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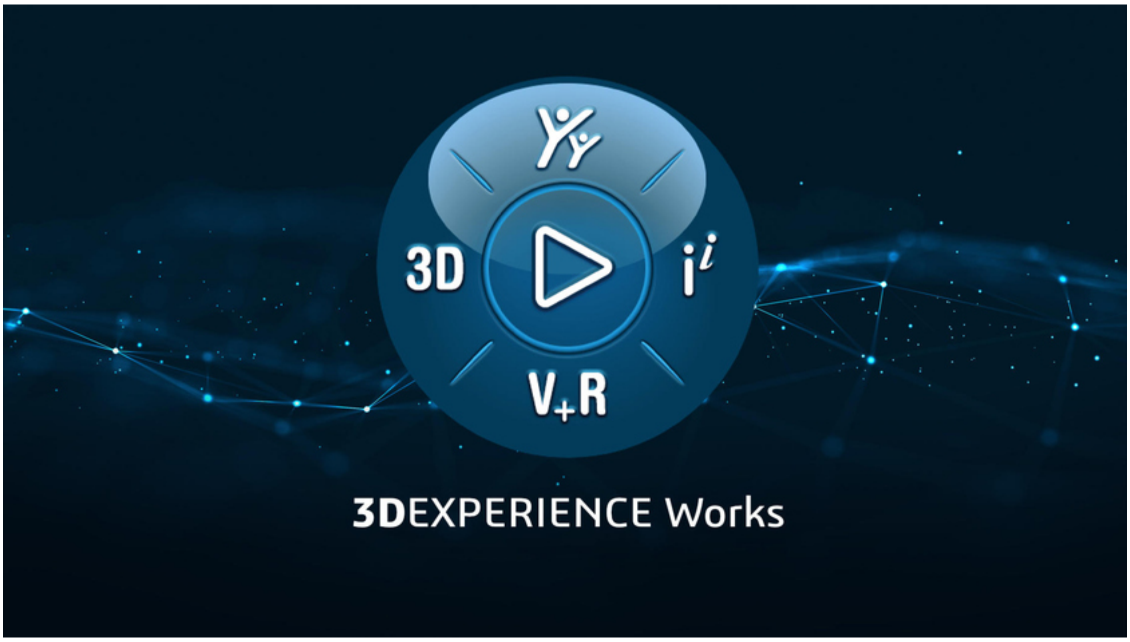

Using 3DExperience as a unified platform for Production Engineering

Master's thesis in Master Program Production engineering

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ABSTRACT

Manufacturing industries are experiencing a surge in technological advancements and innovative practices aimed at creating mass customization while minimizing costs and lead times. Despite this significant shift, the industry is struggling to adapt and embrace these changes fully. Various departments of manufacturing companies continue to work in silos, failing to recognize the huge benefits of concurrent engineering.

Product design teams have been using design software for several decades, but the integration of these systems with other business practices within the manufacturing industry is relatively new. Dassault Systemes' 3D Experience platform aims to address this by offering a unified platform that integrates all the necessary tools and software required by manufacturing companies, fostering a more collaborative environment.

The focus of this study is to explore the integration of three key disciplines i.e. design of equipment, equipment/robot simulation, and factory flow, to promote collaboration and enhance overall effectiveness. By leveraging the available tools on the 3D Experience platform, the study seeks to establish a work structure that integrates the three disciplines.

The study's findings shed light on the presence of numerous tools that foster the establishment of a collaborative environment. The insights gained from the case project have resulted in a comprehension that utilizing these tools holds immense promise in enhancing the productivity and effectiveness of product design teams.

Keywords: Collaboration, Concurrent Engineering, 3D Experience, Equipment design, Robot Simulation, Factory Flow Simulation, PLM System, Work Structure.

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Last but certainly not least, we owe an immeasurable debt of gratitude to our families and friends. Their support and motivation throughout our master's program have been a constant source of inspiration, driving us to strive for excellence in every aspect of our academic journey.

Dhruva Kumar Nagesh & Subin Gowda Surappanahalli Shivappa Gowda, Gothenburg, August 2023

List of Acronyms

Underneath is a list compiled of acronyms in alphabetical order that have been utilized throughout this thesis :

CAD	Computer-Aided Design
DS	Dassault Systemes
KPI	Key Performance Indicator
PLM	Product Lifecycle Management
STEP	Standard for the Exchange of Product Data
3DX, 3DS	3D Experience Platform
OEM	Original Equipment Manufacturer

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1
Introduction

In this chapter, a concise introduction is presented, outlining the study's purpose and providing an overview of the background. The problem statement is described, drawing from the background information, and then refined into a specific research question. Additionally, the scope and limitations of the thesis are discussed, providing readers with a comprehensive understanding of the study's focus.

1.1 Background

In the dynamic and highly competitive world of manufacturing, the industry has witnessed a significant shift towards both globalization and mass customization, triggering a remarkable evolution in manufacturing practices [6]. This transformation has been largely driven by the adoption of cutting-edge technologies, leading to the emergence of virtual manufacturing, which has revolutionized the way manufacturing industries operate. Virtual manufacturing involves the virtual simulation of a factory in software even before its physical installation or aims to enhance existing factories. By digitalizing traditional manufacturing processes, capital requirements for improvements have been reduced, and informed decisions regarding factory installations have become more feasible. Concurrently, design software has been tailored to cater to the needs of the rapidly growing market, ensuring efficiency and adaptability [7][8].

