Dam, Jonas
Hægh, Jacob Døhlen
Mjelde, Mikael Hjortland

Bachelor's thesis

Model Based Definition of Soft-landing Cylinders

Technical datapackage for OneSubsea
Tutors: Mihanyar, Shifteh

May 2023

NTNU
Norwegian University of
Science and Technology

Dam, Jonas
Hægh, Jacob Døhlen
Mjelde, Mikael Hjortland

Model Based Definition of Soft-landing Cylinders

Technical datapackage for OneSubsea
Tutors: Mihanyar, Shifteh

Bachelor's thesis
May 2023

◉ NTNU
Norwegian University of
Science and Technology

Model Based Definition of Soft-landing Cylinders

Technical datapackage for OneSubsea

Bachelor i ingeniørfag - Maskin
Submitted: May 2023
Tutor: Shifteh Mihanyar

Thesis title: **Model Based Definition of Soft-landing Cylinders**	Date: 21.05.2023		
	Number of pages: 82		
	Master thesis:	Bachelor thesis	x
Name: Jacob Døhlen Hægh Jonas van Dam Mikael Hjortland Mjelde			
Tutor: NTNU: Shifteh Mihanyar			
External professional contacts/ tutors: Tutor OneSubsea: Johan Karlsson			

Summary:

This bachelor thesis focuses on the implementation of Model-Based Definition (MBD) to create a comprehensive technical data package for Soft-landing Cylinders designed by OneSubsea. The primary objective is to enable development teams to accurately assess the performance of their designs, identify potential failure points, and discover areas for improvement. Furthermore, the thesis aims to transfer the developed data set to Aarbakke AS, a manufacturing company, and document the distribution process.

The research will concentrate on determining the essential parameters that should be included in the data package and investigating the methodologies required to generate reliable results. Additionally, the thesis will explore the potential for extending the data set across the extended enterprise to enhance quality throughout the entire supply chain. This consideration aims to improve collaboration and communication between the development teams and manufacturers involved in the production process, leading to further improvements in product quality.

The methodology employed will involve a combination of theoretical analysis, data collection, and data analysis techniques. The technical data package will be constructed using appropriate software tools and will incorporate relevant design parameters. The research will emphasize the identification of failure points and areas for improvement, which will be supported by data-driven analysis and predictive modelling.

Ultimately, this thesis seeks to contribute to the advancement of model-based definition in the engineering and manufacturing industry by developing a practical and comprehensive data package for Soft-landing Cylinders. The outcomes of the research states that companies implementing MBD have a great opportunity to improve quality, reduce manufacturing costs, and time which leads to faster time to market. MBD is not fully developed yet, with no universal standard, limited applicability, and companies' resistance to change of their current methods.

Jacob Døhlen Hægh   Jonas van Dam   Mikael Hjortland Mjelde

Foreword

Abstract

This bachelor thesis focuses on the implementation of Model-Based Definition (MBD) to create a comprehensive technical data package for Soft-landing Cylinders designed by OneSubsea. The primary objective is to enable development teams to accurately assess the performance of their designs, identify potential failure points, and discover areas for improvement. Furthermore, the thesis aims to transfer the developed data set to Aarbakke AS, a manufacturing company, and document the distribution process.

The research will concentrate on determining the essential parameters that should be included in the data package and investigating the methodologies required to generate reliable results. Additionally, the thesis will explore the potential for extending the data set across the extended enterprise to enhance quality throughout the entire supply chain. This consideration aims to improve collaboration and communication between the development teams and manufacturers involved in the production process, leading to further improvements in product quality.

The methodology employed will involve a combination of theoretical analysis, data collection, and data analysis techniques. The technical data package will be constructed using appropriate software tools and will incorporate relevant design parameters and performance metrics. The research will emphasize the identification of failure points and areas for improvement, which will be supported by data-driven analysis and predictive modelling.

Ultimately, this thesis seeks to contribute to the advancement of model-based definition in the engineering and manufacturing industry by developing a practical and comprehensive data package for Soft-landing Cylinders. The outcomes of the research states that companies implementing MBD have a great opportunity to improve quality, reduce manufacturing costs, and time which leads to faster time to market. MBD is not fully developed yet, with no universal standard, limited applicability, and companies' resistance to change of their current methods.

Glossary

Terminology

Adobe Reader   Used to view the MBD files

Distribution process   The distribution process describes which channels the product experience, from raw material, manufacturing and until the product can be sent to the user or customer.

Extended enterprise   The extended enterprise includes the contributors to the product and solutions. In the case with the softlanding cylinder the extended enterprise includes OneSubsea, Aarbakke and the customers of OneSubsea using the softlanding cylinder.

MasterCAD   Used to to create precise technical drawings and models

Product lifecycle   A product life cycle is the product lifespan that starts with a product idea and ends when the product is phased out and no longer available in the market.

SolidWorks   Used to create MBD files

Trade-off analysis   Involves assessing the trade-offs between several factors to determine the optimal overall solution

Abbreviations

2D   Two-Dimensional

3D   Three-Dimensional

CAD   Computer Assisted Design

EMS   Electronics Manufacturing Service

GPS   Geometrical Product Specifications

MBD   Model Based Definition

SDG   Sustainable Development Goals

SFTP   Secure File Transfer Protocols

SLC   Soft Landing Cylinder

SWOT   Strength Weakness Opportunity Threats

UN   United Nations

List of contents

List of figures

List of tables

1. Introduction

The introduction introduces the background, motivation and primary objectives of the bachelor thesis.

1.1 Background and motivation

Companies are facing increasing pressure to improve efficiency, reduce costs and speed up manufacturing time[16]. A crucial factor is the global competition, which has led to a crowded marketplace. Therefore, time to market is crucial. Releasing a product early in the market can make a key competitive advantage for a company. This allows them to capture market share and increase profits. Additionally, shorter time to market can help companies reduce costs, improve efficiency, and respond quickly to changes in the market conditions.

As a result of this, manufacturers are exploring innovative technologies and strategies to develop their manufacturing process. A solution to this is to move over to MBD, a digital approach to represent models. 2D Technical drawings have been in use for construction to represent 3D objects for thousands of years and are still present in manufacturing today. MBD delivers the model in a 3D file with all the necessary parameters, such as dimensions and tolerances. This is a superior representation of the model, allowing the manufacturers to see the model as it is. Moving over to a digital approach allows companies to shorten time to market, and manufacturers to speed up their manufacturing time [18].

1.2 Distribution process

The distribution process describes which channels the product experience, from raw material, manufacturing and until the product can be sent to the user or customer. MBD allows the distribution process to be more efficient in the development and manufacturing stage. Therefore, this thesis will document the distribution process regarding development to the manufacturing process.

1.3　Problem statement

The purpose of this thesis is to create a technical data package containing MBD of OneSubsea`s Soft-landing Cylinder. The data package must enable manufacturers to accurately interpret, understand and program the manufacturing process. Subsequently, transfer the data set to Aarbakke AS, a manufacturer, and document the distribution process. The research will focus on the parameters that must be included in the data package and the methods used to generate reliable results. Furthermore, the research should also consider how the set can be extended across the extended enterprise to improve quality across the entire supply chain.

1.4 Objective

The objective represents the desired outcome for the project.

The objective is to:

- Define parameters such as dimensions, tolerances and symbols that must be included in the MBD file to manufacture the SLC
- Create a detailed data package including MBD of the SLC which is useable for manufacturing
- Evaluate the manufacturing process using MBD
- Evaluate the new engineering process using MBD versus current engineering process using 2D technical drawings
- Note! As the original objective, we wanted to test the manufacturing process by doing a full implementation in a factory. However, the factory was not able to receive MBD models. Therefore, we did a factory visit where we presented MBD and got their feedback on how this would impact on their process.
- Create a data package that is representative for OneSubsea, which they can further create MBD files for their products by using our data package as a reference. This defines the research centers of the thesis.

Knowing which parameters are needed in the MBD file and data package is important. Thus, the operator has enough information to manufacture the model. Adding too many parameters makes the model complicated and messy for the operator to read. Therefore, an accurate MBD file is essential and must be readable. To see the difference, the advantages, and disadvantages of both MBD and 2D technical drawings, we need to elevate the manufacturing process. Finally, we desire to make the MBD file of the SLC which is representative for OneSubsea, hence they can further create MBD of their models. Therefor they can adopt the digital approach in the future.

One of the objectives cannot be achieved, as we wanted to examine the manufacturing process by doing a full implementation at the manufacturer. By doing a full implementation we indicate, delivering MBD of the SLC and examine the machine operators simulate the manufacturing process. Observing this process would allow us to preserve how the machine operator structures and program the manufacturing process according to the MBD file. Unfortunately, the

manufacturer was not as developed with MBD as we hoped. Instead, will we present the MBD file, and document their feedback on how this could impact their process, and discuss their thoughts on MBD.

1.5   Research question

What best practices and processes can be utilized to ensure the successful adoption of model based definition for manufacturers and development teams?

2. Theory

Theory delves into the theoretical underpinnings of MBD as the cornerstone of the project, elucidating the principles and concepts that shape assumptions and ultimately leads to the desired project outcome.

2.1 Model based definition

Model Based Definition (MBD) is defined as a method of defining a products design feature within a 3D model. This is a modern engineering practice that has become increasingly popular in recent years. It involves the use of digital models to define the product, including its geometry, dimensions, tolerances, materials, and other relevant information. Instead of creating separate 2D drawings to communicate these details, MBD allows engineers to create a complete and accurate digital model that can be used throughout the product lifecycle [21].
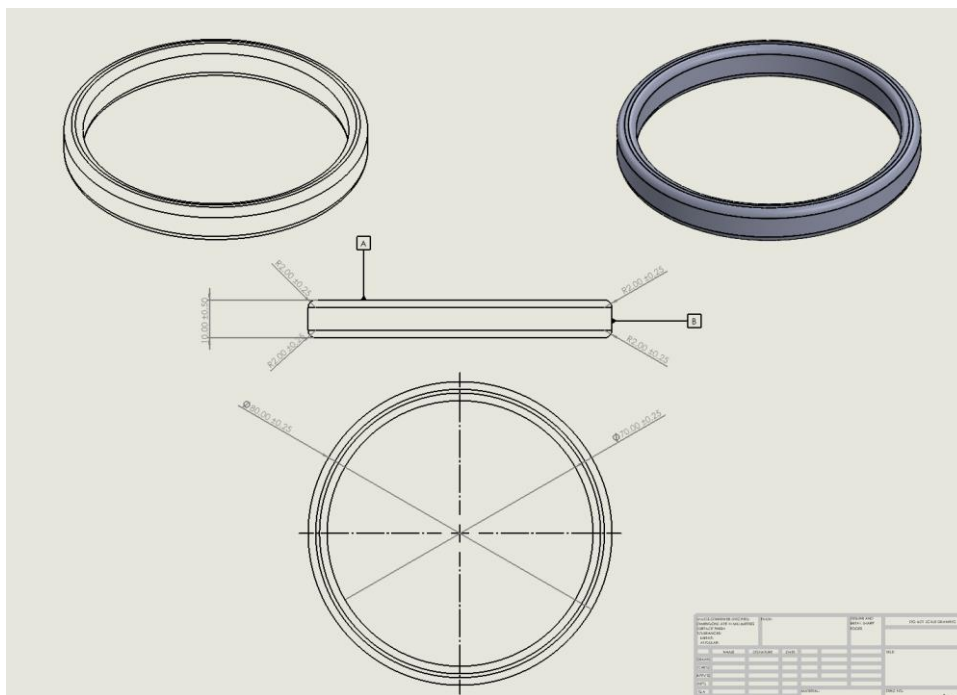
Figure 1: 2D technical drawing of a geometry
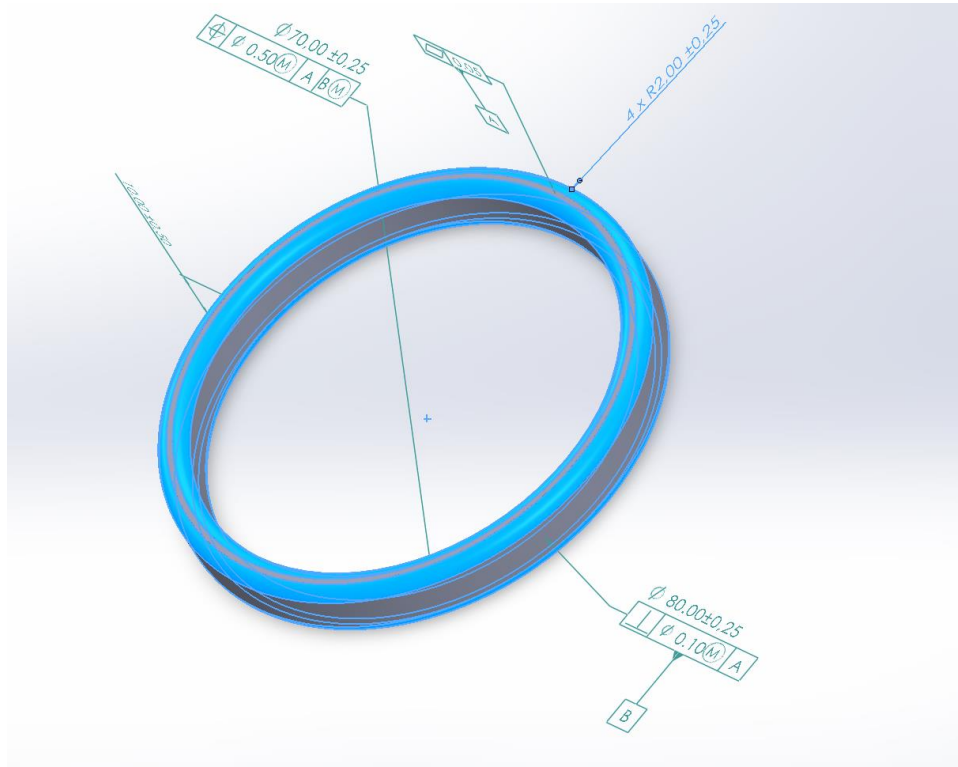
Figure 2: Rotated view with highlighted fillet dimension

The benefits of MBD are numerous. First, it eliminates the need for 2D drawings, which are time-consuming to create and can be prone to errors. With MBD, the digital model serves as the single source of truth, reducing the risk of misinterpretation or miscommunication. Second, MBD improves collaboration between design and manufacturing teams, as everyone is working from the same digital model. This can lead to faster and more efficient product development, as well as fewer errors and rework. Third, MBD can improve product quality by allowing for more accurate and precise manufacturing processes [21].

Overall, MBD is a powerful tool that can improve product development, quality, and efficiency. As technology continues to advance, it is likely that MBD will become even more prevalent in the engineering industry [21].

2.1.1 OneSubsea

The client of the group is OneSubsea's department in Gjøvik. OneSubsea is a supplier of equipment for the oil sector. [1] OneSubsea's main objective is to help oil and gas companies increase their production and recovery rates in a safe, reliable, and cost-effective manner. OneSubsea's solutions enable operators to produce oil and gas from offshore fields in

increasingly challenging environments, including deepwater, high-pressure/high-temperature, and ultra-deepwater[25].

2.1.2 Soft-landing Cylinder

OneSubsea's Soft Landing Cylinder (SLC, Figure 3) is an innovative technology that enables the safe and efficient landing of subsea structures on the seabed. It uses a unique design to absorb impact from wave and current forces, enabling reliable and repeatable performance. The SLC also reduces the landing speed enabling subsea structures to land safely. This reduces the risk of damage and eliminates the need for complex and costly subsea intervention.

Figure 3: Picture of the SLC

2.2 Users

The users of MBD are bound by two parts, development engineers and the machine operators.

Development engineers

The development engineers use MBD to detail data of the design feature such as, dimensions, tolerances and material of a CAD designed model.

Machine operators

The machine operators read the MBD model created by the development engineers to manufacture the product.

2.3 Product lifecycle

A product life cycle is the product lifespan that starts with a product idea and ends when the product is phased out and no longer available in the market. It is typical to divide a product lifecycle into stages. There are several models and views on how to divide the product lifecycle into stages dependent on what your interest in the product is, such as development, sales and marketing, or manufacturing.

Figure 4: Full product lifecycle

The group used a product lifecycle model with 4 stages. These are development, new product introduction, assess & adjust and phaseout.

Development

Development includes activities from the initial product idea to the product being ready to be introduced in the market. The development stage often overlaps with the new product introduction.

New product introduction

New product introduction includes activities to start production of the product.

Assess and adjust

In the assess and adjust stage, the product is in normal production and is assessed and adjusted to operate in the market. The adjustments can be due to bugs or availability of components. In this phase the development team typically makes engineering changes to the product.

Phaseout

In the phaseout phase the product is retired from the market and production is stopped. Activities in this phase can be communication of a last time buy and securing of stock for spare part maintenance.
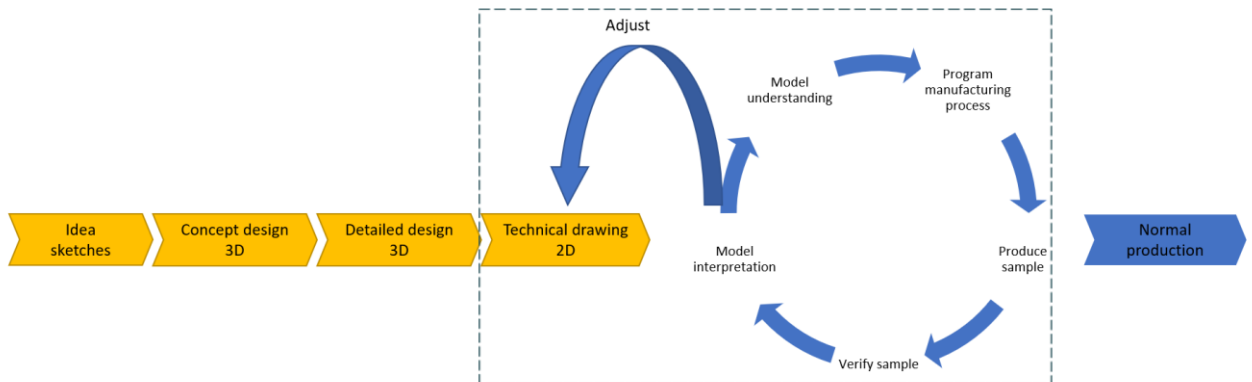
Figure 5: Product lifecycle stages development and new product introduction

When working with MBD, we have focused on the development and new product introduction stages. These two stages include the phases that a product goes through from idea to release to the market. The figure above (Figure 5) shows the phases and steps that are included in the development and new product introduction stage where the yellow areas are the development department at a company, and the blue areas are the manufacturing department.

Ideation is the initial phase where ideas for a new product are generated. This development stage involves sketching ideas by hand and identifying functions. Once the ideas are generated, they are evaluated based on various criteria, including market potential, technical feasibility, cost, and resources required. Ideas that meet the criteria are then developed into a concept, which is the next stage in the product lifecycle.

The next stage is concept design which is the stage in the product lifecycle where the ideas generated in the ideation stage are developed into a more concrete concept. This involves defining the product's features, benefits, and functionality. The concept design is usually done using 3D modelling and tools.

The detailed design process involves transforming the product concept into a detailed design that can be developed and produced. The design process involves creating a visual representation of the product, including the product's look, feel, and functionality. Once the design has been created, it is important to test and refine the design through user testing and feedback. This helps ensure that the design meets the needs and preferences of the target audience and is user-friendly. The result of the detailed design is a detailed 3D model of the product.

After the detailed design the development team must make technical documentation that production can use to produce the product. This is done by transforming the detailed 3D model into 2D technical machine drawings. In these technical drawings all needed information like dimensions and tolerances are defined for the manufacturer to produce the product. The 2D technical drawings are typically handed over from development to manufacturer as pdf documents.

The next step is often an iterative process where the manufacturer reads the 2D technical drawings, do model interpretation and understanding, program the manufacturing process and produce an engineering sample. The engineering sample is verified and go back to the development team for approval or potential adjustments. In the new product introduction process, it is not unusual to go through 3 to 4 iterations making engineering samples before manufacturing can start production with ok quality.

The stages marked in the striped box (Figure 5)shows which stages have the opportunity to become more efficient with MBD.

2.4 Links to UNs sustainability goals

The United Nations' Sustainable Development Goals (SDGs) are a set of 17 global goals adopted by the UN in 2015. The SDGs address various social, economic, and environmental challenges in the world. SDG 9 and SDG 12 specifically address issues related to industry, innovation, infrastructure, and sustainable consumption and production, respectively.

SDG 9, aims to "build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation". This recognizes the potential of new technologies, including MBD, to drive innovation and improve the efficiency and sustainability of industrial processes. MBD can help product development become more efficient, reduce waste, and enhance the quality and safety of manufactured products. By using a digital model to define product requirements and specifications, MBD can also facilitate collaboration and communication between different stakeholders in the design and manufacturing process [29].

SDG 12, aims to "ensure sustainable consumption and production patterns", highlighting the need to reduce waste and promote more sustainable production practices. MBD can play a key role in achieving this goal by enabling companies to design and manufacture products that are optimized for efficiency and sustainability. By using a digital model to define product requirements and specifications, MBD can help reduce material waste, minimize energy consumption, and reduce the environmental impact of manufacturing processes. MBD can also facilitate the use of recycled or renewable materials in product design, further promoting sustainable consumption and production patterns.

Once the design is finalized, the production moves to the manufacturing phase. Aarbakke AS has a range of modern and advanced machinery, including CNC machines, milling machines, and lathes, which are used to produce the components. The company has invested in high-end equipment and employs skilled professionals to ensure the accuracy and quality of the components [1].

2.5 Secure data transfer protocols

When sharing sensitive files such as technical data packages, secure file transfer protocols (SFTP) are needed to protect the information and data during the transfer. SFTP lifecycle starts with encrypting the file from the development team before transmitting. At this point, the file is converted to an unreadable code to those without access. Further, SFTP ensures different authentication methods, securing identification for the sender and the receiver. To verify the integrity of the data during the transfer, digital signatures are used to assure the file is not tampered with or corrupted during transmission. Before the transition, the development team checks if they have access to the server with the authentication key. Once they have access to the server, the file is transmitted safely over the internet.

Without SFTP sensitive information and data is available to be accessed, intercepted, and modified by unauthorized individuals. Although SFTP is safe, some development teams are skeptical. Aarbakke AS declared some of their clients did not feel comfortable sharing their information and files. This was due to the risk of the documents ending up at their competitor's vision. The consequence of this leads to some of their clients not sharing the full documentation of a product they need produced. Specifically, the clients transfer technical drawings to represent the model, and not the 3D file.

2.6 Geometrical product specifications

Geometrical product specification (GPS) is the symbol used in technical drawings. In MBD GPS is a critical component for defining the product geometry and tolerances. GPS provides a standardized way of expressing the tolerances and requirements of the product, which can be incorporated into the 3D model using various software tools. By using GPS in MBD engineers and designers can accurately represent the products' geometry and tolerances, which reduces errors and inconsistencies during the design and manufacturing process [19].

By using GPS, you can:

1. *Improve communication*: GPS is a standardized way of communicating product requirements.

2. *Reduce errors:* By implementing GPS directly into the 3D model, errors and inconsistencies are reduced which results in a higher quality product.

3. *Increase efficiency:* Using MBD with GPS reduces the need for 2D drawings and the need to create the model in other software's such as masterCAD.

2.7   Digitalization and efficiency in engineering

2.7.1   Pre-history of technical drawings

Technical drawings have been used for thousands of years to communicate technical information and specifications for a product or structure. One of the first examples of technical drawings precede to the ancient Egypt and was painted in stone, wood, and papyrus. This civilization produced skillful architects, whose sketches represented primarily buildings and landscapes. The wood tablet (Figure 6) shows a technical drawing of a small chapel (marked in red top right-hand corner) surrounded by trees and a brick wall (in black) near a lake (waves on the left side). The forearm (over the top right tree) is the symbol for "cubit", the old Egyptian unit which represents the width of the garden. The half circles symbolize ten and the two straight lines (left for the forearm) each symbolize one. This adds up the width of the garden to 32-cubit units.

