CM2-BASED PHYSICAL ITEM HIERARCHY IMPLEMENTATION FOR A PRODUCT LIFECYCLE MANAGEMENT SYSTEM

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ABSTRACT

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Configuration Management is a process that provides consistency among the product requirements, the product itself, and associated product configuration information by applying appropriate resources, processes, and tools. Configuration is an arrangement of parts, requirements or data in a particular form, figure, or combination. There can be one or more configuration for a product. Each of them needs to be managed throughout its lifecycle. Software tools which are called Product Lifecycle Management (PLM) tools provide a set of capabilities to manage product configurations and all datasets associated with a product. There is an enterprise configuration management methodology named CM2, proposed by Institute for Process Excellence (IpX), which is also for enterprise product lifecycle change. In this study, generating physical item hierarchy (As Planned/As Released Baseline) which is the first step of the core business processes of CM2 has been integrated to a PLM tool. Owing to this implementation, the generated physical item hierarchy enables to analyze the product with its connected datasets during the development and the production phases and to increase the potential of reuse existing items and associated documents. The

contribution of generating physical item hierarchy through the PLM system to the configuration management applications in the defense industry is explained in the case study.

Keywords: As planned/as released baseline, CM2, configuration management, physical item hierarchy, product lifecycle management

ÖZ

ÜRÜN YAŞAM DÖNGÜSÜ YÖNETİM SİSTEMİ İÇİN CM2 TABANLI FİZİKSEL KALEM HİYERARŞİSİ UYGULAMASI

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Konfigürasyon Yönetimi, uygun kaynaklar, işlemler ve araçlar kullanarak ürün gereksinimleri, ürünün kendisi ve ilgili ürün konfigürasyon bilgileri arasında tutarlılığı sağlayan bir süreçtir. Konfigürasyon, belirli bir biçimde, şekilde veya kombinasyonda olan parçaların, gereksinimlerin veya verilerin bir düzenlemesidir. Bir ürün için bir veya daha fazla konfigürasyon olabilir. Bunlardan her birinin kullanım ömrü boyunca yönetilmesi gerekir. Ürün Yaşam Döngüsü Yönetimi (PLM) araçları olarak adlandırılan yazılım araçları, ürün konfigürasyonlarını ve ürün ile ilişkilendirilmiş tüm veri setlerini yönetmek için bir dizi özellik sağlar. Kurumsal ürün yaşam döngüsü değişikliği için de geçerli olan CM2 adında, Süreç Mükemmelliği Enstitüsü tarafndan tasarlanan, kurumsal konfigürasyon yönetim yöntemi vardır. Bu çalışmada, CM2'nin temel iş süreçlerinin ilk adımı olan fiziksel kalem hiyerarşisi oluşturma (Planlandığı gibi/Yayınlandığı gibi Ana Çizgilendirme) PLM aracına dahil edilmiştir. Bu uygulama sayesinde, oluşturulan fiziksel kalem hiyerarşisi, ürünlerin, bağlanan veri setleriyle beraber geliştirme ve üretim aşamaları boyunca analiz edilmesini ve mevcut kalemler ve ilişkili dokümanların yeniden kullanılma potansiyelinin arttırılmasını

sağlar. Örnek çalışmada PLM sistemi aracılığıyla fiziksel kalem hiyerarşisi oluşturmanın savunma sanayindeki konfigürasyon yönetim uygulamalarına katkısı açıklanmıştır.

Anahtar Kelimeler: Planlandığı gibi/yayınlandığı gibi ana çizgi, CM2, konfigürasyon yönetimi, fiziksel kalem hiyerarşisi, ürün yaşam döngüsü yönetimi

To my dearest family and husband

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LIST OF ABBREVIATIONS

BOM	Bill of materials
CAD	Computer-aided design
CAGE	Commercial and government entity
CAM	Computer-aided manufacturing
CM	Configuration management
CMII	CM2
COTS	Commercial off-the-shelf
EBOM	Engineering bill of material
ECN	Enterprise change notice
ESR	Externally source record
JSP	Java server pages
MQL	Matrix query language
OOTB	Out of the box
PDM	Product data management
PLM	Product lifecycle management
RF	Radio frequency
UI	User interface
UML	Unified modeling language

CHAPTER 1

INTRODUCTION

1.1 Overview of Product Lifecycle Management Systems

Due to the complex nature of today's products, digitalization is an essential for whole product lifecycle. Data belonging to product needs to be kept and managed on digital platform for traceability. Even though traceability is one of the most important reasons, there are many other advantages of digitalization in addition. Digital systems are easily accessible and this provides time saving and multiple access at the same time. Data stored within the digital platform can be organized, standardized and sustainable. It is easy to manage, analyze and report. In addition, digitized information in one system is single source of truth so it is reliable and consistent.

Digitalization of product related data started with Product Data Management (PDM) systems in the late of 1980s [7]. PDM systems are used to store Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) data files. PDM systems are file-based systems. They are not sufficient for managing products. The need to manage the entire lifecycle of the product has led to the emergence of the PLM systems.

Product Lifecycle Management (PLM) is a concept that emerged in the early 2000s [27]. PLM system is one of digital platforms that enables to manage information related with the products. All data related with the product are kept in PLM systems. After development of PLM system, PDM is one of the most important elements of the PLM environment which manages all the product data created and used throughout the product lifecycle and provide exactly the right information at exactly the right time [27].

In the PLM systems, data that cover the entire lifecycle of product are controlled and managed by cross-functional teams, the entire product data stream is in order according to workflow. Owing to this, it contains all the necessary components such as 3D models, drawings and technical data sets, pertaining to every stage of their life cycle, hence, it supports digitalization of products in all aspects.

PLM system brings benefit for companies with a wide range of products in terms of time saving, ease of development, product excellence and competition. Users of PLM system can access product related data easily. Cross functional teams can work together on same platform at the same time. Designers can develop products in a shorter time frame. Products are ready to market in less time. Product related costs reduce owing to facilitated prototyping and reuse. These kind of benefits maximize the value of product portfolio and enhance competitiveness.

1.2 Product Configuration Management in PLM System

Lexical meaning of configuration is an arrangement of parts or elements in a particular form, figure, or combination [22]. Creating a product means creating a product configuration comprised of parts or elements. Product configuration is the principal concept in PLM systems. Product configuration contains functional and physical features of the product. PLM systems offer a set of mechanisms in order to support product configuration management [19]. These mechanisms include creating and controlling documents, design and development of the parts, creating physical structure of them, setting connections between parts and documents and supporting maintenance of product life.

In PLM systems, functional and physical features of product is defined in metadata and datasets in preliminary state. Datasets can be design drawings and specifications. After design is completed according to specifications and product is mature enough, it is presented to review. In this state, CM specialists control and validate the datasets and the structure of the product. Structure of the product is usually controlled over Bill of Materials (BOM). It is the breakdown structure of part objects for a product.

Not only development and structure validation is included in the scope of configura-

tion management, but also change validation is included. Change management is a big topic itself and is part of configuration management. PLM system is also able to manage product changes. Product structure is not be restricted with BOM in PLM systems. It can be built as physical item hierarchy. Physical item hierarchy contains BOM as a document. A baseline can be generated from the physical item hierarchy and it includes BOM and change information of items.

PLM software enables to provide configuration identification, control, status accounting and verification and to track product baselines and workflows in each step of product life. It can provide them according to CM standards. The PLM tool vendors might implement CM standards in their tool. These standards can be military standards like MIL-STD-973, commercial standards like ISO 10007 or enterprise standard like CM2. Developed PLM tool as to CM standards helps manage product configuration faultlessly. In short, digitalization of the product life cycle with PLM systems simplifies configuration management and makes it in compliance with standards.

1.3 Motivation

Physical item hierarchy is a set of hierarchical items such as parts, assemblies or components that constitutes product structure. The PLM software tool that is used in a defense companies enables to represent physical item hierarchy with bill of material (BOM). A BOM is simply defined as a compilation of parts list for a product [32]. However, the BOM is a document that should be included in the physical item hierarchy according to CM2. When the defense company wants to manage configurations according to CM2 standards, the PLM tool in use might not support CM2 standards in every aspect. In such situation, there are two options. One is to change the PLM tool but it requires to migrate all data to new system. It is huge and complex process and costly. Another one is to customize the PLM tool. It is easier with respect to first option if customization of the PLM tool is possible from a technical aspect. In this study, CM2-based physical item hierarchy is created as an alternative to BOM to adapt the PLM tool to CM2 by customization. Moreover, CM2 baseline that is known as As Planned/As Released Baseline is generated from the CM2-based physical item hierarchy.

Whereas change is not traced from BOM, the traceability of change is provided with adaptation of the PLM tool to CM2 on the subject of CM2 baseline. Since As Planned/As Released Baseline includes effectivity of items which is an indicator for validity and feasibility, effectivity is managed and it is useful for change management. The output of CM2 baseline provides input to technical data package which is delivered to customer to describe the product structure. It is necessity for standardization of technical data package. Moreover, it provides input to project management tool to create work package that is a set of assigned tasks. Thus, project can be planned hierarchically. It supports to address complexity, promote reuse and manage product line.

1.4 Organization of the Thesis

The thesis describes CM2-based product structure model implementation in a PLM system. It is organized as follows. In Chapter 2, background information is given about the configuration management, CM2 and PLM. In addition, previous studies about product structuring are investigated.

In Chapter 3, the physical item hierarchy model of CM2 methodology and CM2 baseline are explained in detail.

In Chapter 4, the implementation of the physical item hierarchy and as released baseline in a PLM system is explained by defining software requirements and design details.

In Chapter 5, the usage of PLM tool customization is described through the case study in the defense industry. Functional validation and usability test of the study is performed.

In Chapter 6, the thesis is summarized and concluded. The developmental aspects of the thesis are described as future work.

CHAPTER 2

BACKGROUND

2.1 Configuration Management

Configuration Management (CM) is a comprehensive process for maintaining consistency of any product's performance, functional and physical attributes with its requirements, design, and operational information [2]. This definition of the military standard is taken as a basis in defense industry and this standard offers universal approach for configuration management by defining the common sense CM applications and their underlying fundamental principles. In other words, it describes all information related with the configuration management by defining what should be done and why they should be done.

CM is a critical discipline since it controls the suitability of datasets for the product and provides pre-manufacturing control. Datasets can be design document, process plan and bill of material (BOM). The suitability of the datasets to the product is very important for the accurate and clear manufacturing. Without minimum control of design documents via make-sense processes, practices and measurements, chaos ensues [33]. Chaos causes misdesigning and corrective actions. Therefore, configuration management discipline is a factor that directly affects cost. Although there is such a critical discipline, the organizational culture is very effective in applying configuration management accurately. Standards like Configuration Management Standard ANSI/EIA-649B or CM2 are intended to make configuration management independent of the corporate culture. Moreover, the standards enable the globalization of configuration management in the most effective way rather than according to the corporate culture.

Wherever the product exists, configuration management is mentioned there. When the product configurations is managed correctly, configuration management provides a lot of benefits to manufacturers if done correctly. Frank B. Watts outlines the importance of CM in the following way [33].

CM is a requirement in almost every product manufacturing operation because of the following:

- Design documentation is one of the four critical elements of profitable product manufacturing.
- Design documentation is engineering's product and that documentation is required by almost all the company functions.
- Designs do change and changes need to be accurate, understood, communicated, and tracked.
- Most companies have a degree of chaos, over-control or both in the CM world.
- A function is needed to bridge the gap caused by the lack of communication between engineering and manufacturing teams often found between engineering and the rest of the company [34].
- An executive champion is needed for fostering best-in-class CM.

2.2 Traditional CM versus CM2

Institute for Process Excellence (IpX) is an organization that helps to modernize and integrate company's legacy processes, systems, people, and data [12]. CM2 is the global industry standard that is proposed by IpX for enterprise product lifecycle change and configuration management [11]. As product complexity increases and organizations become more reliant on their supply chains, managing the change process and communicating across the global digital ecosystem is an increasing challenge. Ineffective and inefficient organization structures, processes, and systems leave organizations struggling to improve quality, reduce time-to-market and manage costs [11]. In other words, CM2 is new generation configuration management methodology

that provides a path to integrate process excellence dependent on the availability of appropriate business process infrastructure [35]. In addition to the traditional configuration management, it also describes how to manage products by operating standards. While traditional CM includes only products and design documents, CM2 expands the content in terms of not only engineering but also enterprise wide perspective of the change. This perspective covers all the information that affects safety, security, quality, schedule, cost, profit and facility. CM2 puts emphasis on accommodating change and keeping requirements clear, concise and valid [18]. CM2 aims process excellence and continuous improvement on the ability to change faster and document better by enabling business process infrastructure which includes the processes shown in Table 2.1 [15].

Configuration Management
Requirements Management
Change Management
Release Management
Data Management
Records Management
Document and Library Control
Enabling Software Tools

Table 2.1: Business Process Infrastructure

Information related with the product is not handled in exactly the same way in traditional CM and CM2. While information should be identified, approved, verified and recorded according to traditional CM, it should be structured, linked and owned according to CM2. Managing requirements correlates with how the requirements are identified, structured, linked and owned. Physical Item Hierarchy shows the end item, the items forming the end item and the specifications of them recursively.

2.3 Product Lifecycle Management

Product Lifecycle Management (PLM) is the business activity of managing, in the most effective way, a companys products all the way across their life cycles; from the very first idea for a product all the way through until it is retired and disposed of [27].

The phases of product lifecycle can be shown as in the Figure 2.1. They are categorized as beginning of life (BOL), middle of life (MOL) and end of life (EOL) [24]. The managament of a product is realized by covering requirements of all these phases.

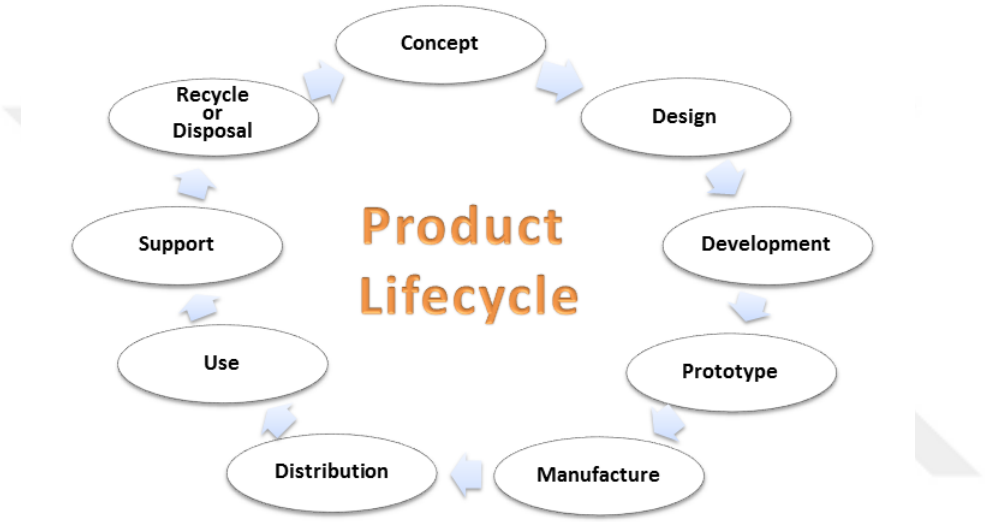


Figure 2.1: Product lifecycle phases

The phases that begins with the concept until distribution are included to BOL. Requirements become clear when determining the product concept. Product is designed based on its requirements. Then, development phase starts and prototype of the product is created. The product is verified and validated with the prototype. When the product is qualified with the prototype, it can be manufactured.

MOL is the phase that the product concept is realized concretely. Distribution, use and support are included in the MOL phase. In this phase, the product is supplied to end-users and it is in use of them. Support for the maintenance of the product is provided during the expected life of the product.

EOL is the phase where the product has reached its end of life. In this phase, the

question of what to do with product reaching the end of its life is asked. The answer of this question can be disassembling, refurbishing, recycling, reassembling, reusing or disposing. Products are disassembled if they will be recycled [4]. Products are refurbished if they will be re-manufactured. The parts of product can be reassembled for reuse. If the product will be eliminated without any part of it is not recycled, it can be scrapped for disposal.

2.3.1 PLM System

PLM System is a software tool for developing and managing product and storing product related data. PLM System is used to control and manage data of products throughout the product life cycle. Therefore, it contains all the necessary components at every stage of life of the products. The generic ones of these components is shown as Table 2.2 [27].

Data Management / Document Management
Visualisation
Part Management / Product Management
Integration
Process Management / Workflow Management
Infrastructure Management
Program Management / Project Management
Product Idea Management
Collaboration Management
Product Feedback Management

Table 2.2: Generic PLM Applications

Not only products are managed in PLM systems but also relations between product and sub-parts or datasets are managed. Data set is described as a set of information in a digital or physical form. Data set can be released as a whole or separately of other

data sets. PLM manages the whole range, from individual part through individual product to the entire portfolio of products [27].

The structure of the PLM system is established according to business processes. Unless the processes are accurate and detailed, PLM systems cannot be more than just a tool. If PLM systems are to be used with the highest efficiency, processes should be well defined. CM2 also advocates this idea. PLM systems help users to access the right document, at the right place, at the right time if there is a process they can apply [32]. When the processes affect more than one division concurrently, PLM systems are used by cross-functional teams. The task of PLM, in one sense, is to provide the necessary conditions for connecting separate information data systems, processes and automation islets [25].

In PLM Systems, key concept is the first step of lifecycle. At this step, product is just as an idea. After deciding concept, product is designed and model of the product is created in Computer-Aided Design (CAD) software as in the Figure 2.2 Manufacturing is the third step after validating the design. Manufactured product is ready to use. It needs to be maintained as last step. Maintenance of the product can be ended with disposal or recycling.

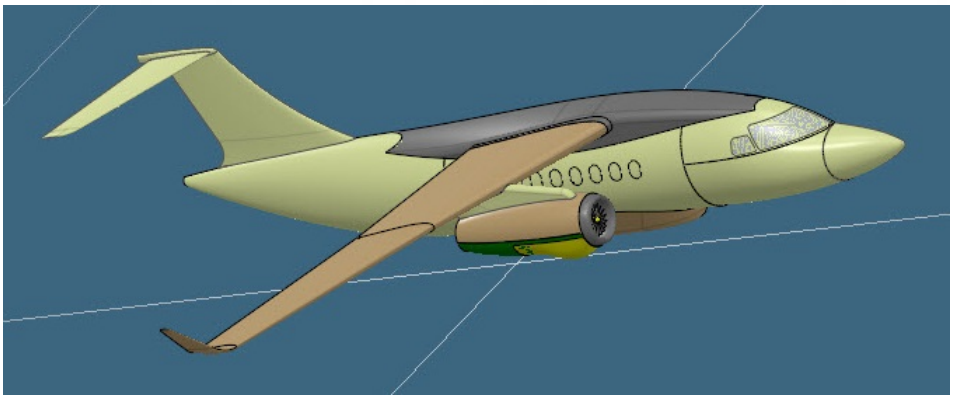


Figure 2.2: CAD model of the example aircraft

Digitalization of the product lifecycle steps relies on a digital twin for the product. PLM systems store and serve huge amounts of information related to the product. The digital twin uses this digital information and makes it available as data and simulation models [5]. Providing data flows in processes throughout the product lifecycle in PLM systems forms the digital thread. The digital thread is described as the pro-

cess for capturing data throughout the product lifecycle and analyzing opportunities to drive down tooling costs and lead times, improving efficiencies and promoting innovation by digitizing the supply chain, manufacturing processes, parts, and in-service data [21]. Owing that PLM systems enable digital twin and digital thread, the product and the communication among the product lifecycle steps are digitized. This digitalization provides full lifecycle traceability for the product.