In light of these advancements, it becomes evident that embracing change and adapting to new methodologies can be challenging for organizations, often resulting in the perpetuation of outdated work structures. The current organizational work structure in many manufacturing setups remains siloed, characterized by disparate departments or teams working in isolation, lacking effective communication and collaboration [9]. Instead of considering the broader goals or impacts on the overall manufacturing process, each department focuses solely on its specific tasks or objectives, leading to rework, reduced traceability, and longer lead times. The transfer of information within departments is often limited to periodic meetings or when design rework is necessary, resulting in potential inefficiencies and communication gaps [9].

To address these limitations and enhance manufacturing efficiency, the industry is increasingly turning to the principles of concurrent engineering. Concurrent engineering is an integrated product development approach that emphasizes collaboration and knowledge transfer among different design experts from the outset of the product development stage[9]. This approach seeks to enhance decision-making and consider product lifecycle aspects, all while significantly reducing lead time [10]. The adoption of concurrent engineering principles facilitates concurrent collaboration between design and manufacturing teams, ultimately leading to a reduction in lead time and a more streamlined development process [10].

While the benefits of concurrent engineering are widely recognized, its widespread implementation in industries remains limited. However, considerable research and development efforts are currently underway to bridge this gap and fully realize its potential [9]. One prominent platform that seeks to implement concurrent engineering principles is the 3D Experience by Dassault Systèmes. This business innovation platform provides organizations with real-time and holistic visions, enabling seamless collaboration among designers who use various design software. Additionally, it offers robust project data organization capabilities through cloud storage [11].

The focus of this thesis is to conduct a comprehensive study of the collaboration features offered by the 3D-Experience platform and explore its potential for integrating three essential disciplines in production engineering projects: equipment design, robot reachability and simulation, and factory flow disciplines. By understanding the platform's capabilities and its potential to enhance concurrent engineering, this research aims to contribute valuable insights to the manufacturing industry, paving the way for more efficient and collaborative manufacturing processes.

1.2 Research Aim

Explore the advantages of integrating the disciplines of 'Design of Equipment', 'Equipment/Robot Simulation', and 'Factory Flow Simulation' in production engineering projects, and develop a standardized work structure for teams operating within a unified collaborative platform.

1.3 Research Question

Based on the background and the research aim provided, the project team formulated the following research questions:

1. *What are the benefits of integrating the 'design of equipment', 'equipment/robot simulation', and 'factory flow simulation disciplines in production engineering projects?*
2. *What are the key components of a standardized work structure that can effectively support teams working under the integrated disciplines of 'Design of Equipment', 'Equipment/Robot Simulation', and 'Factory Flow Simulation' in production engineering projects?*

3. *What are the available collaborative tools within the 3D Experience platform that facilitate collaboration among the disciplines of 'Design of Equipment', 'Equipment/Robot simulation', and 'Factory Flow Simulation'?*

1.4 Objectives

To achieve the thesis goal, the following objectives are formulated:

- The project team will study concurrent engineering methodology and understand the 3DExperience platform.
- The project team will identify the key components in the 3DExperience platform which will make the integration possible for the three disciplines of focus.
- The project team will formulate and suggest a logical work structure for the integration of three focal disciplines using 3DExperience.
- The project team will analyze the benefits for the organizations and demands on them to undergo this change and integrate the three focal domains using the 3DExperience platform.

1.5 Delimitations

To address the research question, the scope of the thesis work was carefully defined. The conventional approach to working in the design and simulation environment was comprehended solely through an extensive review of existing literature and conducting comprehensive qualitative analysis via interviews with experts in the field.

Although Dassault takes a holistic approach to digital manufacturing, including end-to-end product realization solutions, the impact of different manufacturing disciplines is not taken into account, and the emphasis is instead placed solely on equipment design, equipment/robot simulation, and factory flow simulation. These fields are studied using the Prodtex framework, a number of Dassault Systemes courses, and an industrial case project that included aspects of equipment design, equipment simulation, plant layout design, and a significant amount of factory flow simulation.

2
Methodology

This chapter describes the methodology of the thesis work conducted. The methodology mainly includes qualitative and quantitative studies.

The objective of the thesis was to identify and analyze the collaborative tools available within the 3DS platform, with a specific focus on their application in the domains of equipment design, equipment/robot simulation, and factory flow. The overarching goal was to gain a comprehensive understanding of the benefits of collaboration facilitated by the platform and subsequently propose an optimal work structure for projects in these domains. Achieving this required an extensive research effort, delving into the intricacies of design, simulation, and factory flow within the context of the 3DS platform. A thorough examination of the collaborative tools provided by the platform was essential, as it enabled a deeper comprehension of their functionality and their role in promoting collaboration across the mentioned domains. The thesis work entailed a meticulous qualitative study, supplemented by a robust quantitative analysis. Through a critical analysis of the results obtained from both approaches, meaningful conclusions were drawn, ultimately providing valuable insights to address the research question. The objectives of the thesis were carefully formulated to align with the overarching aim, ensuring that their accomplishment would contribute to the achievement of the thesis aim. Consequently, the methodology employed was carefully designed to fulfill these well-defined objectives.