Figure 6: Architectural drawing of a garden (1550-1295 B.C) found in Thebes [14]

Moving forward to the renaissance, technical drawings became more sophisticated. [23] Filippo Brunelleschi, one of the leading architects during the Renaissance, developed the linear representation technique, which allowed to accurately represent 3D objects on 2D surfaces [17]. This method was based on the observation of parallel lines appearing to converge at a vanish point [Figure 7]. The following years, Leonardo Da Vinci used Brunelleschi's technique and produced hundreds of technical drawings of machines. Da Vincis work was very advanced at

the time, where some of his drawings reveals dimensioning and different views on the object (Figure 8) His work was known for its accuracy, precision, and attention to detailing the drawing. This became highly influential for future engineers to establish technical drawings (Figure 8).
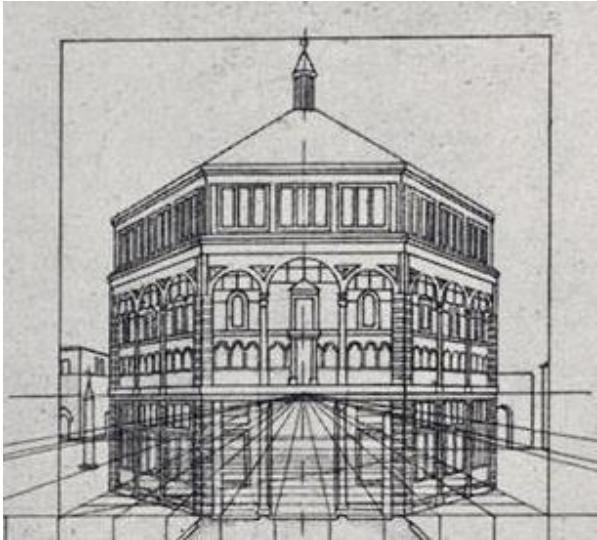
Figure 7: Diagram demonstrating Filippo Brunelleschi perspective technique from a Lost Painting of the Battistero di San Giovanni [17]
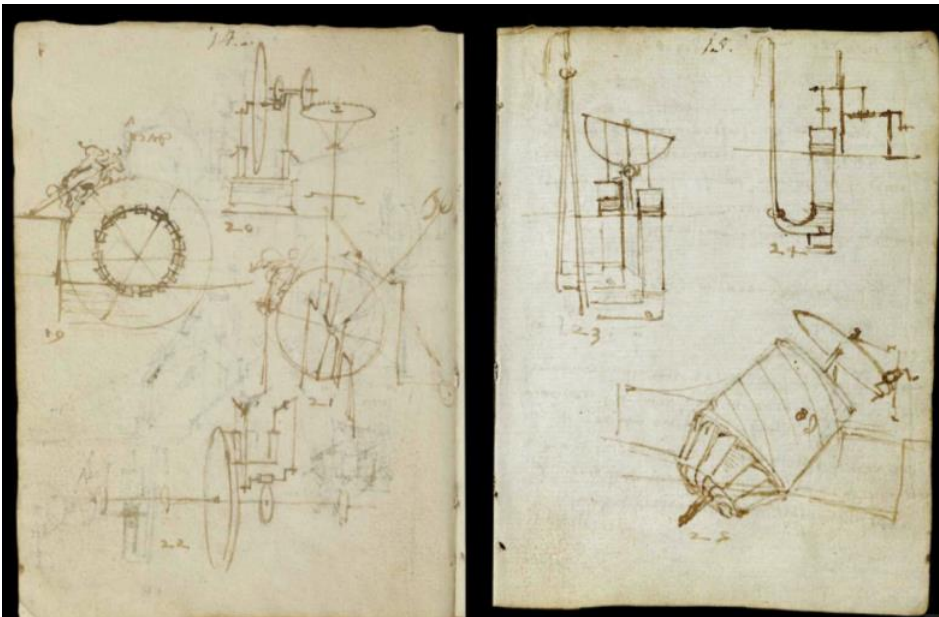
Figure 8: Technical drawing in Leonardo Da Vincis notebook (late 15th- early 16th century), held in Victoria and Albert Museum in London [2]

In the first half of the 19th century, there was still no drafting software to design technical drawings. Engineers produced technical drawings on huge sheets of paper with pencils and

erasers. Although these drawings were certainly more advanced and detailed, they are still comparable to those realized by Da Vinci four-five hundred years ago. The problem with sketching by hand was when a mistake occurred, it could lead to drawing the model all over again. In the 1960s engineers at Boeing, Ford, Citroen, MIT and GM invested greatly, both intellectual and financial, to develop CAD create [11]. CADs' steady development was supported by the rapid growth of electronics, as the main problem lied with the limited performance of computers hardware, hence the extremely long processing times necessary for running the software's. In the early 1990s CAD software's became capable enough for computers, where technical drawings could be done with mouse and keyboard[11].
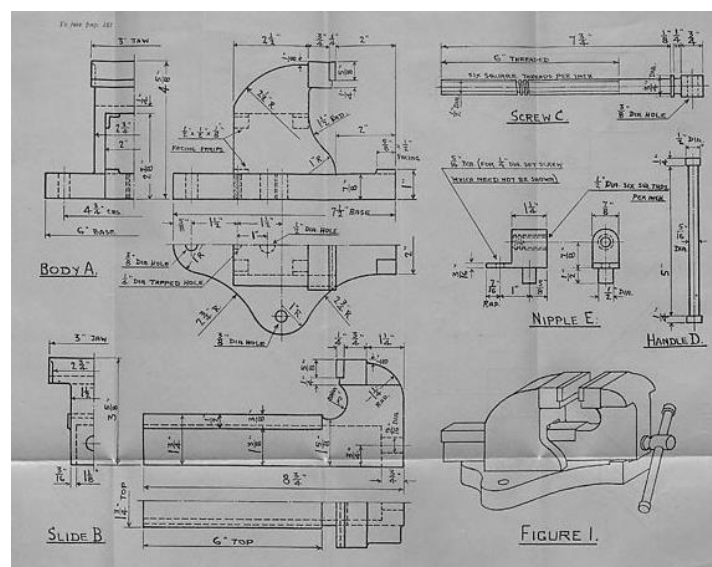
Figure 9: Technical subjects, Higher Grade – (Technical Drawing) 1949 [37]

2.7.2 Current situation technical drawings and manufacturing

Nowadays, technical drawings are realized with mouse and keyboard which allows for greater accuracy and efficiency in the design process. Once a model is created with a CAD program, the engineer can develop blueprints by adding views, dimensions, and tolerances of the model. Afterwards, the blueprints are sent to a manufacturer, where the technical drawing is the complete representation of the model. Machine operators interpret technical drawings and program manufacturing instruments such as CNC machines. This implies determining the appropriate materials, tools, machine parameters as the necessary commands and instructions in the machine's control system. To ensure the finished part meets the specific requirements,

the machine operators must continuously monitor the manufacturing process and make some adjustments, in case of need.

At the manufacturing stage, machine operators rely on technical drawings to program manufacturing instruments such as CNC machines. They must carefully select appropriate materials, tools, and machine parameters, and input the necessary commands into the machine's control system. Throughout the manufacturing process, operators continuously monitor the process to ensure the finished product meets specific requirements, adjusting as necessary.

In a survey done by Roland Berger stated 67% of companies face increasing pressure to improve efficiency and speed up manufacturing, many are turning to digital and automated engineering processes [16]. In addition to CAD softwares, advancements in artificial intelligence and machine learning enable manufacturers leverage data and analytics to optimize operations and improve product quality.

2.7.3 Trends

MBD has been used in the military and aviation industries. In the military, MBD has been used to create more efficient and accurate designs for aircraft, vehicles, weapons, and other military hardware. It has been used to create detailed 3D models of components and assemblies, which can be used to make more accurate and efficient decisions about the design and production process. The data from the 3D models can also be used to create virtual simulations of the parts and assemblies, which can then be tested and verified to ensure they meet the required performance standards. MBD has also been used to create detailed 3D models of aircraft components, which can be used to make more accurate and efficient decisions about the design and production process.

The article "Trends in Model-Based Definition based Assembly Information for High-Value Manufacturing"[9] explores the recent trends in model-based definition (MBD) based assembly information for high-value manufacturing. This method of manufacturing is a shift from conventional 2D drawing-based assembly information and is quickly becoming an industry standard.

MBD-based assembly information allows for more efficient and precise assembly of components, as the 3D models provide a more holistic understanding of the assembly process. This method also reduces the need for costly engineering drawings and physical non-geometric components, such as drawings and tables. Additionally, MBD-based assembly information can also provide a diagnostic tool for assembly and disassembly processes.

This article discusses two major trends in MBD-based assembly information for high-value manufacturing. The first trend is the use of digital twins. Digital twins are virtual models of physical objects that can be used to replicate the behavior of the physical object. This technology allows manufacturers to replicate a real-world device in a virtual environment and make changes to the object before the physical object is ever created. This technology can significantly reduce the cost and time of manufacturing processes.

Augmented reality is the use of computer-generated images, sounds, and other sensory inputs to enhance a user's real-world experience. AR can be used in assembly processes to provide visual and auditory guidance to workers and real-time feedback on the assembly process. This technology can allow manufacturers to increase the speed and accuracy of assembly processes while also reducing costs [9].

2.8   MBD and its applications

MBD is a 3D version of 2D technical drawings. The goal with MBD is to replace the 2D-drawings and combine both the CAD-model and technical drawings into one. The MBD function in CAD-programs has a lot of applications. One function the MBD-application is (Figure 10) that one can click on the dimension and the parts of the model the dimension refers to will be highlighted. Here the dimension shows "3 x R0,80", meaning there is a fillet with a radius of 0.80 millimeter three places on the model. When you click on the dimension the three fillets are highlighted it is visible where it is referring to.

When dimensioning the model in SolidWorks, you have two options. One can either dimension the model manually or use the function called "Auto Dimension Scheme". With "Auto Dimension Scheme" one only must choose datums in the model and then all the dimensions will come automatically [10]. When the model is fully dimensioned you can show the tolerance status on the model. The model is painted in colors depending on if it is over/under constrained or fully constrained. When you are satisfied with the dimensions and tolerance you can start capturing 3D-views. The 3D-views in MBD are the method to promote the model. You capture views of the model from different angles to present all the different dimensions. Although the views are like pictures of the model from a certain angle, one can rotate the model inside the views to get an overview of the dimensions.
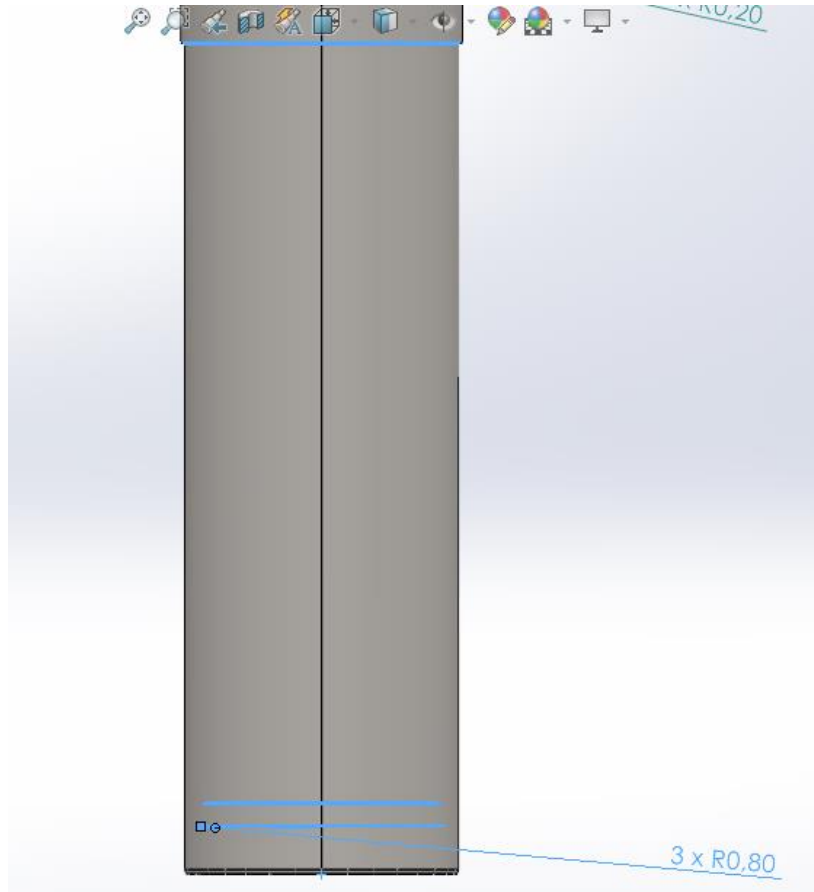
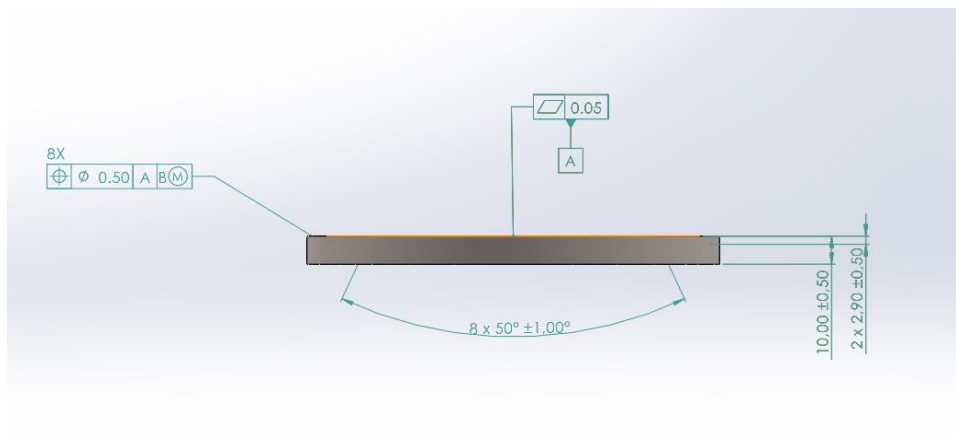*Figure 10: Shot from ROD-model, showing which three fillets it refers to*

Figure 11: After combining the cone-dimensions in front view

3. Methodology

The Methodology chapter outlines the methodology applied throughout the project, presenting a comprehensive overview of the methods and techniques utilized to achieve the results.

3.1 Data collection and analysis

3.1.1 SWOT

The SWOT analysis was conducted to identify and evaluate strengths, weaknesses, opportunities, and threats that can occur when implementing the process. It benefits understanding the internal and external factors that can indicate success.

Internals:

- **Strengths:** Identifies and evaluates the factors which provide an advantages or competitive edge to the business.

- **Weaknesses:** Analyzes the internal factors that interrupt the business' performance or put it at a disadvantage compared to its competitors.

Externals:

- **Opportunities:** Identifies and evaluates the external factors in the market or industry which can be beneficial to the business

- **Threats:** Analyzes the external factors can potentially have a negative impact on the business
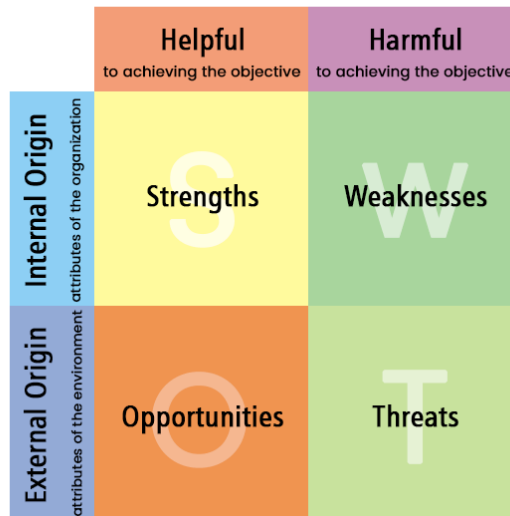
SWOT ANALYSIS

Figure 12: SWOT analysis template [35]

3.1.2 Trade off analysis

The trade-off analysis is used to compare the current solution with an innovative approach. It involves assessing the trade-offs between several factors to determine the optimal solution or decision. The approach behind the analysis begins with identifying key factors or criteria relevant to the current solution and the new one. Each of the criteria is assigned a weight or importance based on the relative significance. Further, the current and new solution is ranked against the criteria and evaluated considering the impact of each option on different criteria. The result of each solution is every criterion multiplied by the importance of the criteria. Tradeoff analysis helps in understanding the trade-offs involved, as improving one criterion may result in a compromise on another.

Table 1:

Trade off analysis template

Criteria	Current solution	New solution	Importance
X	1-6	1-6	1-6
Score			

3.1.3 Value proposition canvas

The value propositions canvas is applied to analyze and understand how MBD creates value for its users.

The figure is divided into two parts, the customer segment profile (on the right, Figure 13) and the value proposition map (on the left, Figure 13). The customer segment profile describes a specified customer segment. This is broken down to what we can observe, customers' jobs, pains, and gains. Customer jobs can be described as what our customer is trying to complete in their work or life. These can be functional, social, and emotional jobs they are trying to complete or perform to satisfy their needs. The gains are the benefits and outcomes our customer wants, such as functional utility, social gains, positive emotional and cost savings. This could be gains required, desired, or expected by the customer. The pains can be expressed as anything that is preventing our customers from getting a job done, or annoys them before, during and after trying to get a job finished.

The value proposition map guides as features of a specific value proposition in a detailed and structured way. This is broken down into products and services, pain relivers and gain creators. The product and services are what we want or can offer to the customer. Gain creators are how the products and services offered create customer gains. They outline how we intend to produce benefits and outcomes for your customer. Pain relivers describes how our products and services reduce or eliminate specific customer pains. They outline how we intend to reduce or eliminate things that annoy your customer.
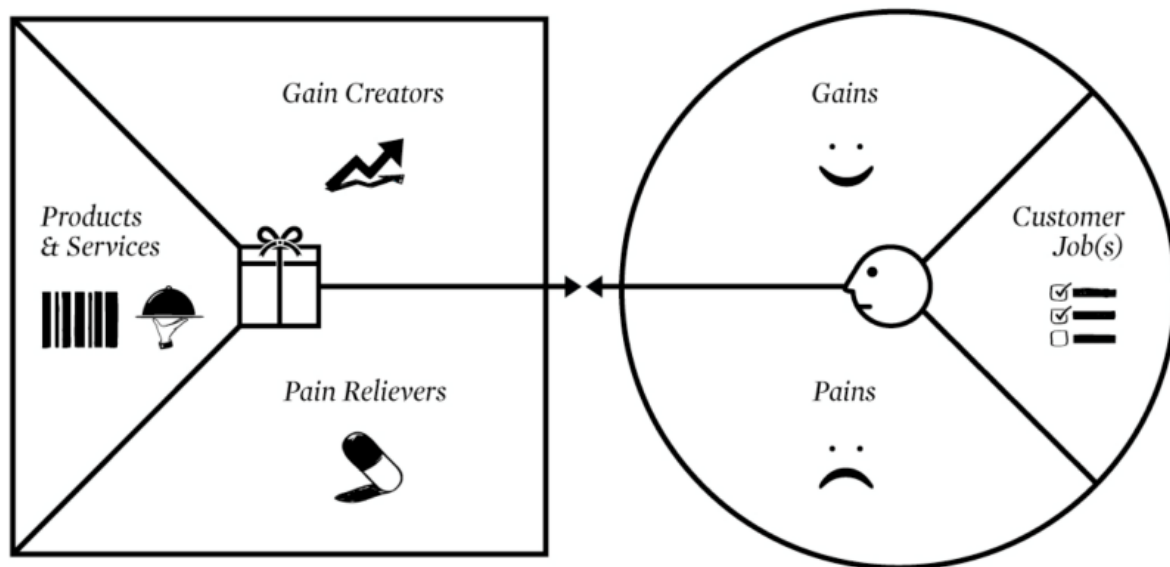
Figure 13: Value proposition canvas template [27]

3.1.4 Statistics

To get an overview of the possibilities and strengths of MBD, statistical analysis was applied. Due to limited data collection of MBD, the group could not run a statistical analysis to test the effectiveness. Instead, the group gathered statistical analysis of MBD conducted by other people. This allowed the group to obtain numbers of how effective MBD is in time and cost reduction, and challenges with the current method.

By leveraging the existing statistical analyses carried out by others, our group can obtain valuable information and data regarding the effectiveness of MBD in various contexts. These analyses provided us with quantitative measurements, such as metrics related to time and cost reduction, as well as insights into the challenges associated with the current methods.

The statistical analyses gathered allowed the group to gain a deeper understanding of the potential benefits and drawbacks of MBD. Additionally, these analyses shed light on the limitations and obstacles faced when implementing MBD, enabling us to identify potential areas for improvement and further research. These analyses served as a valuable source of information, providing us with quantitative evidence and insights that enriched our research and allowed us to draw meaningful conclusions about the effectiveness of MBD.

3.1.5 Meetings

Since the end of January, the group has been diligently working on our bachelor thesis project. It was made a priority to meet with OneSubsea on a consistent basis, ensuring that everyone is on the same page and making progress. In the beginning, one weekly meeting was required to discuss how to initiate the thesis, exchange ideas, and identify any issues that needed to be addressed. These meetings were crucial for establishing a solid foundation for the project and building strong teamwork among the group.

Moving over to mid-March, the group began having more frequent meetings, sometimes meeting multiple times per week. This was due to having more time and the need for more frequent communication to ensure that everything was on track. During these meetings, the group continued to improve ideas, clarify goals, and work through any challenges that occurred.

In addition to meetings among the group members, it was valuable to have regular meetings with the tutors at the university. They provided valuable feedback, guidance, and support throughout the process, helping us to stay focused and motivated. Additionally, the group arranged meetings with manufacturers. This was firstly, to get more insight into the manufacturing process and a better understanding of the current solution today. Secondly, to present the concept with MBD and gather feedbacks from professionals.

3.2 Computer Assisted Design

3.2.1 SolidWorks

SolidWorks CAD is a mechanical design application used by designers to sketch and produce models and drawings. The software lets you produce models with all kinds of features and dimensions with a 3D design approach. With the final model the software lets you either make 2D drawings of the component or you can produce multiple components and create a 3D assembly [12].

The SolidWorks software contains a lot of applications, including MBD which is the application put in use by the group. Inside the MBD-application there are multiple tools that can be used for the model. The MBD-application lets you dimension the model, the same way as with 2D technical drawings, put inside the CAD model. In chapter 3.4 the whole creation process for the MBD-files will be explained from start to finish.

3.2.2 Standard MIL–STD31000A, appendix B Stand

To be able to create a model-based definition file from the CAD-model, the group had to first understand the concept of MBD fully. MBD is not a fully developed subject and is not mainly used by manufacturers today. Therefore, there are not any universal standard on how an MBD file should be presented. The process of understanding MBD, including the MBD-application inside SolidWorks, demanded a lot of research. The research involved watching videos of MBD, reading articles, studying examples of MBD models, and exercising on premade models. A challenge with MBD that occurred from the research was the lack of standardization, meaning there is no standard on how an MBD-file should appear. MIL-STD31000A, appendix B is a standard the group is using. This is the standard used as a starting base for all 3D-views created by the group. The standard has a layout for how each of the 3D-views in the MBD-file should look like, and the content in each 3D-view. Also including the names of each 3D-views in the file [28].

3.2.3 Symbols and tolerances

Designing MBD files includes the use of multiple symbols and tolerances. One type of general tolerance which is frequently used in the MBD-files is the so-called "True position" tolerance (Figure 15).and is shown below on (Figure 15). The symbol on the left is "True position". This tolerance is the total acceptable variation of positioning a feature can have from the exact coordinates the features have in the CAD-model [5]. Next to the "True Position" symbol is the diameter symbol with a value. The value describes the size in diameter that the feature can vary from the exact coordinates. The letters right of the general tolerance, refers to the datums set in the model, which is the reference point for all the dimensions [3]. There is also a letter "M" in these tolerances which stands for the "Maximum Material Condition" or MMC. This means that there is maximum amount of material existing within the given tolerance. MMC for holes or internal features means the smallest hole size within the tolerance, and the opposite for pins or external features [7].

