Done	Ok	
18		()	Assembly - RF check	Cancelled	Cancelled	
19		()	Assembly - Assembly of couplers-bars and mini-tank (*)	Done	Ok	
20		()	Assembly - EB welding of tank (*)	Done	Ok	
21		()	Assembly - RF check (*)	Done	Ok	
22		()	Assembly - Vacuum test (*)	Done	Ok	
22.1	E	()	Leak test of PETS 11GHz (*)	Done	Ok	
23		()	Assembly - Final bake-out (150 °C, 2 h) (*)	Done	Ok	
24		()	Assembly - Packaging (N2) (*)	Done	Ok	
25		()	Assembly - Shipping to SLAC (*)	Done	Ok	
30	E	()	Traveller	Done	Ok	

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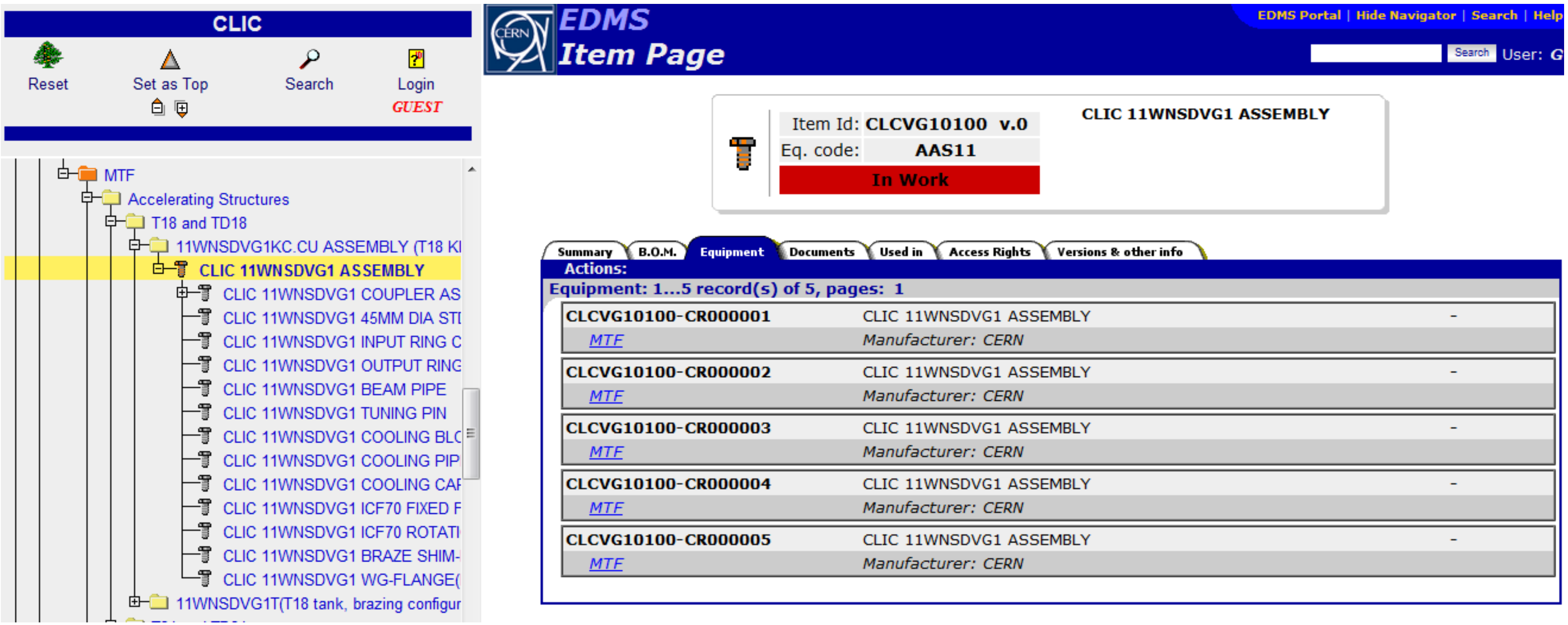
Appendix 6: Equipment versions in EDMS



Appendix 7:
Project Plan Proposal for the CLIC RF Equipment Identification

Version 0.1

Version history

VERSION	DATE	AUTHOR	APPOVED BY
0.1	16.07.2010	MARGARITA SAIFOULINA	GERMANA RIDDONE

I have carefully assessed the project plan for the CLIC RF equipment identification. This document has been completed in accordance with the requirements of the CLIC (Compact Linear Collider) RF (Radio Frequency) Structure Development team at CERN (European Organization for Nuclear Research).