2.1 Qualitative study

The qualitative study for the thesis work included the following elements.

2.1.1 Literature study

Literature study: To gather relevant information and gain an understanding of the thesis scope, a comprehensive literature review was conducted. This involved searching for publications in reputed databases such as SpringerLink, ScienceDirect, Google Scholar, Scopus, and Chalmers University Library. Various keywords were employed during the search, including "3DExperience," "Concurrent Engineering," "PLM systems," "Collaboration," and "Collaborative platform." The Boolean operator "AND" was utilized to refine the search results. For instance, searches were performed on combinations such as "3DExperience AND Collaboration," "3DExperience AND PLM systems," and "Concurrent Engineering AND Collaboration." Due to the scarcity of publications directly related to the topic, no filters were applied based on publication date or number of citations. Each paper's abstract was carefully reviewed, and publications containing relevant information were thoroughly examined. The literature review process was meticulous, ensuring the inclusion of all pertinent findings in the literature study results section.

2.1.2 Interviews

Since the literature study did not provide sufficient information on the thesis topic, it was imperative to conduct interviews with industry experts to gain valuable insights. The main objective of these interviews was to understand the current work culture within the industry, particularly in relation to collaboration between design, equipment/robot simulation, and factory flow. The interviews were categorized into two distinct segments: interviews with designers/simulation engineers and interviews with managers. A semi-structured approach was adopted, allowing for open discussion and the opportunity for further probing and questioning. Two interviews were conducted online, while the other two were conducted in person.

Interviewee A, an expert in automotive fixture design with over 25 years of experience, shared insights gained from working with four different design software programs. Interviewee B, an expert in robot simulation focusing on reachability and accessibility, possessed 16 years of experience and proficiency in five different software programs. Interviewee C, the managing director of Prodtex, brought over 20 years of experience in production and robotics to the table. Lastly, Interviewee D, a manager overseeing a technical team in Dassault Systemes' industry service, drew from 25 years of experience in implementing PLM systems across various companies and industries. The implications derived from these interviews are presented in the results chapter, providing valuable perspectives and industry-specific insights to inform the thesis work.

2.1.3 Documents and courses:

In addition to engaging in a comprehensive analysis of literary sources and conducting interviews with industry experts, we delved into documents and training materials provided by Dassault systems and Prodtex. These resources contained an abundance of information pertaining to the 3DS platform, concurrent engineering, and collaborative working methodologies. They proved to be invaluable in gaining insights into Dassault's unique perspective and approach towards manufacturing, as well as discerning the numerous advantages associated with leveraging the 3DS platform for seamless collaboration. These materials were procured from the Dassault Systems partner portal and their official website. However, it is worth noting that access to these resources is limited to Dassault's employees and partners. Nevertheless, through our affiliation with Prodtex, we were able to obtain and peruse these documents and training materials, further enriching our understanding of the subject matter at hand.

Further, many courses were completed related to 3DS collaboration, factory flow simulation, equipment design, and process flow from 3DExpereince EduSpace. The courses are 1. Get started with the 3DX platform, 2. Get started with 3DX collaborative innovation, 3. Get started with a collaborative designer for CATIA V5, 4. Get started with project planning, 5. Explore the factory simulation engineer role, 6. Explore the plant layout designer role, 7. Explore change manager role, 8. Explore Equipment and Layout engineer role, 9. DELMIA – Brand essentials, 10. CATIA – Brand essentials, 11. SIMULIA – Brand essentials, 12. Solution Architect.

The completion of the aforementioned courses, supplemented by the thorough examination of the accompanying documents, bestowed upon us a profound and comprehensive understanding of the applications and collaborative tools within the 3DS platform. This enhanced comprehension greatly facilitated our analysis of the platform and its inherently collaborative nature. The courses themselves were instrumental in providing us with invaluable hands-on experience, employing a model-based learning approach that allowed for practical application and a deeper understanding of the platform's functionalities. Through these courses, we were able to immerse ourselves in the intricacies of the platform, fostering a heightened level of expertise and insight in our analysis.

2.2 Quantitative analysis

For the quantitative analysis, the thesis team decided to delve into a use case associated with Prodtex. This particular use case would have its focus on design, simulation, and factory flow. However, as our thesis work progressed, an intriguing project emerged within the realm of Prodtex. It became apparent that this project possessed the ideal qualities to serve as an exemplification for our thesis work, offering a fitting solution to our research question. This project proved instrumental in deepening our comprehension of the hands-on collaborative working methodology employed by the 3DS platform, ultimately illuminating its inherent advantages.