On (Figure 15) with the datums shown there is a tolerance symbol above the datum A. This symbol represents the flatness of the surface the dimension refers to. Next to the flatness symbol there is a value of 0.05mm. The flatness tolerance illustrates that the surface is as flat as possible within ±0.05mm. The perpendicularity tolerance is shown on above datum B (Figure 15). This tolerance can be used in two different scenarios. The first scenario is for surfaces as the perpendicularity tolerance refers to the tolerance for a surface or feature that is perpendicular, or 90°, from a datum surface or line. The other scenario is the axis control shown on the figure (Figure 15). When the axis control is called out it refers to a cylindrical boundary. This is a line perpendicular to the datum feature, where the axis of the feature referenced to must lie [8]. The example on (Figure 15) shows an example of the axis control with a tolerance of 0.10mm.

In (Figure 16) there is a dimension for two holes in the model with a true position tolerance. Above the true position tolerance, you can see the diameter with a tolerance for the two holes. Next to the diameter value there is a symbol with a value of 20.00mm ±0.50mm. This symbol refers to the depth of the two holes, meaning the holes are 20.00mm deep with a tolerance of 0.50mm. In the notes in the MBD-files there is a description of the surface texture for the model. On (Figure 17) and (Figure 18) you can see an explanation for the symbols and the values in the symbol.
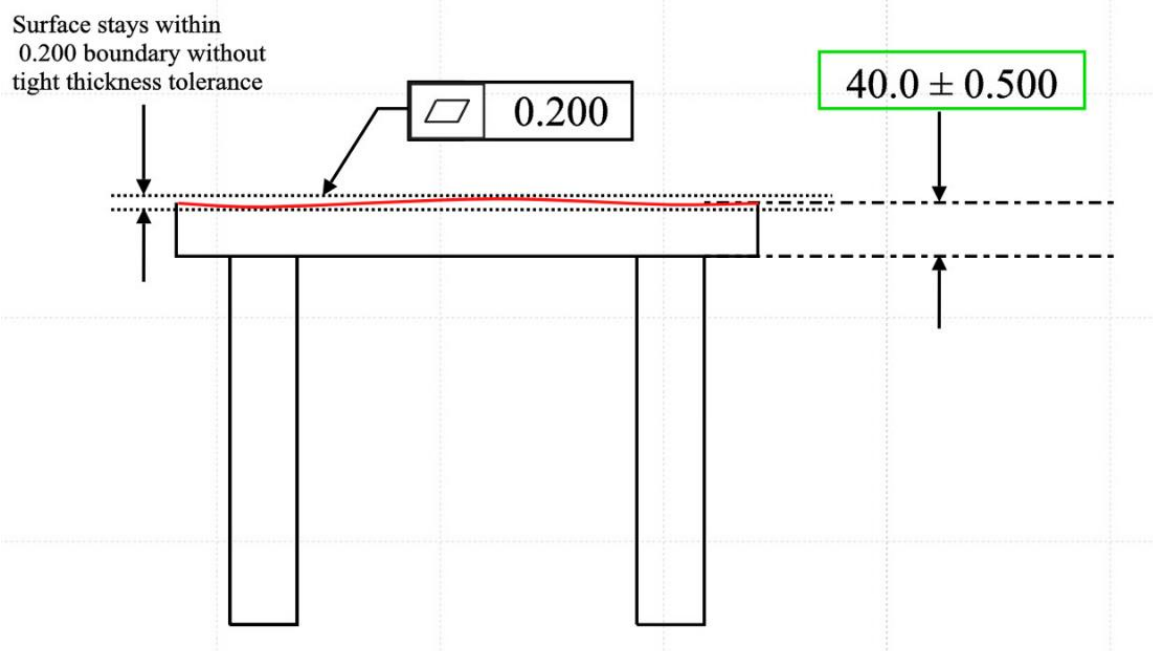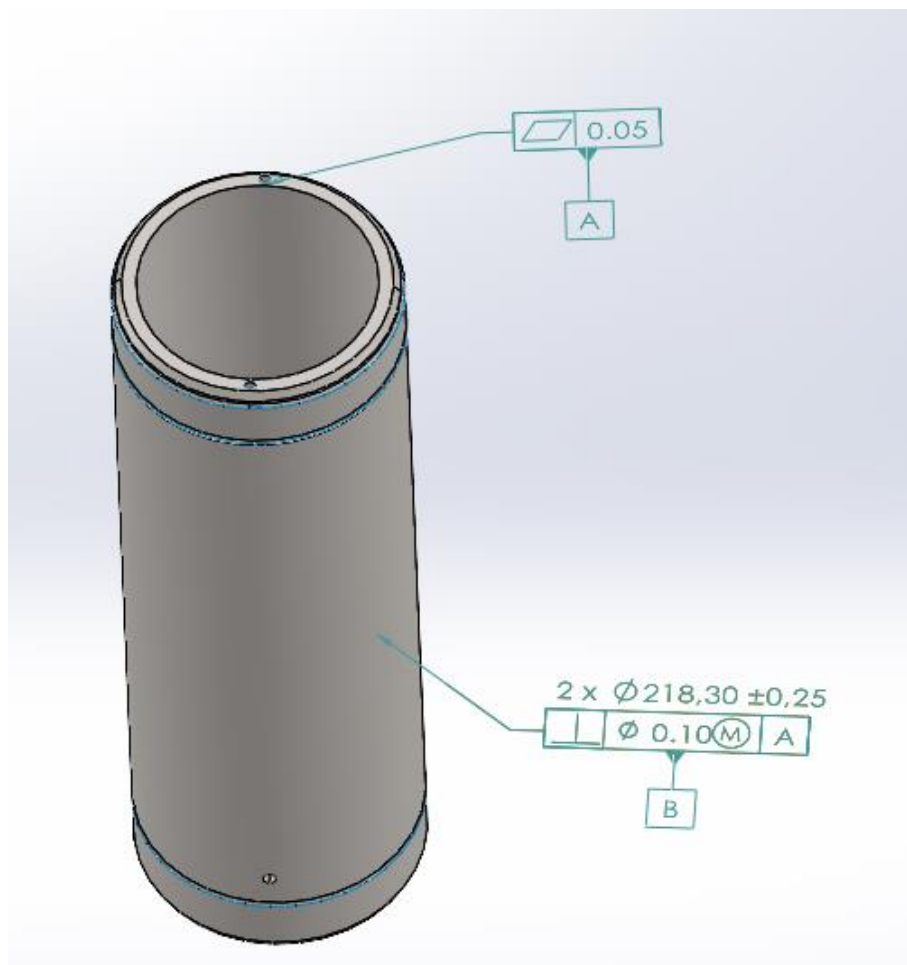
Figure 14: The flatness tolerance [34]

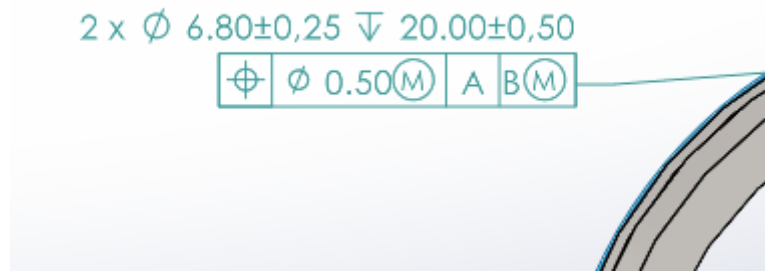*Figure 15: Datums with different geometrical tolerances*

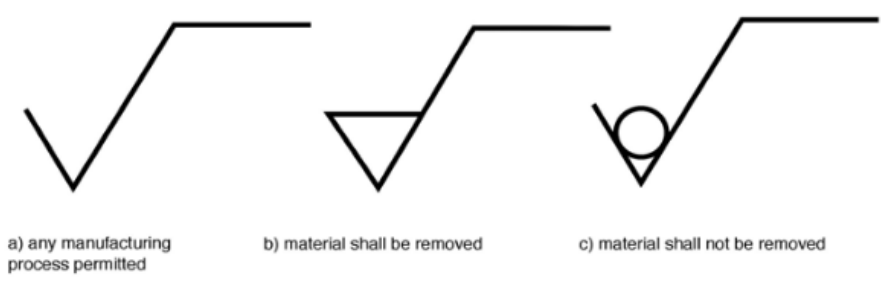*Figure 16: Dimensions and tolerance for two holes*

a) any manufacturing process permitted

b) material shall be removed

c) material shall not be removed

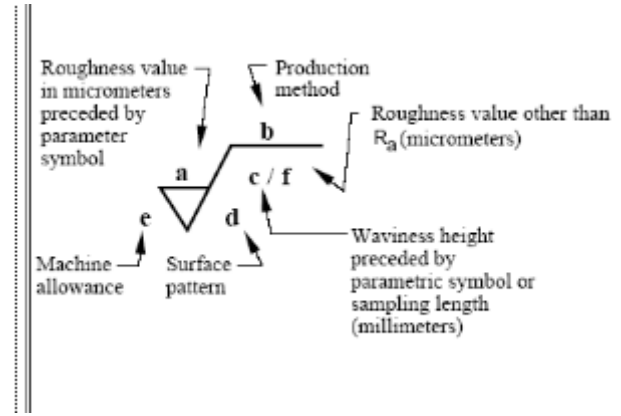*Figure 17: Surface texture symbols [36]*

Figure 18: Surface texture explanation [33]

3.3 MBD creation process

To create the model-based definition technical data package the group had to go through several steps. The CAD-model used is the Soft-Landing cylinder delivered by OneSubsea. The design process of the MBD-file in this chapter is for the ITM-0273579-component. There is some difference in the process for the components and these will be explained in the result.

1. The first step in the creation process was to receive all components of the SLC. OneSubsea sent a step-file of the assembled SLC, which the group opened in SolidWorks and used the tool "Pack and Go" to get a step-file of each singular component included. With the "Pack and Go" tool all included components are saved as step-files in the folder chosen.

2. When creating an MBD-file you must be precise to fully present all information regarding the model. Firstly, the group explored the different tools and functions in the MBD application in SolidWorks to plan the process. There are two different dimension tools when using MBD, and the group used a combination of them. The first tool is "Auto Dimension Scheme" where you select the datums for the model. then all dimensions are added automatically. As shown on (Figure 19), the datums selected for this model are "Plane1" for Datum A, and "Cylinder1" for Datum B. The datums shown on the figure (Figure 19), are the datums selected for this model are "Plane1" for Datum A, and "Cylinder1" for Datum B. Further, the (Figure 20) presents the result of the "Auto Dimension Scheme" tool.

3. The most common tolerance on the model is ±0.5mm. To add the tolerances for the dimensions, there is a menu when selecting a dimension where you can choose different tolerance types. The tolerance type selected by the group was "Symmetric" which means "± a value", and next you simply write the value desirable in the box below. The "True Position" tolerances is added with the tool "Geometric Tolerance". When all values are filled, you select the dimension you want the tolerance to link with. The holes dimensions, shown on (Figure 22), has a dimension of the depth of the hole. To add this dimension, you select the hole dimension and choose the "Depth/Deep" symbol for the "Dimension Text" box.

4. After the use of "Auto Dimension Scheme" there is need for adjustments to present the dimensions in an orderly way. The goal is to divide the dimensions into different annotation views which later are used for the 3D-views. There are three basic annotation views. They are Front-, Top- and Right- views, but one can add as many as desirable. Firstly, the group sorted all views in the three basic annotation views to get an overview and scout for adjustments. To place the dimensions into the different annotation views you choose the dimension and select "Annotation view" and which view it should be added in.

5. The next step was to capture the 3D-views. To capture a 3D-view you select one of the annotation views, rotate the model if desirable, and click "Capture 3D-view". On (Figure 21) you can see a menu of all annotation views in the model, and here you can select which annotation view to be included in the 3D-view. What this means is that all dimensions associated with the annotation views selected are included in the 3D-view. For instance, on (Figure 22) where all dimensions are included means that when you rotate the model, you can see the views associated with another annotation view not visible from that angle. The first draft of the MBD-file was the one sent to the manufacturer (Figure 23). Here you can see several 3D-views with names according to what they present.

6. After the manufactory visit there was a need for adjustments and improvements. For starters, there are multiple dimensions with the value of 90°±1.00°, which need to be combined into one dimension. Firstly, all cone dimensions were removed, and the tool "Pattern Feature" was selected. This tool lets you select all features of the same value you wish to combine. After these features were combined the group used "Size Dimension" tool which got the value 12x 90°±1.00°. This means that twelve cone features have the value of 90°±1.00° (Figure 24) The same process was for the cones with the value 180°±1.00°, which resulted in 8x 180°±1.00°.

7. Further, the group started to improve the 3D-views and reduce the number of views in the file. Many of the views of the model were not necessary. Therefore, the "Heith" 3D-view was deleted, and all the dimensions were added to the "Front-view". Further, the hole dimensions in both Top- and Bot-view were combined in the Top-view. Both cone dimensions were sorted to the Right-view where two fillet dimensions are located.

Lastly, there was made a section view where all the diameters of the cylinder were sorted into. The section view is created by selecting the tool, "Section View", and choose where on the model you want to cut. The group chose to split the model in half with the "Right Plane" and rotated the model to have an isometric view (Figure 25).

8. Some information can't be added with dimensions and is therefore added with "Notes". "Notes" is a tool in the MBD application where you can add notes with desirable content into the different annotation views. The notes added for the MBD-file created by the group were sent with the standard the group used as a baseline for the layout of the MBD-file. According to the MIL-STD31000A, appendix B standard, the notes should include tolerances, standards, general tolerances, and properties of the model. As (Figure 27) shows, the notes include surface texture, screw threads, and the general tolerance for the edges. A challenge the group met when creating these notes, was the lack of symbols in SolidWorks. The standard for the edges has a symbol which SolidWorks didn't supply, which is why it says "External" and "Internal". To represent the notes in an orderly way there was captured a new 3D-view with just the notes and model. The last general tolerance on the list is the general tolerance profile, which says that all features have a tolerance of 1mm unless otherwise specified. To add this tolerance symbol there is a tool inside the notes which is "Insert DimXpert General Profile Tolerance" and then you choose the desirable value.

9. The MBD-files for all components in the SLC have the same layout for the 3D-views. In addition to all the separate MBD-files for the components there was made an MBD-file for the assembly of the SLC. The layout of an assembly file should appear differently since the urge of what to present is different for each singular component. For starters, when creating an assembly file, you first add all components that should be included. The tool "Insert Component" is used, and the components are placed in the view. When all components are added, you can start to use the tool "Mate" to assemble the model. Since all components have a cylinder shape, the mate tool "Concentric" places the circular components along the same center. The next mate tool used is "Coincident" which places two planes of components together. To find the exact position of each component in the assemble model, the group used the file sent by OneSubsea, which was the whole assemble model, and used a section view to get the placement of the inner components. When the model was constructed together, the next

35

step was to add a "BOM" and an "Exploded view" of the model. The BOM is a list of all included components, including all desirable information about them. To construct an exploded view, the tool "Exploded view" was used. With the "Exploded view" tool you, step by step, choose one component at a time and drag the component in a direction away from the model to deconstruct it (Shown on (Figure 28)). The group decided that the exploded view should have all components deconstructed along the same y-axis. Using a tool named "Balloon", names each component with an individual number. You simply click on the "Balloon" tool and then click on each singular component and drag the balloon on the desirable placement. The reason for the use of the balloons is to link the exploded view to the BOM. After each component has an individual number, you can use the tool "Bill of Materials" and select the size and placement of the table. Each component is included in the table with the number of the balloons. Lastly, you adjust the BOM-table to include all information desirable to represent each component with detailed information.
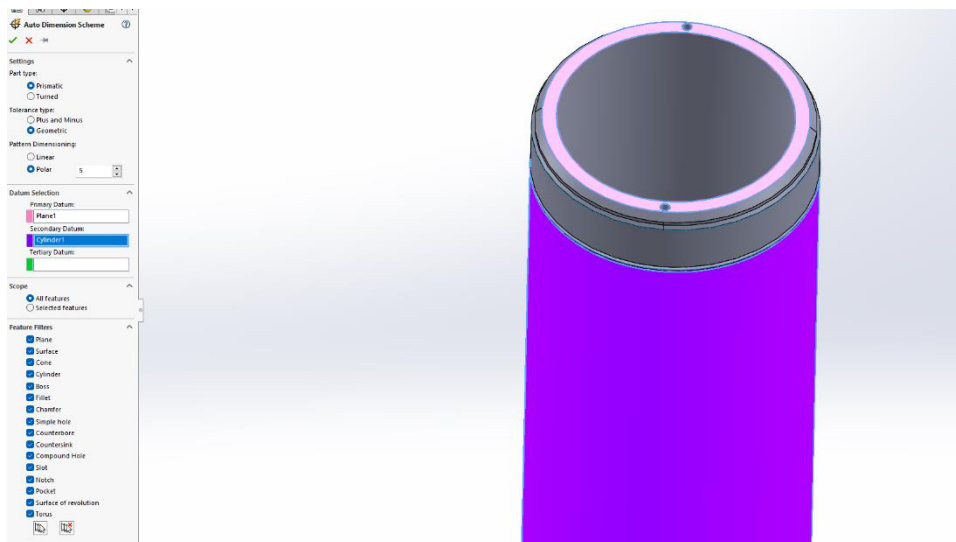
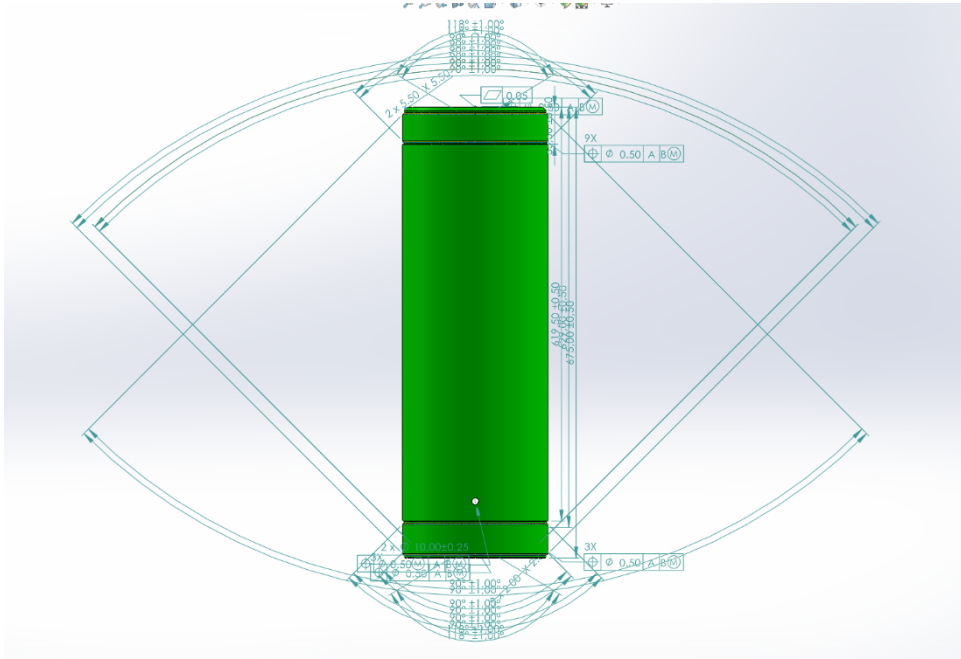*Figure 19: Auto Dimension Scheme of ITM-0273579*

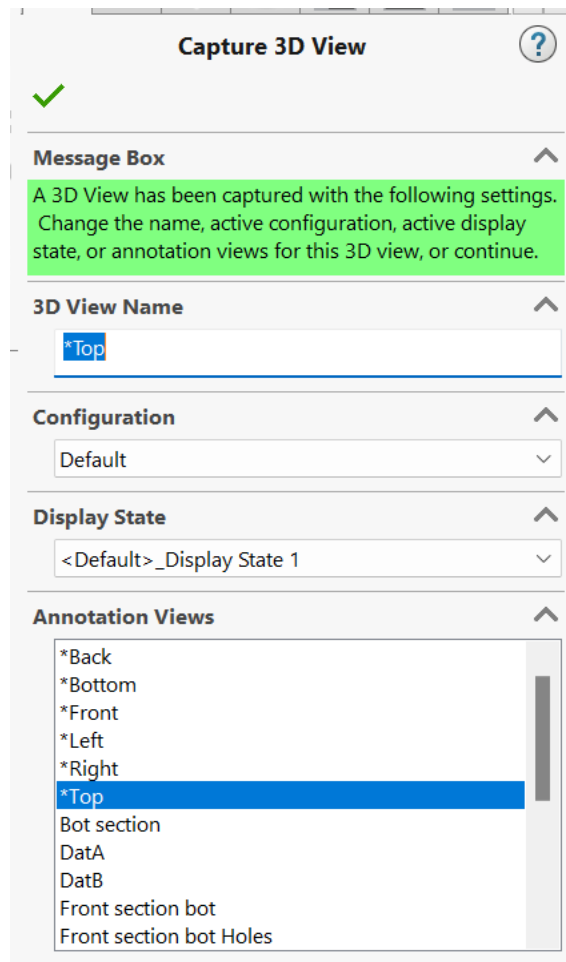*Figure 20: After Auto Dimension Scheme of ITM-0273579*

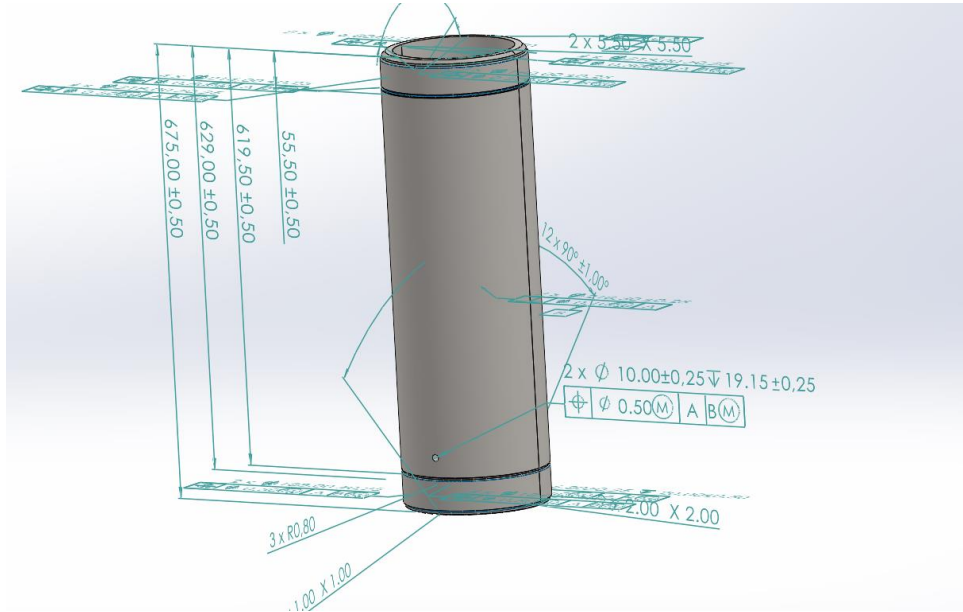*Figure 21: Capturing 3D-views and menu with view selection*
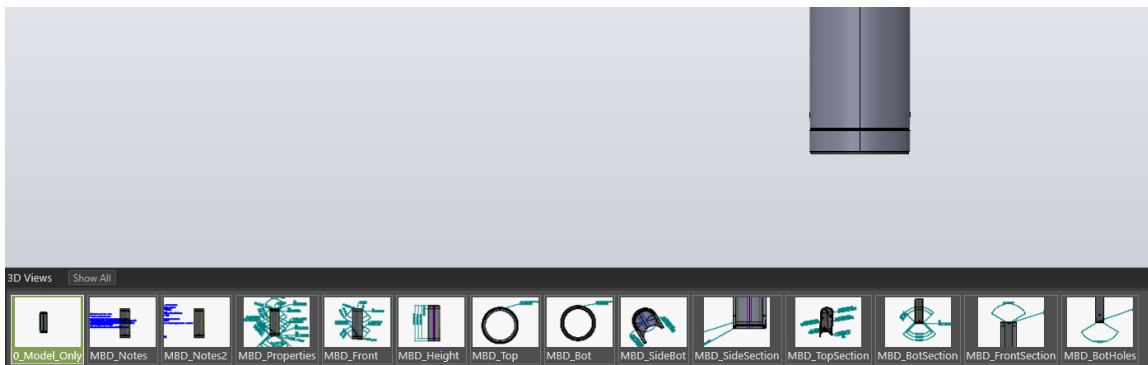
Figure 22: Rotated view with all dimensions