At the highest level, the objective of PLM is to increase product revenues, reduce product-related costs, maximise the value of the product portfolio, and maximise the value of current and future products for both customers and shareholders [28]. To achieve this goal, configuration management must be applied according to operating standards and these operating standards must be performed correctly. This is a part of the process, this is not the responsibility of the PLM system, as PLM system is just a tool for managing product configurations in a digital environment.

2.4 Literature Review

In the literature, there are some works related to various PLM implementations and product structure. Boton et al. [6] studied comparison of PLM and Building Information Modelling (BIM) from the product structure point of view. Bill of Material (BOM) is examined for the product structure. It is the breakdown structure of part objects for a product. In that study, BOM is a document in the physical item hierarchy; it does not show whole product structure alone as this study.

Schuh et al.'s study [26] presents product structure with a set of six customized reference models by addressing the specific needs of each existing project type. In their approach, all products related data is represented by product structure. It shows similarity with our study since both emphasize that PLM is a systematical concept to design, manage and control all the information related with the product and the product structure is key element of PLM. That study declares that product structuring starts with the requirements identification of every stakeholder along the entire product lifecycle. That is the common point of our study since CM2 defends that development plan starts with the definition of the application requirements and the basis for detailed

design, then, they are extended into a physical item hierarchy.

According to Brière-Côté et al.'s study [3], product structure is central to PLM systems. They emphasize the importance of defining, managing and exploiting the relationships between the different representations of product data and structure. The idea that even though product structure and BOM are similar notions, they are distinct data models. This idea supports this study. Two product structures are mentioned to support main structure approach in that study. They are level-by-level model and nonisomorphic hierarchies model. The former represents that all of the views can agree on and connect to a common product decomposition. The latter declares that each view develops its own product structure. The meaning of "views" is accepted as described in the Van der Hamer and Lepoeter's study [31]. They are multiple levels of abstraction such as representation or diagram. The former shows similarity with our study in terms of product structure model representation, while the latter shows similarity from the point of equivalent item representation. In other words, the latter supports the reuse of items. The main part is Adaptive Generic Product Structure (AGPS) approach that is structure-based approach to the management of product variety in engineering-to-order product families is introduced. It differs from our study because it is based on variant management.

In Svensson and Malqvist's study [29], importance of product structure management is emphasized on interdisciplinary process. According to that study, different disciplines can have different requirements so they should be able to meet them through same product structure. It resembles the idea that different type of design basis documents address different departments such as design, manufacturing planning or integration. Other similar point of this study is describing product structure as dynamic since it needs to update as to changes. In addition, Svensson and Malqvist's study also examines the subject with regards to information system and configuration management and it discusses the idea on a case study from the automotive industry.

Although, the subject is different, Wu et al.'s study [35] is similar to our study in terms of expressing its content based on CM2 context. That study proposes a change management framework under the CM2 standards and its industrial implementation based on the design and manufacturing domains of PLM and enterprise resource plan-

ing (ERP) systems. While Wu et al.'s study clarifies change management according to CM2 standards, our study clarifies product structure. Both explain the main idea through the perspective of the PLM.

CHAPTER 3

PHYSICAL ITEM HIERARCHY

Creating physical item hierarchy is a main point of this thesis. In this section, CM2 approach for physical item hierarchy is explained and how a baseline is derived from physical item hierarchy is described.

3.1 Definition

All sub components that make up an end item product are called items. If product is shown in tree structure, all the items that constitutes the end item are connected to each other with parent child relationship and form physical item hierarchy as shown in the Figure 3.1.

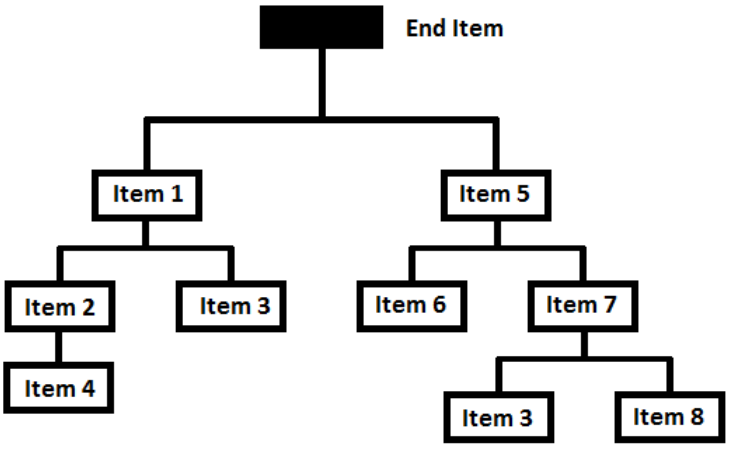


Figure 3.1: Physical item hierarchy draft

3.2 CM2 Approach for Product Structure

CM2 approach contains all product life cycle stages as concept, design, develop, build, produce, maintain, modify and decommission. CM2 keep all these stages in perspective based on V-model shown in the Figure 3.2.

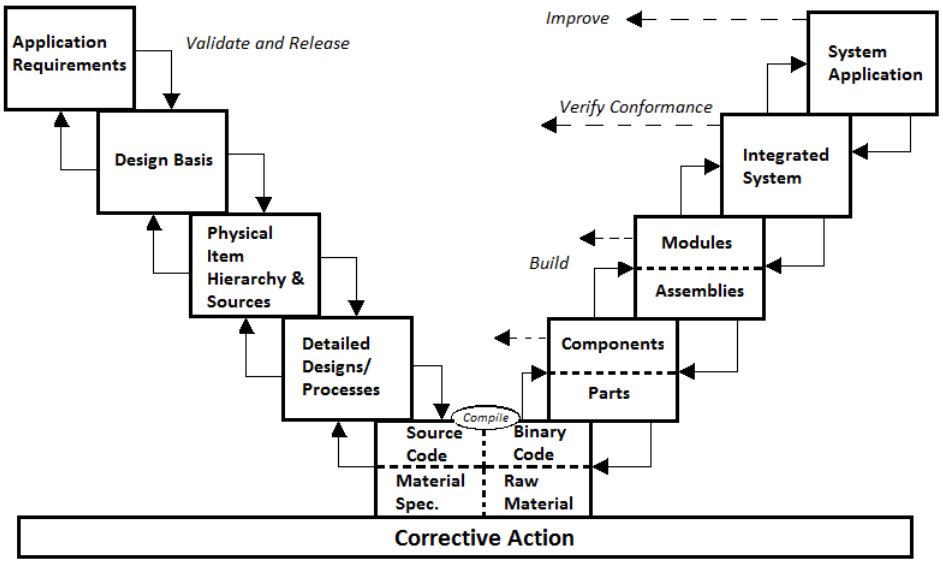


Figure 3.2: V-model for development [15]

The key concept is specified by the first step of V-model which is application requirements. Design basis is created from the key concept. Design basis is used while structuring product. Product structure is shown with physical item hierarchy. For design and develop stages, physical item hierarchy and sources are used for detailed design. Then, product is produced and maintained by subsequent processes. Product starts its life by releasing concept document and its life ends with retirement of the last definitive document [15].

Product is defined top-down according to left side of the V-model. It is built by bottom-up approach in the right side. The 4-tier CM2 process is composed of the V-model for development of new product. The 4-tier CM2 process is comprised of 9 steps as seen in the Figure 3.3. Tiers shows high level plan, detailed plan, design and process, building and testing end item respectively. The left side of the V-model is for creating and validating documentation. Steps 1 to 6 of 4-tier, 9 step process represent

left side of the V-model. The right side of the V-model is for building prototypes and the first end-item. Step 7 and 8 represent right side of the V-model. The last step of process represents corrective actions which is at the bottom of V-model. Corrective actions represents changes on the right side to resolve non-conformance.

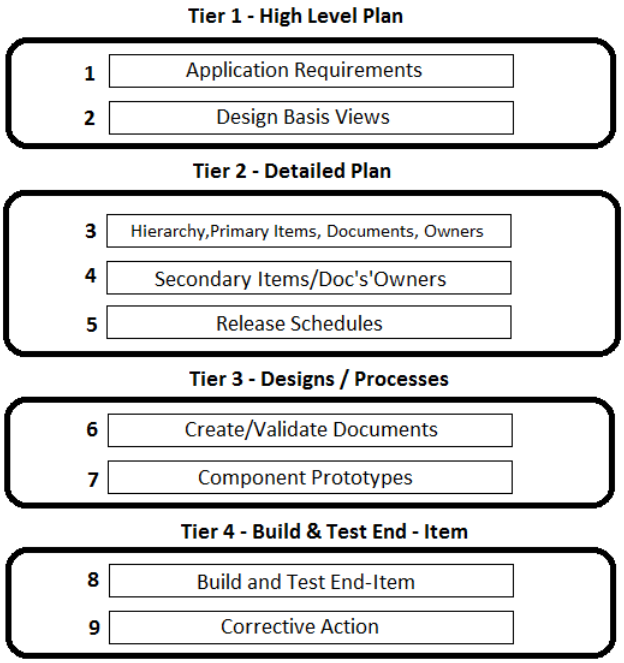


Figure 3.3: 4-Tier, 9 step CM2 process [16]

Physical item hierarchy is created at the third step of process. The first two steps must be properly defined for the creation of a physical item hierarchy. Describing application requirements that is the first step of process specifies what product must do. Application requirements include applicable laws, industry standards, regulations, contractual agreements and user expectations. After completion of describing application requirements, the next step is to develop the design basis that is accepting application requirements as an input. To create physical item hierarchy, the concept of design basis should be well understood.

3.2.1 Design Basis

Design basis specifies what product can do. It includes four main sets of information which are functional specifications, system schematics, 3-D model and interfaces and

process views. It contains five sets of information with the addition of schematic parts list known as the bill of material as shown in the Figure 3.4.

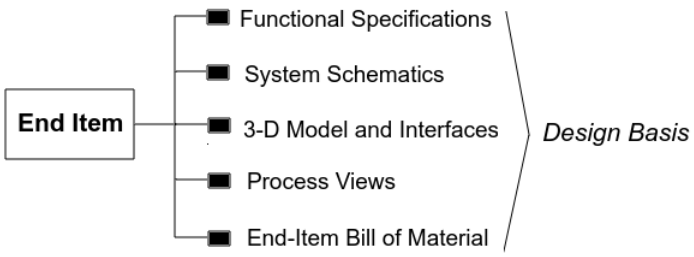


Figure 3.4: Design basis of end item [15]

While functional specifications, system schematics and 3-D model and interfaces represent design part of end item, process views represent process information. All of them are developed concurrently.

Functional specifications are documents that define the functional capabilities of a product, system, facility or process. Functional specification document should include all requirements from high-level to raw materials.

System schematics represent drawings of closed-loop system which is contained in the product. There are functional components in closed-loop system. The interaction of those components with each other is described in the system schematic.

The 3-D models are CAD models. Their shape and size is described in this type of data set. Interface drawings show the interface of two interacting objects with each other in a closed-loop system.

Process views are described for life cycle phases of the products. Data set of process views clarifies steps of the process one by one. How these steps should be applied is expressed in the process plan. There is one process view for each the phases such as production, test, operation, maintenance, repair and decommission.

After design basis views are created, they are released. Release of them means that they are validated and ready to use. If they need to change, they must be revised. The physical item hierarchy facilitates to show general view of structure by representing

current validated documents.

3.2.2 Physical Item Hierarchy

Physical item hierarchy is a framework that supports management of information about physical items [15]. Physical items are linked to each other and information data sets are linked to items in physical item hierarchy as shown in the Figure 3.5. Besides, facilities can be represented with physical item hierarchy. When creating physical item hierarchy of facility, the items are replaced by factory buildings and physical item hierarchy is used instead of BOM. Physical item hierarchy can be used in different industries by changing the item and document types with appropriate ones according to specific sector. For instance, if it is created for information technology, end item can be replaced by software system, there can be diagrams and operation manuals instead of system schematics and process views respectively and items are replaced with components of software system such as server, database.

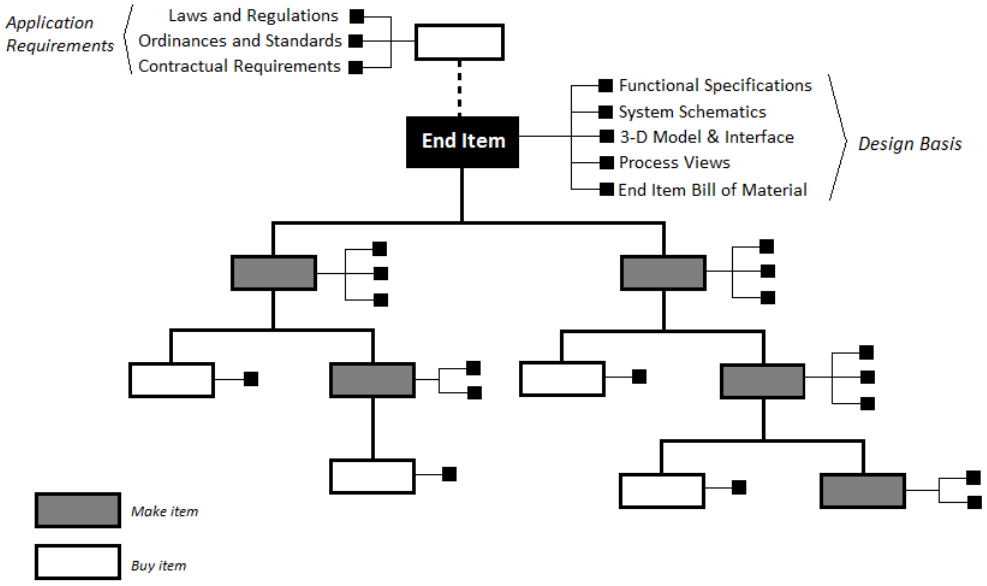


Figure 3.5: Physical item hierarchy [18]

Each item in the physical item hierarchy has its own unique set of documented requirements. The documents are identified with type, number, revision information. Application requirements are linked to place holder of end item. As shown in the

Figure 3.5, the information whether item is make or buy is represented in the physical item hierarchy. Make item indicates that it is repairable, buy item indicates that it is replaceable. Make or buy decision is an important decision in order to affect cost and time to design and manufacture [1]. Therefore, it is a subject that should be considered comprehensively. The tree structure under each level comprises of the items in its BOM.

All items which are shown in physical item hierarchy of end item are categorized as primary items. Documents connected to the item are primary documents. Physical item hierarchy of end item consists of primary items and primary documents. Moreover, there are secondary items and documents. They are connected to primary documents. Secondary items can be equipment and tool that are used to develop, produce, test, operate and maintain primary items. Secondary documents can be documents of secondary items which are used to support secondary items or they can be connected to primary documents directly to standardize processes. The Figure 3.6 illustrates that secondary items are connected over the process plan of the primary item. According to this figure, process plan of primary item contains tool A and equipment XYZ and the secondary document named standard process describes standardization information of the process which is written in process plan.

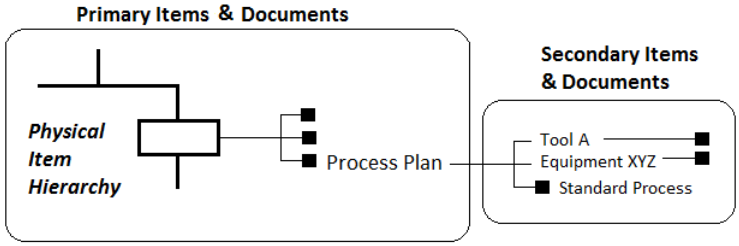


Figure 3.6: Relation between primary and secondary items/documents [16]

The most important point about physical item hierarchy is managing all requirements and associated changes with one common CM process. Every item in the physical item hierarchy should be released. Once released, modification of those items requires change process. Accommodating change and keeping requirements clear, concise and valid are required to provide a basis for as-planned/as-released baseline.

3.2.3 As-Planned/As-Released Baseline

The CM2 model is comprised of 19 core business process categories shown in the Table 3.1 [17]. The business process infrastructure consists of strategic business plan and first eight core business processes. The power of the CM2 model comes from this process infrastructure of CM2 model. The domain of CM includes categories 1.0 through 7.0. In this section, first core business process which is As-Planned/As-Released Baseline is explained in detail.

1.0 As-Planned/As-Released Baselines
2.0 4-Tier, 9-Step Development Process
3.0 Naming, Numbering and Reuse
4.0 Data and Record Integrity
5.0 Document Validation and Release Records
6.0 Changes and Revision Records
7.0 As-Built Records
8.0 Information Systems
9.0 Facilities and Asset Management
10.0 Security, Safety and Environmental
11.0 Business Program Management
12.0 Research and Development Engineering
13.0 Marketing, Sales and Contracts
14.0 Supply Chain Management
15.0 Order Fulfillment and Verification
16.0 Support, Operation and Maintenance
17.0 Human Resources and Training
18.0 Financial Accounting and Reporting
19.0 Process Oversight and Internal Audit

Table 3.1: Core Business Processes

The product structure hierarchy is shown by As Planned/As Released Baselines and it identifies each element of the product along with their related documents and access to the key attributes of each element and each document. How the information

is organized and how the information has changed are represented by baseline and baseline also indicates the visibility of pending changes as in the Figure 3.7. In other words, CM2 baseline called as planned/as released baseline is instant item hierarchy that defines the current status of the configuration by showing released items and planned changes. It is derived from design basis.