2.2.1 Case description: SweMaint project

SweMaint, a prominent Swedish enterprise, operates as a premier provider of maintenance and repair services tailored to wagon owners and various rail freight operators. Within the extensive repertoire of services offered by the company, their workshops specialize in a comprehensive range of operations including preventive wagon maintenance, wheel maintenance, corrective repairs, and an extensive inventory of materials. Notably, one of these workshops is situated in Gothenburg, with a primary focus on the task of wheel maintenance. When worn-out or defective wheels are detached from the wagons, they undergo a series of steps within the workshop. These operations are meticulously carried out to restore the wheels to their optimal condition, ensuring their seamless reintegration into the wagons.

As part of its expansion plans, the company is poised to introduce a new maintenance process known as the 'IS3 process' in their Gothenburg workshop. This procedure involves the removal and disposal of discs from the wheels, followed by assessment and adjustment of the axle based on specific requirements and its current condition. Subsequently, the turned axle undergoes the fitting of a fresh set of discs, rendering the wheelset fully prepared for utilization. Given the novelty of this process, the workshop necessitated the installation of four machines. These machines encompass a pressing machine, an axle-turning machine, a disc-turning machine, and a magnetic particle testing machine. In order to facilitate the smooth flow of operations, a well-organized logistics arrangement was imperative within the designated process area. To handle the substantial weight of the axles and discs, overhead cranes and forklifts were employed, in the existing processes within the workshop. The company had designated a buffer area within the workshop to accommodate the new IS3 process, ensuring optimal efficiency and productivity.

However, the company found itself uncertain about whether the allocated buffer area would be sufficient to accommodate all the machines required for the new IS3 process. Additionally, careful attention needed to be given to the logistics arrangement, ensuring ample space for the movement of parts within the area and providing a comfortable working environment for the operators. Given these considerations, it became imperative to thoroughly analyse the space requirements and devise an optimal layout for the work area, promoting efficient functionality and seamless part movement. Of particular significance was the press machine, which performed two operations within a single cycle. The positioning of the turning machines also demanded careful deliberation, as accessibility to the chip collector by the forklifts was a crucial factor. Due to space constraints, the forklifts were restricted to certain dedicated areas along the periphery, necessitating the appropriate orientation of the turning machines. Furthermore, the company sought to validate the effectiveness of the new process through simulations, ensuring that the desired output could be achieved using the newly acquired machines. With a target of 8-10 wheelsets per day, this validation process would enable SweMaint to gain a comprehensive understanding of the process, identify potential bottlenecks, determine the required number of operators, and validate the logistics arrangement. In light of these requirements, SweMaint sought our assistance in assessing the space requirements, proposing an optimal plant layout, suggesting resources for part movement, and conducting simulation-based validation of the process.

This particular example serves as a compelling illustration of the collaborative nature inherent in the 3DS platform. Prodtex graciously afforded us the opportunity to participate in this project, assigning us the necessary roles within the platform. SweMaint, on the other hand, supplied us with crucial information such as the dimensions of the dedicated workshop area and a 2D drawing depicting the machines involved. While a textual description of the process was provided, it was necessary for us to create simple CAD models for the plant layout. Additionally, a CAD model of an overhead crane for the workshop needed to be developed, with careful attention given to incorporating engineering constraints and kinematics, all of which required simulation. Furthermore, the design of the plant layout was of paramount importance, and conducting a discrete event simulation was indispensable in order to validate the effectiveness of the process.

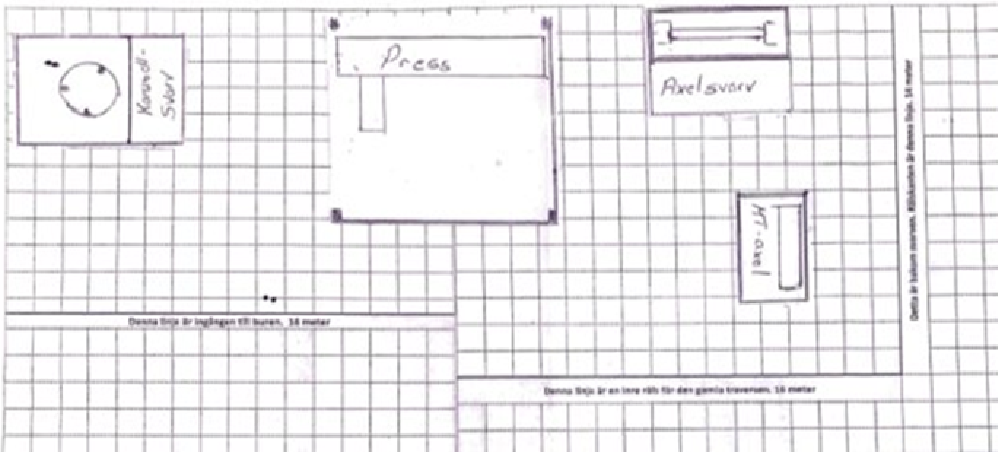

Figure 2.1: Initial layout sketch provided by SweMaint

One of the team members was assigned with 'Factory Simulation Engineer' role which contained Plant Layout Design and Factory Flow Simulation application. The other person was assigned Equipment & Layout Engineer role which contained Part Design Essentials, Equipment Simulation, and Plant Layout Design application along with several other apps. A collaborative space was created for the project in the 3DS platform and work was divided according to the roles. Each undertaking was approached in a collaborative manner, allowing us to gain profound insights into Dassault's manufacturing engineering approach and comprehend the pivotal role played by the 3DS platform in fostering collaborative endeavors.