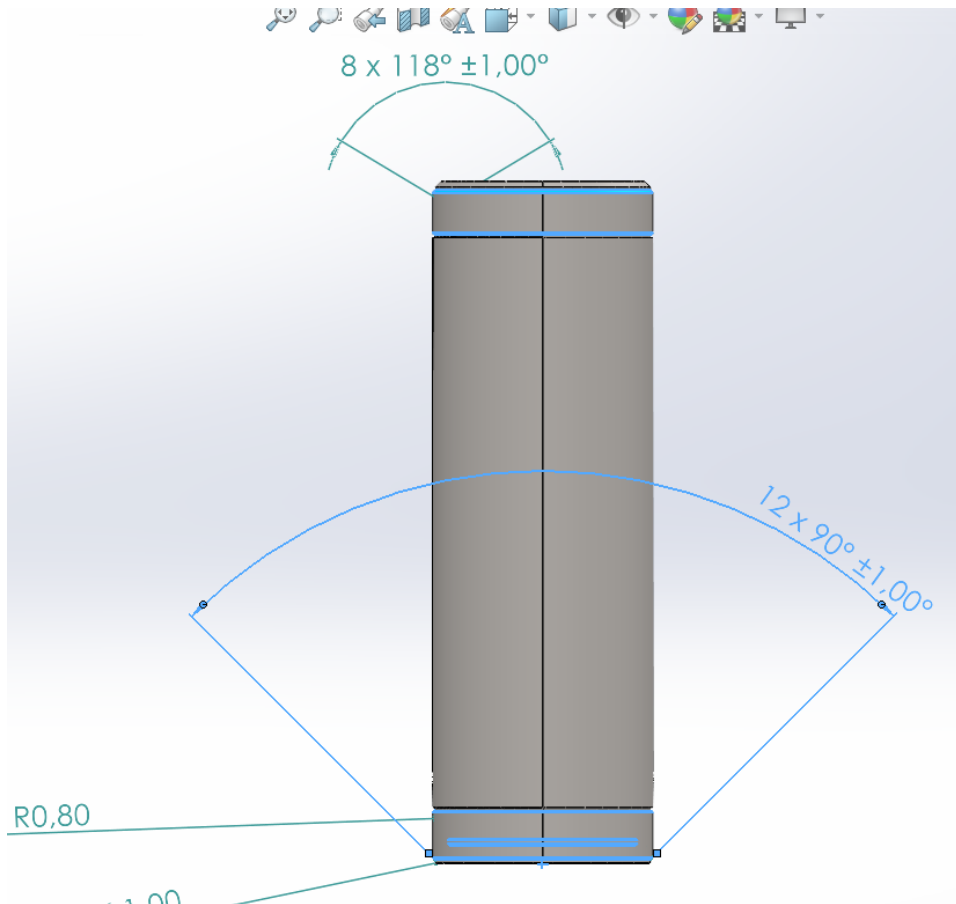*Figure 23: The first draft of the MBD-file sent to manufacturer*

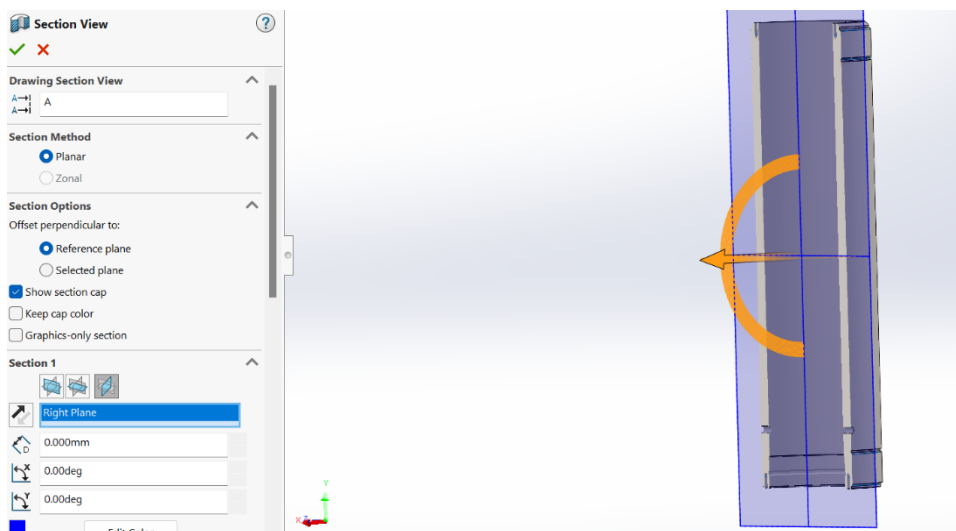*Figure 24: After pattern feature tool and combining all cones with the same value*

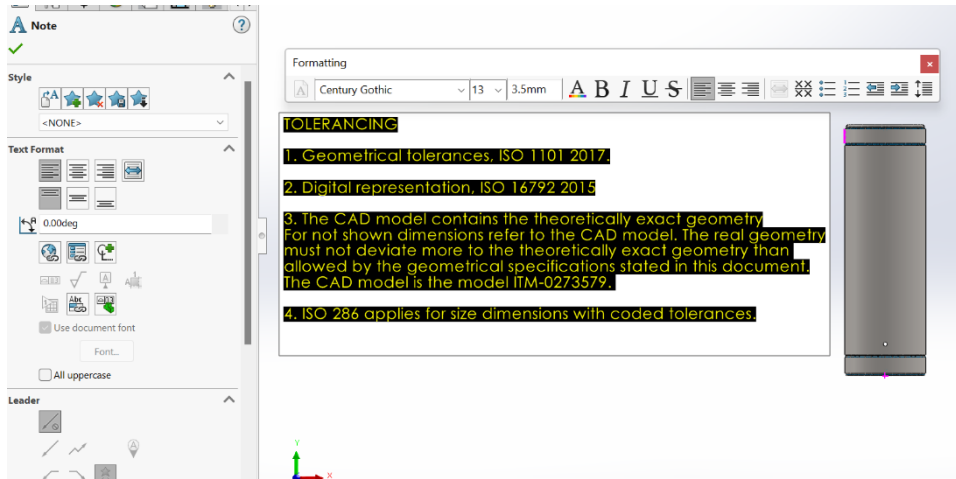

Figure 25: Creating a section view with the right plane
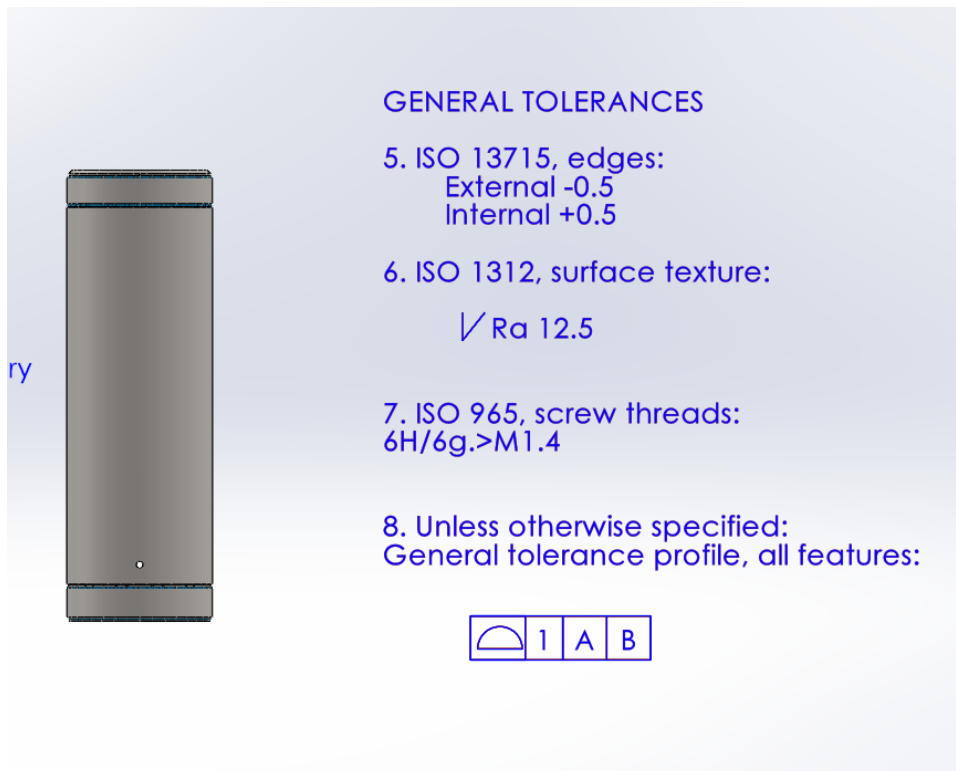
Figure 26: Adding and writing notes for the model

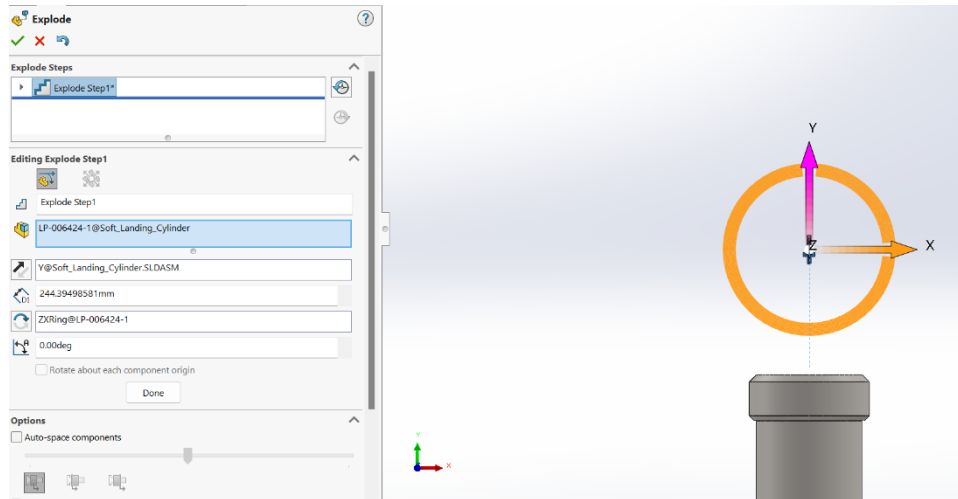*Figure 27: General tolerance for the model*

Figure 28: Creating exploded view for the assembly

Limitations during the creation process

There were some limitations encountered on the way creating the MBD-file. For instance, due to limited time and the deadline for the bachelor thesis, the group couldn't fully put the SLC to production with the MBD-files. The group chose to use the CAD software, SolidWorks, due to the university license being accessible for students. If the group was going to use the software Creo, which the standard MIL-STD31000A, appendix B [28] is mainly designed for, the group had to learn a new software from the start. Due to time limitations, the conclusion was to use SolidWorks where the group has experience. SolidWorks had some limitations with MBD. For instance, SolidWorks lacks a few symbols which were needed for the MBD-files to fully be complete. Also, SolidWorks can't save files as jt-files, which was a challenge when the files were sent to the manufactory.

4. Results

The results obtain experimentations and analyses, showcasing the empirical evidence that validates our hypotheses, sheds light on key insights, and contributes to the advancement of knowledge in the manufacturing field. Thus, paving the way for further exploration and future applications in manufacturing and development.

4.1 MBD effectiveness and efficiency

4.1.1 S.W.O.T MBD

The assembling of the SWOT was completed by the group's experience with creating a MBD model of the SLC, assumptions, visiting Aarbakke AS manufactory, and interweaving the R&D department at Fideltronik.

During the creation process of the MBD-files, the group experienced several capabilities with MBD. With all information regarding the model gathered in the same file, some of the subprocesses need to be improved or become more efficient. While working on the MBD-files, the group had to adjust the model several times. This allowed the group to get a good understanding of creating and adjusting the MBD-file. The group's experience with MBD was evaluated and put into the SWOT.

Visiting Aarbakke manufactory allowed the group to join a meeting with OneSubsea regarding potentially manufacturing with the MBD approach. At the visitation, Aarbakke explained their manufacturing process today and views on MBD. Thereby, the group noted the most vital details from the meeting and contemplated over the notes. The data was used to make assumptions or inputs directly to the SWOT.

Having a meeting Fideltronik, an EMS manufacturer, allowed the group to present the foundation with MBD and gather feedback regarding their thoughts on MBD. Fideltronik has deep knowledge and expertise in how development teams and manufacturers work together.

Through the meeting, the group gathered the most vital information from Fideltronik. After the meeting, the group evaluated the information using this as inputs to the SWOT.
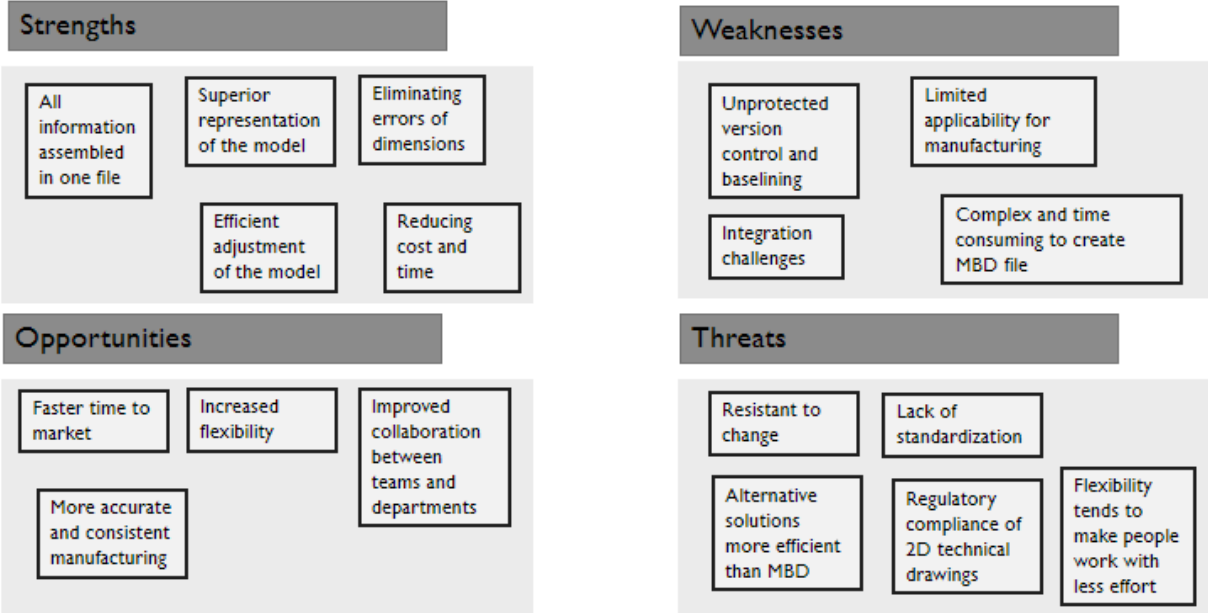

Figure 29: SWOT analysis of MBD

The SWOT (Figure 29) displays the external opportunities and threats and the internal strengths and weaknesses for MBD.

Strengths

Starting with the internal strengths, MBD is a superior representation of the model. The replacement of 2D drawings with 3D models represents the model as it is. Today, machine operators have broad knowledge of manufacturing mechanical parts from 2D drawings with rarely no errors. Moving over to MBD prevents the operator from assuming and guessing the geometry of the model. By using the 3D model as a reference, inconsistencies, and manufacturing errors due to misinterpretations of technical drawings are minimalized, reducing rework and associated costs[21].

Eliminating errors of dimensions on the model reduces time in the manufacturing process. When the machine operator programs the manufacturing process, it is crucial that the finished product qualifies within the correct dimensions and tolerances. Manufacturing an inaccurate product is both costly and time consuming. Therefore, the operator spends a lot of time viewing the controlling the model and manufacturing process. If some of the dimensions are not listed

in the technical drawing, MBD allows the operator to retrieve the dimension from the model. Therefore, the development team does not need to resend another technical drawing with added dimensions, nor the manufacturer to guess the dimension. This can possibly save up to a week of time.

The products produced will always have a need for improvement. Reading and interpreting the 2D-drawings in today's engineering is a time-consuming process. Firstly, you must change the product in the CAD program, and further create a new technical drawing for the new product. Replacing the technical drawings with MBD will make this process more efficient. With the dimensions and tolerances collected in the same file, the adjustment of the file will be less comprehensive. For example, if you change the height of a model, the dimensions in the MBD section will change simultaneously. An exception is if the dimensions are not the exact same value as in the CAD model. If this is the case, the process still would change a lot of time since it is in the same file, so you must only change the value of the dimension.

Weakness

On the other hand, there are some weaknesses with MBD. There is limited applicability to manufacture with MBD. Thus, MBD is not greatly developed yet, and most manufacturers produce from 2D drawings. Also, companies need to transition from 2D technical drawings to MBD, which can involve a steep learning curve for the engineers and other stakeholders. This requires training in new software tools and an understanding of 3D modeling and annotation techniques. The learning curve can impact the companies during the implementation, leading to inefficient production and additional costs in the initial stages.

When working with 2D technical drawings, the development team sends the approved version that should be used for production as a pdf file to the manufacturer. It then becomes very clear what are the baselines the manufacturer shall use when producing the actual product. When working with MBD in a collaborative approach between the development team and manufacturer what is the baselined and approved version gets less clear as both the development team and manufacturer may introduce changes.

Opportunities

Moving to the externals, MBD can deliver more accurate and consistent manufacturing. According to the survey conducted by Roland Berger [13], manufacturers are facing pressure to reduce costs and increase efficiency. Delivering a more accurate and consistent manufacturing, makes the manufacturing distribution process more efficient by shortening the processing time reading and understanding the model. Thus, more consistent manufacturing reduces the risk of errors of the finished product. Initially leading to fewer incidents of time dilation, miscommunication, and extra costs.

Storing all information in one file enables improved collaboration and communication between development teams and manufacturers. This is firstly due to containing all information regarding a model in one file, making it easier for the stakeholders to share and collaborate across different teams and departments. This improves communication and reduces inaccuracies due to misinterpretation. Minimalizing manufacturing errors also leads to trusting the customers and a better reputation for the manufacturer. Where having a good relationship with customers is crucial for future collaboration or partnership.

The time elimination by adapting to MBD can shorten time to market. Time to market can directly impact a company's revenue and competitiveness. This is because the earlier a product is delivered on the market, the sooner it can generate sales and potential customers. Additionally, if some customers prefer changes or customizations for the product, companies obtain a faster opportunity to respond and deliver. Therefore, companies manage to work more agile. This also applies for changes due to environmental or social concerns about the product.

Moving on to flexibility, MBD could enhance flexibility because of time elimination, increased communication and collaboration, reduced risks, and digitalization of the manufacturing process. This is seen as both an opportunity and a threat to MBD. Flexibility enables employees to work more agilely, respond quickly and adapt faster to change. This could also increase the product range, with more variants easier to do customizations.

Threats

On the other hand, flexibility tends to decrease the company's cohesion between employees and work with less effort [26]. This can potentially lead to decreased quality, miscommunication, and inefficiencies [26]. An example of this could be that the machine operators skip the process of understanding the model and move right to program and set up the manufacturing process.

This could lead to errors in the manufacturing process such as missing dimensions. It is still crucial that the operators inspect the model and clarify the geometry.

Another threat is that there is no universal standardization for MBD. There are different standards to use which describe how data should be delivered. This can cause complications and make companies uncertain of which standard to use when they adapt to MBD. Additionally, manufacturers tend to use different MBD standards of each other. The universal standards delivering representations of a model are still 2D technical drawings. Many manufacturers have regulatory compliance to use 2D drawings in manufacturing. This blocks customers from delivering the model with MBD.

Further, some companies are resistant and stubborn when it comes to adapting to change. Because their current method has been successful in the past, they may be concerned about changing it. This is due to risks such as potential disruption in their current operations, investments needed for implementation and the uncertainty of the outcome. They may fear adopting MBD can put them at a disadvantage relative to their competitors. Instead of changing to other technology they keep their current to avoid disrupting their existing operations. New technology may come in the upcoming years, to efficient the manufacturing process and reduce manufacturing costs which require less change in the company's approaches. An upcoming technology more efficient than MBD constitutes the last threat to MBD.

To sum up the SWOT, the group assumes reducing cost and time is the biggest strength with MBD. The biggest weakness is that it still has limited applicability for manufacturing, making it harder for companies to implement. Shortening time to market is seen as the greatest opportunity for MBD. Finally, resistance to change is seen as the biggest threat, as companies want to keep their current methods.

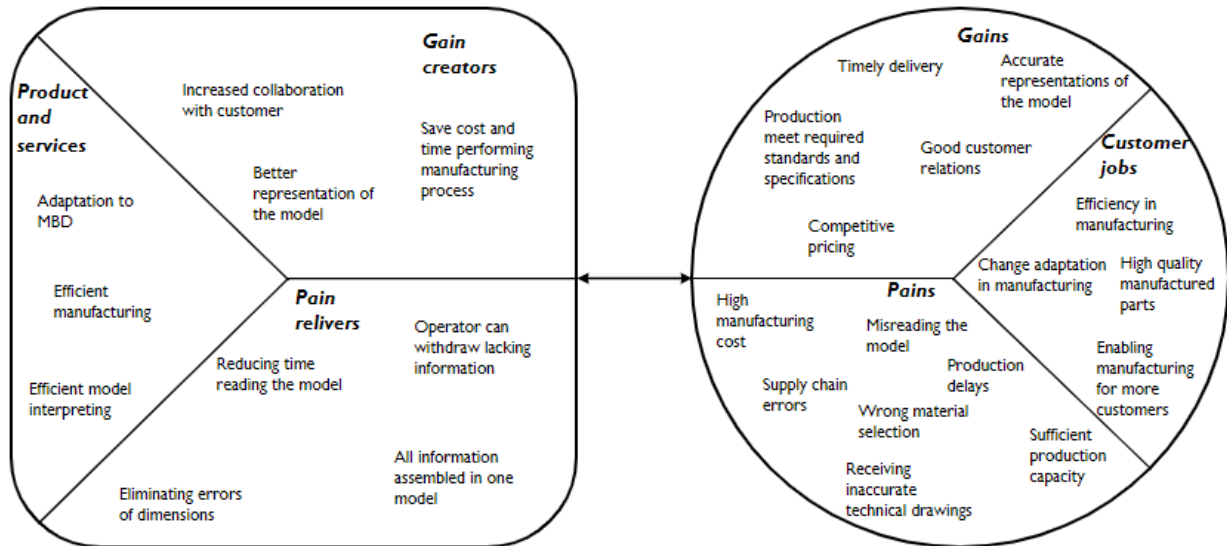## 4.1.2 Value proposition canvas for manufacturers

Figure 30: Value proposition canvas for manufacturers

The value proposition (Figure 30) was made for the users of MBD, highlighting its potential value for them. As MBD dedicates most value to manufacturers, the center of attention was laid on them. The value proposition is made in the form that focuses on potential gains and pains MBD can adjust.

Customer jobs

The customer segment profile reveals observable manufacturers segments. Manufacturer customer jobs are trying to manufacture high quality products, as well as doing this efficiently. This job fulfills the manufacturers' emotional need because producing high quality products allows them to feel satisfied with the work. Efficiency in manufacturing provides the functional need to stay inside the budget of time and cost. Because of the current situation, manufacturers try to respond to change adaptation in manufacturing. This job involves staying updated with sustainable and modern manufacturing methods. Additionally, enabling manufacturing for more customers. Manufacturers rely on having customers where developing different manufacturing methods is important.

Gains

It is required that the manufacturer delivers the product on time. Delivering on schedule or before is beneficial for them, thus gaining trust from their customers. Good customer relations are crucial for collaboration and keeping their customer. Competitive pricing also aligns with keeping customers and attracting new ones. When technical drawings and model documentation are delivered to the manufacturer, it is expected that the files are representative to manufacture the model. This is not always the case, leading to time consumption interpreting the model. Lastly, the manufactured product meets the required standards and specification from their customer. This is important so they do not need to remanufacture the model.