AS-PLANNED/AS-RELEASED BASELINE

End Item ID No: _____ Date/Time: _____/_____

Physical Items			Documented Requirements						Planned Changes		
Hierarchy (Qty per)	Item ID Number	Item Name	Type	Number	Revision	Release Date	Efective Date	ECN	A/D	Effectivity	ECN
0	NNNN	Application	LW	NNNN	R	DMY					
			RG	NNNN	R	DMY	DMY	NNN			
			CT	NNNN	R	DMY	DMY	NNN			
			ST	NNNN	R	DMY	DMY	NNN			
1	NNNN	End-Item	FS	NNNN	B	DMY	DMY	NNN	D	DMY	NNN
			FS	NNNN	C	DMY	DMY		A	DMY	NNN
			SS	NNNN	E	DMY	DMY	NNN	D	DMY	NNN
			SS	NNNN	F	DMY	DMY		A	DMY	NNN
			3D	NNNN	D	DMY	DMY	NNN	D	DMY	NNN
			3D	NNNN	E	DMY	DMY		A	DMY	NNN
			PV	NNNN	E	DMY	DMY	NNN	D	DMY	NNN
			PV	NNNN	F	DMY	DMY		A	DMY	NNN

Figure 3.7: As-planned/as-released baseline [16]

As planned/as released baseline represents instant hierarchy of item so it has creation date as seen on the top right of the Figure 3.7. Identification number of end item is written on the top left and also in the content of baseline document. It consists of three parts. The first part shows physical items that reside in hierarchy. The second part shows primary documents of physical items. The last part shows planned changes of primary documents.

The first part has three columns that are hierarchy number, item id number and item name. The first column shows the hierarchy order. An application is represented by zeroth hierarchy and the end item resides under it. Item id number is unique number for primary items. Item name is a description of item.

The second part has six columns that are type, number, revision. For application requirements, LW, RG, CT and ST type abbreviations symbolize laws, regulations, contracts, industry standards respectively. For end item requirements, FS, SS, 3D, PV type abbreviations symbolize functional specification, system schematics, 3D model

and process views as mentioned in Chapter 3.2.1. These requirements can also be used for primary items of the end item. The second column shows id number of primary documents. Each primary document is created, validated and released. When it created, it has a revision information. The third column shows a revision of primary documents. When it released, it has a release date. The fourth column shows a release date of primary documents. It is written as DMY that symbolizes day, month, year. The fifth column shows effective date that represents when a newly released document is to be used. If the document has enterprise change notice (ECN), it differs from release date. However, if the document does not have ECN, it is same with release date. The sixth columns show ECN id number. ECN is a form that is used to implement a change request and it includes a baseline impact matrix which includes superseded and superseding item and documents.

The third part has three columns that are A/D, effectivity and ECN. In the first column, A/D symbolizes add or delete. According to ECN, add or delete information is provided from the impact matrix. Delete information represents superseded item or document and add information represents superseding item or document. In the second column, effectivity shows an effectivity of ECN which specifies when superseding items and documents are to be used in place of superseded items and documents. The last column indicates which ECN the change was made to.

To illustrate, one physical item hierarchy is created as in the Figure 3.8. It has application requirements at the top of hierarchy. The end item named 9876 has four primary documents, one of them is shown as BOM. There is a change for BOM document. It revised from A to B. End item has two primary items with their primary documents. According to BOM change, primary item named 1234 is superseded with item 2345.

When an item or document is revised, it is represented in the baseline as a record. If as-planned/as-released baseline is created from example in Figure 3.8, it will be like the one given in the Figure 3.9.

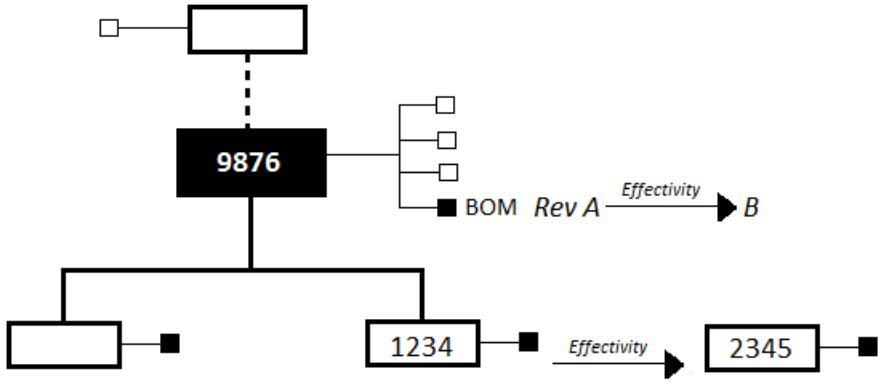


Figure 3.8: Physical item hierarchy with change example

AS-PLANNED/AS-RELEASED BASELINE

End Item ID No: 9876 Date/Time: _____/_____

Physical Items			Documented Requirements						Planned Changes		
Hierarchy	Item Number	Item Name	Type	Number	Revision	Release Date	Efective Date	ECN	A/D	Effectivity	ECN
0	NNNN	XXXXXX	TT	NNNN	R	DMY					
1	9876	End-Item	TT	NNNN	R	DMY	DMY	NNN			
			TT	NNNN	R	DMY	DMY	NNN			
			TT	NNNN	R	DMY	DMY	NNN			
			BM	9876	A	DMY	DMY	NNN	D	DMY	NNN
			BM	9876	B	DMY	DMY		A	DMY	NNN
1	NNNN	XXXXXX	TT	NNNN	R	DMY	DMY	NNN			
1	1234	XXXXXX	TT	1234	R	DMY	DMY	NNN	D		NNN
1	2345	XXXXXX	TT	2345	A	DMY	DMY	NNN	A		NNN

Figure 3.9: As-planned/as-released baseline of change example [18]

CHAPTER 4

TOOL EXTENSION

In this chapter, the implementation of physical item hierarchy and CM2 baseline to the PLM system are explained. Firstly, what is done as the tool extension is defined. Secondly, how it is done is clarified. PLM system design and functionalities are described according to the processes of the defense company.

4.1 Scope of the Tool Extension

Customized PLM system is 3DExperience Platform developed by Dassault Systemes. Two products of 3DExperience Platform are used in the company which are CATIA and ENOVIA as in the Figure 4.1 [30]. The former is used for CAD and the latter is used for data lifecycle management.

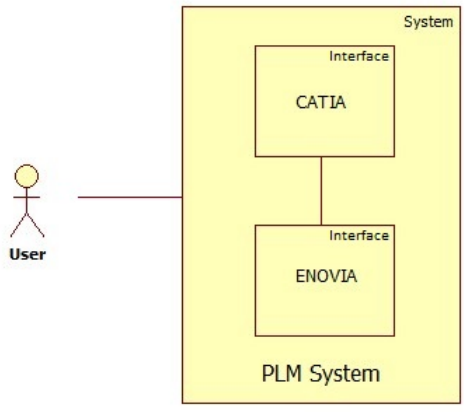


Figure 4.1: Block diagram

In this study, ENOVIA is extended by customization since it does not contain physical

item hierarchy view and baseline as clarified in CM2 methodology.

In ENOVIA, physical item hierarchy is shown by Engineering BOM (EBOM) table as out of the box. The illustrative example is the aircraft surface model which of CAD is seen in Figure 2.2 in Chapter 2. Figure 4.2 shows EBOM table view of the illustrative example .

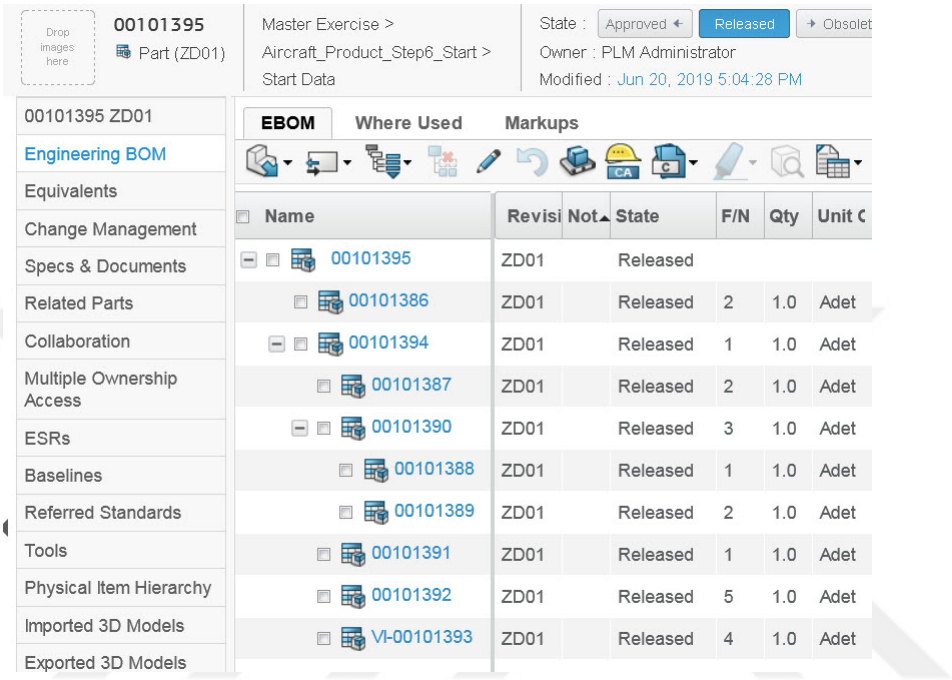


Figure 4.2: Engineering BOM table of illustrative example

As seen in the Figure 4.2, EBOM table displays only part list of end item. It displays single level items when it is opened first but it can be expanded. Thus, all level items can be shown. However, requirement documents which are connected to items are not displayed in EBOM table view. The view of physical item hierarchy which explained in CM2 methodology should display primary items and primary documents together. In this tool extension, displaying physical item hierarchy view according to CM2 is provided by customizing the PLM tool.

This tool extension is done for the defense industry company Emerald which manufactures missiles. In this company, change management has not managed through PLM system yet. It has managed through Enterprise Resource Planning (ERP) system and there is not any integration for change management. However, for as-planned baseline, change information is required as explained in Chapter 3. Therefore, as long

as there is not any integration between PLM system and ERP system or changes are not managed in PLM system in Emerald, CM2 baseline cannot be implemented as "As-Planned/As-Released Baseline" in PLM system. Consequently, it is implemented as only "As-Released Baseline" in this study. In the road map of the company, performing change management through PLM system is planned. When it is managed from PLM system, as-released baseline will be basis for creating full baseline with change information.

4.2 Design Details of the Tool Extension

In this section, software requirements are clarified and software design is explained by giving information about development platform, data structure, algorithm and design views.

4.2.1 Software Requirement Analysis

The requirements are specified through use cases. Actor of the system is user that uses the PLM system. User can have the role, namely, designer, configuration specialist, manufacturing planning specialist or administrator. There are nine use cases as in Figure 4.3. The administrator and the designer have all of them. The configuration specialist and the manufacturing specialist have five of them in Figure 4.4.

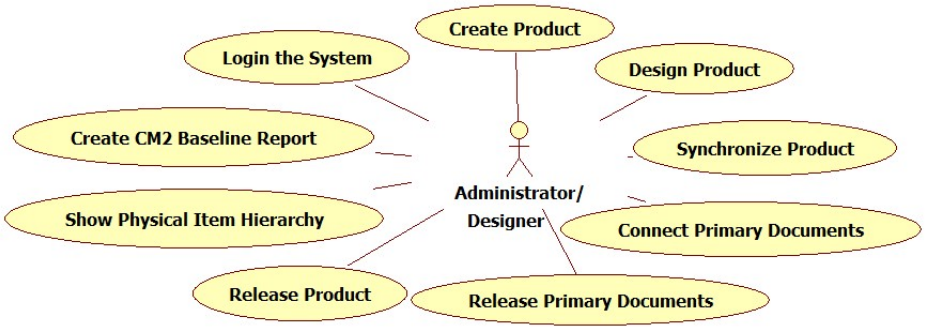


Figure 4.3: Use case diagram for designer/administrator

For realizing "Show Physical Item Hierarchy" and "Create CM2 Baseline Report" use

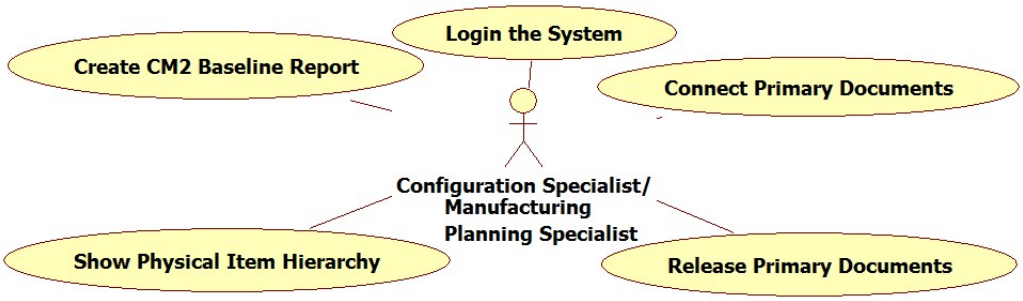


Figure 4.4: Use case diagram for configuration specialist/manufacturing planning specialist

cases, other seven use cases are prerequisites. Summary of all use cases is described in Table 4.1.

Login the System: *User should login the PLM system.*
Create Product: *User should create a product in CATIA.*
Design Product: *User should design created product in CATIA by inserting other single part or assembly part below.*
Synchronize Product: *After design the product, user should synchronize the product from CATIA to ENOVIA. EBOM will be displayed in ENOVIA after synchronization.*
Connect Primary Documents: *User should connect primary documents of items which resides on product BOM.*
Release Primary Documents: *User should release primary documents of items.*
Release Product: *User should release the product to manufacture.*
Show Physical Item Hierarchy: *User shows physical item hierarchy as explained in CM2 model.*
Create CM2 Baseline Report: *User creates as-released baseline report as explained in CM2 model.*

Table 4.1: Summary of Use Cases

For implemented use cases that are "Show Physical Item Hierarchy" and "Create CM2 Baseline Report", requirements are derived from the CMII/IPE Model [17] as follows:

1. The tool can provide visibility of current configuration.
2. The tool can display parent-to-child relationships between physical items using BOM which are identified by type, number and revision level.
3. The tool can use bill of material to provide a fully exploded (or indented) view of the physical(primary) items contained in each end-item product, facility or IT system.
4. The tool can compare the primary items contained in two or more bills of material, including fully exploded bills, and identify their similarities and differences.
5. The tool can display the linkages from each primary item to its own unique set of design and process requirements (or primary documents)
6. The tool can support as-released product baseline formats and data fields per the template provided in the CMII/IPE Model. Each baseline carries the same identity as the product.
7. The tool can display the release date for each primary document.
8. The tool can provide a standardized metadata template for each type of physical item.
9. The tool can provide a metadata template for each document type.
10. The tool can provide views of any physical item and access to any document by "clicking" on that item or document and also provide access to the metadata for any item or document.
11. The tool can support identification schemes for physical items which may include Commercial And Government Entity (CAGE) code which is a five-character ID number used extensively within the federal government [9], model numbers, item ID numbers, names and descriptions.

12. The tool can support identification schemes for documents which may include document type, number, revision level and CAGE code.

13. The tool is able to identify all active applications for any primary or secondary physical item or document.

4.2.2 Software Design Details

The physical item hierarchy view and CM2 baseline is designed by object-oriented approach. The software is implemented with Java on Eclipse Oxygen IDE platform. User interfaces are deployed by Schema Agent (Spinner). Schema Agent is a MQL command driven tool. It is used to view and update schema of ENOVIA. MQL is the Matrix Query Language which consists of a set of command that help the administrator set up and test an ENOVIA Live Collaboration database quickly and efficiently. The top level component diagram that contains software development components, application components and their relationship is seen in Figure 4.5

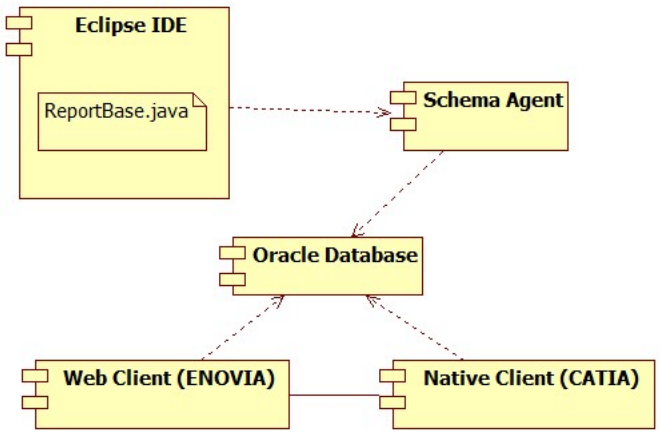


Figure 4.5: Top level component diagram

Physical item hierarchy represents the items and documents connected by BOM relationship and reference document relationship respectively. The items are connected hierarchically. Consequently, data structure is organized in tree structure.

User enters input to system by designing product in CATIA. After entering input data, it needs to be synchronized with ENOVIA for displaying output data provided

by tool extension. The output of tool extension is displayed from ENOVIA to the user. Below context diagram shows the design relationship which includes provided input and received output between the user and the other major components of the system.

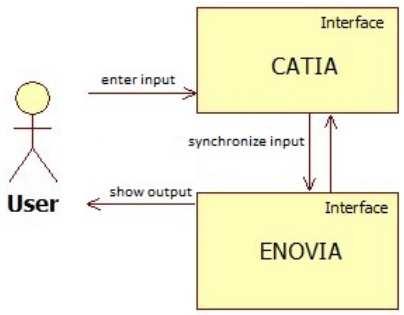


Figure 4.6: Context diagram

The system codes are written in Java programming language. The software of ENOVIA is comprised of a lot of classes. However, the tool extension pertains to some of them. Figure 4.7 shows the UML class diagram which summarizes which classes relate to implemented physical item hierarchy. This diagram is not used for code generation directly, It is used for sketching of implementation-related part of the system [13]. The PLM System contains two subsystems that are CATIA and ENOVIA. VPMReference is type of CAD objects in CATIA. VPMRepReference is type of drawing print object in CATIA. VPMReference and VPMRepReference objects are associated with aggregation relationship. VPMReference object has at most one VPMRepReference object. The methods named createProduct and designProduct implies that product is created and assembled from other parts and products. If drawing is connected to product as primary document, VPMReference object is connected to VPMRepReference object by insertDrawing method. When VPMReference object synchronized from CATIA to ENOVIA by synchronizeVPMReferenceToPart method, system creates a Part object automatically.Therefore, each Part object has exactly one VPMReference object in the system. If VPMReference object has VPMRepReference object, system also creates a DrawingPrint object and connect to the Part object automatically. Part object has zero or more Document objects. EngineeringDocument, ESR and Standard are subclasses of Document class.