Through diligent and comprehensive qualitative and quantitative studies, the data acquired from these endeavors are carefully analyzed, leading to the derivation of insightful and meaningful conclusions. These conclusions are instrumental in addressing the research question at hand. Notably, these investigations shed light on the multitude of benefits derived from the seamless collaboration between various domains, including design, equipment/robot simulation, and factory flow, facilitated by the utilization of the 3DS platform. The resulting understanding of these benefits serves as a valuable foundation for suggesting an optimal work structure for teams engaged in collaborative projects utilizing the platform. This work structure aims to foster effective collaboration, enabling teams to leverage the full potential of the 3DS platform in similar endeavors.

Figure 2.2: Wheelsets stored for maintenance

3
Results

A rigorous qualitative and quantitative analysis has been performed, with findings interpreted to address the thesis' objectives. In this chapter, the overview of all the results drawn is presented with relevant visualization.

3.1 Literature Review

In this section, the results from the literature review conducted are presented.

3.1.1 Concurrent engineering & Product Lifecycle Management

This section of the chapter highlights the literature review conducted regarding the project. The content is divided into sections based on the subject being addressed and its implications.

The product development phase in the manufacturing industry is complex due to various factors and constraints. However, embracing the principles of Concurrent Engineering during the design phase can help streamline the process. Concurrent Engineering involves close collaboration between design and manufacturing teams to address different aspects of the product design. The ultimate aim is to reduce rework, lower costs and lead times, and improve the overall quality of the end product [9].

Concurrent Engineering, as defined by the Institute for Defence Analysis, exemplifies a systematic methodology, encompassing the integrated concurrent design of products and their associated processes, which encompass manufacturing and support [9]. Leveraging Concurrent Engineering principles empowers manufacturing industries to effectively incorporate production considerations at the nascent stages of the design process, thus effectively reducing the need for subsequent rework [10]. By intertwining the design and manufacturing aspects from the outset, Concurrent Engineering fosters an environment conducive to streamlining operations and enhancing overall efficiency.

The early engagement of downstream endeavors, such as manufacturing, in the realm of concurrent engineering is commonly referred to as the overlapping of design activities [10]. Rework, a consequence of this overlap, is an inherent aspect that must be taken into consideration when estimating the duration of the design development period. The majority of rework stems from imperfect data that is transmitted during the initial stages of the design process or from the influence of tasks that are regarded as interdependent under the principles of concurrent engineering [10]. While it may appear advantageous to concurrently engage in downstream activities alongside upstream activities in order to reduce product lead time and enhance the quality of the product, this approach requires accurate, error-free information to be shared, resulting in the absence of rework. It has been observed that it is preferable to overlap tasks that are independent of one another during the various phases of product design. The literature [10] also proposes the utilization of a set-based concurrent engineering approach, as opposed to a point-based approach, in order to minimize rework. Set-based concurrent engineering entails having a range of potential solutions at hand before settling on a final design, thereby facilitating the process of narrowing down the most suitable design without having to repeatedly rework a single design, as is typically the case with point-based concurrent engineering. The application of set-based concurrent engineering eliminates the need for extensive rework or the search for new solutions in the event of errors.

According to the literature [12], it is evident that the costs associated with product realization are significantly higher in a concurrent engineering loop compared to a sequential approach. However, in the latter, production costs are proportionately higher due to the lengthy iteration loops that need to be carried out. Concurrent engineering loops embody the principles of team collaboration, fostering increased communication and internal discussions to resolve issues and achieve goals. In order to achieve heightened productivity, the teams assembled should be highly interactive, whether they are physically co-located or connected virtually. Virtual teams transcend the confines of a single building or country, enabling a concurrent engineering loop to operate seamlessly across boundaries. Effective communication is crucial for the success of a concurrent engineering loop, necessitating a robust infrastructure and appropriate tools. In the case of a product design team, the primary focus lies in design discussions, reviews, and error identification, typically conducted during meetings or design review sessions. The utilization of relevant tools is imperative to facilitate smooth and efficient interactions. It is worth noting that the conventional methods and tools employed in traditional industries are in need of improvement, as relying solely on outdated means such as emails or presentations does not adequately convey the intricacies of rework details [12].

The implementation of concurrent engineering principles brings about improvements in various aspects of the design phase and early involvement in manufacturing. However, it necessitates adjustments to the overall product lifecycle management to align with this paradigm shift. The initial step in effecting these changes is gaining a comprehensive understanding of the challenges and requirements within the industry that necessitate such transformations. These include the adoption of virtual design practices, the utilization of predefined modules for configuring new product platforms, fostering effective collaboration to manage rework and mitigate supply chain errors, and establishing a robust knowledge management system that is accessible to all stakeholders to enhance and expedite product development [13]. In conjunction with these initiatives, the implementation of a comprehensive system that integrates all relevant data and information onto a single platform is crucial to facilitate the efficient manufacturing of products. An effective product lifecycle management (PLM) system, coupled with seamless collaboration among stakeholders, opens up greater opportunities to serve customers by creating superior products in less time and at a reduced cost, thereby minimizing manufacturing errors and enhancing overall product quality [13].