MANAGEMENT CERTIFICATION - Please check the appropriate statement.

X **The document is accepted.**

______ The document is accepted pending the changes noted.

______ The document is not accepted.

COMMENTS:

The CLIC study is ending its conceptual design phase, during which the project feasibility had to be demonstrated. The following phase, if approved, will be the technical design phase involving all process of industrialisation and mass production. Hundreds of RF structures and components will be needed and for them complete equipment identification, including all data needed for traceability purpose. At present a simplified identification exists for RF test structures and RF test components. For the future serial production, this identification is not sufficient, as it does not include all the required information. Therefore this project proposal is fully approved by me, as it reveals to be mandatory for our future items. Based on CERN general rules for equipment identification, the identification for CLIC RF components will have to be defined in detail and implemented as being part of the present management tools.

I fully accept the changes as needed improvements and authorize initiation of work to proceed. Based on our authority and judgment, the continued operation of this project is authorized.

23.07.2010, Germana Riddone

Name and date
Project Supervisor

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1 Project content

1.1 Background

The purpose of the project is to describe requirements of the CERN equipment identification standards and to upgrade identification of the CLIC RF components and accelerating structures, as well as to deploy new standards into the engineering data management systems used by the CLIC RF Structure Development group.

The proper identification will provide benefit of an easier mechanical design process and components' traceability of the whole product life cycle in the different levels of intra- and inter-organizational integration. The integration includes bidirectional flow of components including materials and manufacturing workflow procedures.

The equipments will be labelled according to the CERN's equipment identification scheme, which will guarantee uniqueness within CERN domain. Local administrators of the engineering data management systems will take care of the information regarding new equipment identification of RF components by creating, manipulating and managing identifiers in databases.

1.2 Objectives and Descriptions

- Upgrade the existing equipment identification material of RF components and accelerating structures

- Configure and deploy the new identification standards to the CERN engineering data management systems

1.3 Limitations

The main limitations of the project are the equipment identification standards defined by CERN and the already existing identification documentation of CLIC RF components and accelerating structures.

1.4 Tasks

Main tasks are:

1. Document project
2. Configure and deploy the equipment identifiers
3. Upgrade the material
4. Upload the finished work in to the systems

1.5 Quality target

The aim of the project is to deliver new upgraded equipment identifiers by the respect of CERN quality assurance procedures within the given time frame.

2 Deliverables

2.1 Parts of the deliverables

Deliverable	Description
Project plan	Report of initiating and planning phases
Risk analysis report	Analysis of limitations
Work breakdown structure	Structure of the responsibilities and tasks
Progress report	Reporting of progress at the end of every phase
Equipment identification document	Final document/outcome of the project

Figure 1: Parts of deliverables (HAMK 2010)

2.2 Schedule / project milestones

See the implementation chapter 6.

2.3 Means of delivery

Deliverable	Means of delivery
Project plan	Returned at the end of the course
Risk analysis report	Planning phase of the implementation
Work breakdown structure	Included to the planning phase of the implementation
Progress report	At the end of every phase of the imple-mentation
Equipment identification document	At the beginning of the execution phase of the project

Figure 2: Means of delivery (HAMK 2010)

At the end of the project, an equipment identification document should be delivered to the EDMS support for the approval. The criteria for ending the project will be when the project objectives have been met.

3 Project background

3.1 Background documents

- The document which defines the LHC project part identification:

Mottier, M. 1999. LHC Part Identification. EDMS id. 103551. CERN-LHC. Genève, Switzerland. Available: [https://edms.cern.ch/file/103551/1.0/Qap206.pdf]

- The document which defines conventions of the SPS equipment identification:

Billen, R. 2005. Quality Assurance, Conventions for Identifiers of Equipment in the SPS. EDMS id. 605968. The Accelerators & Beams Department. Genève, Switzerland. Available: [https://edms.cern.ch/file/605968/2/SPS-C-QA-0001-01-10.pdf]

- The document which defines conventions of the equipment identification for the LHC entities and their parameters for the control centre:

Billen, R. Lauckner R. 2004. Quality Assurance Instruction, Naming of LHC Entities and Their Parameters for the CERN Control Centre. CERN LHC. Genève, Switzerland. Available: [https://edms.cern.ch/file/462596/1/LHCEntityParameterSemantics-v3.pdf]