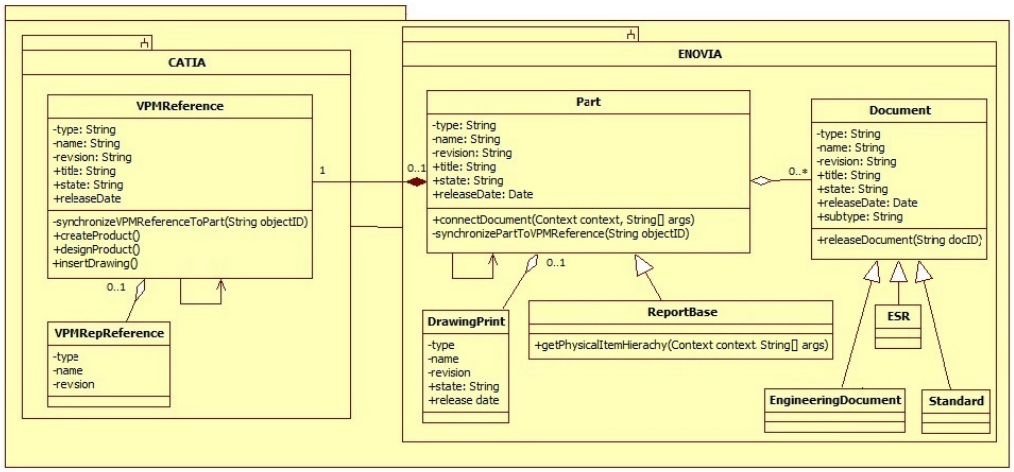


Figure 4.7: Class diagram

ReportBase class is subclass of Part class. The part that is creating physical item hierarchy of tool extension is implemented in this class by getPhysicalItemHierarchy method. In this method, object id of part is declared from hypertext reference, Instance of DomainObject is created with object id. Related objects are gotten with relationship patterns that are EBOM, part specification, reference document, referred standard and externally source record and type patterns that are part, drawing print, engineering document, standard and externally source record (ESR) to the output as MapList. This method is defined as expand program of PhysicalItemHierarchy command. PhysicalItemHierarchySummaryToolBar menu is created and set toolbar of the command object. This menu is placed to part actions menu as seen in the left side of Figure 4.10. PhysicalItemHierarchySummary table is created with columns that are name, title, type, subtype, revision and release date. This table is called via command settings and filled via getPhysicalItemHierarchy method. Type, name, revision information should be contained certainly according to CM2 physical item hierarchy model. Title, type, subtype and release date is added to imply as-released baseline. New views can be created with other attributes owing to the fact that ENOVIA provides a feature for creating view.

Figure 4.8 shows the workflow of activities provided by implementations. First activity state which is "Release Product" is prerequisite for performing others. The states that are "Show Physical Item Hierarchy" and "Show CMII Baseline" shows the activ-

ities of tool extension. To perform these states, user should display properties screen of the product as in Figure 4.9. "Show Physical Item Hierarchy" state is performed by clicking "Physical Item Hierarchy" command from actions menu at the left side of properties screen. "Show CMII Baseline" state is performed by clicking "CMII Baseline" command from "CMII Baseline" field in properties screen.

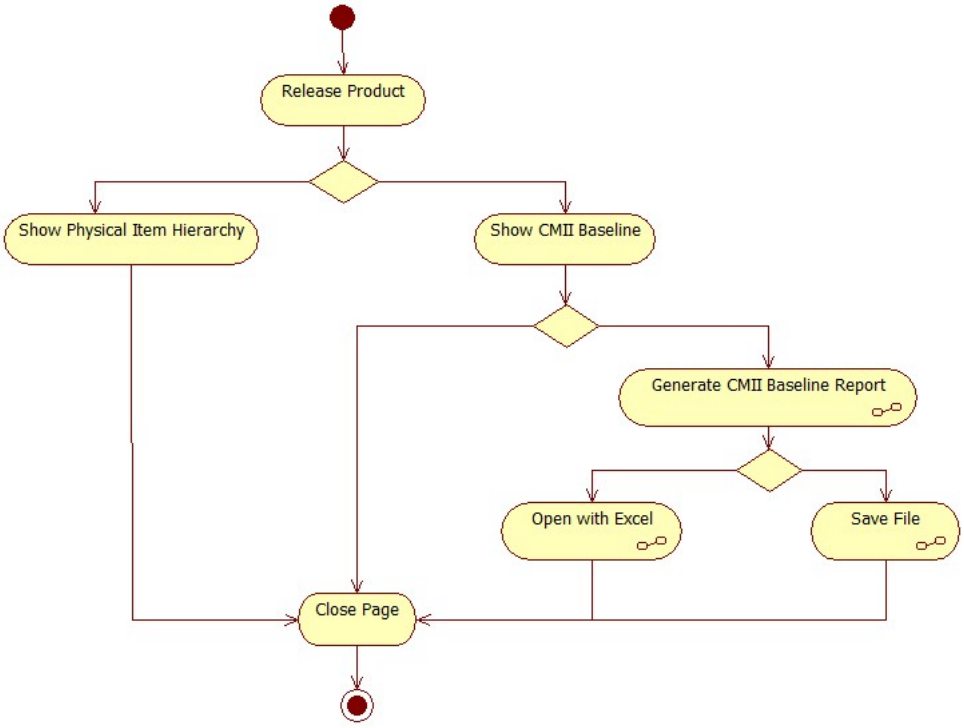


Figure 4.8: Activity diagram of customization functions

Figure 4.10 shows physical item hierarchy of illustrative example by clicking "Physical Item Hierarchy" command. It is provided by customization of ENOVIA. Illustrative example contains items belonging to right side surface model of aircraft product. It is comprised of hatch and right hand side aircraft product in first level. Fuselage, upper fairing product, turbine engine end, wing end and lower fairing end reside under right hand side aircraft product. Upper fairing product is comprised of upper fairing styling data and upper fairing surfaces in third level. End item is aircraft product which has name as 00101395. All parts under the end item are primary items according to CM2 physical item hierarchy model. End item has four primary documents which are schematic, system requirements specification document, process plan and drawing. They are seen bottom of physical item hierarchy as being connected to end

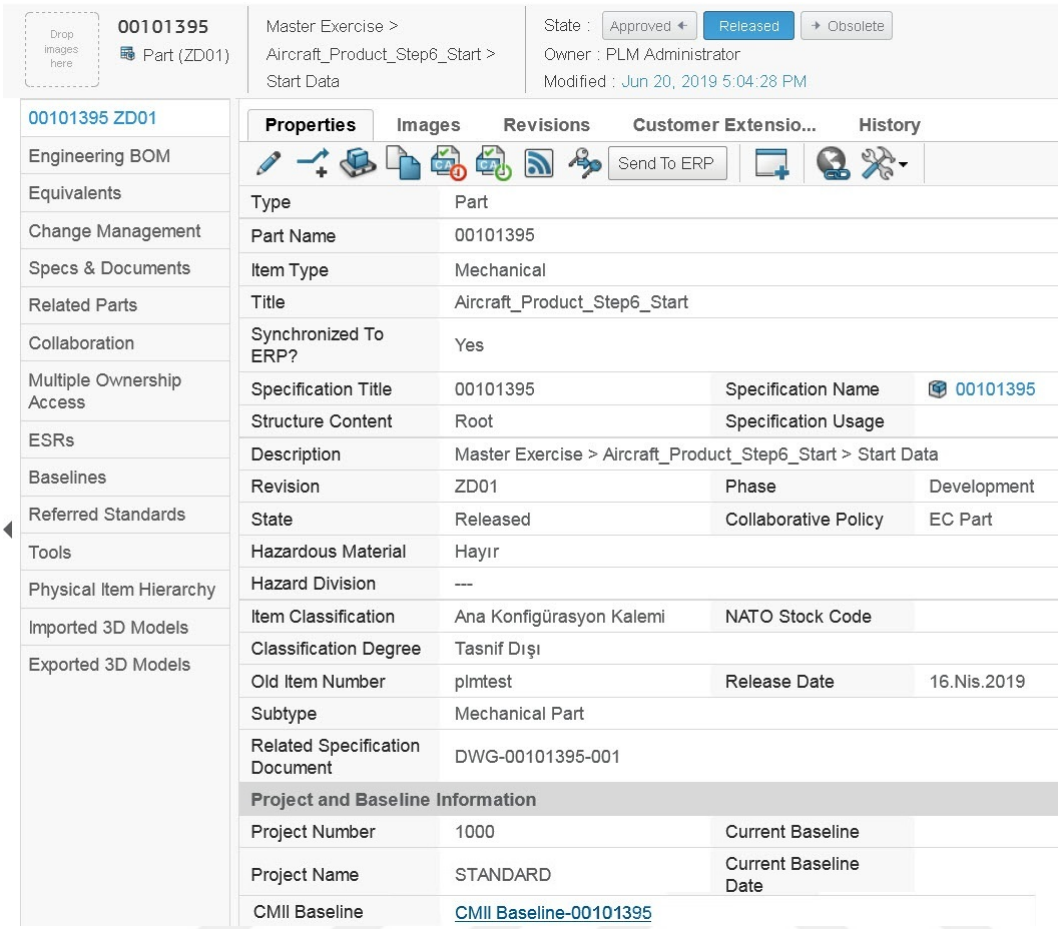


Figure 4.9: Properties screen of end item

item in the Figure 4.10. All primary items excluding lower fairing end have drawing as primary document.Lower fairing end is a vendor item and it has subsystem requirements specification document as primary document. Release date of drawing print objects are null since drawings are released depending upon parts in this company contrary to CM2. CM2 defends that primary documents should be released and revised. The revision level should not be assigned to physical item. Therefore, physical items should not be released and they should be traced with their primary documents [15].

The second part of tool extension is generating as-released baseline. This part is shown by "Show CMII Baseline" state in activity diagram. For this part, part properties web form is customized and a field that is CMIIBaseline is added to this screen as seen bottom of Figure 4.9. The expression of the field is command which is given the

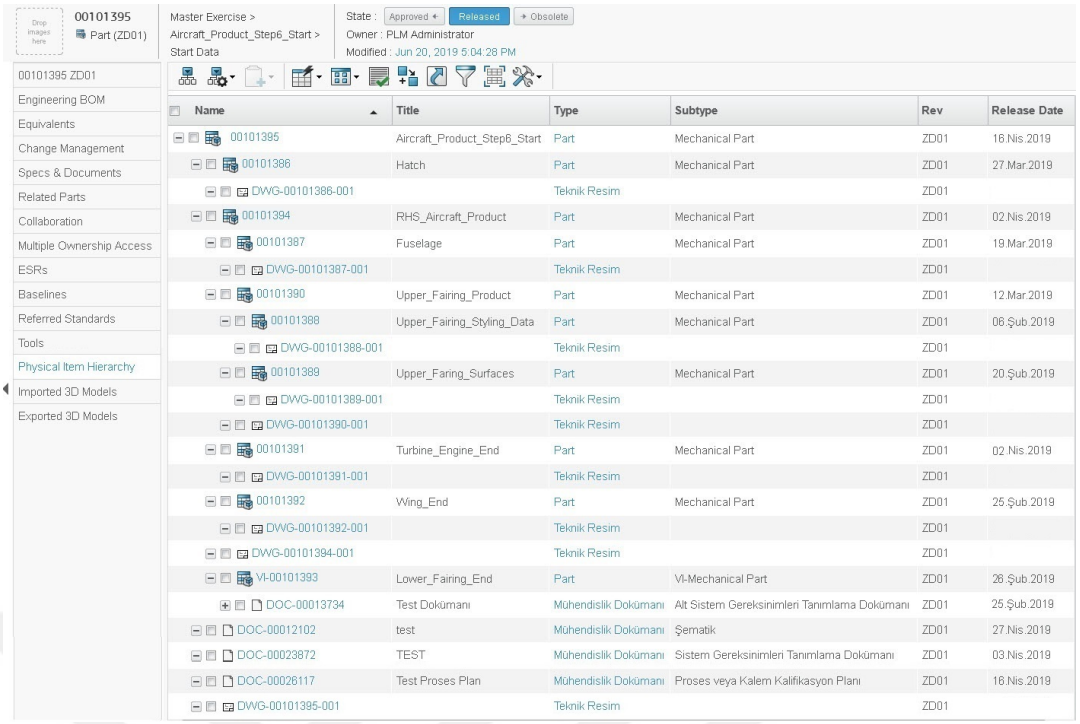


Figure 4.10: Physical item hierarchy of illustrative example

name as CMII Baseline with item name. When the user clicks this command, a new page which displays as-released baseline of the item is opened as seen in the Figure 4.11. It consists of one command for generating CM2 baseline report that is shown by "Generate CMII Baseline Report" state in Figure 4.8, end item id, date, time and table of baseline. This page is generated with JSP and this JSP is defined in hypertext reference setting of CMIIBaseline field. A code in this JSP finds all sublevel items of the end item which are connected with EBOM relationship and sublevel items of that items recursively till there is not any sublevel item. After finding sublevel items, primary documents are found which are connected with reference document relationship to items. Information on items and primary documents are kept in StringBuilder object as table. The table contains first seven columns of CM2 as-planned/as-released baseline displayed in Figure 3.7 in Chapter 3. There is one more column in this table since hierarchy column in CM2 template is represented with order no and hierarchy no columns together. This table displays instant as-released baseline of the item.

The command at the top of CMII Baseline page is for generating CM2 baseline report in Excel format. When the user clicks this command, download page is opened

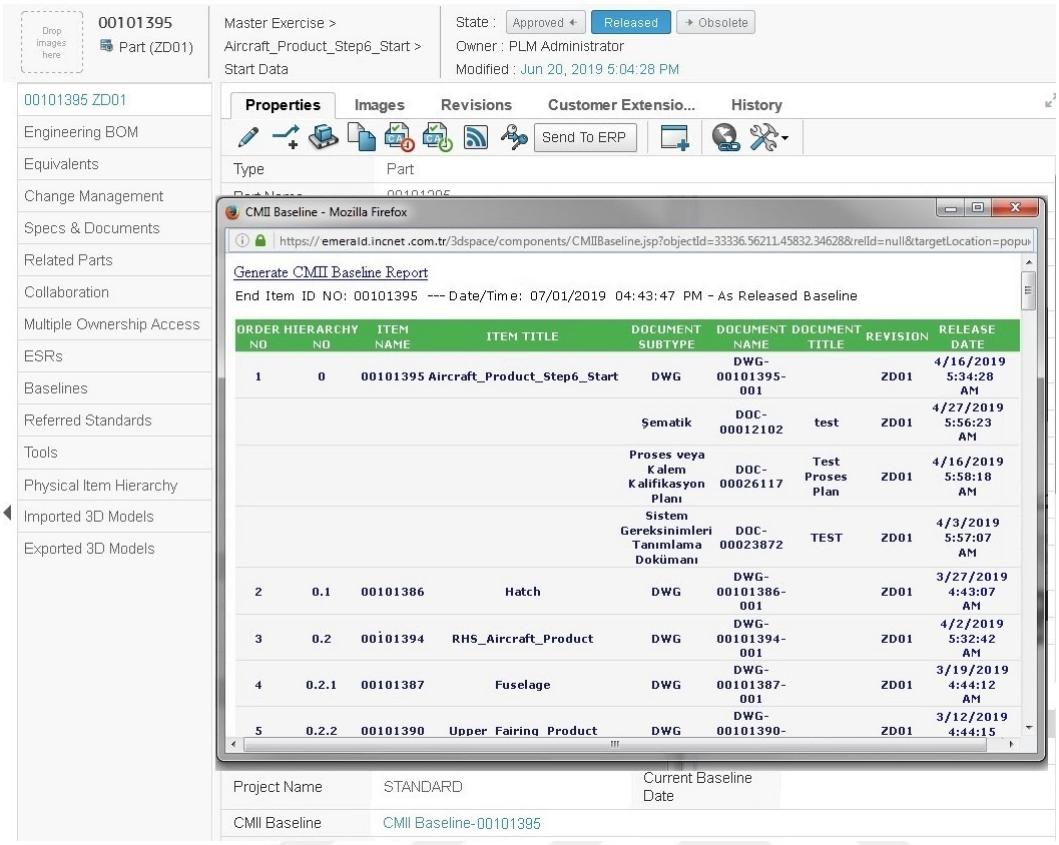


Figure 4.11: CMII Baseline page

as seen in the Figure 4.12. The states in the activity diagram that are "Open with Excel" and "Save File" become available by this page. This page is generated with JSP named CMIIBaselineReport. All baseline information in the table is written to HSSFWorkbook object. This object is written to ByteArrayOutputStream object. This object is transformed to Byte array. The content length of page response is set as length of the array. After that, page response is declared by OutputStream object that is constituted with Byte array. This provides to write content of created HSSFWorkbook object to the Excel file. The user can open or save CMII Baseline file in Excel format as in the Figure 4.13. When the user chooses to save file, it is saved in ".xls" extension. Despite drawings have not release date attribute in customized system, release date of connected item to the drawing is written to file for drawings since they are released with the item at the same time.

All implementations are deployed with the Spinner tool excluding JSP implementations. For the Spinner deployment, excel files in Appendix A are prepared and then,

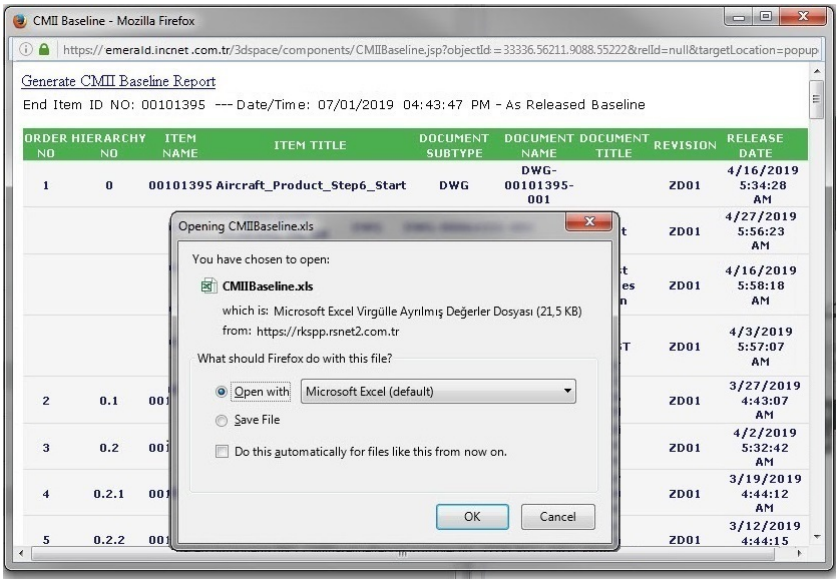


Figure 4.12: CMII Baseline download page

	A	B	C	D	E	F	G	H	I
1	AS RELEASED BASELINE								
2	END ITEM ID NO: 00101395				DATE/TIME: 05/24/2019 08:54:50 PM				
3									
4	PHYSICAL ITEMS				DOCUMENTED REQUIREMENTS				
5									
6	ORDER NO	HIERARCHY NO	ITEM NAME	ITEM TITLE	DOCUMENT SUBTYPE	DOCUMENT NAME	DOCUMENT TITLE	REVISION	RELEASE DATE
7	1	0	00101395	Aircraft_Product_Step6_Start	DWG	DWG-00101395-001		ZD01	4/16/2019 5:34:28 AM
8					Şematik	DOC-00012102	test	ZD01	4/27/2019 5:56:23 AM
9					Proses veya Kalem Kalifikasyon Planı	DOC-00026117	Test Proses Plan	ZD01	4/16/2019 5:58:18 AM
10					Sistem Gereksinimleri Tanımlama Dokümanı	DOC-00023872	TEST	ZD01	4/3/2019 5:57:07 AM
11	2	0.1	00101386	Hatch	DWG	DWG-00101386-001		ZD01	3/27/2019 4:43:07 AM
12	3	0.2	00101394	RHS_Aircraft_Product	DWG	DWG-00101394-001		ZD01	4/3/2019 5:32:42 AM
13	4	0.2.1	00101387	Fuselage	DWG	DWG-00101387-001		ZD01	3/19/2019 4:44:12 AM
14	5	0.2.2	00101390	Upper_Fairing_Product	DWG	DWG-00101390-001		ZD01	3/12/2019 4:44:15 AM
15	6	0.2.2.1	00101388	Upper_Fairing_Styling_Data	DWG	DWG-00101388-001		ZD01	2/26/2019 3:52:12 AM
16	7	0.2.2.2	00101389	Upper_Faring_Surfaces	DWG	DWG-00101389-001		ZD01	2/20/2019 3:52:12 AM
17	8	0.2.3	00101391	Turbine_Engine_End	DWG	DWG-00101391-001		ZD01	3/22/2019 5:56:23 AM
18	9	0.2.4	00101392	Wing_End	DWG	DWG-00101392-001		ZD01	2/25/2019 5:58:18 AM
19	10	0.2.5	VI-00101393	Lower_Fairing_End	Alt Sistem Gereksinimleri Tanımlama Dokümanı	DOC-00013734	Test Dokümanı	ZD01	4/3/2019 5:57:07 AM

Figure 4.13: CMII Baseline excel view

they are deployed to the system by user-invoked program, which are created during Spinner installation, on MQL command tool. Spinner is able to add, modify, delete, register and unregister schema via executing invoked program.