Even with the adoption of a comprehensive PLM system, product designers continue to encounter numerous challenges throughout the design process. One of the primary challenges lies in effectively managing the engineering data that is generated. It is crucial to establish better organizational structures and systems for managing engineering data and revisions, ensuring their accessibility and ease of retrieval. Traditional knowledge management systems often prove inadequate in capturing, compiling, and retrieving design knowledge and experiences within a collaborative product design environment [13]. Finding a system that efficiently addresses these challenges remains a formidable task, as the existing solutions primarily cater to document management, engineering data, and workflow management [13].

3.1.2 3DExperience platform

The literature available solely on the 3DExperience platform is very less. It was noticed that no study has been conducted entirely on the 3DExperience platform. The few papers available are based on studies where 3DS has been used in specific projects or applications. In such cases authors have written about the 3DS platform and in very few instances detailed comments are made on the platform and its architecture.

Presently, a large number of software exists in the world of 3D designing in industrial engineering. To mention a few, we have AutoCAD & Inventor by Autodesk, Solid Edge & NX Unigraphics by Siemens, Catia & Solid Works by Dassault Systemes, Microstation & ProjectWise by Bentley Systems, and many more [14]. However, there are few software or tool which enables collaboration between departments in industrial engineering. For example, Vault by Autodesk enables members of a team to share projects and information collaboratively and also connect with suppliers. Teamcenter PLM software by Siemens provides administration and data management throughout the lifecycle of a product. This software allows us to plan, develop, and deliver products with numerous tools present in it. Creo by PTC offers users the chance to work in a multi-CAD environment to avoid inefficiencies and redundancies. The Bentley software provides a collaborative environment that allows content and products to be shared in a more controlled and managed way [14].

With similar intentions, Dassault Systemes has developed the 3DEXPERIENCE platform. "Dassault Systemes refer to it as a business experience platform that will make it easy to create value and customer experiences with an all-in-one software for all departments" [15]. "This online platform provides industry-leading applications for each of the company's departments, from sales marketing to engineering: Design & Engineering, Manufacturing & Production, Simulation, Governance & Lifecycle, 3D Design Experience for Professionals" [14]. "Dassault's 3D experience solution takes the data management platform as the core and builds an enterprise-level platform integrating modeling, simulation, collaboration, and management to boost the digital transformation of enterprises" [16]. Dassault offers a comprehensive life-cycle solution that encompasses a range of software tools for 3D design, analysis, simulation, and business intelligence. These software applications cater to various aspects of the enterprise, such as engineering design, optimization, manufacturing, installation, project management, business operations, and supply chain management. With a diverse array of modules at their disposal, users have the flexibility to select and combine specific ones that align with their unique business requirements [16]. It offers an interactive collaborative environment using 3D design software, analysis, simulation, and intelligence in a single user-friendly interface. In addition to providing economically efficient and streamlined experiences, this alternative also affords considerable advantages in terms of flexibility, adaptability, security, and efficiency, particularly with regards to fostering global collaboration[14]. The platform provides the capacity to integrate the business activities of a corporation and product development processes, placing the client at the center of a system. With 3DExperience, enterprises can bring their stakeholders into the innovation process, contributing to the end-to-end process of creating smart products. The 3DExperience platform facilitates the establishment of social enterprises, wherein customers and external stakeholders are actively engaged in the innovation process[17].

The platform offers various solutions under its 12 industries which include Aerospace & Defense, Architecture, Engineering & Construction, Business services, Cities & Public Services, Consumer Packaged Goods – Retail, Home & Lifestyle, High-Tech, Industrial Equipment, Infrastructure, Energy & Materials, Life Sciences & Healthcare, Marine & Offshore, and Transportation & Mobility [17]. The platform is accessed through specific roles designated by different solutions under each industry. Dassault has made the platform available on-premise, on public cloud or private cloud. The platform has four primary areas that correlate to the four portions of its distinctive logo. These include social and collaborative apps, information intelligence apps, content and simulation apps, and 3D modeling apps. The most robust mechanical design program from Dassault Systèmes, Catia, is available to users in the 3D modeling sector, along with all its distinctive modules, including Part Design, Drafting, Generative Wireframe & Surface, etc. Users of the simulation area have access to the software programs Delmia and Simulia, which are excellent resources for simulating and emulating various systems and designs. Basic tools like notes are available in information intelligence apps. The collaborative section of the 3DExperience Platform is its most interesting feature, as it allows users to connect their work environments through the cloud in a simple way and contact colleagues immediately via chat [14]. The platform offers virtual worlds for consumers and businesses to envision sustainable technologies. This is accomplished with the aid of its high-end software, such as Catia for 3D design, product development, and analysis. Delmia is used for engineering manufacturing processes, which allows us to plan, manage, and take better advantage of the time. Simulia provides realistic simulation and Finite Element Analysis, and Enovia for managing and storing all the information pertaining to materials, geometrics, modifications, or projects, in general. [14].