- The document which defines the equipment identification of the electrical circuits and power converters for the LHC injection lines:

Billen, R. Zerlauth, M. 2006. Quality Assurance Definition, Naming of Electrical Circuits and Power Converters for: LHC Injection Lines, CNGS. CERN Accelerators & Beams Department. Genève, Switzerland. Available: [https://edms.cern.ch/file/754862/3/AB-PC-QA-0001-01-10.pdf]

3.2 Laws and regulations

- The document, which presents the part identification scheme for all equipments under the CERN responsability:

Widegren, D. Mottier, M. 2004. Quality Assurance, CERN Equipment Identification. EDMS id. 100243. CERN-LHC. Genève, Switzerland. Available: [https://edms.cern.ch/file/100243/2.2/qap208v2-2.pdf]

3.3 Other documents

The documents regarding CLIC RF components and accelerating structures identification in the following folder:
\\cern.ch\dfs\Departments\AB\Projects\CLIC Structures\RF structure development\EDMS-MTF

4 Project tasks

4.1 Tasks

1. Research of the provided background information regarding CERN quality assurance of the equipment identification
    - 1.1. CERN equipment identification
    - 1.2. LHC equipment identification
    - 1.3. SPS equipment identification
    - 1.4. CLIC RF accelerating structure identification
    - 1.5. CLIC RF component identification
2. Upgrade the CLIC RF components and accelerating structures identification materials
3. Configure and deploy the upgraded content to the data management systems
4. Project Management
    - 4.1. Write the project plan
        - 4.1.1. Write Risk Analysis
        - 4.1.2. Write Work Breakdown structure
    - 4.2. Write phase progress reports
    - 4.3. Write the final CLIC RF equipment identification report

4.2 Estimated workload

Will be defined when planning Work Breakdown Structure

5 Project resources

5.1.1 Shareholders

- CLIC BE-RF

- Project manager: the main contact person of the project
- Local administrator of EDMS in the CLIC RF Structure Development
- Local administrator of MTF: system responsible in the CLIC RF Structure Development
- Mechanical engineer: an expert in RF components and accelerating structures
- Project supervisor

- EDMS support GS/ASE/EPS

- The main EDMS support contact person
- Responsible for MTF
- GS/ASE/EPS section leader
- Responsible for the EDMS/MTF trainings
- Responsible for the inventory management in MTF

5.1.2 Responsibilities and powers

- CLIC BE-RF

- Project manager: document project, contact project shareholders
- Local administrators of EDMS and MTF: update materials
- Mechanical engineer: provide knowledge of RF components and structures, including drawings
- Project supervisor: project supervising

- EDMS support

- Service/support/information providing of EDMS/MTF
- Project supervising EDMS/MTF
- Trainings
- Inventory management support of MTF

5.2 Parallel suppliers

The main supply chain members' and collaboration partners' participation in the equipment identification process will help to define identifiers that can be traced through the supply chain by all members.

5.3 Facilities

Facility	Purpose
Office room 18-3-048	Working on the project
Auditorium CR-3-030	Meetings
EDMS support, 112/3-022	Meetings in the office room

Figure 3: Facilities (HAMK 2010)

5.4 Tools

Tool	Purpose
EDMS	Engineering and Equipment Data Management
MTF	Product Life Cycle Management
Agile6	System for EDMS management
Infor EAM	System for MTF management
Microsoft Office Package for Project management Microsoft Office Word Microsoft Office Excel Microsoft Office Project	Project management
Microsoft Access inventory database	Inventory management
CDD	CERN Drawing Directory

Figure 4: Tools (HAMK 2010)

6 Implementation plan

6.1 Phases

Phase	Duration	Start	Finish
1. Initiating			
2. Planning			
2.1 Project plan			
2.2 Implementation schedule			
2.3 Work breakdown structure(WBS)			
2.4 Risk analysis report			
3. Executing			
3.1 Action 1: Progress report of configuring and deploying the equipment identifiers			
3.2 Action 2: Progress report of upgrading the material			
3.3 Action 3. Progress report of uploading the finished work in to the systems			
4. Analyzing results			
4.1 Equipment identification document			
4.2 Project success report			

Figure 5: Implementation phases

Duration of phases to be determined by project manager

Phase 1. Initiating
The approved project plan proposal by project supervisor will start the initiating phase of the implementation and will end at the beginning of the planning phase. During the initiating phase the implementation proposal should be presented to the EDMS support.