Sequence diagram in the Figure 4.14 depicts interaction between objects in a sequential order. It summarizes existing system functions and added tool extension functions.

In the sequence diagram, existing system functions are first nine functions and they

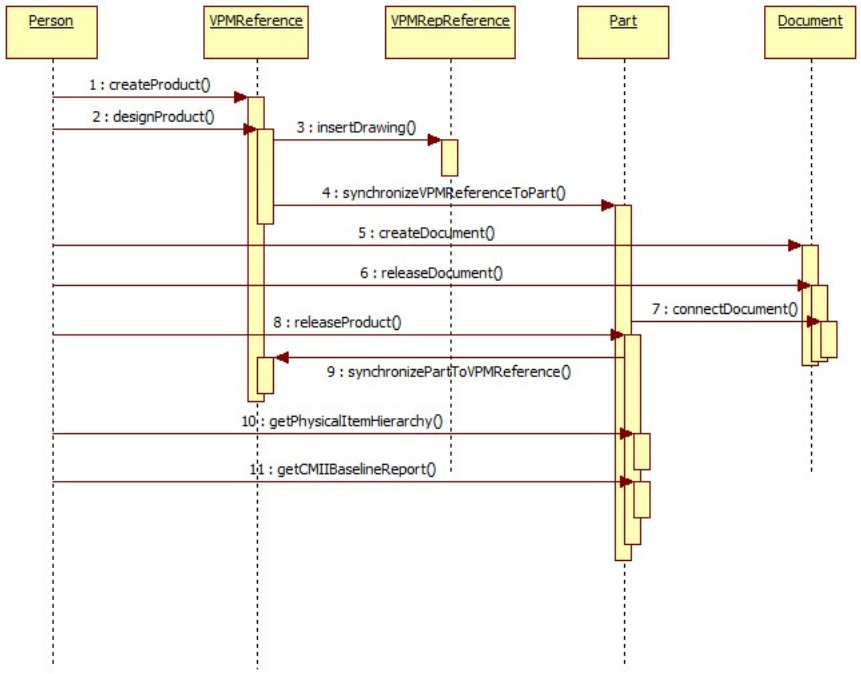


Figure 4.14: Sequence diagram for tool extension functions

are prerequisite for applicability of the tool extension. User is Person object in 3DExperience Platform. To display physical item hierarchy, if there is not any existing product, user should create and design product in CATIA. Product or part in CATIA is created as VPMReference object. While designing, the product is connected to primary items and if drawing is needed, user can insert drawing to product. Drawing is created as VPMRepReference object. After design of the product, user promotes the product in CATIA and synchronizeVPMReferenceToPart function is triggered. The product is synchronized to ENOVIA by synchronizeVPMReferenceToPart function and Part object that will be connected to VPMReference is created by the system automatically. Then, if primary documents are not existing, user can create and release primary documents and connect them to part object. If released primary documents are existing in the system, user can connect them to part directly. After released primary documents are connected to Part object, user releases it. When the Part object is released, it synchronizes with connected VPMReference object by synchronizePartToVPMReference method. The product is ready to display physical item hierarchy and as-released baseline when it is released. Functionality related with the physical item hierarchy implementation is represented with getPhysicalItemHierarchy func-

tion and functionality related with the CM2 baseline implementation is represented with getCMIIBaselineReport function. After one product is released by providing prerequisites in the PLM System, these functionalities can be used by the users.

To sum up, tool extension comprises of two parts which are displaying physical item hierarchy in ENOVIA and generating CM2 baseline from ENOVIA. The details and steps of development is explained by UML diagrams and UI views. CM2 baseline implementation does not totally involve as-planned/as-released baseline as in the CM2 methodology. It involves only as-released part of CM2 baseline. However, there is a possibility to modify the implementation when the company begins to use change management applications in 3DExperience Platform. All implementations is applied to the custom system. Therefore, the scenarios and the system usage is special to the company and they are not same with OOTB version of 3DExperience Platform.

CHAPTER 5

CASE STUDY FROM EMERALD COMPANY

In this chapter, physical item hierarchy of a real product from defense industry is analyzed as a case study. The telemetry system which is a subsystem of a missile is considered as a product. The utilization of customization explained in Chapter 4 is exemplified by this product. Functional validation of the implementation is provided and its usability test is performed.

5.1 Telemetry System

A telemetry system is a subsystem of a missile which is comprised of transmitter, antenna, battery, encoder, sensors and cable network. Telemetry systems are often used for diagnostics in artillery systems where unused space can be found in the ogive or payload compartments or by the simple replacement of a nose-located fuze [8]. In the missile company, the warhead is replaced with telemetry system and it is used for flight testing. The book entitled Telemetry Systems Engineering shows telemetry system for the flight testing of a missile as in Figure 5.1 [14].

In the missile company, telemetry system samples data which is calculated by an algorithm of navigation, guidance and autopilot and data which is acquired from the sensors in seeker, inertial measurement unit, control drive system, power supply or power management unit with specific time intervals and sends to ground systems.It is not used in main configuration. It is used in test configuration. The sub-parts of this product vary according to test objectives. For example, if vibration test will be performed, it contains vibration sensor. Also, it can contain other type of sensors for another tests.

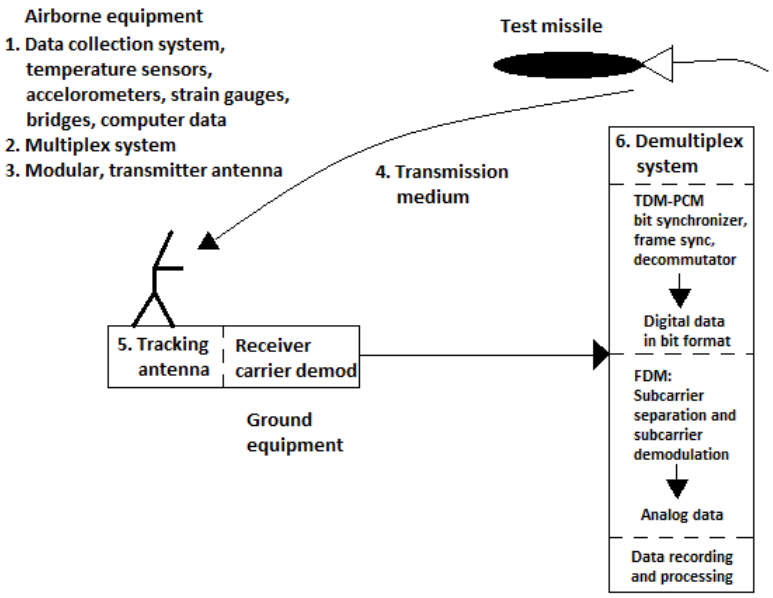


Figure 5.1: Missile test example of telemetry system overview [14]

The telemetry system in the missile is seen as in Figure 5.2. It consists of transmitter, antenna, encoder, power management controller card, telemetry power supply and body. The telemetry records information transmitted to the ground during the flight of the missile from a transmitter located on the missile by using telemetry stations deployed on the ground. The information received by the telemetry can be one of the following.

- acceleration information from the inertial measurement unit in the missile,
- angular velocity measurements,
- the position,
- speed,
- guidance information calculated from the missile computer,
- guidance information calculated from the missile computer,
- information about the target received from the seeker,
- status information about the functionality of all avionics on the missile.

In addition, information about the flight environment can be obtained by using sensors that are not in tactical missile configuration such as vibration, pressure and temperature placed on the missile for testing purposes.

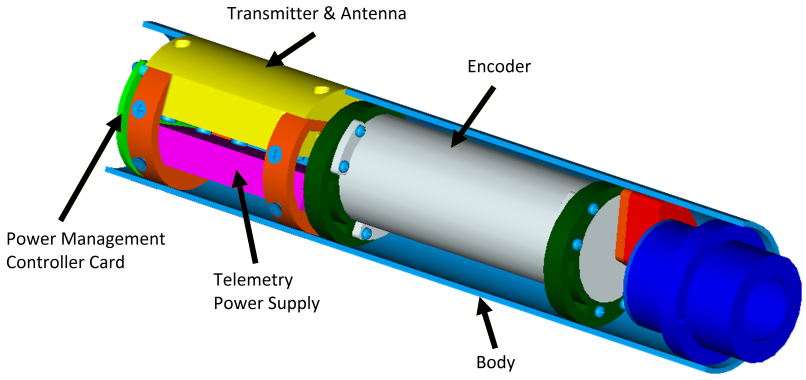


Figure 5.2: Missile telemetry system

The encoder of the telemetry system samples analog and digital data in specific intervals and transforms to specific format. The transmitter performs the modulation required to send the data collected in a series to the ground station via radio frequency connection. The sensor converts physical data such as vibration, temperature, pressure into electrical signals that the encoder can receive. The antenna emits the modulated RF signal into space. The battery supplies the energy required for the telemetry system to perform its function.

The end item is the telemetry system in this case study. The telemetry system product is entitled as "Deneme Başlığı Komplesi" in the missile company. The CAD model of "Deneme Başlığı Komplesi" is seen as in Figure 5.3. After the CAD model is created in CATIA, the BOM structure of the product is synchronized to the ENOVIA. When the sub-parts and end item are released with the primary documents, the physical item hierarchy can be displayed.

In the company, application requirements are not stored in the PLM System so they could not be shown in the physical item hierarchy. Therefore, the physical item hierarchy of the telemetry system covers the part starting with the end item in Figure 3.5 in Chapter 3. The physical item hierarchy of end item is in three levels. Twenty nine single parts and one assembly part reside at one level below that product. The assembly part has seventeen sub-parts at the third level. All of this parts are primary

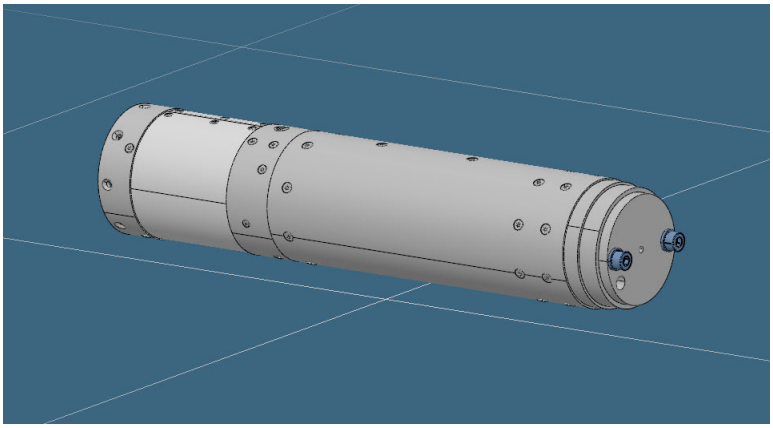


Figure 5.3: CAD model of the telemetry system

items in the physical item hierarchy. Each primary item has one or more primary documents according to its type. The physical item hierarchy of this product is shown in Figure 5.4 with item number, item name, type, subtype, revision and release date information. Technical drawing objects do not have item name and subtype information. They live dependent to primary items as long as their lifecycle. The number of primary items and primary documents is displayed as one hundred nine objects in the lower right corner of the figure.

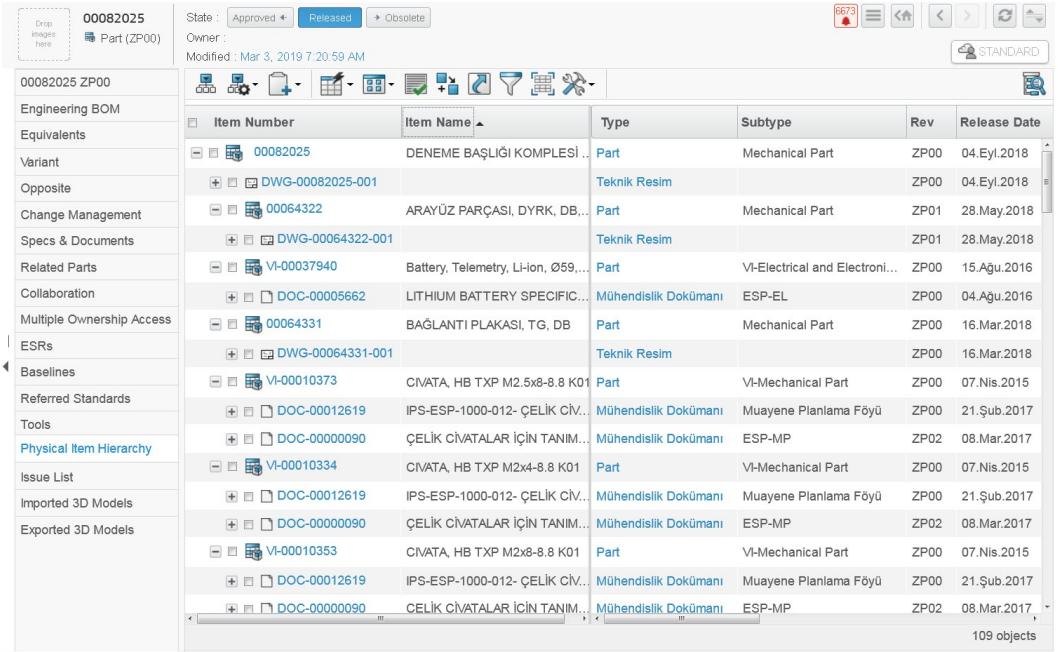
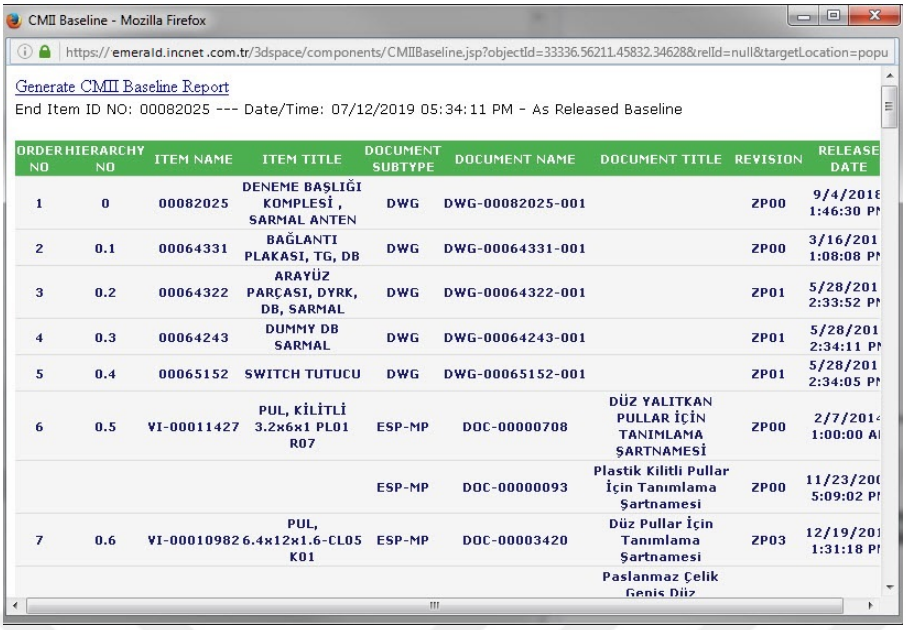


Figure 5.4: Physical item hierarchy view of the telemetry system

The items are categorized to make items and buy items. While make items are development items, buy items are vendor items in this product. The item number of buy items starts with "VI" prefix. Each item has at least one primary document. The primary documents change to item categorization. While development items have drawing as a primary document, vendor items have technical specification documents. Since all document types on the CM2 design basis model such as BOM document and process plan are not existing in this company, it is not possible to create exactly the same physical item hierarchy with the CM2 model. Its applicability depends on processes of company so processes can restrict the application unless implemented as in CM2 methodology.

The CMII Baseline screen for the telemetry system is displayed in Figure 5.5. The end item and first six primary items are seen in this as-released baseline view. The end item and first four items are development items. Each of them has drawing as primary document since development items in Emerald are specified with drawings. The subtype of drawings is designated as DWG. First four items apart from end item are connector plate, interface part, dummy part, and switch holder respectively. Sixth item is lock washer and seventh item is washer. Each of them has two specification documents as primary documents. The subtype that starts with ESP prefix represents technical specification documents. The hierarchy numbers of these six items show that they reside at one level below the end item. The revision and the release date of items are seen in this view.