Pains

Pains defines as anything annoying the manufacturer or prevents them from doing a job. Misreading the model and wrong material selection can prevent the finished product from meeting the specific requirements. Production delays and sufficient production capacity prevent delivery on time to the customer. This could lead to dissatisfaction in their work and doubt from their customers. Receiving inaccurate technical drawings or other critical information regarding the model, causing extra work for the operators, adjustments for the customer or in the worst-case misconceptions of the finished product. Consequently, conflicts between the manufacturer and customer could occur discussing who is paying for the mistake. Supply chain errors such as not sharing critical information and unexpected risks, may be costly in terms of costs and collaboration. An instance of this could be not sharing information regarding a manufacturing error. High manufacturing costs influence the price, making it hard to stay in the competitive market.

Gain creators

The value proposition map guides as features of specific value proposition MBD delivers its users. Starting with the gain creators, MBD is a better representation of the model in comparison to the current solution. Generally, 2D technical drawings are used today, where the development team claims the drawings are the representation of the model. Consequently, the manufacturer needs to study and interpret the geometry of the model. MBD allows the model to represent itself and shows the dimensions on the model as it is. The more complex geometry of a model, the more time-consuming the process of interpreting the model will be. With all the information

about the model gathered in the same file, the process of understanding the model, especially with more complex models, will be reduced. Therefore, the cost and time of manufacturing simultaneously will be reduced. Lastly, MBD enables efficient collaboration with the customer.

Pain relivers

MBD delivers various pain relivers to its users. Occasionally development teams deliver inaccurate technical drawings or messy files to the manufacturer. With MBD the operator can easily withdraw lacking information, eliminating errors of dimensioning. Having all the information regarding the model on file also makes it easier for the operator to read and find crucial information. Following the current situation with 2D drawings, manufacturers request the CAD file of the model if information is lacking. The CAD file display data of how the model was built in their CAD software. Although this file is considered safe to transfer according to SFTP, there is a small risk the file could end up in the wrong hands.

Product and services

The product and services and services MBD delivers is efficient manufacturing, efficient model interpreting for the machine operators and a change adoption to MBD.

4.1.3 Statistics of MBD

According to a study, 44% of respondents used primary drawings with supplementary models, while 3D-CAD models only received 26% of responses. Drawings and primary 3D-CAD models with supplementary drawings each received 15% of responses. Overall, 74% of respondents used a drawing in some way, showing their continued importance in data transfer. While 85% of responses used 3D-CAD models, only 41% used them as the sole or primary source of information.

The survey then asked if the respondents could produce a part to specification with only a 3D-CAD model and no drawing, receiving 25 responses. Only 4% of respondents said "no", while 36% said they could do it without any issues. The remaining 60% stated they could produce the part, but would need to manually check the model's dimensions. Of those, 40% would need to consult with the customer to gather manufacturing and inspection details. The respondents were asked about the inspection equipment they use in-house. Notably, no respondents reported outsourcing inspections. The most selected options were visual inspections, non-CMM gauges,

and CMMs using 3D-CAD models only, in descending order. In different research, it was found up to a 97% decrease in time used on CMM workflow [20].

4.2 Trade off analysis

The trade off analysis (Table 2:, Table 3:) compares the approach using 2D technical drawings and MBD in the current situation today. The comparison is applied to get an overview of the differences in efficiency between the two approaches. Therefore, MBD and 2D technical drawings will be ranked from 1-6 of how effective and efficient they are. The ranking of MBD is based on the group's experience with MBD and assumptions. The rank of 2D technical drawings is based on the current situation and supported by Fideltronik. The importance depends on how the company wants to position itself in the market. For example, a company who wants to manufacture product range with high number customizable product variants, flexibility may be the most important, while a company producing parts for the medical industry, quality may be the most important criteria. In the trade off analysis, we have ranked the importance based on OneSubsea.

Table 2:

Trade off analysis ranking importance, MBD, and 2D technical drawings

Criteria	Model Based Definition (1-6)	2D Technical drawings (1-6)	Importance (1-6)
Quality	5	6	6
Efficiency in design	5	4	4
Efficiency in engineering	6	5	5
Efficiency by doing engineering changes	6	4	6
Communication efficiency	6	4	5
Workforce competence	2	6	6
Data integration	6	3	4
Version control	3	6	6
Model clarity and interpretation	6	4	6
Flexible	5	3	4
Score	**50**	**45**	

Trade off analysis results of MBD and 2D technical drawings

Criteria	Model Based Definition	2D technical drawings
Quality	30	36
Efficiency in design	20	16
Efficiency in engineering	30	25
Efficiency by doing engineering changes	36	24
Communication efficiency	30	20
Workforce competence	10	30
Data integration	24	12
Version control	18	36
Model clarity and interpretation	36	24
Flexible	20	12
Result	**234**	**229**

Quality

The importance of quality means how important the quality of the MBD or technical drawing is for the manufacturer to produce the model, every dimension and tolerance describing the geometry and other specifications must be contained. Thus, it is ranked 6.

MBD is ranked 5 and 2D technical drawings are ranked 6. Technical drawings are ranked higher than MBD because they have been used for centuries and are the current solution today. Also, they have been under constant adjustment and improvement. MBD is not a fully developed subject yet, although it is possible to make quality MBD files for manufacturers.

Efficiency in design

Efficiency in design is defined as how fast and productive the approaches are designing information regarding the model. This is ranked 4 because the speed of the design phase is not crucial.

One of the findings making MBD of the SLC was that the process went faster than making 2D technical drawings. Fideltronik also stated that the time of designing 2D technical drawings can take up to days-weeks depending on how complex the model is. With MBD the process only took a few hours when getting to know the approach. Therefore, the ranking was 5 for MBD and 4 for 2D technical drawings.

Efficiency in engineering

This refers to the ability of each process to convert inputs into useful outputs with minimal errors. Because efficiency in engineering can reduce costs, it is ranked 5.

By using the MBD approach, it is assumed the process is simple to gather the correct information regarding the model. Also, it can reduce errors. The approach with 2D technical drawings needs more understanding from the machine operator and can be time consuming. If some information is lacking, the manufacturing process can be misleading, and errors can occur. For that reason, MBD is ranked 6 and 2D technical drawings 5.

Efficiency by doing engineering changes

In the product lifecycle, the product often needs to go through the adjustment step 3-4 by the development department. The adjustment step is usually very time consuming which slows down the product development. The importance is ranked as 6 because of the negative impact of a slow adjustment phase.

Adjusting the model with MBD can be faster than 2D drawings. This is because the process of designing the MBD is quicker. Also, the understanding process to program the manufacturing process will be faster. Consequently, MBD is ranked 6 and 2D technical drawings 4.

Communication efficiency

The communication between customer and operator must be efficient due to, the same reason as the engineering process to be efficient, timelines or other allegations. If there is some misunderstanding or lack of information regarding the model the operator must be able to

communicate with the customer efficiently to solve the issue. Also, standard communication during the manufacturing process to ensure the result will be as desired, and therefore the importance of communication to be efficient has been ranked 5.

MBD allows the machine operators to withdraw information in one file, allowing all the workers to communicate with one file. Communicating details with the 2D technical drawings approach can be more misleading because the file contains multiple documents. For that reason, MBD is ranked 6 and 2D technical drawings 4.

Workforce competence

For the engineering process and design of the drawings or MBD-file to be efficient, the workforce competence must be high. Therefore, the importance of workforce competence is ranked as 6.

As MBD is not as developed in the work field today, there are few companies which have the competence to operate with MBD. On the other hand, using 2D technical drawings is widely spread, where every manufacturer can use this approach. Consequently, MBD is ranked 2 and 2D technical drawings 6.

Data integration

The next criterion is data integration, which means that the information or data is gathered into the same file or view. The importance of the applicable criterion is not as high as some of the criteria due to today's situation and is ranked 4.

Storing data with MBD can be used with one file with no additional documents. To store information with 2D technical drawings, multiple documents are needed. Therefor the ranking of MBD is 6 and 3 for 2D technical drawing.

Version control

Version control is ranked as six because the importance that all parties involved operate with the exact same version of the drawings or MBD file is crucial. With model clarity and interpretation, it means the importance that the operator and customer can understand and interpretate the model. This criterion is also crucial due to misunderstanding and defectively manufactured products and is therefore ranked 6.

The file format used for 2D technical drawings is pdf. They cannot be changed after being converted to a pdf file. Thus, the workers can be sure that the files are not tempered with. There is more uncertainty with the MBD files. If the procedures are followed correctly, there should not be any issues, but the risk is not eliminated. Therefore, the rank om MBD is 3 and 6 for 2D technical drawings.

Model clarity and interpretation

The model clarity and interpretation criteria are defined as how clearly each of the approaches represents the model, additionally how simple it is to interpret the model. It is crucial the machine operator understands the model to avoid manufacturing errors and time waste. Thus, it is ranked 6.

MBD represents the model as it is with all additional information in the model. 2D technical drawings illustrate 2D drawings of the 3D model, expressing all dimensions and tolerances. MBD is a better representation of the model, making it more clear for the operators to interpret. Consequently[21], MBD is ranked 6 and 2D drawings 4.

Flexibility

This criterion deals with how flexible each of the approaches is. Because the industry of OneSubsea does not mass produce products, this is ranked 4.

MBD can be more flexible than using 2D technical drawings. This is because of reduced time and increased collaboration enabling the workers to act more agile, responsive, additionally, adapt faster to change. Therefore, MBD is ranked 5, and 2D technical drawings 3.

Result

The result of the trade off analysis (Table 3:) indicates that the approach of MBD is slightly more efficient than 2D technical drawings. MBD scored 236 and 2D technical drawings scored 229 of possible 312 points.

4.3 Technical data package

Earlier in the chapter about the creation process the result was explained, but in this chapter the result will be presented with a checklist and pictures of the different models. Due to confidential information about the parts not every component will be presented, but the layout for the MBD-files is the same so there is no need to present every part. In the chapter about the creation process the ITM-0273579-component is used as an example, the same goes for this chapter.

The standard, MIL-STD31000, appendix B [28] was used as a baseline for the MBD-files for the SLC and declare how the different 3D-views should appear and contain. With the standard you divide the views into categories from 0 to 5 where they all contain different information for the model, and all the 3D-views' name starts with the number of the category. Below are figures of all the 3D-views for the ITM-0273579-component. Firstly, there is a 3D-view named "0_Model_Only" () (Figure 31) which represents just the model without any dimensions. The second view is a map for all the 3D-views in the file, with a description of what the different 3D-views contain and is named "1_Site_Map" (Figure 32). Further is category number 2 which contains the titles for the file, such as file descriptions or model number and name, etc.

 This 3D-view is named "2_Titles" (Figure 33). According to the standard there must also be a 3D-view with the properties for the model where for instance the material is declared, and this view is named "3_Properties" (Figure 34). For the MBD-file to be fully functional there must be a view where all the standards used are declared, and all general tolerances for the model are clarified, which in the groups MBD-files are named "4_Notes" (Figure 35). Lastly, there is category number five, which contains all the dimensions of the model. Category five is the only category with a different layout for some of the components, and the reason is the difference in complexity for the components. Here there are several views to represent the model in an orderly way. The first view in category five is "5_Set_Datums" (Figure 36) which is a view declaring the datums of the model. Further is a view containing all dimensions for the model, which you can rotate to examine all dimensions in the same view (Figure 37). The next views are 3D-views set from different aspects of the model, which in this case are "5_Front" (Figure 38), "5_Top" (Figure 39), "5_Right" (Figure 40) and "5_Section" (Figure 41). The section view of the model is a view representing all diameters for the cylinder in an orderly way. The front-, top-

and right-view are views from the three different aspects with the dimensions visible from that angle.

3D-views – Components
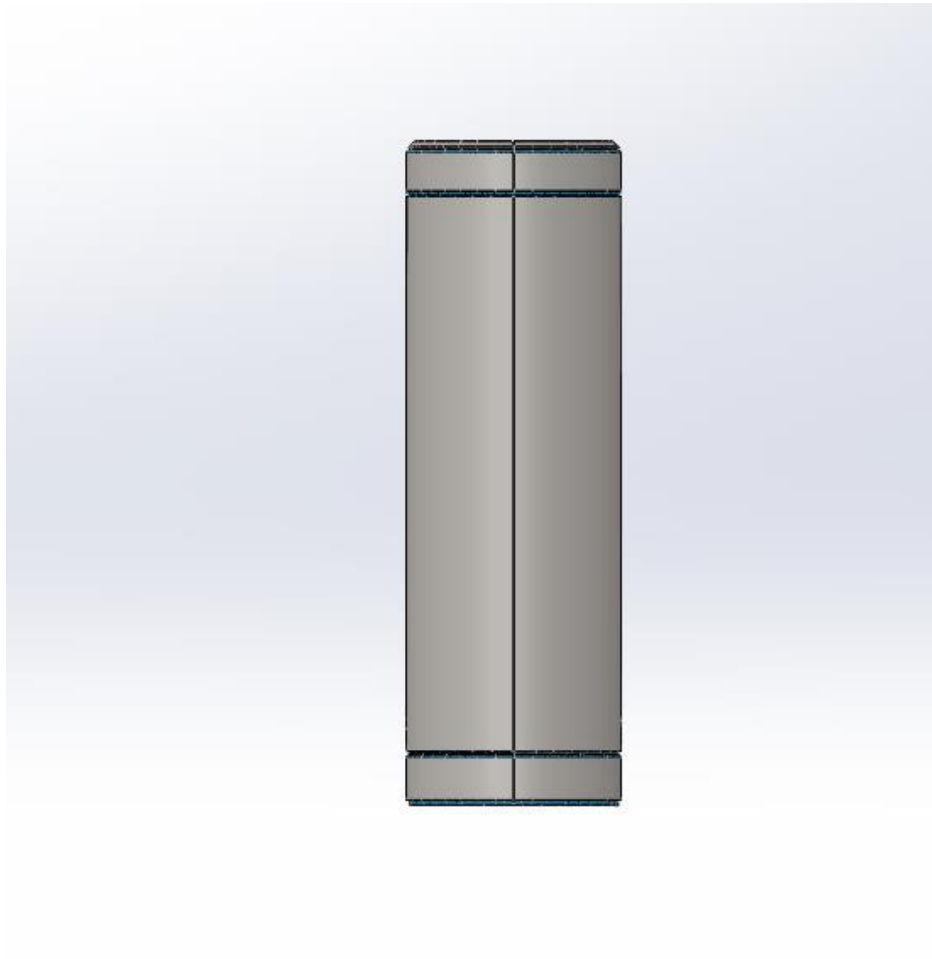
Figure 31: View "0_Model_Only" containing just the model

3D MAP

0_Model_Only - shows just the model with all dimensions hidden

2_Titles - shows title block information

3_Properties - shows information regarding properties

4_Notes - shows tolerances and general tolerances for the model

5_Set_Datums - setting datums

5_All_Dimensions - shows all the dimensions of the model

5_Front - shows the front view of the model

5_Top - shows the dimensions of the holes on the top and bottom

5_Right - shows the right view of the model

5_Section_Top - shows the radius dimensions on the sylinder
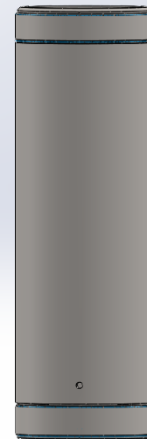
Figure 32: View "1_Site_Map" with a description of all views included

Titles

Title:
ITM-0273579

Part Number:
ITM-0273579

Originally Created By:
OneSubsea

File description:
Bachelor Assignment NTNU

Last saved:
09.05.2023 23:37:29

Figure 33: View "2_Titles" with file description, part number, etc.

58

Properties

Material:
Plain Carbon Steel

Dimension Units:
mm

Mass:
63.000000 kg

Model Description:
SL-180 CYLINDER HOUSING

Standard:
EN 10219 S355J2H+N
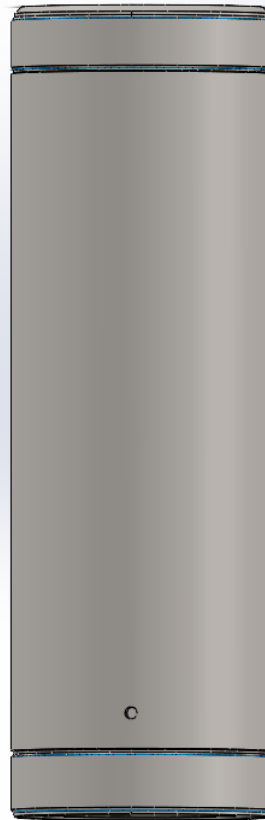
Figure 34: View "3_Properties" with all the properties of the model

TOLERANCING

1. Geometrical tolerances, ISO 1101 2017.

2. Digital representation, ISO 16792 2015

3. The CAD model contains the theoretically exact geometry
For not shown dimensions refer to the CAD model. The real geometry
must not deviate more to the theoretically exact geometry than
allowed by the geometrical specifications stated in this document.
The CAD model is the model ITM-0273579.

4. ISO 286 applies for size dimensions with coded tolerances.

GENERAL TOLERANCES

5. ISO 13715, edges:
   External -0.5
   Internal +0.5

6. ISO 1312, surface texture:

   $\sqrt{}$ Ra 12.5

7. ISO 965, screw threads:
6H/6g.>M1.4

8. Unless otherwise specified:
General tolerance profile, all features:

Figure 35: View "4_Notes" with all information regarding tolerances for the model

59
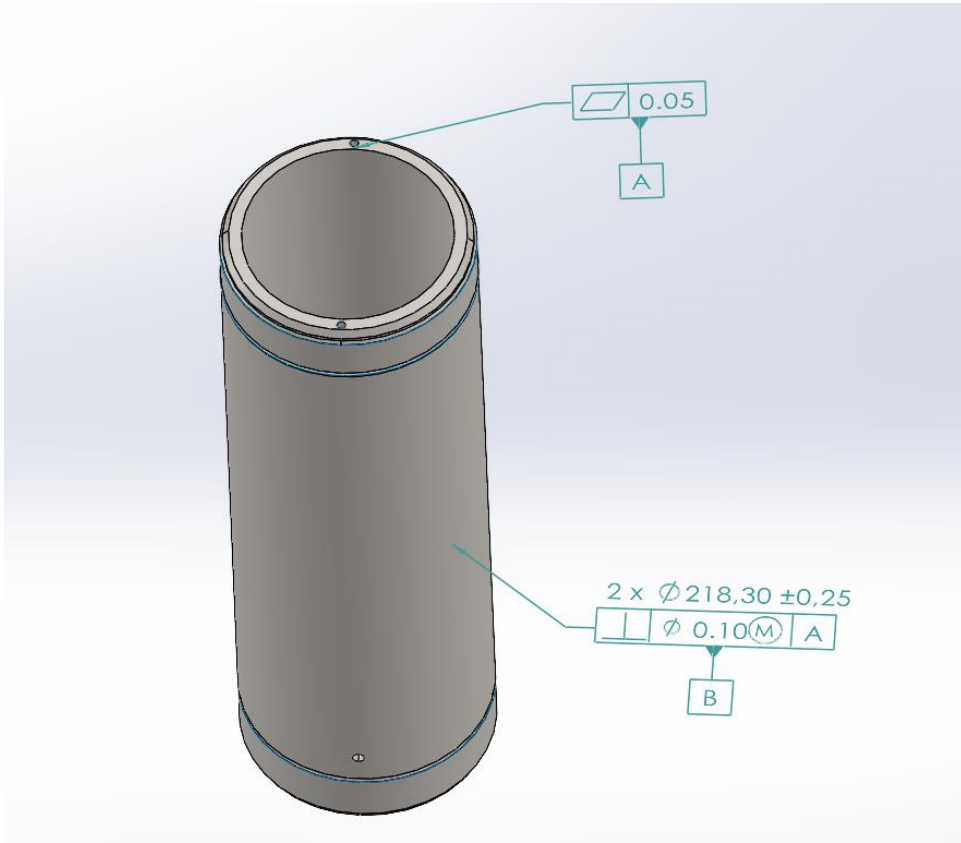
Figure 36: View "5_Set_Datums" with a view just showing the datums of the model
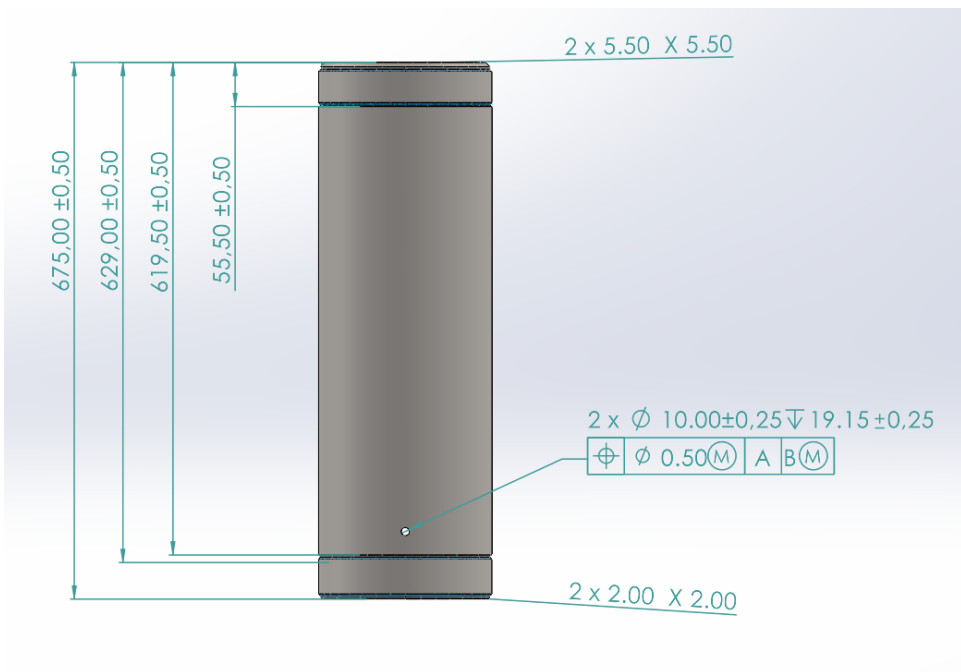
Figure 37: View "5_All_Dimensions" with a view including all dimensions of the model
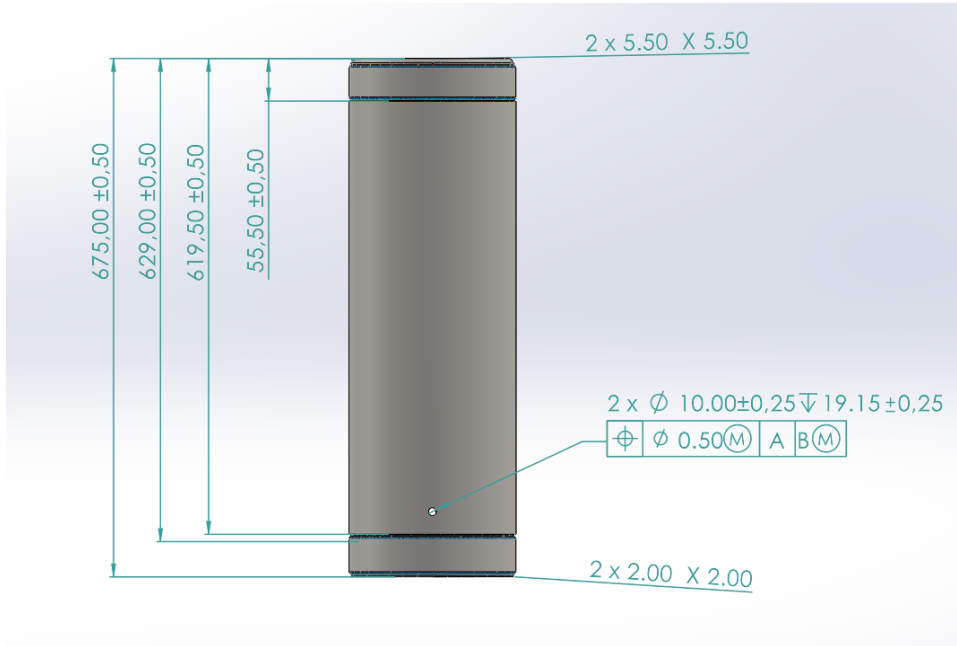
Figure 38: View "5_Front" a view showing the dimensions from the front of the model
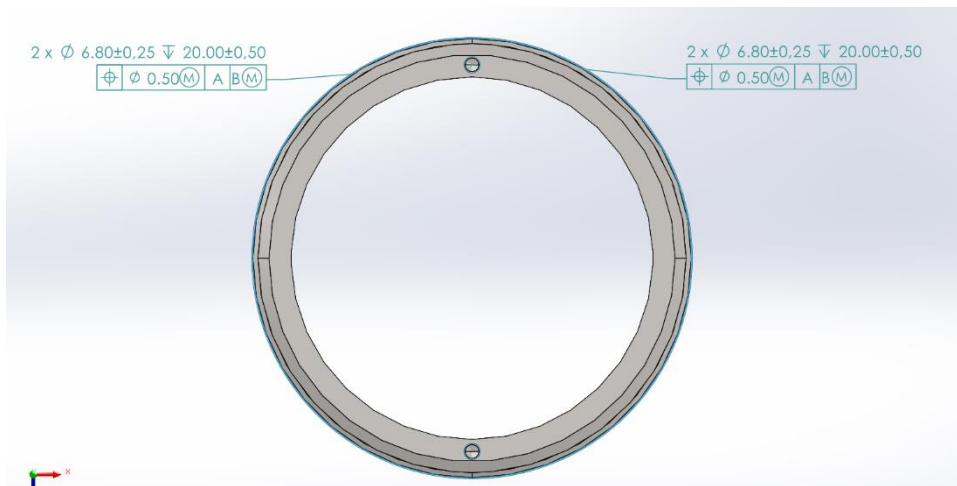
Figure 39: View "5_Top" a view showing the dimensions from the top of the model