The teaching environment for the Industry of the Future (IoF) is significantly shaped by the 3DExperience platform. It provides on-cloud teaching resources across several fields, including engineering, design, project management, and other sectors connected to 3DS industries, and delivers a peer-learning experience through a website. By providing access to this vast knowledge base, the platform helps engineers and students gain knowledge and skills that are in line with market demands. Connecting people with shared interests throughout the globe and facilitating seamless knowledge sharing through an easy-to-use interface is a key feature of the platform. By immersing students in real-world case studies and projects in a collaborative setting, 3DS, which emphasizes project-based learning (PBL) as its primary technique, empowers learners. This hands-on method encourages critical thinking and active learning, moving away from passivity and giving students the skills, they need to solve real-world problems. By combining these cutting-edge teaching approaches, the 3DExperience platform serves as a leading force in educating the next generation of professionals for the opportunities and challenges that await them in the exciting world of Industry of the Future (IoF)[14].

''Dassault's 3D experience platform is powerful and can integrate Building Infrastructure Management (BIM) environment to provide highly collaborative method" [16]. On the one hand, the industry requires the use of sophisticated 3D design and simulation tools, and on the other, it needs a flexible, strong, and reliable data management platform. This integrated solution can manage data efficiently over the full product lifetime, from the initial design stage to production, installation, and ongoing maintenance, all on a single, integrated platform. The features that are present in the platform to aid such integration according to the literature[16] are:

1. Cloud-based architecture: This system server stores information about individual projects and 3D models uniformly, rather than a variety of pieces of information scattered throughout each workstation. Hence, no matter where and when users access the system, they are always able to access the relevant and most accurate information to perform their tasks.

2. Manage BIM information in the database: Since traditional Building Information Modelling (BIM) software often uses file-based information storage, maintaining data accessibility outside of the file's physical boundaries can be difficult, creating complexities and inefficiencies. The 3DS platform, in comparison, takes a more complex approach by storing BIM data as discrete components within a single database and structuring all pertinent data pertaining to each component as a separate object. This database-centric method has several benefits, including the ability to browse, query, count, and change

certain BIM data based on the component list without having to access the complete 3D model. The 3DS platform considerably improves data management capabilities and streamlines the retrieval and manipulation of BIM data for numerous design applications in construction tasks by adopting this data organization paradigm.

3. Built-in collaborative work mode: Authorized users are granted access privileges by the cloud-based platform, allowing them to log on to the collaborative setting and actively take part in the project. This platform integrates a variety of roles and cooperative working techniques, including authority management, data version control, object lock security, and a wide range of other features. These features have been painstakingly created to enable smooth real-time online cooperation between people with various professional backgrounds and work teams. For instance, in a project, designers from the structural, bridge, pipeline, and other professions can work together on the same platform to complete real-time design duties. This synchronous modeling function can quickly identify design process flaws and determine whether there is model interference.

4. Integrate a consistent user experience: The system has done a great job of consolidating all of our background data into a single database. This makes it incredibly easy for personnel to share data and work with various software modules without having to worry about data exchange or format conversion. In addition, all the foreground application modules are built on a standardized 3D graphics platform, which ensures uniform procedures and graphical outcomes. As a result, it is possible to streamline the workflow and improve operational efficiency without having to transition between different graphics platforms.

According to the Deputy general manager and chief engineer of China Railway fourth bureau group Mr. Wu Jun, ''The 3D experience platform of Dassault system will become a revolutionary change in our construction field. Before the construction of the project, you can see the 3D integration effect and experience it, effectively solving some mistakes in the design" [16]. Construction progress can be compared with the plan, process nodes can be analyzed, and factors that can affect the progress can be assessed.

The strategic vision of Dassault Systèmes (3DS) effectively accommodates novel product development methodologies and facilitates early customer engagement. The platform serves as a potent catalyst for fostering innovation, affording the opportunity for diverse enterprise stakeholders to actively partake in the innovation process. This collaborative involvement fosters value generation and the creation of intelligent products throughout the entire product lifecycle, encompassing design to eventual recycling [17]. Such an innovative paradigm is poised to exert a substantial influence on engineering practices, heralding a transformative impact on the field. This brings changes from Discipline Collaboration to Social Industry World, Product to Business Modelling, Document Management to Experience Management, Search to Dashboard Intelligence, and Product Attributes to Consumer Experiences. By virtue of its online architecture, the 3DEXPERIENCE environment empowers enterprises to conduct comprehensive testing and evaluation at any stage of a product or service's development lifecycle, thus allowing them to gauge the ultimate experience they are poised to deliver to their customers[17].