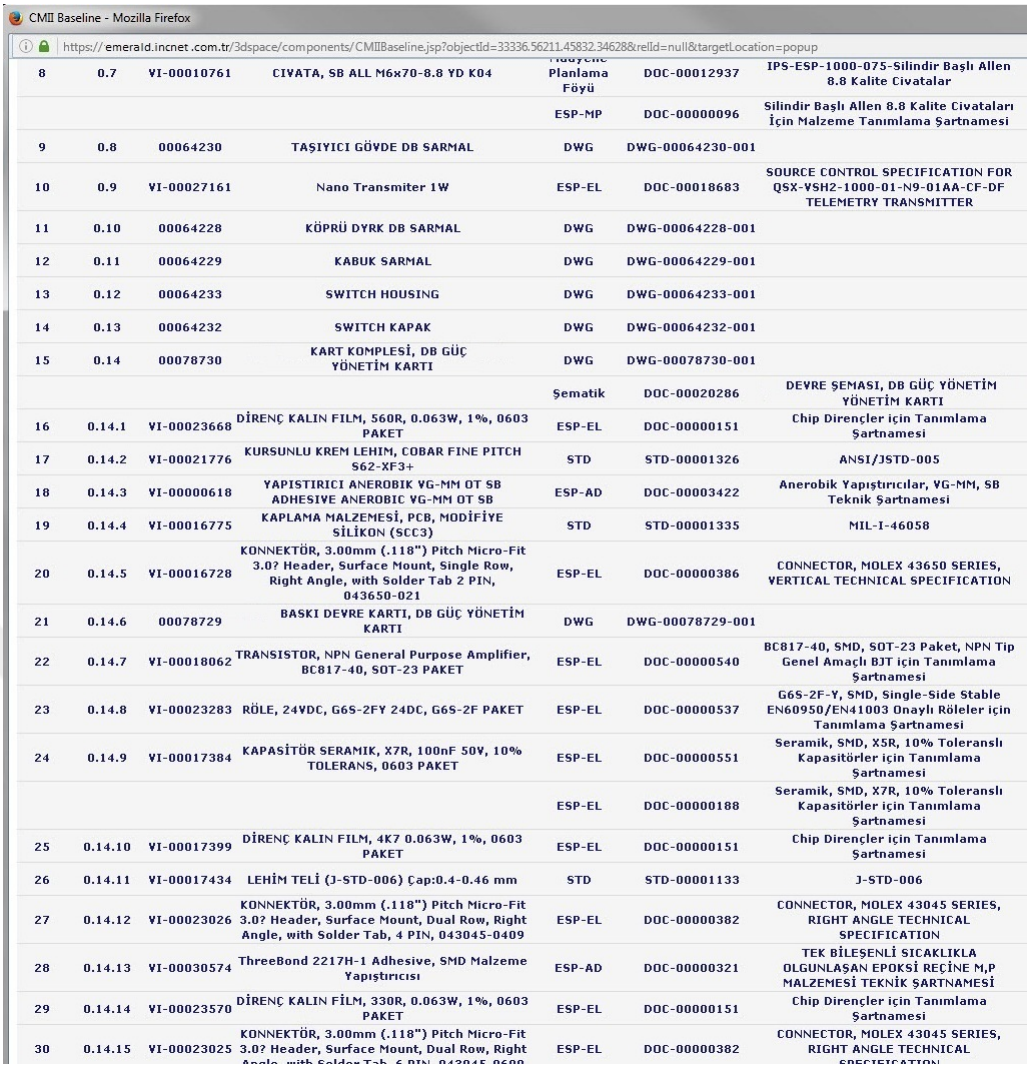
The rest of the baseline in Figure 5.6 and Figure 5.7 is shown without revision and release date information to scale the images. Eighth item is bolt. It has two primary documents. First is functional specification document and second is material identification specification. Ninth item is carrier body. It is development item and it has only drawing as a primary document. Tenth item is nano transmitter. It is a vendor item and it has source control specification document. Eleventh, twelfth, thirteenth and fourteenth items are bridge, skin, switch housing, switch cap, respectively, which are development items. Each has only one drawing as a primary document. Fifteenth item is the power management controller. It is an electronic assembly item. As the hierarchy numbers show, the seventeen items that follow this item are below it. This item has two primary documents that are drawing and schematic. The first item be-



ORDER NO	HIERARCHY NO	ITEM NAME	ITEM TITLE	DOCUMENT SUBTYPE	DOCUMENT NAME	DOCUMENT TITLE	REVISION	RELEASE DATE
1	0	00082025	DENEME BAŞLIĞI KOMPLESİ , SARMAL ANTEN	DWG	DWG-00082025-001		ZP00	9/4/2018 1:46:30 PM
2	0.1	00064331	BAĞLANTI PLAKASI, TG, DB	DWG	DWG-00064331-001		ZP00	3/16/201 1:08:08 PM
3	0.2	00064322	ARAYÜZ PARÇASI, DYRK, DB, SARMAL	DWG	DWG-00064322-001		ZP01	5/28/201 2:33:52 PM
4	0.3	00064243	DUMMY DB SARMAL	DWG	DWG-00064243-001		ZP01	5/28/201 2:34:11 PM
5	0.4	00065152	SWITCH TUTUCU	DWG	DWG-00065152-001		ZP01	5/28/201 2:34:05 PM
6	0.5	VI-00011427	PUL, KİLİTLİ 3.2x6x1 PL01 R07	ESP-MP	DOC-00000708	DÜZ YALITKAN PULLAR İÇİN TANIMLAMA ŞARTNAMESİ	ZP00	2/7/2014 1:00:00 AM
				ESP-MP	DOC-00000093	Plastik Kilitli Pullar İçin Tanımlama Şartnamesi	ZP00	11/23/200 5:09:02 PM
7	0.6	VI-00010982	PUL, 6.4x12x1.6-CL05 K01	ESP-MP	DOC-00003420	Düz Pullar İçin Tanımlama Şartnamesi	ZP03	12/19/201 1:31:18 PM
						Paslanmaz Çelik Genis Düz		

Figure 5.5: CMII Baseline view of the telemetry system

low the power management controller is resistance. It is a vendor item and it has the specification document as a primary document. The second item below it is leaded solder paste. Primary document of it is standard document that is released by IPC (Association Connecting Electronics Industries). The standard includes general requirements for the characterization and testing of the leaded solder paste [20]. Third item is adhesive and it has the technical specification as a primary document. Fourth item is coating material and it has standard document that is military specification as a primary document. Fifth item is connector and the primary document of it is technical specification. Sixth item is printed circuit board. It is a development item and it has drawing as a primary document. All other items below power management controller upto thirty third item are vendor items. They have technical specification documents excluding the eleventh item. Eleventh item is solder wire and primary document of it is standard. Thirty third item in Figure 5.7 is in second level as seen from hierarchy number. That is screw pin and it has the material identification specification as a primary document. Thirty fourth, forty first, forty second, forty third, forty forth, forty fifth, forty sixth and forty seventh items are bolts and each of them has two primary documents. One with "ESP" subtype is identification specification. Another one with "Muayene Planlama Föyü" subtype is technical specification. Thirty fifth item is

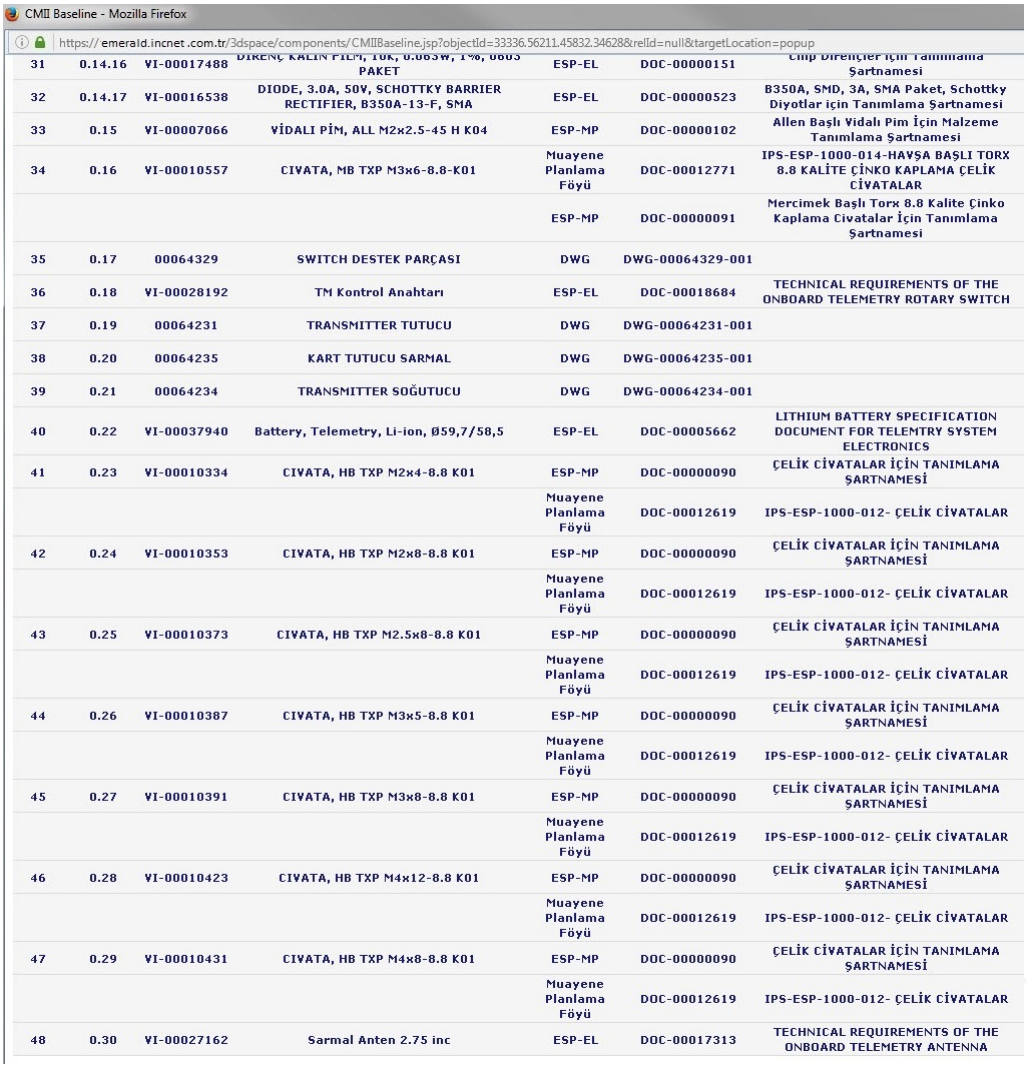


8	0.7	VI-00010761	CIVATA, SB ALL M6x70-8.8 YD K04	Planlama Föyü	DOC-00012937	IPS-ESP-1000-075-Silindir Başlı Allen 8.8 Kalite Civatalar
				ESP-MP	DOC-00000096	Silindir Başlı Allen 8.8 Kalite Civataları İçin Malzeme Tanımlama Şartnamesi
9	0.8	00064230	TAŞIYICI GÖVDE DB SARMAL	DWG	DWG-00064230-001	
10	0.9	VI-00027161	Nano Transmiter 1W	ESP-EL	DOC-00018683	SOURCE CONTROL SPECIFICATION FOR QSX-VSH2-1000-01-N9-01AA-CF-DF TELEMETRY TRANSMITTER
11	0.10	00064228	KÖPRÜ DYRK DB SARMAL	DWG	DWG-00064228-001	
12	0.11	00064229	KABUK SARMAL	DWG	DWG-00064229-001	
13	0.12	00064233	SWITCH HOUSING	DWG	DWG-00064233-001	
14	0.13	00064232	SWITCH KAPAK	DWG	DWG-00064232-001	
15	0.14	00078730	KART KOMPLESİ, DB GÜÇ YÖNETİM KARTI	DWG	DWG-00078730-001	
				Şematik	DOC-00020286	DEVRE ŞEMASI, DB GÜÇ YÖNETİM YÖNETİM KARTI
16	0.14.1	VI-00023668	DİRENÇ KALIN FILM, 560R, 0.063W, 1%, 0603 PAKET	ESP-EL	DOC-00000151	Chip Dirençler için Tanımlama Şartnamesi
17	0.14.2	VI-00021776	KURSUNLU KREM LEHIM, COBAR FINE PITCH S62-XF3+	STD	STD-00001326	ANSI/JSTD-005
18	0.14.3	VI-00000618	YAPISTIRICI ANEROBIK VG-MM OT SB ADHESIVE ANEROBIC VG-MM OT SB	ESP-AD	DOC-00003422	Anerobik Yapıştırıcılar, VG-MM, SB Teknik Şartnamesi
19	0.14.4	VI-00016775	KAPLAMA MALZEMESİ, PCB, MODİFİYE SİLİKON (SCC3)	STD	STD-00001335	MIL-I-46058
20	0.14.5	VI-00016728	KONNEKTÖR, 3.00mm (.118") Pitch Micro-Fit 3.0? Header, Surface Mount, Single Row, Right Angle, with Solder Tab 2 PIN, 043650-021	ESP-EL	DOC-00000386	CONNECTOR, MOLEX 43650 SERIES, VERTICAL TECHNICAL SPECIFICATION
21	0.14.6	00078729	BASKI DEVRE KARTI, DB GÜÇ YÖNETİM KARTI	DWG	DWG-00078729-001	
22	0.14.7	VI-00018062	TRANSISTOR, NPN General Purpose Amplifier, BC817-40, SOT-23 PAKET	ESP-EL	DOC-00000540	BC817-40, SMD, SOT-23 Paket, NPN Tip Genel Amaçlı BJT için Tanımlama Şartnamesi
23	0.14.8	VI-00023283	RÖLE, 24VDC, G6S-2FY 24DC, G6S-2F PAKET	ESP-EL	DOC-00000537	G6S-2F-Y, SMD, Single-Side Stable EN60950/EN41003 Onaylı Röleler için Tanımlama Şartnamesi
24	0.14.9	VI-00017384	KAPASİTÖR SERAMIK, X7R, 100nF 50V, 10% TOLERANS, 0603 PAKET	ESP-EL	DOC-00000551	Seramik, SMD, X5R, 10% Toleranslı Kapasitörler için Tanımlama Şartnamesi
				ESP-EL	DOC-00000188	Seramik, SMD, X7R, 10% Toleranslı Kapasitörler için Tanımlama Şartnamesi
25	0.14.10	VI-00017399	DİRENÇ KALIN FILM, 4K7 0.063W, 1%, 0603 PAKET	ESP-EL	DOC-00000151	Chip Dirençler için Tanımlama Şartnamesi
26	0.14.11	VI-00017434	LEHİM TELİ (J-STD-006) Çap:0.4-0.46 mm	STD	STD-00001133	J-STD-006
27	0.14.12	VI-00023026	KONNEKTÖR, 3.00mm (.118") Pitch Micro-Fit 3.0? Header, Surface Mount, Dual Row, Right Angle, with Solder Tab, 4 PIN, 043045-0409	ESP-EL	DOC-00000382	CONNECTOR, MOLEX 43045 SERIES, RIGHT ANGLE TECHNICAL SPECIFICATION
28	0.14.13	VI-00030574	ThreeBond 2217H-1 Adhesive, SMD Malzeme Yapıştırıcısı	ESP-AD	DOC-00000321	TEK BİLEŞENLİ SICAKLIKLA OLGUNLAŞAN EPOKSİ REÇİNE M,P MALZEMESİ TEKNİK ŞARTNAMESİ
29	0.14.14	VI-00023570	DİRENÇ KALIN FİLM, 330R, 0.063W, 1%, 0603 PAKET	ESP-EL	DOC-00000151	Chip Dirençler için Tanımlama Şartnamesi
30	0.14.15	VI-00023025	KONNEKTÖR, 3.00mm (.118") Pitch Micro-Fit 3.0? Header, Surface Mount, Dual Row, Right	ESP-EL	DOC-00000382	CONNECTOR, MOLEX 43045 SERIES, RIGHT ANGLE TECHNICAL

Figure 5.6: CMII Baseline of the telemetry system cont.

switch support part. This item is the development item and the primary document of it is the drawing. Thirty sixth item is telemetry rotary switch. The primary document of it is technical requirements specification. Thirty seventh, thirty eighth and thirty ninth items are transmitter holder, card holder and transmitter cooler respectively. All of them are development items and each has one drawing as a primary document. Fortieth item is battery for the telemetry system and it has lithuim battery specification document. Lastly, forty eighth item is helical antenna. Primary document of it is the technical requirements document.

When pressed "Generate CMII Baseline Report" command from the top of "CMII Baseline" page, the content of the downloaded excel file is seen as in Figure 5.8.