8 x 118° ±1,00°

12 x 90° ±1,00°

3 x R0,80

2 x 1.00 X 1.00
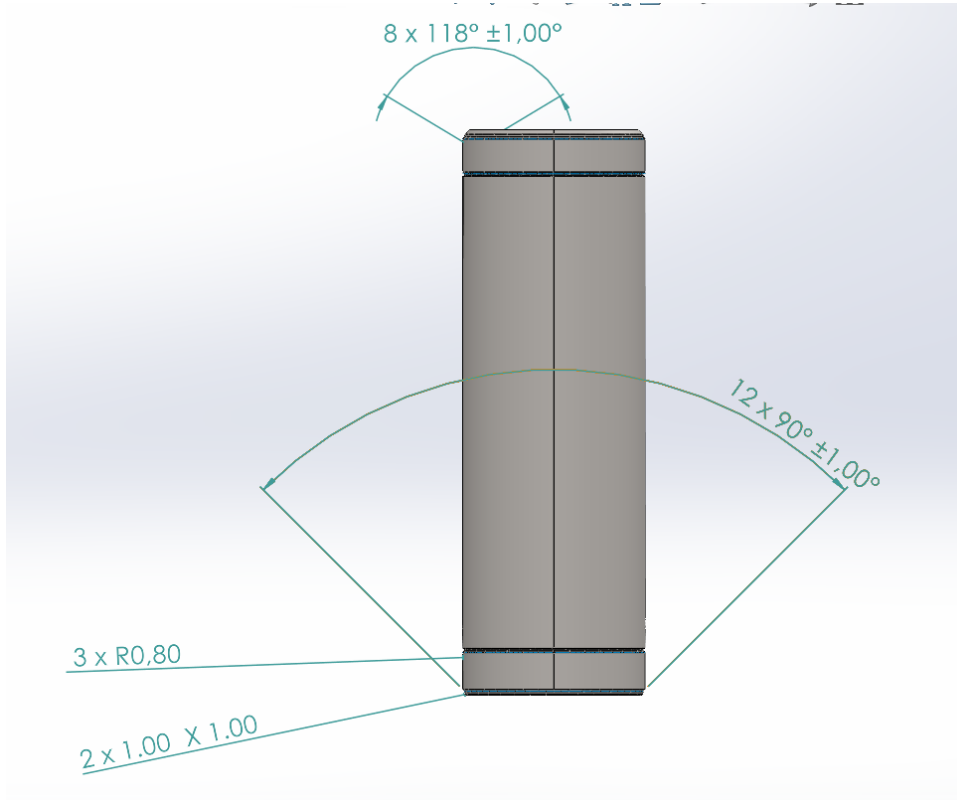
Figure 40: View "5_Right" a view showing the dimensions from the right of the model

4 x ⌀213,00 ±0,25

2 x ⌀180,00 ±0,25

4 x ⌀214,00 ±0,25

4 x ⌀218,00 ±0,25

4 x ⌀184,00 ±0,25

2 x ⌀188,00 ±0,25
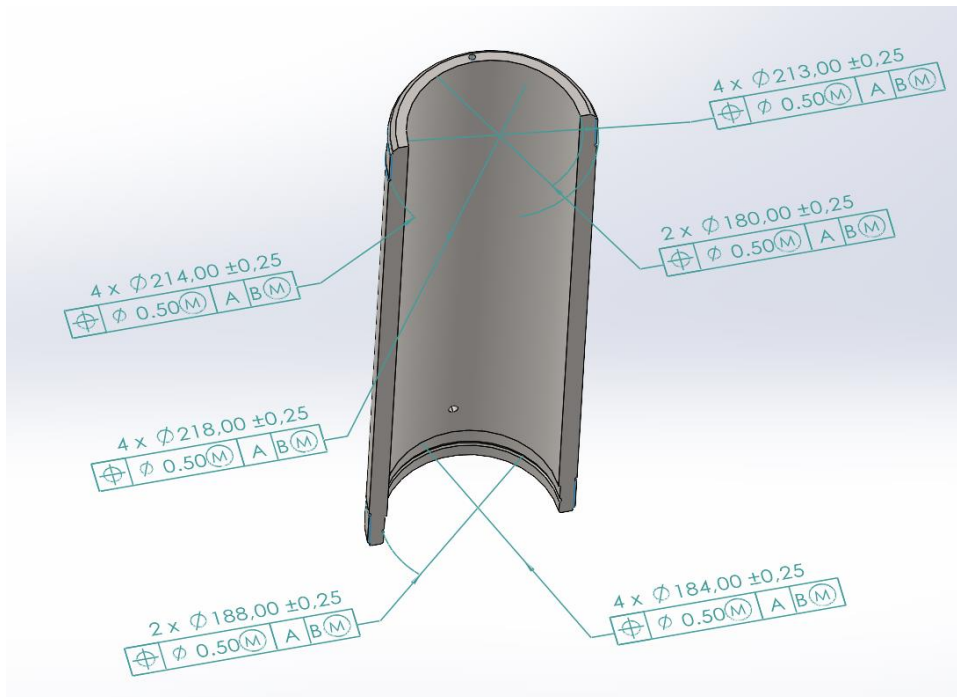
Figure 41: View "5_Section" showing a section view with all diameters of the cylinder

Assembly

The need for content in a MBD-file for an assembly is different from the components. In the assembly there is no need for all dimensions, but a BOM and an exploded view of the model. Below are figures showing both the exploded view and BOM used for the assembly. The exploded view shows a fully deconstructed SLC with a balloon connected to each component with an individual number. As the (Figure 42) shows, there is one component without a balloon, which is because it is an exact copy of component number 6. When there are several copies of the same component there is no need for several balloons with the same number.

On (Table 4:) there is a picture of the BOM. The BOM includes a list of all components, ordered by number from 1 to 13, the name for each component and the quantity of each component. Here you can see that there is only one component with the quantity of two, which is component number 6. The content in the BOM was sent by OneSubsea, such as the standards used, description and material. The last column, mass, was added with information for each component from the SolidWorks file.
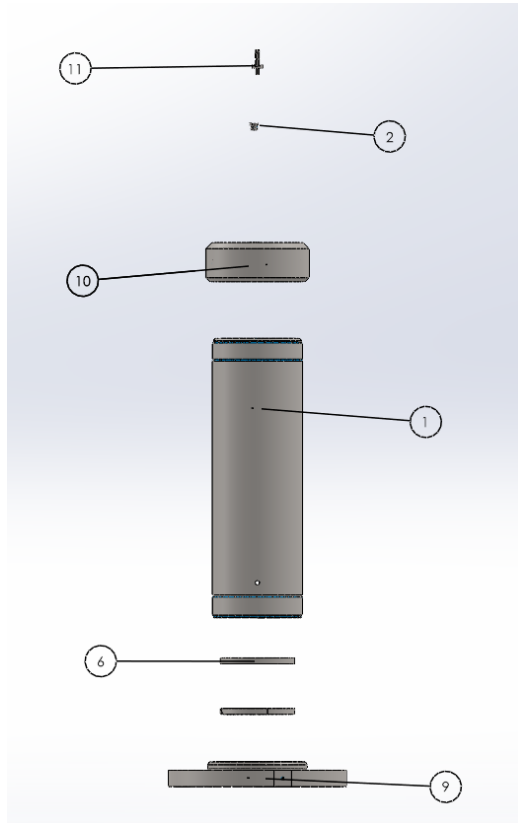
Figure 42: Upper half of the exploded view
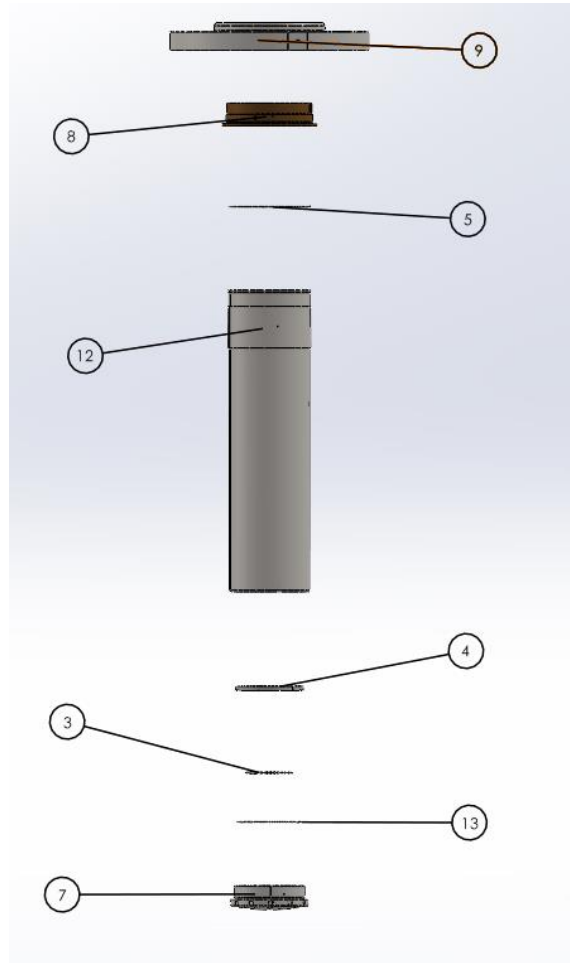
Figure 43: Under half of the exploded view

Table 4:

BOM for the assembly of the SLC

ITEM NO.	PART NUMBER	QTY.	Description	Material	Standard	MASS
1	ITM-0273579	1	SL-180 CYLINDER HOUSING	Plain Carbon Steel	EN 10219 S355J2H+N	63.000000
2	ITM-0128176	1	PLUG WITH GASKET - DRILLED TO NOZZLE	Plain Carbon Steel		1.000000
3	ITM-0276809	1	O-RING ORAR00240	Plain Carbon Steel		1.000000
4	ITM-0273956	1	SL-180 SEAL PLATE	AISI 316 Annealed Stainless Steel Bar (SS)	ASTM A240 316	1.000000
5	ITM-0273699	1	SL-180 O-RING	Plain Carbon Steel		1.000000
6	ITM-0273681	2	SLYDRING Ø 180/175/15	Plain Carbon Steel	NA	1.000000
7	ITM-0273588	1	SL-180 PISTON	Plain Carbon Steel	EN 10225 S355G10+N/G10+M	8.000000
8	ITM-0273586	1	SL-180 BUSHING-GLAND	Aluminum Bronze	ASTM B148 UNS C95800	2.000000
9	ITM-0273585	1	SL-180 BOTTOM FLANGE	Plain Carbon Steel	EN 10225 S355G10 + N/G 10+M	33.000000
10	ITM-0273583	1	SL-180 END CAP	Plain Carbon Steel	EN 10225 S355G10+N/G10+M	20.000000
11	LP-006424	1	SCREW HEX HEAD	Plain Carbon Steel	ISO 3506-1/-2 A4-80	2.000000
12	ITM-0273581	1	SL-180 ROD 500	Plain Carbon Steel	EN 10219 S355J2H+N	54.000000
13	ITM-0276810	1	O-RING ORAR00252	Plain Carbon Steel		1.000000

4.4 Manufacturers feedback and evaluation

A key objective for Aarbakke is to have the dimensions of the model set in the middle of the tolerance range to avoid potential issues. They prefer to adapt and make necessary adjustments throughout the production process. Additionally, it is important for Aarbakke to be able to rotate the model, remove objects and turn it over, revolve the contour, and place it within specified tolerances.

When it comes to file formats, Aarbakke requests the original file, ideally in addition to the step file, as the step file breaks the history and limits the ability to make modifications. However, customers often hesitate to provide the original file due to concerns about sharing proprietary construction information. Regarding file formats, Aarbakke mentions that the Jt file is equivalent to Siemens uT Files. They also note that they do not require "Jx" files, as errors can occur in the 3D model or drawing if adjustments are made to only one of them. Therefore, it is necessary to manually check the 3D model with the accompanying drawing to identify any errors.

A significant issue arises when the customer claims that the machine drawing is valid, rather than the model itself. This becomes problematic if the machine drawing is poorly executed. To mitigate such challenges, Aarbakke programs measurements into the MasterCAD system. With the MBD solution, little to no programming in MasterCAD is needed. Using MBD you can put the model right into MasterCAD if the model is good enough. When utilizing MBD, Aarbakke can omit the documentation part, as all the necessary information is embedded within the model. The documentation requirements vary from customer to customer and are usually individually determined.

Having a meeting with Fideltroniks technical manager for R&D and project manager, it was observed that they primarily work with CNC machines and prefer using 2D drawings to check tolerances and dimensions. However, they find 3D models to be sufficient in most cases, rendering 2D drawings unnecessary. They emphasized the importance of accurate 3D models throughout the production stages but acknowledged challenges with file compatibility between different software,

Fideltroniks suggested establishing a standardized norm for tolerances and pointed out the need to have density information in material properties for confirmation. They operate in a fully

digital environment, handle everything within their system, and have strict quality standards where they reject 200-500 defective parts per million.

The estimated time for designing parts varies from 1-2 hours for simple parts to 2 weeks for complex parts. Mould production takes around 4 weeks, with 8-10 weeks dedicated to the mould itself and 2-3 weeks for the 3D model creation. Adjustments are made depending on the specific circumstances, and Fideltroniks emphasized the benefits of integrating everything into a single 3D model for seamless interaction.

5. Analysis and discussion

Analysis and discussion contain analyses and engage in discussion of the obtained results, delving into their significance, implications, and limitations.

5.1 Analysis of findings

5.1.1 Value Proposition

Value creation for development teams

Adopting the MBD can offer valuable fundamentals for its users. For the development team, MBD can speed up the design phase, creating files representing the model and adjustment phase. Speeding up this phase and the manufacturing process could ensure companies get their products faster to the market [21]. This allows a company to gain a competitive edge by capitalizing on early in the market entry. By being the first to offer a product in the market, the company can establish itself as industry leader, attracting early adopters, and capture a larger market share. Enabling faster time to market also allows businesses to generate revenue and profits sooner, maximizing their return on investments. Additionally, it provides an opportunity to gather real-world feedback and insight from customers, which can be invaluable for refining the product and addressing any potential issues.

While integrating MBD instead of 2D technical drawings, it increases efficiency in the engineering process. With MBD all information regarding the model is gathered in the same file, which leads to several upsides. For instance, with all information assembled into the same 3D model, the adjustment process of the model gets more efficient. Instead of adjusting the model and further producing a new technical drawing with the updated model. MBD adjusts updates from the model automatically. Also, while integrating MBD in today's engineering process, it eliminates the error of dimensions. From the group's own experience, the dimensions from the use of MBD get updated with the model and automatically have the exact same value as in the CAD model.

Value creation for manufacturers

The user who gets the most value is the manufacturers. Trading off the 2D technical drawings with MBD ensures a superior representation of the model, making it easier for the machine operator to interpret. The more complex model, the more efficient is MBD. This is because a complex model needs countless section views, forcing the operator to read complicated data. Storing all details and information regarding the model in one file allows for better collaboration and communication among the stakeholders. Aarbakke stated that sometimes they receive models, the documentation is messy. Therefore, keeping track of every document can be tricky.

MBD allows the operator to easier withdraw lacking information from the model, since it's all in the same file as the CAD model. By either the use of a measure tool, or to look through the design process of the model, the operator can collect the lacking information. This is seen as an essential strength, eliminating the need for more model documentation from the development team and reducing manufacturing errors due to a lack of dimensions.

The most crucial value MBD delivers to manufacturers is reduction in time, costs, and errors in the manufacturing process. These three factors are impressed by the same functionality of MBD, superior representation of the model. This could remove the pressure for reducing time, costs, and manufacturing errors.

5.1.2 Challenges with MBD

The transition from the current way of working to using MBD process presents a significant challenge. A successful transition to MBD will require new training and software to ensure accurate technical data is delivered to the customer. Furthermore, the transition to MBD will require the development of new processes and procedures to ensure that the MBD data is maintained and updated as needed. The group has found the following issues must be addressed to ensure a successful transition:

Limited applicability for manufacturing

Limited technical know-how and applicability of MBD makes it hard for companies to implement the digital approach. This can cause complications if the development team or manufacturer wants to change their manufacturing process. If only the manufacturer desires to

change to MBD, development teams may change manufacturing partner to stay with their current solution.

Lack of standardization

There is no universal standard for MBD. This makes it hard for companies to adopt because of uncertainty of which standard fits the best. Having no certain method of delivering MBD files can cause challenges due to loss of data integrity, communication, and collaboration among the stakeholders. Today, 2D technical drawings have standards on how they should be delivered. Therefor it is simpler for companies to stay with the current solution.

Unprotected version control and baselining

When a model is set up for manufacturing, it is crucial the development team and the manufacturers are assured they are producing the correct model. When companies deliver 2D technical drawings they always deliver them in pdf files which are unchangeable. When delivering MBD of a model the file is still changeable when the manufacturer receives it. If a manufacturing error occurs, there can be complications agreeing who is responsible. For instance, the development team may be addressing everything was fine with the MBD, but when the manufacturer received it, one operator changed it and passed it onto the one programming the manufacturing process. One the other hand, when the operator changes the MBD file, they might solve an error in the model, and therefor prevented a manufacturing error.

Integration challenges

Integrating MBD for a company can be complex. To integrate MBD in a company, the employees need training and courses. Manufacturers would mostly need training in how to gather data from a 3D model and how they can communicate details. The development teams would need training in how to design accurate MBD files on a model. This could have considerable costs and be time consuming. From the group's experience, learning how to design MBD on models took approximately 90 hours with former no experience of MBD. After studying standard MIL-STD31000A, appendix B training with premade models, the group were able to design MBD on models consistently.

5.1.3 Analysis of objectives

The objective represented what the group saw as the desired outcome of the project.

Define parameters such as dimensions, tolerances and symbols that must be included in the MBD file to manufacture the SLC.

For the manufactory to produce the SLC from the MBD-files created, all dimensions, tolerances and symbols must be included in the file. From the use of "Auto Dimension Scheme" tool, and manual dimensioning for adjustments, all information needed are included in the files. The only downside is the lack of some symbols in SolidWorks which prevented some key symbols, like the edge tolerance symbols, from being added to the file.

Create a detailed data package including MBD of the SLC which is useable for manufacturing.

The MBD-files were created according to the MIL-STD31000A, appendix B standard. With the use of this standard there was one limitation, which was the standard being originally made for the use of the software Creo. Despite the limitation, a detailed MBD-file was made for all components in the SLC, with all necessary information regarding the components included. Also, there is a detailed description of the creation process for one of the components and the assembly.

Evaluate the manufacturing process using MBD.

During the visit to Aarbakke, the machine operators explained to us how they would approach the MBD file and execute the manufacturing process. The process was similar to how they manufactured with 2D technical drawings. Gathering feedback and explanations from Aarbakke enabled the group to evaluate the manufacturing process using SWOT analysis and a value proposition canvas. The SWOT evaluated strengths, weaknesses, opportunities, and threats of MBD which dealt with both the manufacturing and engineering process. The value proposition canvas evaluated the value proposition MBD creates for its users, focusing on the manufacturers. This evaluated which pains and gains in the manufacturing process MBD ether would create gains and relieve pains.

Evaluate the new engineering process using MBD versus current engineering process using 2D technical drawings.

To evaluate the new engineering process versus the current process, the trade off analysis was applied. The analysis ranked how effective MBD or 2D technical drawings were in terms of

several factors. The findings were that MBD was more effective in design, engineering, doing engineering changes, communication, data integration, model clarity and flexibility.

Note! As the original objective, we wanted to test the manufacturing process by doing a full implementation in a factory. However, the factory was not able to receive MBD models. Therefore, we did a factory visit where we presented MBD and got their feedback on how this would impact on their process.

To get a full overview and be a part of the manufacturing process, the group wanted to do a full implementation at a manufacturer. This would allow the group to document and witness the manufacturing process in a more detailed way. However, the group managed to present MBD of the rod of the SLC and get manufacturers feedback on how this could impact their process.

Create a data package that is representative for OneSubsea, which they can further create MBD files for their products by using our data package as a reference. This defines the research centers of the thesis.

The group concurs that the data package is detailed and understandable to further create MBD-files for different models. This was not tested but the representation, according to the MIL-STD31000A, appendix B standard, is clear in the models. Therefore, engineers at OneSubsea with common CAD knowledge should manage to use the data package as a reference.

5.2 Change adoption

The adoption of Model-Based Definition (MBD) requires significant changes in company behavior and new tools and processes. Because 2D technical drawings have been in use for thousands of years to represent 3D objects, this is a substantial change. This method was updated from its version thousands of years ago onto how it is used today. Since this works excellent today, companies may forget to look for other solutions to efficient their model representation. This change requires a shift in mindset towards 3D models as the primary source of product definition. Companies must move away from relying on 2D drawings and embrace the use of 3D models to communicate product information. This can be challenging for employees who are accustomed to working with 2D drawings and may be resistant to change.

To overcome this challenge, companies need to provide training to employees on how to work with 3D models and understand the benefits of MBD. They can also establish a "Model-Based Enterprise" (MBE) culture, where MBD is integrated into all aspects of the organization, from design to manufacturing and quality control. This would require a shift in collaboration between departments. MBD allows for better communication between design, manufacturing, and quality control departments since they all have access to the same 3D model. However, this requires departments to work together more closely and communicate effectively. Companies need to establish "MBD champions" in each department who can promote the use of MBD and encourage collaboration.

Finally, MBD requires the use of new tools and processes. Companies need to use 3D modelling software that supports MBD and integrate it with their existing software systems. They also need to establish standard processes for creating and managing 3D models, such as defining the necessary product information and tolerances. By embracing these changes, companies can benefit from improved product quality, increased efficiency, and reduced costs.

5.3 Implementation for future engineers

In the future, the implementation of Model-Based Definition (MBD) is likely to become increasingly common as organizations seek to improve efficiency and reduce errors in product design and development. Implementing MBD requires a significant shift in the way engineers think about product design and development. As technology continues to advance, the implementation of MBD is also likely to become more accessible and affordable. Currently, implementing MBD can be expensive and require significant resources. However, advances in cloud-based software and hardware can make MBD more accessible to smaller companies and even individual designers.

Instead of relying on drawings to convey design intent, MBD requires engineers to capture all the product's information within the 3D CAD model. This includes geometric dimensioning and tolerancing (GD&T), material specifications, surface finishes, and other important information.