Phase 2. Planning
The planning phase will start by writing the project plan for the implementation and will end by starting executing process. During the planning phase the implementation schedule and work breakdown structure (WBS) should be done.

Phase 3. Executing

Executing will starts by EDMS approval of the implementation project. Executing phase consists of three action phases during which progress reports should be provided.

Phase 4. Analyzing

Analysis will start after the end of execution process of the implementation. At the end of the project, success analysis results of the project should be presented to the CLI RF group, EDMS support, collaboration partners and suppliers.

6.2 Requirements analysis

EDMS proposed for the CLIC RF team to define its own equipment identifiers and has given exact requirements of the quality assurance. Those requirements are found at the background documentation in chapter 3. The implementation process should be done by respect of the CERN quality assurance mandate. The risk analysis report of the implementation should be added to the appendices.

6.3 Standards

Standards defined by the CERN quality assurance mentioned previously, seen in chapter 3.

6.4 Results

Results will be seen during the documentation analysis.

6.5 Reporting and communication

6.5.1 External reporting

Once officially published, the equipment identification document should be distributed to the suppliers and collaboration partners.

6.5.2 Internal reporting

Information	How	Whom	When
Meetings	Minutes	CLIC RF - EDMS	On a weekly basis
Progress phase re-ports	EDMS	Project manager	At the end of every phase
Technical support	Email	EDMS	When needed

Figure 6: Internal reporting (HAMK 2010)

6.5.3 Internal communication

Project shareholders will stay in contact about project meetings with the email and cell phone.

6.6 Meetings

6.6.1 Project meetings

Meetings will be scheduled using Outlook or Indico and will be held in the auditorium or in the office room.

6.6.2 Planning meetings

The project team meets on a daily basis to discuss and work on the project.

6.6.3 Project reviews

Below are shown all the compulsory meetings during the project. Dates of weekly meeting will be determinate by the project manager.

Event / date	Participants	Issues and practices
Initiating	All project members	Introduction of the project
Weekly meeting / **Week X,**	Project group and supervisor	Writing the project plan
Weekly meeting / **Week X,**	Project groups and supervi-sor	Creating project folder in EDMS

Weekly meeting / **Week X,**	All project members CLIC BE/RF	Introduction of the project plan
Weekly meeting / **Week X,**	All project members	Progress analysis Execution phase
Weekly meeting / **Week X,**	All project members	Introduction of the final equipment identification document
Weekly meeting / **Week X,**		

Figure 7: Project meetings (HAMK 2010)

6.7 Change management

All open questions will be handled in weekly meeting with the project supervisor.

7 Documentation plan

7.1 Project folders

Project folder to be created in the EDMS database

7.2 Documentation standards

Document templates provided by CLIC and the CLIC RF development group

7.3 Version control

Version control of documents will be responsibility of the project supervisor

7.4 Document management

All documents should be stored in EDMS database and in the CERN server, in the CLIC Structure Development folder: \\cern.ch\dfs\Departments\AB\Projects\CLIC Structures\RF Structure Development\EDMS-MTF

8 References

Billen, R. Zerlauth, M. 2006. Quality Assurance Definition, Naming of Electrical Circuits and Power Converters for: LHC Injection Lines, CNGS. CERN Accelerators & Beams Department. Genève, Switzerland. Available: [https://edms.cern.ch/file/754862/3/AB-PC-QA-0001-01-10.pdf]

Billen, R. 2005. Quality Assurance, Conventions for Identifiers of Equipment in the SPS. EDMS id. 605968. The Accelerators & Beams Department. Genève, Switzerland. Available: [https://edms.cern.ch/file/605968/2/SPS-C-QA-0001-01-10.pdf]

Billen, R. Lauckner R. 2004. Quality Assurance Instruction, Naming of LHC Entities and Their Parameters for the CERN Control Centre. CERN LHC. Genève, Switzerland. Available: [https://edms.cern.ch/file/462596/1/LHCEntityParameterSemantics-v3.pdf]

HAMK. 2010. Template of project plan. FUAS - Federation of UAS, summer course.

Mottier, M. 1999. LHC Part Identification. EDMS id. 103551. CERN-LHC. Genève, Switzerland. Available: [https://edms.cern.ch/file/103551/1.0/Qap206.pdf]

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