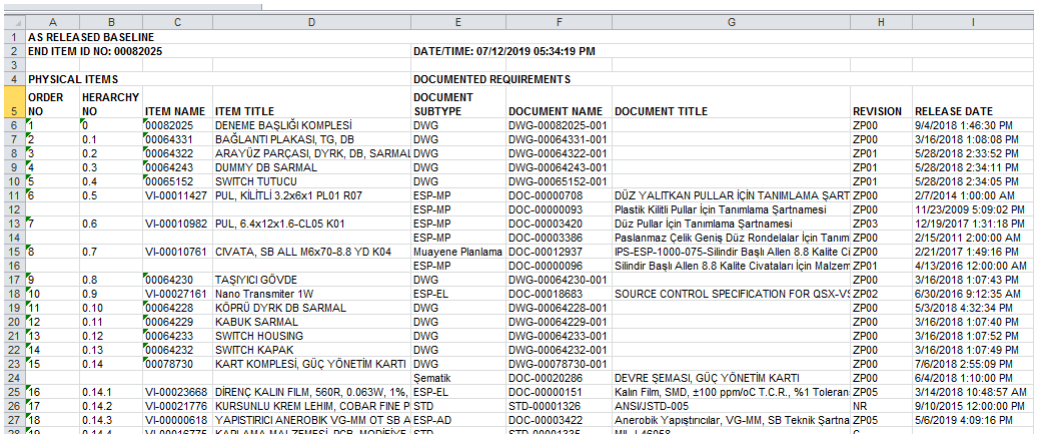


31	0.14.16	VI-00017488	DİRENÇ KALIN FİLM, 10K, 0.063W, 1%, 0603 PAKET	ESP-EL	DOC-00000151	Chip Dirençler için Tanımlama Şartnamesi
32	0.14.17	VI-00016538	DIODE, 3.0A, 50V, SCHOTTKY BARRIER RECTIFIER, B350A-13-F, SMA	ESP-EL	DOC-00000523	B350A, SMD, 3A, SMA Paket, Schottky Diyotlar için Tanımlama Şartnamesi
33	0.15	VI-00007066	VİDALI PİM, ALL M2x2.5-45 H K04	ESP-MP	DOC-00000102	Allen Başlı Vidalı Pim İçin Malzeme Tanımlama Şartnamesi
34	0.16	VI-00010557	CIVATA, MB TXP M3x6-8.8-K01	Muayene Planlama Föyü	DOC-00012771	IPS-ESP-1000-014-HAVŞA BAŞLI TORX 8.8 KALİTE ÇİNKO KAPLAMA ÇELİK CİVATALAR
				ESP-MP	DOC-00000091	Mercimek Başlı Torx 8.8 Kalite Çinko Kaplama Civatalar İçin Tanımlama Şartnamesi
35	0.17	00064329	SWITCH DESTEK PARÇASI	DWG	DWG-00064329-001	
36	0.18	VI-00028192	TM Kontrol Anahtarı	ESP-EL	DOC-00018684	TECHNICAL REQUIREMENTS OF THE ONBOARD TELEMETRY ROTARY SWITCH
37	0.19	00064231	TRANSMITTER TUTUCU	DWG	DWG-00064231-001	
38	0.20	00064235	KART TUTUCU SARMAL	DWG	DWG-00064235-001	
39	0.21	00064234	TRANSMITTER SOĞUTUCU	DWG	DWG-00064234-001	
40	0.22	VI-00037940	Battery, Telemetry, Li-ion, Ø59,7/58,5	ESP-EL	DOC-00005662	LITHIUM BATTERY SPECIFICATION DOCUMENT FOR TELEMTRY SYSTEM ELECTRONICS
41	0.23	VI-00010334	CIVATA, HB TXP M2x4-8.8 K01	ESP-MP	DOC-00000090	ÇELİK CİVATALAR İÇİN TANIMLAMA ŞARTNAMESİ
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012- ÇELİK CİVATALAR
42	0.24	VI-00010353	CIVATA, HB TXP M2x8-8.8 K01	ESP-MP	DOC-00000090	ÇELİK CİVATALAR İÇİN TANIMLAMA ŞARTNAMESİ
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012- ÇELİK CİVATALAR
43	0.25	VI-00010373	CIVATA, HB TXP M2.5x8-8.8 K01	ESP-MP	DOC-00000090	ÇELİK CİVATALAR İÇİN TANIMLAMA ŞARTNAMESİ
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012- ÇELİK CİVATALAR
44	0.26	VI-00010387	CIVATA, HB TXP M3x5-8.8 K01	ESP-MP	DOC-00000090	ÇELİK CİVATALAR İÇİN TANIMLAMA ŞARTNAMESİ
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012- ÇELİK CİVATALAR
45	0.27	VI-00010391	CIVATA, HB TXP M3x8-8.8 K01	ESP-MP	DOC-00000090	ÇELİK CİVATALAR İÇİN TANIMLAMA ŞARTNAMESİ
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012- ÇELİK CİVATALAR
46	0.28	VI-00010423	CIVATA, HB TXP M4x12-8.8 K01	ESP-MP	DOC-00000090	ÇELİK CİVATALAR İÇİN TANIMLAMA ŞARTNAMESİ
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012- ÇELİK CİVATALAR
47	0.29	VI-00010431	CIVATA, HB TXP M4x8-8.8 K01	ESP-MP	DOC-00000090	ÇELİK CİVATALAR İÇİN TANIMLAMA ŞARTNAMESİ
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012- ÇELİK CİVATALAR
48	0.30	VI-00027162	Sarmal Anten 2.75 inc	ESP-EL	DOC-00017313	TECHNICAL REQUIREMENTS OF THE ONBOARD TELEMETRY ANTENNA

Figure 5.7: CMII Baseline of the telemetry system cont.

Template of the excel file content is matching with as-released part of Figure 3.7 in Chapter 3.

The case study shows that some document types that should be in design basis like BOM document, process plan and 3D model are not existing in this company. Therefore, even though physical item hierarchy is formed and as-released baseline is created, they do not totally match the CM2 Model. However, the CM2 model can be applied to the current process and it can be used with existing item and document types. The processes in the company and the usage of the PLM system are always open to improvement. This case study is the part of an improvement.



	A	B	C	D	E	F	G	H	I
1	AS RELEASED BASELINE								
2	END ITEM ID NO: 00082025				DATE/TIME: 07/12/2019 05:34:19 PM				
3									
4	PHYSICAL ITEMS				DOCUMENTED REQUIREMENTS				
5	ORDER NO	HERARCHY NO	ITEM NAME	ITEM TITLE	DOCUMENT SUBTYPE	DOCUMENT NAME	DOCUMENT TITLE	REVISION	RELEASE DATE
6	1	0	00082025	DENEME BAŞLIĞI KOMPLESİ	DWG	DWG-00082025-001		ZP00	9/4/2018 1:46:30 PM
7	2	0.1	00064331	BAĞLANTI PLAKASI, TG, DB	DWG	DWG-00064331-001		ZP00	3/16/2018 1:08:08 PM
8	3	0.2	00064322	ARAYÜZ PARÇASI, DYRK, DB, SARMAL	DWG	DWG-00064322-001		ZP01	5/28/2018 2:33:52 PM
9	4	0.3	00064243	DUMMY DB SARMAL	DWG	DWG-00064243-001		ZP01	5/28/2018 2:34:11 PM
10	5	0.4	00065152	SWITCH TUTUCU	DWG	DWG-00065152-001		ZP01	5/28/2018 2:34:05 PM
11	6	0.5	VI-00011427	PUL, KİLİTLİ 3.2x6x1 PL01 R07	ESP-MP	DOC-00000708	DÜZ YALITKAN PULLAR İÇİN TANIMLAMA ŞART	ZP00	2/7/2014 1:00:00 AM
12					ESP-MP	DOC-00000093	Plastik Kilitli Pullar İçin Tanımlama Şartnamesi	ZP00	11/23/2009 5:09:02 PM
13	7	0.6	VI-00010982	PUL, 6.4x12x1.6-CL05 K01	ESP-MP	DOC-00003420	Düz Pullar İçin Tanımlama Şartnamesi	ZP03	12/19/2017 1:31:18 PM
14					ESP-MP	DOC-00003386	Paslanmaz Çelik Geniş Düz Rondelalar İçin Tanım	ZP00	2/15/2011 2:00:00 AM
15	8	0.7	VI-00010761	CIVATA, SB ALL M6x70-8.8 YD K04	Muayene Planlama	DOC-00012937	IPS-ESP-1000-075-Silindir Başlı Allen 8.8 Kalite Ci	ZP00	2/21/2017 1:49:16 PM
16					ESP-MP	DOC-00000096	Silindir Başlı Allen 8.8 Kalite Civataları İçin Malzem	ZP01	4/13/2016 12:00:00 AM
17	9	0.8	00064230	TAŞIYICI GÖVDE	DWG	DWG-00064230-001		ZP00	3/16/2018 1:07:43 PM
18	10	0.9	VI-00027161	Nano Transmiter 1W	ESP-EL	DOC-00018683	SOURCE CONTROL SPECIFICATION FOR QSX-V	ZP02	6/30/2016 9:12:35 AM
19	11	0.10	00064228	KÖPRÜ DYRK DB SARMAL	DWG	DWG-00064228-001		ZP00	5/3/2018 4:32:34 PM
20	12	0.11	00064229	KABUK SARMAL	DWG	DWG-00064229-001		ZP00	3/16/2018 1:07:40 PM
21	13	0.12	00064233	SWITCH HOUSING	DWG	DWG-00064233-001		ZP00	3/16/2018 1:07:52 PM
22	14	0.13	00064232	SWITCH KAPAK	DWG	DWG-00064232-001		ZP00	3/16/2018 1:07:49 PM
23	15	0.14	00078730	KART KOMPLESİ, GÜÇ YÖNETİM KARTI	DWG	DWG-00078730-001		ZP00	7/6/2018 2:55:09 PM
24					Şematik	DOC-00020286	DEVRE ŞEMASI, GÜÇ YÖNETİM KARTI	ZP00	6/4/2018 1:10:00 PM
25	16	0.14.1	VI-00023668	DİRENÇ KALIN FILM, 560R, 0.063W, 1%,	ESP-EL	DOC-00000151	Kalın Film, SMD, ±100 ppm/oC T.C.R., %1 Toleran	ZP05	3/14/2018 10:48:57 AM
26	17	0.14.2	VI-00021776	KURSUNLU KREM LEHIM, COBAR FINE P	STD	STD-00001326	ANSI/JSTD-005	NR	9/10/2015 12:00:00 PM
27	18	0.14.3	VI-00000618	YAPISTIRICI ANEROBIK VG-MM OT SB A	ESP-AD	DOC-00003422	Anerobik Yapıştırıcılar, VG-MM, SB Teknik Şartna	ZP05	5/6/2019 4:09:16 PM

Figure 5.8: Excel output of CMII Baseline of the telemetry system

5.2 Functional Validation

The implementation of the physical item hierarchy and the as-released baseline is analyzed by the configuration specialists in the company. They validate the implementation since it shows primary items and primary documents together in one hierarchical view and it enables to see instant as-released baseline as described in the CM2 Model. The functions which are validated by the users are explained below.

- The physical item hierarchy provides general view to display product structure with the specification documents. It enables to see which item connected to which specification document in one screen. It is an essential feature for analyzing the configuration of the product as a whole with documents. It eases the traceability of the primary items and primary documents. For instance, when the item is in review state, the configuration specialist checks accuracy of the item configuration from physical item hierarchy view and then, approves it to release.

- In this company, the vendor items are categorized as COTS, source controlled product and outsourced development product. Each of them is specified with the predetermined appropriate document. According to primary document information of the vendor items, the category information is inferred directly from the physical item hierarchy. For example, if the vendor item has a document with standard type, the user can understand that the category of this item

is COTS.

- If any item in the physical item hierarchy has the test result report as a primary document, if the item changes, the information that tests need to be re-performed and the document must be updated can be directly inferred from the physical item hierarchy. For example, the user knows that the range of the missile changes. When the user displays physical item hierarchy of the missile and sees that the missile has the test document, s/he deduces that the change affects the test results so tests related to the range should be re-performed and test document should be revised.

- When any change is requested for the product, the items included in the BOM of the product and the documents defining these items are examined one by one and the impact analysis of the change is performed. Owing to CM2 Baseline, affected items and documents is analyzed easily from single view by using hierarchical data. For example, the third level item in product BOM is planned to change. User analyzes primary documents of the item and upper level primary items and primary documents from CM2 Baseline.

- The technical data package delivered to the customer for consists of BOM information of the product and documents describing the items in the BOM. "Generate CMII Baseline" functionality of the implementation generates the package content so that the effort required for technical data package preparation is minimized. For instance, when the customer wants to have technical data package at the end of the project, all data required in the technical data package is prepared quickly with the help of CM2 baseline and physical item hierarchy and delivered to the customer.

- The primary document types in the physical item hierarchy are examined to determine whether the primary items can be reused in another product. For example, if the product to be produced is similar to an existing product, it is decided according to the information obtained from the primary documents which parts should be reused. In the light of this information, product structure is created and detailed design is done.

5.3 Usability Test

Usability testing is a systematic way of observing actual users trying out a product and collecting information about the specific ways in which the product is easy or difficult for them [10]. Comparative usability testing is applied in this study. Users compare the new features provided by the software implementation with the old version of the system thorough a task. The methods that are user testing thinking aloud and usability metrics are used for the usability test. While user testing thinking aloud method provides to verbalize users' thoughts while they interact with the software system, usability metrics method provides to establish quantitative measurements regarding effectiveness, efficiency and satisfaction [23]. User testing is made by performing a task in the system. Usability metric is the number of clicks while performing the task. The user who tests the usability of the implementation is the configuration specialist. The task that is preparation of the technical data package delivery is chosen for the usability test since the steps of this task involve using all of the features of the software implementation. The technical data package delivery consists of the list that contains items in all levels with their specification documents and the downloaded copy of specification documents. The list has the columns which are hierarchy number, item number, item name, document number, and document revision. The CMII Baseline includes the required information for the list. In the old version of the system, the steps required for the user to prepare the technical data package are given below.

Let's assume that the user sees the meta data screen of the end item as in Figure 4.9 in Chapter 4.

1. Display BOM of the product
2. Customize table view to show required columns
3. Expand all levels to the list
4. Export the list to the Excel file
5. Split into columns
6. Click the item in the BOM list

7. Find the related specification document from "Specs and Documents", "ESRs" or "Referred Standards" menu which are seen in actions menu in the left side of Figure 4.9.
8. Click the specification document
9. Download the document
10. Back to the BOM list
11. Repeat the steps 6-10 for all items in the BOM list

Each step above corresponds to seperate click in the system. In the new customized system, the user clicks the CMII Baseline command. S/he clicks the "Generate CMII Baseline" command and saves the Excel file. In this way, the number of clicks for the first five steps decreases to three clicks. For finding specification document, the user directly clicks "Physical Item Hierarchy" command from the actions menu. The table of Physical Item Hierarchy directly shows the specification documents with the items together so the user does not need to search them from the actions menu in metadata screen of the item as mentioned in the steps 6 and 7. Then, the number of clicks for downloading document decreases from five to three. Since the document download is done for each item, the number of clicks for document download is multiplied by the number of items in the physical item hierarchy. Thus, the reduction in the number of clicks is the number of items multiplied by two. When x equals the total reduction in clicks and y equals the number of items in the physical item hierarchy, the total reduction in the number of clicks is calculated by equation 51. The equation shows that as the number of items in the physical item hierarchy increases, reduction in clicks increases. Thus, the task is completed more quickly by saving time.

$$x = 2 + 2y \tag{51}$$

At the end of the usability test, while the reduction in clicks is the result of the usability metrics method, the user's opinion about saving on time and facilitating the user's work is the result of the user testing - thinking aloud method.

CHAPTER 6

CONCLUSION

The study of the CMII-based physical item hierarchy implementation in a PLM system is concluded in this chapter. Possible future improvements related to this study are described.

6.1 Achievements

The notion of the product lifecycle covers the stages of the product from key concept to disposal. The product lifecycle is managed through the software tool named PLM system. PLM system is essential for the companies due to track all process applied to the product in one system. The PLM system is essential tool for the digitalization of the company processes.

The one important field where PLM system is used is product configuration management. CM is the process for creating, analyzing, and tracking the physical and functional features of the product according to the requirements, operational standards and processes. Product structure is a breakdown structure of the objects which constitutes the product. Analyzing product structure is one of the tasks of configuration specialists.

CM2 is an enterprise standard that describes the processes of configuration management by the operational standards. In this thesis, CM2-based product structure model, namely, physical item hierarchy is explained. The physical item hierarchy is a tree structured model of the product which shows the connected parts and released specification data sets. Physical item hierarchy is used for creating product baseline named

CM2 baseline. CM2 baseline shows the as planned/as released baseline of the product. All requirements and associated changes are managed with it.

The physical item hierarchy is implemented to the PLM system and as released baseline of the items is generated from the physical item hierarchy in the defense company using customized PLM system. Although the process of the company's configuration management is not totally the same with the CM2 model, the implementation is done in the most similar way.

As a case study, the physical item hierarchy of a telemetry system is analyzed. The primary items and primary documents of the product are described. The case study shows that some primary documents that are mentioned in CM2 model are not existing since the process in company is not compatible with CM2 model. However, if the company adapts its processes to the CM2 model, the physical item hierarchy can be used more effectively and process excellence for product structuring can be achieved.

6.2 Future Work

As explained in Chapter 3, the CM2 baseline is comprised of two parts, namely, as planned and as released. As planned baseline is involved in change management. Since the change management is not performed in the PLM system, as planned baseline is not implemented in this study. Therefore, change can be managed in the PLM system and the as planned baseline implementation can be done in the future.

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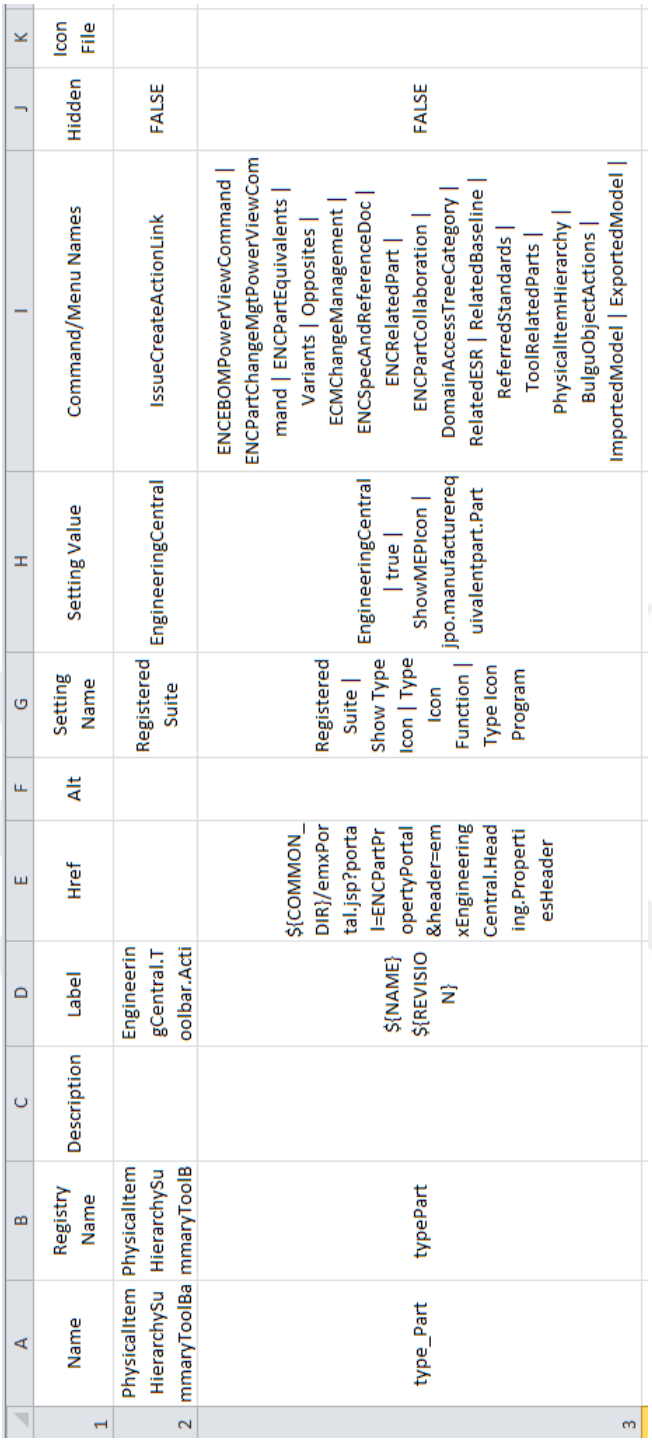
APPENDIX A

SPINNER EXCEL FILES

The spinner excel files shown in Figure A.1, Figure A.2, Figure A.3, Figure A.4, and Figure A.5 is imported to the PLM system for creation of web page content.