To implement all this information successfully, engineers must follow a well-defined process that includes the creation of an MBD schema. A MBD schema is a set of rules and guidelines that define how the 3D CAD model should be created and annotated to ensure consistency and accuracy created by OneSubsea together with a Swedish company. The US standard "MIL-STD-31000A" appendix B contains a suggested schema. It is claimed the suggested schema is compliant with the corresponding ASME standard ASMY Y14:41. The GPS MBD schema includes guidelines for creating 3D CAD models, specifying GD&T, and managing the data associated with MBD. It also includes a set of best practices for creating and using MBD data throughout the product lifecycle.

The document outlines the key elements of an MBD schema, including:

- Titles: The management data displayed here shall be in the data set according to 16792:2015. This means they do not necessarily need to be in the model if the management "data set" is relayed by other means through the data set
- Properties: Data such as material, surface condition/heat treatment, dimension units, weight, and surface area in mm^2
- Notes: Notes includes general information about the part

The document also includes a detailed example of how these elements can be combined to create a comprehensive MBD schema for production systems. This example demonstrates how the MBD schema can be used to provide a complete and accurate digital representation of the product, including all necessary manufacturing, inspection, and quality control information.

In conclusion, the implementation of MBD is expected to continue growing. With advances in technology, MBD is likely to become even more accurate and efficient, leading to increased productivity and efficiency in various industries. Additionally, as MBD standard becomes more accessible, it has the potential to transform the design and manufacturing processes, leading to faster product development and improved communication throughout the product lifecycle.

5.4 Fabricator analysis

Aarbakke's equipment and machinery were assessed to ensure they can handle the required operations for manufacturing the Soft-Landing Cylinder. Their machining capabilities, such as CNC machines, lathes, and milling equipment, will be evaluated. Additionally, their expertise in working with the specific materials specified in the MBD data package. Aarbakke is recognized for its expertise in various manufacturing processes, including turning, milling, and welding. These processes are crucial in producing high-quality components and ensuring the integrity of the final product.

Compatibility with MBD Data:

Clear communication channels will be established between OneSubsea's design team and Aarbakke to ensure a shared understanding of the MBD data. This includes geometric dimensioning and tolerancing (GD&T), annotations, and other relevant information. It will be crucial to confirm that Aarbakke's software systems, such as CAM software, can effectively import and interpret the MBD data package provided by OneSubsea.

Tolerance Analysis:

Aarbakke implements comprehensive quality control measures throughout the manufacturing process to identify and address any deviations or defects. These methods typically include:

1. Inspection and Testing: Aarbakke performs meticulous inspections and testing at various stages of production. This includes dimensional inspections using advanced measuring equipment such as coordinate measuring machines (CMMs) or optical measuring systems. They verify that the components meet the specified tolerances, surface finish requirements, and other critical parameters.
2. Statistical Process Control (SPC): Aarbakke utilizes SPC techniques to monitor and control key manufacturing processes. They collect and analyse data from process parameters to identify trends, detect any potential variations, and take corrective actions promptly. This approach helps ensure consistent quality and reduces the risk of non-conformances.
3. Non-Destructive Testing (NDT): Aarbakke employs non-destructive testing methods such as ultrasonic testing, liquid penetrant testing, or visual inspections to identify any

internal or surface defects that may impact the component's integrity. NDT techniques allow for the detection of flaws without damaging the workpiece.

Collaboration and Feedback:

Aarbakke and OneSubsea's design team will establish a constructive and collaborative relationship to ensure a successful manufacturing process. Frequent communication will be encouraged, allowing for a seamless exchange of feedback and knowledge sharing. This collaborative approach aims to optimize both the design and manufacturing processes.

Aarbakke will have an active role in providing feedback on the Model-Based Definition (MBD) data package. They will be invited to review the clarity of annotations and identify any areas where improvements can be made to enhance manufacturability. This feedback loop will enable continuous improvement and refinement of future MBD data packages, ensuring they align more effectively with Aarbakke's manufacturing capabilities and processes.

Documentation and Traceability:

Aarbakke will be expected to adhere to proper documentation practices throughout the manufacturing process. This includes maintaining records of inspections, measurements, non-conformances, and any deviations from the MBD data package. Such documentation facilitates traceability, troubleshooting, and serves as a future reference. Establishing a system to track the version history of the MBD data package will ensure that both OneSubsea and Aarbakke have access to the correct and latest revisions.

5.5   UNs sustainability goals

MBD aims to improve the efficiency and effectiveness of product design, development, and manufacturing processes. By connecting MBD to the UN's sustainability goals, there are several ways in which MBD can contribute to advancing sustainability initiatives.

SG9: *Industry, Innovation, and Infrastructure*

With MBD the entire product development process gets digitized and integrated when gathering all information of the model in the same file, which allows for better representation of the model. The efficiency and effectiveness in the engineering and manufactory process, which the use of MBD allows, reduces the energy consumption during the processes. The gains with the use of MBD in today's engineering and manufacturing processes, as presented earlier, contribute to the fostering of the development of sustainable infrastructure and promoting technological advancements.

SG12: *Responsible Consumption and Production*

With the use of MBD in today's engineering and manufacturing processes, it facilitates development of products that are resource-efficient and environmentally friendly. When every aspect of the process is developed by using a 3D model, where all information of the product is included, it allows the designers to optimize the use of material. MBD reduces the error of production which reduces the use of material. It also enables the integration of product lifecycle management systems. MBD allows for better tracking and management of products throughout their lifecycle.

6. Conclusion

In the conclusion, the group summarize the key findings and insights derived from our study, highlighting the overall impact and contributions of our work, and offering concluding remarks that not only summarize the research outcomes but also provide valuable recommendations for practical implementation and avenues for future research.

6.1 Summary of findings

Our conclusions are based on experience and knowledge obtained by:

1. Createing MBD-files for OneSubsea Soft-landing-Cylinder

2. Literature study of 2D technical drawins

3. Factory visit at Aarbakke AS

4. Interviews with engineers and key people at Aabrekke and Fideltronik

5. Help and support from our supervisor at NTNU, Shifteh Mihanyar and at OneSubsea Johan Karlsson

To get to a conclusion we performed further analysis of our results using:

1. SWOT analysis

2. Trade off analysis

3. Value proposition canvas

Our conclusion is that tools and process using MBD provide significant opportunities for both development teams and manufacturers. By integrating MBD in today's manufacturing and development processes, the development teams and manufacturers will be able to collaborate more efficiently. This will result in:

1. Speed up the development process and new product introduction, which lead to faster time to market

2. Improved quality as both development teams and manufacturers can contribute with their knowledge and experience through improved collaboration

3. Improved flexibility and customization of products as MBD opens for easier ways of adjusting and modifying designs

However, we have experienced several obstacles and hinders in adopting MBD into the development and manufacturing process. We recommend any company that wants to implement MBD to address these obstacles and hinders. The key obstacles and hinders are:

1. Training of employees

2. Lack of MBD standards

3. Behavioral resistant to change

Training of employees

The cost of adapting to MBD can be considerably high since all employees need training and courses to learn the use of MBD. Also, all employees must adapt to the new method, which could lead to some challenges.

Lack of MBD standards

So far it has not been developed a clear standard and best practice on how MBD should be used. See chapter 6.3 Future Research Direction and Limitations.

Behavioral resistant to change

A challenge to consider before the use of MBD is the behavioral change of the employees. 2D-drawings have been used for thousands of years and to adapt to a whole different method might be a challenge for several people. There is a need for a change of tools and to provide a lot of training for the employees for MBD to be integrated. Integrating MBD in schools and courses will help employees and students get used to MBD.

6.2 Contribution to the fields

Through rigorous research and analysis, our team critically assessed OneSubsea's draft for an MBD standard, identified areas where improvements could be made to enhance its user friendliness and functionality. Leveraging our engineering expertise and knowledge of MBD principles, we suggested and implemented modifications that aligned with Onesubsea's requirements while optimizing the overall design.

6.3 Future research directions and limitations
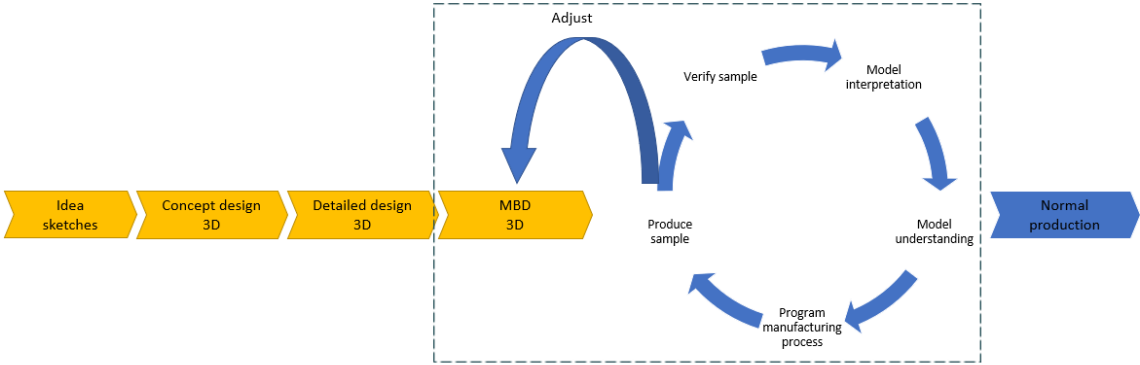
Figure 44: Product lifecycle with MBD approach

The future work of the thesis is to transfer the MBD-files of the SLC send to the manufacturer and manufacture the SLC. In the manufactory process one can get results on which step and how MBD improves the whole process (Figure 44), or if there are challenges one can adjust according to the feedback from the manufacturer. At this stage, they can execute a more comprehensive and detailed trade off analysis with 2D drawings and MBD to understand which factors are most affected. This trade off analysis manages to deal with how much what savings, expenses or and time consumption both the companies made. Obtaining numbers of savings, expansion and time consumption allows the companies to distinguish in detail how effective

MBD is for them. At this stage, they get a more detailed description of what still needs to be improved with MBD for it to be effective, and if it is valuable to adapt quickly.

Lastly, some developments are needed before MBD can be used. There is a need for standardization regarding how the files should be presented before they can be fully integrated into today's engineering and manufacturing process. To test this one can, document the distribution with different models. Testing manufacturing of MBD from simple, intermediate, and complex models enables vision for how machine operators respond to different models. Here, they can gather data of how effective MBD was for different models and compare results. Further, one can test which standardization suits the best for all models and adjust the standardization according to the test results. Finally, document how the standardization should be applied so it can be applied for the future.

Unfortunately, this could not be done due to the time limitations and resources of the bachelor thesis. The workforce in the group was 3 students with a time limit of 5 months. To test a detailed distribution process, the SLC would need to be manufactured with MBD.

Bibliography

[1] Aarbakke (2023). *Aarbakke – What we do*. [online] URL: https://www.aarbakke.no/what-we-do/

[2] Art, in, History, August 31st, S. | and Comment, 2018 L. a (n.d.). Leonardo da Vinci's Earliest Notebooks Now Digitized and Made Free Online: Explore His Ingenious Drawings, Diagrams, Mirror Writing & More | Open Culture. [online] URL: https://www.openculture.com/2018/08/leonardo-da-vincis-earliest-notebooks-now-digitized-and-made-free-online.html

[3] Cogorno, G. R. (2020). *Datums.* 3rd Edition ed. [online] accessengineeringlibrary.com. URL:
https://www.accessengineeringlibrary.com/content/book/9781260453782/chapter/chapter4https://www.accessengineeringlibrary.com/content/book/9781260453782/chapter/chapter4

[5] Gdandtbasics.com. (2015). *True Position – GD&T Basics.* [online] URL: *https://www.gdandtbasics.com/true-position*

[6] Gdandtbasics.com. (n. d.). *Profile of a Surface | GD&T Basics.* [online] URL: *https://www.gdandtbasics.com/profile-of-a-surface*

[7] Gdandtbasics.com. (n. d.). *Maximum Material Condition (MMC) | GD&T Basics.* [online] URL: *https://www.gdandtbasics.com/maximum-material-condition*

[8] Gdandtbasics.com. (n. d.). *Perpendicularity | GD&T Basics.* [online] URL: *https://www.gdandtbasics.com/perpendicularity*

[9] Goher, Kamran, et al. (2020). Model-Based Definition and Enterprise: State-of-the-art and future trends. [online] researchgate. URL: https://www.researchgate.net/publication/346001935_Model-Based_Definition_and_Enterprise_State-of-the-art_and_future_trends

[10] Help.solidworks.com. (n. d.). *Auto Dimension Scheme Tool – 2021 – SOLIDWORKS Help.* [online] URL: *https://help.solidworks.com/2021/english/SolidWorks/sldworks/r_auto_dimension_scheme_propertymanager.htm*

[11] https://rarehistoricalphotos.com/. (2019). Life before the invention of AutoCAD, 1950-1980 - Rare Historical Photos. [online] URL: https://rarehistoricalphotos.com/life-before-autocad-1950-1980/

[12] INTRODUCING SOLIDWORKS. (n. d.). URL: https://my.solidworks.com/solidworks/guide/SOLIDWORKS_Introduction_EN.pdf

[13] lenkavisionfactory (2023). The advantages and disadvantages of flexible working. [online] VISION_FACTORY. [online] URL: https://www.visionfactory.org/post/the-advantages-and-disadvantages-of-flexible-working

[14] Metmuseum.org. (2022). URL: https://www.metmuseum.org/art/collection/search/544801

[15] Mos.org. (2019). Inventor. [online] URL: https://www.mos.org/leonardo/inventor

[16] Mynewsdesk. (n.d.). The pressure is on for manufacturers – more than half would prefer to give up in-house manufacturing – and thus risk losing a strategic competitive advantage. [online] URL: https://www.mynewsdesk.com/rolandberger/pressreleases/the-pressure-is-on-for-manufacturers-more-than-half-would-prefer-to-give-up-in-house-manufacturing-and-thus-risk-losing-a-strategic-competitive-advantage-3170863

[17] Nelson-atkins.org. (2021). GAINING PERSPECTIVE. [online] URL: https://nelson-atkins.org/gates/gaining-perspective.html

[18] Nguyen, J. (n.d.). *MBD (Model-Based Definition): 2023 Edition*. [online] www.capvidia.com. Available at: https://www.capvidia.com/blog/mbd-model-based-definition-guide [Accessed 19 May 2023]. URL: https://www.capvidia.com/blog/mbd-model-based-definition-guide

[19] Nielsen, Henrik S. (11.05.15). *HN Metrology Consulting.* [online] URL https://www.hn-metrology.com/gps.htm

[20] Ruemler, S.P., Zimmerman, K.E., Hartman, N.W., Hedberg, T. and Barnard Feeny, A. (2016). Promoting Model-Based Definition to Establish a Complete Product Definition. *Journal of Manufacturing Science and Engineering*, 139(5). doi:https://doi.org/10.1115/1.4034625. URL:https://asmedigitalcollection.asme.org/manufacturingscience/article/139/5/051008/377561/Promoting-Model-Based-Definition-to-Establish-a

[21] Sofeast. (n. d.). *What is Model Based Definition (MBD) and its benefits?* [online] URL: https://www.sofeast.com/glossary/model-based-definition-mbd-and-benefits/

[22] Sonntag, M. (2019). *Product distribution strategy: The ultimate guide.* [online] Repsly.com. URL: https://www.repsly.com/blog/consumer-goods/everything-you-need-to-know-about-product-distribution

[23] SolidFace 3D CAD. (2020). Technical Drawing: History, Types and Applications - SolidFace. [online] URL: https://solidface.com/technical-drawing/

[24] The Basics of Geometric Dimensioning and Tolerancing | GD&T (2018). *The Basics of Geometric Dimensioning and Tolerancing (GD&T).* [online] Formlabs. URL: https://formlabs.com/blog/gdt-geometric-dimensioning-and-tolerancing/

[25] Yahoo Finance. (n.d.). OneSubsea's Importance in the Schlumberger-Cameron International Deal. [online] URL: https://finance.yahoo.com/news/onesubsea-importance-schlumberger-cameron-international-080624514.html?guccounter=1

[26] Itsupplychain.com. (n. d.). *Common Supply Chain Errors and How to Avoid Them – IT Supply Chain.* [online] URL: https://itsupplychain.com/common-supply-chain-errors-and-how-to-avoid-them/

[27] Key Strategic Ingredients Part II 13, Appendix 1, Politecnico Milano Prof. Andrea Rangone, Osterwalder et al., 2014

[28] A Suggested MBD Schema for OneSubsea, Appendix 2, Senior Mechanical Design Engineer, Strypet, Yngve

[29] Fn.no. (n. d.). *Industri, Innovasjon og Infrastruktur.* [online] URL: https://www.fn.no/om-fn/fns-baerekraftsmaal/industri-innovasjon-og-infrastruktur

[30] Fn.no. (n. d.). *Ansvarlig forbruk og produksjon.* [online] URL: https://www.fn.no/om-fn/fns-baerekraftsmaal/ansvarlig-forbruk-og-produksjon

[31] Eabeng.no. (n. d.). *Soft Landing System.* [online] URL: https://www.eabeng.no/soft-landing-system

[32] Mohamed Sami. (2017). *Trade-off Analysis Technique – Make the decision easier.* [online] URL: https://melsatar.blog/2017/09/23/trade-off-analysis-technique-make-the-decision-easier/

Pictures:

[33] Engineersedge.com. (n. d.). *ISO Surface Parameter Symbols.* [online] URL: *https://www.engineersedge.com/manufacturing/_iso_surface_roughness_symbols_terminology_13090.htm*

[34] Gdandtbasics.com. (n. d.). *Table using the GD&T flatness symbol.* [online] URL: https://www.gdandtbasics.com/flatness

[35] Javatpoint.com. (n. d.) *SWOT ANALYSIS.* [online] URL: https://www.javatpoint.com/swot-full-form

[36] Leach, Richard. (Jan. 2001). *Graphical symbol for surface texture where complimentary information is required. From ISO 1302: 2000.* [online] URL: https://www.researchgate.net/figure/Graphical-symbol-for-surface-texture-where-complimentary-information-is-required-from_fig31_263237968

[37] digital.nls.uk. (n.d.). Browse and search > 1946-1950 - Senior Leaving Certificate Examination (including Day School Certificate (Higher) General paper) > 1949 > (183) Technical Subjects, Higher Grade - (Technical Drawing) - Figures - Scottish school exams -

National Library of Scotland.   [online]   URL:
https://digital.nls.uk/exams/browse/archive/130131958?mode=fullsize

Attachments

Activity number	Activity	Description	Working hours
1	MBD data package	-Assemble a MBD technical data package on the Soft-landing Cylinder	x
1.1	Planning	-Plan every activity regarding assembling the MBD data package	x
1.2	Learn MBD tools in SolidWorks	-Watch videos detailing MBD in SolidWorks -Do exercises with MBD with premade models	x
1.3	Create MBD on the SLC Cylinder	-Dimension, tolerancing and view management	x
1.3.1	Defining dimensions on the SLC	-Define all dimensions -Make sure all dimensions are visible	x
1.3.2	Tolerances	-Define all tolerances -Make sure all tolerances are visible defined according to GPS standards	x
1.3.3	Create views	-Approach design and create views - Combine views -Delete unnecessary views	x
1.3.4	Name views	- Name views according to MIL-STD-31000A, appendix B	x
1.4	Create Technical Data package	-Including all files in the data package -Make sure everything organized	x
2	Manufactory (Aarbakke) distribution process	-Meeting with Aarbakke and document the distribution process	x
2.1	Planning	-Plan every activity regarding the manufactory distribution process	x
2.2	Transfer MBD file of the Rod to Aarbakke	-Make sure the file is compatible with their software	x
2.3	Meeting with Aarbakke	-Gather information of their manufacturing, engineering, and their thoughts on MBD	x
2.3.1	Prepare for meeting with Aarbakke and OneSubsea	-Prepare presenting the MBD file -Prepare questions	x
2.3.2	Meeting with Aarbakke	-Discuss MBD and the MBD file of the Rod -Gather feedback and Q&A	x
2.3.3	Document Feedback and Q&A	-Write a document with all the feedback and Q&A -Sort all information	x

2.4	Improve quality from feedback	-Improve the MBD files -Improve the data package	x

Appendix 1 – Key Strategic Ingredients Part II 13

The Value Proposition Canvas
The Business Model Canvas
Entrepreneurship LAB

Prof. Andrea Rangone – andrea.rangone@polimi.it

POLITECNICO MILANO 1863

The Value *Proposition* Canvas

(Osterwalder et al., 2014)

POLITECNICO MILANO 1863   2

The value of the Canvas

The Canvas results from a deep academic investigation on the business model ontology (i.e. essential concepts and elements) but also from a concrete business need

It is presented in a unified, simple and intuitive way, that enables interaction and collaboration between people (also from different disciplines and backgrounds), thus being significantly appealing for practitioners (e.g. entrepreneurs and managers)

The power of a universal, visual, simple language

The Value Proposition Canvas

The **Value Proposition Canvas** makes explicit how you are creating value for your customers. It helps you to design products and services your customers want
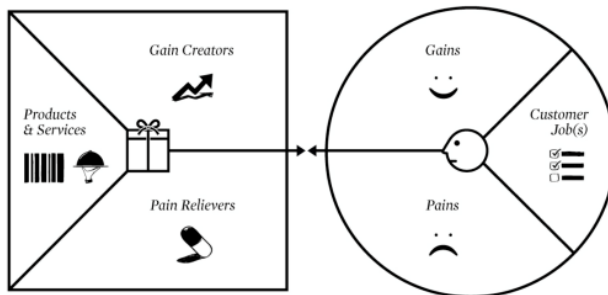
The Value Proposition Canvas: Customer Profile

The **Customer (Segment) Profile** describes a specific customer segment in a very structured and detailed way. It breaks the customer down into its jobs, pains and gains
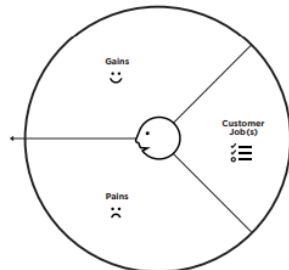
The Customer profile describes **what you can observe**   Osterwalder et al., 2014

90

The Value Proposition Canvas: Customer Profile - Jobs

Jobs describe the things your customers are trying to get done in their work or in their life. A customer job could be the tasks they are trying to perform and complete or the needs they are trying to satisfy (functional, social, emotional jobs)

Guiding Questions

- What is the one thing that your customer couldn't live without accomplishing? What are the stepping stones that could help your customer achieve this key job?
- What are the different contexts that your customers might be in? How do their activities and goals change depending on these different contexts?
- What does your customer need to accomplish that involves interaction with others?
- What tasks are your customers trying to perform in their work or personal life? What functional problems are your customers trying to solve?
- Are there problems that you think customers have that they may not even be aware of?
- What emotional needs are your customers trying to satisfy?
- What jobs, if completed, would give the user a sense of self-satisfaction?
- How does your customer want to be perceived by others? What can your customer do to help themselves be perceived this way?
- How does your customer want to feel? What does your customer need to do to feel this way?
- Track your customer's interaction with a product or service throughout its lifespan. What supporting jobs surface throughout this life cycle?
- Does the user switch roles throughout this process?

Osterwalder et al., 2014

POLITECNICO MILANO 1863

6

The Value Proposition Canvas: Customer Profile - Gains

Gains describe the outcomes and benefits your customers want. Some gains are required, expected, or desired by customers, and some would surprise them (Gains include functional utility, social gains, positive emotions, and cost savings)

Guiding Questions

- Which savings would make your customers happy? Which savings in terms of time, money, and effort would they value?
- What quality levels do they expect, and what would they wish for more or less of?
- How do current value propositions delight your customers? Which specific features do they enjoy? What performance and quality do they expect?
- What would make your customers' jobs or lives easier? Could there be a flatter learning curve, more services, or lower costs of ownership?
- What positive social consequences do your customers desire? What makes them look good? What increases their power or their status?
- What are customers looking for most? Are they searching for good design, guarantees, specific or more features?
- What do customers dream about? What do they aspire to achieve, or what would be a big relief to them?
- How do your customers measure success and failure? How do they gauge performance or cost?
- What would increase your customers' likelihood of adopting a value proposition? Do they desire lower cost, less investment, lower risk, or better quality?

Osterwalder et al., 2014

POLITECNICO MILANO 1863

7

The Value Proposition Canvas: Customer Profile - Pains

Pains describe anything that annoys your customers before, during, and after trying to get a job done or simply prevents them from getting a job done. Pains also describe risks, that is, potential bad outcomes, related to getting a job done badly or not at all

Guiding Questions

- How do your customers define too costly? Takes a lot of time, costs too much money, or requires substantial efforts?
- What makes your customers feel bad? What are their frustrations, annoyances, or things that give them a headache?
- How are current value propositions under performing for your customers? Which features are they missing? Are there performance issues that annoy them or malfunctions they cite?
- What are the main difficulties and challenges your customers encounter? Do they understand how things work, have difficulties
- getting certain things done, or resist particular jobs for specific reasons?
- What negative social consequences do your customers encounter or fear? Are they afraid of a loss of face, power, trust, or status?
- What risks do your customers fear? Are they afraid of financial, social,
- or technical risks, or are they asking themselves what could go wrong?
- What's keeping your customers awake at night? What are their big issues, concerns, and worries?
- What common mistakes do your customers make? Are they using a solution the wrong way?
- What barriers are keeping your customers from adopting a value proposition? Are there upfront investment costs, a steep learning curve, or other obstacles preventing adoption?

Osterwalder et al., 2014

POLITECNICO MILANO 1863

8

The Value Proposition Canvas: an example of Customer Profile
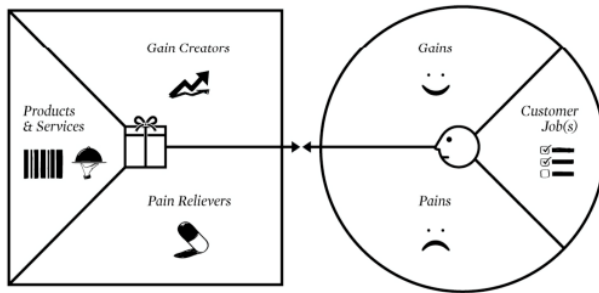
Tesla electric cars

The Value Proposition Canvas: Customer Profile – Common Mistakes

- Making several customer segments into one profile
- Mixing jobs and outcomes
- Focusing on functional jobs only and forgetting social and emotional jobs
- Listing hobs, pains, and gains with your value proposition in mind
- Identifying too few jobs, pains, and gains (right level of disaggregation)
- Being too vague in descriptions of pains and gains

The Value Proposition Canvas: Value Map

The **Value (Proposition) Map** describes the features of a specific value proposition in your business model in a more structured and detailed way. It breaks your value proposition down into products and services, pain relievers, and gain creators.
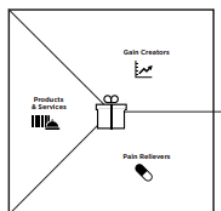
The Value map describes **what you can design**

Osterwalder et al., 2014

The Value Proposition Canvas: Value Map – Products & Services

The list of all **Products & Services** you want to / can offer (characteristics & features)
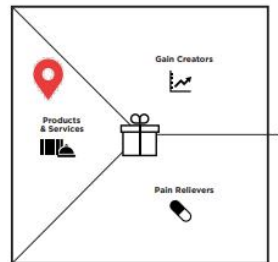
Osterwalder et al., 2014

The Value Proposition Canvas: Value Map – Gain Creators

Gain Creators describe how your products and services create customer gains. They explicitly outline how you intend to produce outcomes and benefits that your customer expects, desires, or would be surprised by, including functional utility, social gains, positive emotions, and cost savings

Guiding Questions

Could your products and services…
- … create savings that please your customers? In terms of time, money, and effort.
- … produce outcomes your customers expect or that exceed their expectations? By offering quality levels, more of something, or less of something.
- … outperform current value propositions and delight your customers? Regarding specific features, performance, or quality.
- … make your customers' work or life easier? Via better usability, accessibility, more services, or lower cost of ownership.
- … create positive social consequences? By making them look good or producing an increase in power or status.
- … do something specific that customers are looking for? In terms of good design, guarantees, or specific or more features.
- … fulfill a desire customers dream about? By helping them achieve their aspirations or getting relief from a hardship?
- … produce positive outcomes matching your customers' success and failure criteria? In terms of better performance or lower cost.
- … help make adoption easier? Through lower cost, fewer investments, lower risk, better quality, improved performance, or better design.

Osterwalder et al., 2014

The Value Proposition Canvas: Value Map – Pain Relievers

Pain relievers describe how exactly your products and services alleviate specific customer pains. They explicitly outline how you intend to eliminate or reduce some of the things that annoy your customers before, during, or after they are trying to complete a job or that prevent them from doing so

Guiding Questions

Could your products and services…
- … produce savings? In terms of time, money, or efforts.
- … make your customers feel better? By killing frustrations, annoyances, and other things that give customers a headache.
- … fix under-performing solutions? By introducing new features, better performance, or enhanced quality.
- … put an end to difficulties and challenges your customers encounter? By making things easier or eliminating obstacles.
- … wipe out negative social consequences your customers encounter or fear? In terms of loss of face or lost power, trust, or status.
- … eliminate risks your customers fear? In terms of financial, social, technical risks, or things that could potentially go wrong.
- … help your customers better sleep at night? By addressing significant issues, diminishing concerns, or eliminating worries.
- … limit or eradicate common mistakes customers make? By helping them use a solution the right way.
- … eliminate barriers that are keeping your customer from adopting value propositions? Introducing lower or no upfront investment costs, a flatter
- learning curve, or eliminating other obstacles preventing adoption.

Osterwalder et al., 2014

The Value Proposition Canvas: Value Map – Common Mistakes

- List all your products and services rather than just those targeted at a specific segment
- Add products and services to the pain reliever and gain creator fields
- Offer pain relivers and gain creators that have nothing to do with the pains and gains in the customer profile
- Make the unrealistic attempt to address all customer pains and gains

The Value Proposition Canvas: the fit between the Customer Profile and the Value Map
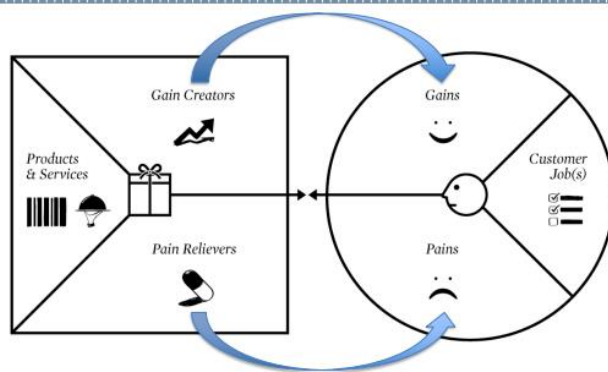
The Value Proposition Canvas: an example (Masterminding)*

*From a Top Project in Entrepreneurship Lab, A.A. 2021/22

94
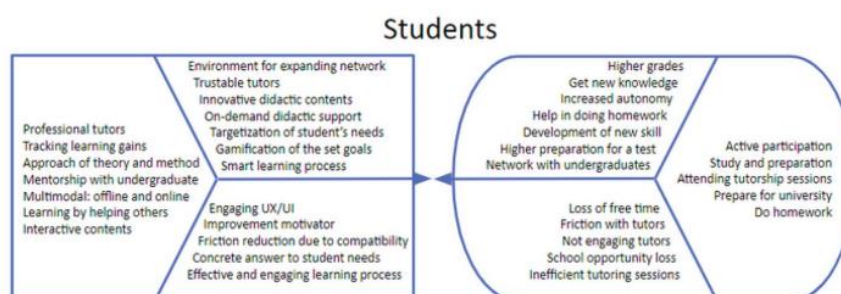
The Value Proposition Canvas: an example (Masterminding)*

In the example, the customer segment is represented by high school students.
Specifically, these customers have some activities to do and experience some feelings (customer jobs):
- Studying and being prepared for the in-class tests (e.g., homework);
- Building the knowledge for the university;
- Enjoying the learning process and discovering their own passion(s).

In doing this, there are some obstacles (pains):
- Studying requires time, reducing free time to have fun;
- Often lectures and tutorship' sessions are felt boring;
- Possible lost of opportunities in school.

And also some advantages (gains):
- Having good grades and getting new knowledge;
- Be more autonomous;
- Receiving support in the learning process.

The Value Proposition (left side) builds upon these characteristics to offer a service matching the identified needs.

*From a Top Project in Entrepreneurship Lab, A.A. 2021/22

Appendix 2 – A Suggested MBD Schema for OneSubsea

A Suggested MBD Schema for OneSubsea

Yngve Strypet, Senior Mechanical Design Engineer
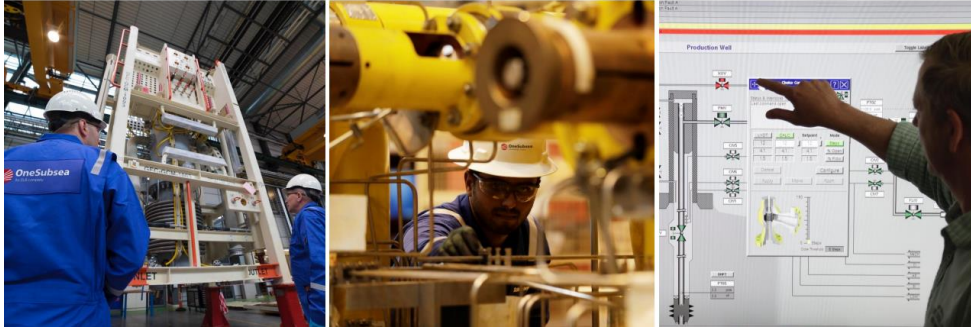
Introduction

- **A MBD model organizational schema** has been developed as a suggestion for Onesubsea engineers producing product definitions in Creo Parametric models.
  - The schema is to be used in a MBD Workshop for Onesubsea engineers.

- This includes a MBD adapted start-part "**start_part_mbd.prt**" to be used for Creo Parametric 4.0.
- The start-part has been adapted from a provided Subsea non-MBD start-part "**start_part.prt**", considering the following and other things:
  - Combination state naming
  - Combination state settings
  - Notes, e.g. general, property, tolerancing etc.
  - Strategy for managing the display of annotations and supplementary geometry (e.g. datum axis)
  - Strategy for managing thew display of other entity types than the above using hide/show, or layers and layer states.
  - Detail settings to control the visual appearance of annotations.

- **The start-part is currently limited to features produced by machining** (material removal)

- Along with the start part it is recommended to create a **document with a set of rules**, instructions and recommendations
  - For the purpose of the workshop, this is limited to this PowerPoint document where the basic workflow is described.
  - A recommendation is to establish a MBD workflow manual when to deploy MBD at Onesubsea.

Schema

- The term "MODEL BASED DEFINITION (MBD) – MODEL ORGANIZATIONAL SCHEMA" comes from US standards, i.e. not ISO GPS.

- It is about organizing the product definitions in the 3D CAD-model
  - **It is the 3D CAD model equivalent to formats and templates for 2D drawings**.
  - E.g. how to display data traditionally displayed in the title block of the drawing but now in the 3D CAD model
  - E.g. how to relay the specifications traditionally displayed in 2D drawings views but instead using **combination states** (Creo Parametric term) in 3D CAD models.
  - How to name the combination states.

- Along with CAD document templates there should also be a document describing the schema, general workflow, rules and recommendations.
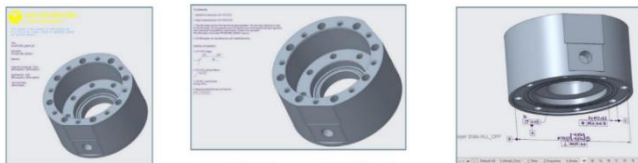
Schema inspiration

- The US standard "MIL-STD-31000A" appendix B contains a suggested schema using Creo Parametric.
  - It's claimed the described schema is compliant with the corresponding ASME standard, ASME Y14.41.

- It is not uncommon companies base the name of the combination states on the above standard.

- If you attend the PTC MBD training (1-day online course) the schema used there is also based on MIL-STD-31000A appendix B.

- The naming of the combination states used in the suggested schema for Onesubsea is inspired by the PTC online training schema and MIL-STD-31000A appendix B.

Schema, combinations state naming

- Naming convention for combination states from MIL-STD-31000A, Appendix B.

The following is a list of suggested Combined States:

State Name	Description of Contents Displayed
0_Model_Only	Although it is not required for MBD this view is recommended to quickly hide all annotation displaying only the model
MBD0_Default	Legal notice, Proprietary notice, ITAR notice and/or other company specific notices. NOTE: File to be saved in this state
MBD1_Site_Map	Notes identifying all available combination views – 3D roadmap
MBD2_Titles	Title Block information (Company name, design description, model number, cage code, design signatures, block tolerances, material and finish requirements)
MBD3_Properties	Overall boundary dimensions, mass properties, material, finish requirements and title block information
MBD3_Characteristics	Optional – Key characteristics
MBD4_Notes	General note information
MBD5_Set_Datums	Set datums
MBD6_User_Derfined	Exploded Views and Assembly Unique views
MBD7_User_Defined	Define the details of the Machining operations using annotations
MBD8_User_Defined	Define the details of the Welding operations using annotations

Combination state naming – suggestion for Onesubsea

State	Description	Comment
Default_All	This state is not really part of the schema. It always exists in Creo and should be regarded as the state you do your general creo work in. If you are not using MBD you will be working in this state by default, until creating and/or switching to another combinations state. For the Onesubsea workflow, it's recommended to use this tab while creating annotations for easy finding them before redistributing the annotations to other combination states. Refer to the description of the workflow later in the document.	Cannot be removed Do not publish!
0_Model_Only*	There is usually only one state with this number and name. This tab displays the model without any annotations. Main purpose is to display a clean view when opened in Creo View. The * indicated the state is the default state and will be displayed as default view in Creo View, if the following option is also activated in Creo View: "File\Options\General\Loading\Autoload the PVS file's default view".	Required, Publish!
1_Map	Usually one state to guide the user in finding the annotations if the model contains so many features and annotations that it is hard for the receiver to find relevant information. If you have 10+ combination states starting with 5-8 you might want to consider creating a map state. For map states notes are displayed which reference the features of each combination state starting with 5-8. Furthermore each note is html linked to the corresponding combination state so that the receiver can easily and quickly get to the information.	Optional, Publish!
2_Titles	There is usually only one state with this number and name. It contains the metadata corresponding to those of a title block of a traditional drawing, e.g. names, article numbers, creator, date of creation etc.	Required, Publish!
3_Properties	There is usually only one state with this number and name. Here the information traditionally displayed in the drawing title block regarding properties are displayed. Examples: material, surface treatment, weight, surface area, etc.	Required, Publish!
4_Notes	There is usually only one state with this number and name. Here all notes are displayed, such as tolerancing information and special specifications like "mask before anodization".	Required Publish!
5<LETTER><_OPTIONAL TEXT>	It is not uncommon to have multiple states with this number unless a simple component. Number and name according to the following sequence: 5A, 5B, 5C, etc. As many states as needed to clearly display all datums of the model should be used. A recommendation is to gather the predominant system in the state 5A if these can be clearly displayed. The predominant system fixates all (or all necessary) degrees of freedom of the component. Rule of thumb: Primary orients the component, secondary positions and tertiary handles the remaining dofs if not handled by primary and secondary. Other datums, utilized to more clearly express design intent and to produce shorter tolerance chains, are recommended to be displayed from state 5B and further. Usually also geometrical specifications such as size tolerances and geometrical tolerances of the datum features are also displayed in these states.	Required unless there are no datums, Publish!
6<LETTER>><_OPTIONAL TEXT>	Reserved for assembly information. [MBD IS CURRENTLY NOT DEVELOPED FOR ASSEMBLIES AT ONEWSUBSEA]	Required if applicable Publish!
7<LETTER>><_OPTIONAL TEXT>	There are usually multiple states with this number (unless a simple component), e.g. 7A, 7B, 7C, etc., as many states as needed to clearly display all specifications other than datum and assembly specifications. Examples: Size tolerances, geometric tolerances, edge specifications, surface texture specifications, Onesubsea's own specification types. Comment : In MIL-STD-31000A, Appendix B the 7_ states are reserved for specifications of machined features. At Onesubsea the 7_ states it is recommended for general specifications of features produced by any manufacturing method except assembly but including machined features of assemblies: machined, sheet metal molded or others. In the mil-std the 8_number is reserved for features produced by welding. [The use of 8_ for features produced by welding is not currently established at Onesubsea]	Required if applicable Publish!

Combination state naming - suggestion

State	Description	Comment
8<LETTER><_OPTIONAL TEXT>	Weld specifications «Currently not available at Onesubsea»	Required if applicable Publish!
_All	This state is where all annotations can be displayed if wanted. This is the final state created when all necessary annotations have been defined. Otherwise the tab should not exist. This tab shall not be published to Creo View (or other derivative).	Optional Do not publish!
Revision	This state is predefined in the template for general parts. The intention is to collect and display all revision notes here. However, if this is handled through Teamcenter this state may be superfluous.	TBD, may be handled through Teamcenter?
_	It's ok to have user purpose combination state not intended for publish, e.g. "_to_do_later" or "_change_in_next_version". To differentiate this type of info from product definitions place in tabs starting with "_".	Optional

---

Titles / Properties

- **2_Titles**
- The management data displayed here shall be in the data set according to is 16792:2015. This mean they do not necessarily need to be in the model if the management "data set" is relayed by other means through the data set.
- **Which data to have in the model, pushed from Teamcenter and which not to have?**
- **Recommendation:** Study ISO16016 for legality and protection marking.

- **3_Properties**
- Some data is specification and other is only info
- **Material** is specified in Teamcenter today.
  - Today: A text string can be specified optionally in Creo. The CAD document creator must make sure there is a match to the team center specification attribute.
  - Today: It is up to each CAD document creator to specify correct density for mass properties calculations.
- **Surface Condition / Heat Treatment**
  - Today: specified as text string in CAD model (unsure if in Teamcenter as well).
  - How to specify standard surface conditions/treatment can be found in ISO standards. See example below.
  - If specific surfaces are to have specific conditions specified, the general method is to do that through surface finish requirements. There are semantic issue with using symbols why this is not clear how to specify. There are a text-bases approach provided through ISO 1302. Also a Creo note could be created suing the e.g. coating standard specification suggestions (like below).
  - An option for the general specification would be to move Surface Condition / Heat treatment specification to the 4_notes state to where the general surface texture requirement is specified.

Notes

- **4_Notes**
  - Here general requirements and note type specifications are presented.
  - The TOLERANCING section specifies the tolerancing standard system.
  - **Note 1;** By specifying certain version, complicated traceability circumstances are mitigated, otherwise the standard version that apply the date of preparation of drawing ...
    - Otherwise note 1 is not necessary. Use the symbols and the iso GPS system applies, through the ISO6015 invocation principle, excluding specific standards, e.g. ISO 16792 or general tolerancing standards (2768, 8062 etc).
    - The currently active ISO 1101 version is 2017. This version is only supported by Creo 7.0.0.0 and forward. From Creo 7.0.1.0 GD&T Advisor also support ISO 1101:2017. However ISO 5458:2018 for patterns will most likely not be supported by any future Creo 7 version. **ITS RECOMMENDED TO DISCUSS THIS AND DECIDE ON COMMON RULES FOR USAGE** (switch to Creo7 soon or stick with Creo 4.0 a while?).
  - **Note 2;** ISO 16792:2015 needs to be specified according to the standard itself.
  - **Note 3,** is partially necessary due to requirements from ISO16702 and partially there for clarification. The exact phrases used are not dictated by the standard (there are no examples for how to specify).
  - **Note 4** is required by ISO 16792, if there are sizer tolerances specified using the coding system of ISO286, e.g. Ø20H7 for a hole.
  - **Note5;** A recommendation is to have general edge requirements canceling the old ambiguous specification like "sharp edges to be broken". Specific requirements for specific edges can also be specified using ISO 13715. If used the text "ISO 13715" needs to be specified according to the standard itself.
  - **Note6;** A recommendation is to at least use the simplest form of general surface specification (can be enhanced). Specific specifications can also be specified using similar symbols but there may be "semantic" issue as discussed later.
  - **Note7;** Optional, no reference to this standard is specified to be specified. It's much clearer if specified though. Also it can be used if general default thread tolerances are to be changed to other than default tolerances (6H/6g for internal and external for M1.6 and bigger).
  - **Note 8;** Recommended method over ISO 2768 for specification of general tolerances for machined and sheetmetal workpieces. Already adopted by other general tolerancing standards such as ISO 8062-4 for molded workpieces. Very soon a new general tolerancing standard for the purpose is to be released, ISO 22081.
  - **General note type specifications** can also be specified here. If so, add title GENERAL NOTES and add the notes continuing the numbering from previous note. If applicable add a leader note pointing on the feature/features of which the specification apply to.
  - If the note gets "too long", create a new note in the annotation feature "4_notes" in the Footer at the bottom of the model tree.
  - Also other predefined annotations for other workpiece types than machined could be put in the annotation feature in the start-part, starting with "4_". That way, you just chose the appropriate note and discard the others starting with "4_" keeping the number of start-parts (templates) down, e.g. 4_NOTES_MOULDED_PLASTIC and 4_NOTES_MOULDED_METAL etc.
  - **NOTE!** The number can be used by downstream software to separate the specifications from each note.
  - **NOTE!** If to use MBD and Creo 2D drawing (.drw) then display the "4_NOTES" annotation in the drawing DO NOT specify it again in the drawing.

See note!

Examples, the section is not available in the start-part!

Comment to notes

- Invoking 1101:2012 invokes the following standards.
- Not that all but one are locked to a specific version, making traceability easier.
- NOTE! If invoking ISO1101:2017 (which Creo does not support fully, currently) then more "currently active" versions are invoked.

Standarder invoked from ISO1101:2012

Standard	Titel
ISO 12180-2:2011	Geometrical product specifications (GPS) — Cylindricity — Part 2: Specification operators
ISO 128-24:1999	Technical drawings — General principles of presentation — Part 24: Lines on mechanical engineering drawings
ISO 1660:1987	Technical drawings — Dimensioning and tolerancing of profiles
ISO 2692:2006	Geometrical product specifications (GPS) — Geometrical tolerancing — Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)
ISO 5458:1998	Geometrical Product Specifications (GPS) — Geometrical tolerancing — Positional tolerancing
ISO 5459:2011	Geometrical product specifications (GPS) — Geometrical tolerancing — Datums and datum systems
ISO 8015:2011	Geometrical product specifications (GPS) — Fundamentals — Concepts, principles and rules
ISO 10579:2010	Geometrical product specifications (GPS) — Dimensioning and tolerancing — Non-rigid parts
ISO 12180-1:2011	Geometrical product specifications (GPS) — Cylindricity — Part 1: Vocabulary and parameters of cylindrical form
ISO 12181-1:2011	Geometrical product specifications (GPS) — Roundness — Part 1: Vocabulary and parameters of roundness
ISO 12181-2:2011	Geometrical product specifications (GPS) — Roundness — Part 2: Specification operators
ISO 12780-1:2011	Geometrical product specifications (GPS) — Straightness — Part 1: Vocabulary and parameters of straightness
ISO 12780-2:2011	Geometrical product specifications (GPS) — Straightness — Part 2: Specification operators
ISO 12781-1:2011	Geometrical product specifications (GPS) — Flatness — Part 1: Vocabulary and parameters of flatness
ISO 12781-2:2011	Geometrical product specifications (GPS) — Flatness — Part 2: Specification operators
ISO 14660-1:1999	Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions
ISO 14660-2:1999	Geometrical Product Specifications (GPS) — Geometrical features — Part 2: Extracted median line of a cylinder and a cone, extracted median surface, local size of an extracted feature
ISO 17450-2:—1	Geometrical product specifications (GPS) — General concepts — Part 2: Basic tenets, specifications, operators and uncertainties

If version is not given then the latest version apply. The version is given after ":", e.g. 1987 in 1660:1987.