	A	B	C	D	E	F	G	H	I	J
1	Name	Registry Name	Description	Label	Href	Alt	Setting Name	Setting Value	Users	Hidden
2	PhysicalItemHierarchy	PhysicalItemHierarchy	Physical Item Hierarchy Command Object	Physical Item Hierarchy	${COMMON_DIR}/emxIndentedTable.jsp?objectID=${ID}&type=Part&expandProgram=ReportBase:getPhysicalItemHierarchy&table=PhysicalItemHierarchySummary&selection=multiple&sortColumnName=Name&sortDirection=ascending&toolbar=PhysicalItemHierarchySummaryToolBar&header=emxEngineeringCentral.Common.RelationsPageHeading&HelpMarker=emxhelppartspecifications&parentRelName=relationship_ItemBase&freezePane=Name,Title		Image | Registered Suite | Target Location	${COMMON_DIR}/images/iconSmallFromFolder.gif | EngineeringCentral | content	Part Family Coordinator | Team Design Engineer | Supplier | Employee | Compliance Engineer | Sales Engineer | Buyer | ECR Coordinator | Customer | Design Engineer | ECR Chairman | ECR Evaluator | Manufacturing Engineer | Product Obsolescence Manager | Senior Design Engineer | Senior Manufacturing Engineer | Component Engineer | VPLMViewer	FALSE

Figure A.1: Spinner command data



	A	B	C	D	E	F	G	H	I	J	K
1	Name	Registry Name	Description	Label	Href	Alt	Setting Name	Setting Value	Command/Menu Names	Hidden	Icon File
2	PhysicalItemHierarchySummaryToolBar	PhysicalItemHierarchySummaryToolB		Engineering Central.Toolbar.Acti			Registered Suite	EngineeringCentral	IssueCreateActionLink	FALSE	
3	type_Part	typePart		${NAME} ${REVISION}	${COMMON_DIR}/emxPortal.jsp?portal=ENCPartPropertyPortal&header=emxEngineeringCentral.Heading.PropertiesHeader		Registered Suite | Show Type Icon | Type Icon Function | Type Icon Program	EngineeringCentral | true | ShowMEPIcon | jpo.manufacturereq uivalentpart.Part	ENCEBOMPowerViewCommand | ENCPartChangeMgtPowerViewCommand | ENCPartEquivalents | Variants | Opposites | ECMChangeManagement | ENCSpecAndReferenceDoc | ENCRelatedPart | ENCPartCollaboration | DomainAccessTreeCategory | RelatedESR | RelatedBaseline | ReferredStandards | ToolRelatedParts | PhysicalItemHierarchy | BulguObjectActions | ImportedModel | ExportedModel |	FALSE	

Figure A.2: Spinner menu data

	A	B	C	D
1	Name	Registry Name	Description	Hidden (boolean)
2	PhysicalItemHierarchySummary	PhysicalItemHierarchySummary		FALSE

Figure A.3: Spinner table data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Table Name	Column Name	Column Label	Col Description	Expression Type	Expression	Href	Setting Names	Setting Values	Users	Alt	Range	Update	SortType	Column Order	Hidden
2	PhysicalItem HierarchySummary	Name	Item Number		business object	name	${COMMON_DIR}/emxTree.jsp?mode=insert	Editable | Registered Suite | Show Type Icon | Target Location | Width	false | EngineeringCentral | true | popup | 160	all				none	1	FALSE
3	PhysicalItem HierarchySummary	Title	Item Name		business object	$<attribute [attribute_Title].value >		Admin Type | Editable | Field Type | Input Type | Registered Suite | Required | Width	attribute_Title | false | attribute | textbox | EngineeringCentral | true | 144	all				none	2	FALSE
4	PhysicalItem HierarchySummary	Type	emxEngineeringCentral.Common.Type		business object	type	${COMMON_DIR}/emxTree.jsp	Admin Type | Editable | Registered Suite | Show Type Icon | Target Location | Width	Type | false | EngineeringCentral | false | popup | 160	all				none	3	FALSE
5	PhysicalItem HierarchySummary	SubType	.FormField.SubType		business object	$<attribute [attribute_SubTypeI.v		Admin Type | Editable | Field Type | Input Type | Registered Suite | Width	attribute_SubType | false | attribute | textbox | EngineeringCentral | 120	all				none	4	FALSE
6	PhysicalItem HierarchySummary	Revision	.TableField.ShortRevision		business object	revision		Editable | Registered Suite | Width	false | EngineeringCentral | 32	all				none	6	FALSE
7	PhysicalItem HierarchySummary	ReleaseDate	emxComponents.Decision.ReleaseDate		set			Column Type | Registered Suite | Sort Type | format | function | program	program | Components | date | date | getReleaseDate | emxDecision	all				none	7	FALSE

SpinnerTableColumnData

Figure A.4: Spinner table column data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	WebForm Name	Field Name	Field Label	Field Description	Expression Type	Expression	Href	Setting Names	Setting Values	Users	Alt	Range	Update	Field Order
2	type_Part	CMIIBaseline	FormField.CMII Baseline		businessobject	evaluate['CMII Baseline-' + $<name>]	${COMPONENT_DIR}/CMIIBaseline.jsp	Field Size | Group Name | Registered Suite	21 | CMIIBaseline | EngineeringCentral					18

Figure A.5: Spinner web form field data

APPENDIX B

CMII BASELINE OF TELEMETRY SYSTEM

AS RELEASED BASELINE
END ITEM ID NO: 00082025

DATE/TIME: 07/12/2019 05:34:19 PM

PHYSICAL ITEMS

DOCUMENTED REQUIREMENTS

ORDER NO	HERARCHY	ITEM NAME	ITEM TITLE	DOCUMENT SUBTYPE	DOCUMENT NAME	DOCUMENT TITLE	REVISION	RELEASE DATE
1	0	00082025	DENEME BAŞLIĞI KOMPLESİ	DWG	DWG-00082025-001		ZP00	9/4/2018 1:46:30 PM
2	0.1	00064331	BAĞLANTI PLAKASI, TG, DB	DWG	DWG-00064331-001		ZP00	3/16/2018 1:08:08 PM
3	0.2	00064322	ARAYÜZ PARÇASI, DYRK, DB, SARMAL	DWG	DWG-00064322-001		ZP01	5/28/2018 2:33:52 PM
4	0.3	00064243	DUMMY DB SARMAL	DWG	DWG-00064243-001		ZP01	5/28/2018 2:34:11 PM
5	0.4	00065152	SWITCH TUTUCU	DWG	DWG-00065152-001		ZP01	5/28/2018 2:34:05 PM
6	0.5	VI-00011427	PUL, KİLİTLİ 3.2x6x1 PL01 R07	ESP-MP	DOC-00000708	DÜZ YALITKAN PULLAR İÇİN TANIMLAMA ŞARTNAMESİ	ZP00	2/7/2014 1:00:00 AM
				ESP-MP	DOC-00000093	Plastik Kilitli Pullar İçin Tanımlama Şartnamesi	ZP00	11/23/2009 5:09:02 PM
7	0.6	VI-00010982	PUL, 6.4x12x1.6-CL05 K01	ESP-MP	DOC-00003420	Düz Pullar İçin Tanımlama Şartnamesi	ZP03	12/19/2017 1:31:18 PM
				ESP-MP	DOC-00003386	Paslanmaz Çelik Geniş Düz Rondelalar İçin Tanımlama Şartnamesi	ZP00	2/15/2011 2:00:00 AM
8	0.7	VI-00010761	CIVATA, SB ALL M6x70-8.8 YD K04	Muayene Planlama Föyü	DOC-00012937	IPS-ESP-1000-075-Silindir Başlı Allen 8.8 Kalite Civatalar	ZP00	2/21/2017 1:49:16 PM
				ESP-MP	DOC-00000096	Silindir Başlı Allen 8.8 Kalite Civataları İçin Malzeme Tanımlama Şartnamesi	ZP01	4/13/2016 12:00:00 AM
9	0.8	00064230	TAŞIYICI GÖVDE	DWG	DWG-00064230-001		ZP00	3/16/2018 1:07:43 PM
10	0.9	VI-00027161	Nano Transmiter 1W	ESP-EL	DOC-00018683	SOURCE CONTROL SPECIFICATION FOR QSX-VSH2-1000-01-N9-01AA-CF-DF TELEMET	ZP02	6/30/2016 9:12:35 AM
11	0.10	00064228	KÖPRÜ DYRK DB SARMAL	DWG	DWG-00064228-001		ZP00	5/3/2018 4:32:34 PM
12	0.11	00064229	KABUK SARMAL	DWG	DWG-00064229-001		ZP00	3/16/2018 1:07:40 PM
13	0.12	00064233	SWITCH HOUSING	DWG	DWG-00064233-001		ZP00	3/16/2018 1:07:52 PM
14	0.13	00064232	SWITCH KAPAK	DWG	DWG-00064232-001		ZP00	3/16/2018 1:07:49 PM
15	0.14	00078730	KART KOMPLESİ, GÜÇ YÖNETİM KARTI	DWG	DWG-00078730-001		ZP00	7/6/2018 2:55:09 PM
				Şematik	DOC-00020286	DEVRE ŞEMASI, GÜÇ YÖNETİM KARTI	ZP00	6/4/2018 1:10:00 PM
16	0.14.1	VI-00023668	DİRENÇ KALIN FILM, 560R, 0.063W, 1%, 0603 PAKET	ESP-EL	DOC-00000151	Kalın Film, SMD, ±100 ppm/oC T.C.R., %1 Toleranslı Chip Dirençler için Tanımlama Şartname	ZP05	3/14/2018 10:48:57 AM
17	0.14.2	VI-00021776	KURSUNLU KREM LEHIM, COBAR FINE PITCH S62-XF3+	STD	STD-00001326	ANSI/JSTD-005	NR	9/10/2015 12:00:00 PM
18	0.14.3	VI-00000618	YAPISTIRICI ANEROBIK VG-MM OT SB ADHESIVE ANEROB	ESP-AD	DOC-00003422	Anerobik Yapıştırıcılar, VG-MM, SB Teknik Şartnamesi	ZP05	5/6/2019 4:09:16 PM
19	0.14.4	VI-00016775	KAPLAMA MALZEMESİ, PCB, MODİFİYE SİLİKON (SCC3)	STD	STD-00001335	MIL-I-46058	C	
20	0.14.5	VI-00016728	KONNEKTÖR, 3.00mm (.118") Pitch Micro-Fit 3.0? Header, Su	ESP-EL	DOC-00000386	CONNECTOR, MOLEX 43650 SERIES, VERTICAL TECHNICAL SPECIFICATION	ZP00	7/1/2011 12:00:00 AM
21	0.14.6	00078729	BASKI DEVRE KARTI, GÜÇ YÖNETİM KARTI	DWG	DWG-00078729-001		ZP00	5/31/2018 2:13:49 PM
22	0.14.7	VI-00018062	TRANSISTOR, NPN General Purpose Amplifier, BC817-40, SC	ESP-EL	DOC-00000540	BC817-40, SMD, SOT-23 Paket, NPN Tip Genel Amaçlı BJT için Tanımlama Şartnamesi	ZP00	9/17/2009 12:00:00 AM
23	0.14.8	VI-00023283	RÖLE, 24VDC, G6S-2FY 24DC, G6S-2F PAKET	ESP-EL	DOC-00000537	G6S-2F-Y, SMD, Single-Side Stable EN60950/EN41003 Onaylı Röleler için Tanımlama Şartna	ZP00	9/17/2009 12:00:00 AM
24	0.14.9	VI-00017384	KAPASİTÖR SERAMIK, X7R, 100nF 50V, 10% TOLERANS, 06	ESP-EL	DOC-00000551	Seramik, SMD, X5R, 10% Toleranslı Kapasitörler için Tanımlama Şartnamesi	ZP00	9/16/2009 12:00:00 AM
				ESP-EL	DOC-00000188	Seramik, SMD, X7R, 10% Toleranslı Kapasitörler için Tanımlama Şartnamesi	ZP03	3/22/2018 11:07:47 AM
25	0.14.10	VI-00017399	DİRENÇ KALIN FILM, 4K7 0.063W, 1%, 0603 PAKET	ESP-EL	DOC-00000151	Kalın Film, SMD, ±100 ppm/oC T.C.R., %1 Toleranslı Chip Dirençler için Tanımlama Şartname	ZP05	3/14/2018 10:48:57 AM
26	0.14.11	VI-00017434	LEHİM TELİ (J-STD-006) Çap:0.4-0.46 mm	STD	STD-00001133	J-STD-006	NR	12/29/2015 4:00:00 AM
27	0.14.12	VI-00023026	KONNEKTÖR, 3.00mm (.118") Pitch Micro-Fit 3.0? Header, Su	ESP-EL	DOC-00000382	CONNECTOR, MOLEX 43045 SERIES, RIGHT ANGLE TECHNICAL SPECIFICATION	ZP00	7/1/2011 12:00:00 AM
28	0.14.13	VI-00030574	ThreeBond 2217H-1 Adhesive, SMD Malzeme Yapıştırıcısı	ESP-AD	DOC-00000321	TEK BİLEŞENLİ SICAKLIKLA OLGUNLAŞAN EPOKSİ REÇİNE M,P MALZEMESİ TEKNİK ŞA	ZP00	7/4/2013 12:00:00 AM
29	0.14.14	VI-00023570	DİRENÇ KALIN FİLM, 330R, 0.063W, 1%, 0603 PAKET	ESP-EL	DOC-00000151	Kalın Film, SMD, ±100 ppm/oC T.C.R., %1 Toleranslı Chip Dirençler için Tanımlama Şartname	ZP05	3/14/2018 10:48:57 AM
30	0.14.15	VI-00023025	KONNEKTÖR, 3.00mm (.118") Pitch Micro-Fit 3.0? Header, Su	ESP-EL	DOC-00000382	CONNECTOR, MOLEX 43045 SERIES, RIGHT ANGLE TECHNICAL SPECIFICATION	ZP00	7/1/2011 12:00:00 AM
31	0.14.16	VI-00017488	DIRENÇ KALIN FILM, 10K, 0.063W, 1%, 0603 PAKET	ESP-EL	DOC-00000151	Kalın Film, SMD, ±100 ppm/oC T.C.R., %1 Toleranslı Chip Dirençler için Tanımlama Şartname	ZP05	3/14/2018 10:48:57 AM
32	0.14.17	VI-00016538	DIODE, 3.0A, 50V, SCHOTTKY BARRIER RECTIFIER, B350A-	ESP-EL	DOC-00000523	B350A, SMD, 3A, SMA Paket, Schottky Diyotlar için Tanımlama Şartnamesi	ZP00	9/16/2009 12:00:00 AM
33	0.15	VI-00007066	VİDALI PİM, ALL M2x2.5-45 H K04	ESP-MP	DOC-00000102	Allen Başlı Vidalı Pim İçin Malzeme Tanımlama Şartnamesi	ZP02	8/10/2016 12:00:00 AM
34	0.16	VI-00010557	CIVATA, MB TXP M3x6-8.8-K01	Muayene Planlama Föyü	DOC-00012771	IPS-ESP-1000-014-HAVŞA BAŞLI TORX 8.8 KALİTE ÇİNKO KAPLAMA ÇELİK CİVATALAR	ZP00	2/21/2017 8:51:26 AM
				ESP-MP	DOC-00000091	Mercimek Başlı Torx 8.8 Kalite Çinko Kaplama Civatalar İçin Tanımlama Şartnamesi	ZP01	4/28/2016 12:00:00 AM
35	0.17	00064329	SWITCH DESTEK PARÇASI	DWG	DWG-00064329-001		ZP00	3/16/2018 1:08:04 PM
36	0.18	VI-00028192	TM Kontrol Anahtarı	ESP-EL	DOC-00018684	TECHNICAL REQUIREMENTS OF THE ONBOARD TELEMETRY ROTARY SWITCH	ZP01	2/2/2017 9:09:32 AM
37	0.19	00064231	TRANSMITTER TUTUCU	DWG	DWG-00064231-001		ZP00	3/16/2018 1:07:46 PM
38	0.20	00064235	KART TUTUCU SARMAL	DWG	DWG-00064235-001		ZP00	3/16/2018 1:07:58 PM
39	0.21	00064234	TRANSMITTER SOĞUTUCU	DWG	DWG-00064234-001		ZP00	3/16/2018 1:07:55 PM
40	0.22	VI-00037940	Battery, Telemetry, Li-ion, Ø59,7/58,5	ESP-EL	DOC-00005662	LITHIUM BATTERY SPECIFICATION DOCUMENT FOR TELEMTRY SYSTEM ELECTRONIC	ZP00	8/4/2016 12:00:00 AM
41	0.23	VI-00010334	CIVATA, HB TXP M2x4-8.8 K01	ESP-MP	DOC-00000090	HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATALAR İÇİN TANIMLA	ZP02	3/8/2017 2:05:47 PM
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012-HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATA	ZP00	2/21/2017 7:47:51 AM
42	0.24	VI-00010353	CIVATA, HB TXP M2x8-8.8 K01	ESP-MP	DOC-00000090	HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATALAR İÇİN TANIMLA	ZP02	3/8/2017 2:05:47 PM
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012-HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATA	ZP00	2/21/2017 7:47:51 AM
43	0.25	VI-00010373	CIVATA, HB TXP M2.5x8-8.8 K01	ESP-MP	DOC-00000090	HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATALAR İÇİN TANIMLA	ZP02	3/8/2017 2:05:47 PM
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012-HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATA	ZP00	2/21/2017 7:47:51 AM
44	0.26	VI-00010387	CIVATA, HB TXP M3x5-8.8 K01	ESP-MP	DOC-00000090	HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATALAR İÇİN TANIMLA	ZP02	3/8/2017 2:05:47 PM
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012-HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATA	ZP00	2/21/2017 7:47:51 AM
45	0.27	VI-00010391	CIVATA, HB TXP M3x8-8.8 K01	ESP-MP	DOC-00000090	HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATALAR İÇİN TANIMLA	ZP02	3/8/2017 2:05:47 PM
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012-HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATA	ZP00	2/21/2017 7:47:51 AM
46	0.28	VI-00010423	CIVATA, HB TXP M4x12-8.8 K01	ESP-MP	DOC-00000090	HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATALAR İÇİN TANIMLA	ZP02	3/8/2017 2:05:47 PM
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012-HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATA	ZP00	2/21/2017 7:47:51 AM
47	0.29	VI-00010431	CIVATA, HB TXP M4x8-8.8 K01	ESP-MP	DOC-00000090	HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATALAR İÇİN TANIMLA	ZP02	3/8/2017 2:05:47 PM
				Muayene Planlama Föyü	DOC-00012619	IPS-ESP-1000-012-HAVŞA BAŞLI TORX 8.8 KALİTE VE A2/A4 PASLANMAZ ÇELİK CİVATA	ZP00	2/21/2017 7:47:51 AM
48	0.30	VI-00027162	Sarmal Anten 2.75 inc	ESP-EL	DOC-00017313	TECHNICAL REQUIREMENTS OF THE ONBOARD TELEMETRY ANTENNA	ZP00	11/14/2017 1:02:02 PM

Figure B.1: CMII Baseline of telemetry system