In this case study, the 3DExperience platform was employed to conduct the virtual commissioning of a robot cell housing the ABB IRB 4600 robot. In this case study [15], the 3DExperience platform was employed to conduct the virtual commissioning of a robot cell housing the ABB IRB 4600 robot. The company possessed an extensive repository of layout schematics and CAD data, which were readily integrated into the 3DS platform to construct the virtual cell. To complete the simulation, additional machinery, equipment, fixtures, tools, and other crucial components were created using Catia Part Design, Catia Assembly Design, and Delmia Equipment Design. The robot program, encompassing robot positions, as well as speed and acceleration parameters, seamlessly interfaced with the Delmia environment. A key advantage of deploying the 3DExperience platform across the organization was the universal accessibility of all models and parts to various departments. This streamlined collaboration, fostering interdisciplinary cooperation and knowledge sharing, underscores the platform's efficacy in facilitating comprehensive virtual simulations and optimizing overall operational efficiency within the company. ‘’ A big advantage of 3DExperience is that everything is done in the same software environment, when switching between apps only the available functions and buttons change. For example, when a product is constructed in Catia, just switch to a Delmia app and the product follows, and a set of new functions appear” [15]. Another advantage of the platform is that, once the virtual commissioning is carried out the same model can be used for discrete event simulation and other layout analysis.

Even though the 3DExperience platform is a useful tool for virtual commissioning, it is vital to note that its implementation does take some work. Delmia, a part of the 3DExperience package, could run into issues when dealing with intricate robot programming provided directly by robot providers. Before a program may be executed successfully in the simulation environment provided by Delmia, some degree of program simplification is frequently required. Also, important to keep in mind is the possibility of decreased simulation performance and longer initialization times for Delmia. To guarantee smooth and effective operations, these restrictions should be considered when planning and carrying out virtual commissioning duties[15].

During a particular project [18], the 3DX platform was effectively used for capturing and managing requirements, effectively allocating them to various entities involved in the process. The platform also made it easier to establish different configuration features and options based on predetermined technical rules, which finally resulted in the development of a variety of product configurations. Different platform modules, such as the requirement management module, variant management module, version management, and traceability module, effectively supported these functionalities.

The 3DX platform's smooth integration of requirements written in external formats (such as Word and Excel files) together with pertinent images that could be easily loaded into the requirement management application was a notable feature. The setting of features, options, and regulations turned out to be simple chores, which added to the software's general usability and adaptability. Comprehensive training sessions are available, together with well-organized online documentation, to improve users' proficiency. This effectively reinforced understanding and promoted proficiency in using the software. Additionally, the platform's smooth online and CAD interface integration greatly sped up the configuration process. For instance, the instantaneous visibility of a new configuration option in the CAD interface once it was developed in the online interface sped up and simplified the process of creating a product[18].

The 3DExperience platform is an excellent tool for Systems Engineering. The platform may be used to create and manage tests and requirements that can be tracked throughout the whole lifecycle. The definition of functional and component architectures with defined interfaces is also provided, using a model-based approach. To further strengthen your skills in behavior modeling, you can also use dynamic and static models from several engineering disciplines. Additionally, the platform enables you to generate documentation from the items controlled by the 3DS platform and engage in virtual prototyping [19].

3.2 Interviews

In this section, the results from the interview conducted are presented.

3.2.1 Interview with designers:

Based on the insights gathered from the conducted interviews, it has been ascertained that companies generally do not adhere to a standardized set of procedures throughout a project's lifecycle. Depending on the type of project at hand, customary modifications are made as deemed necessary to ensure project completion. The interviewees have observed that this modus operandi has proven to be effective, and thus, they perceive no need for any significant alterations to the existing work structure.

When it comes to forming project teams, the selection process is primarily based on the project's requirements and the specialized skill sets possessed by the individuals. However, it is important to note that team composition may vary depending on the scale and complexity of the project. The team leader assumes the responsibility of assembling the necessary resources, taking into consideration the pertinent questions that arise. As the project progresses and details become clearer, specific tasks are assigned to respective engineers.

In terms of collaboration within current project teams, the interviewee highlights a lack of substantial cooperation between different disciplines, particularly between the robotics and design teams. The standalone robot simulation software employed by numerous robot suppliers does not integrate seamlessly with robots from other suppliers. Consequently, it becomes exceedingly challenging for layout designers to have their designs verified by simulation specialists, as the software utilized differs, necessitating the conversion of data into a STEP file each time. This process is not only time-consuming but also hinders the regular updating of the latest information, often leading to miscommunication. The interviewee emphasizes that there is a significant amount of file conversion required to facilitate usage by different teams. However, there are instances where project teams encounter difficulties accessing various file formats, thereby necessitating the sharing of native file formats.

In terms of knowledge management and PLM (Product Lifecycle Management) systems utilized by the interviewees, they express a strong desire for an enhanced PLM system that effectively handles revisions, purchase orders, and other data management issues. The existing PLM systems they have encountered are notably slow, making it time-consuming to locate files and retrieve necessary data. One interviewee specifically mentions facing numerous challenges with the PLM and knowledge management systems they have worked with, as they are compelled to utilize the system provided by the project company. Consequently, they encounter significant problems and find themselves personally validating data by physically visiting factories or stations within the factories. Furthermore, the interviewee perceives a degradation in the flow of information along the management chain.

The interviewees unanimously agree that communication within the team requires substantial improvement, particularly when it comes to resolving issues. They express a pressing need for a new system that facilitates continuous information updates, along with a shared platform for raising and addressing issues. Regarding the manner in which they present issues to their team members, they have found a method that works well for them. They currently discuss issues during daily stand-up meetings, utilize email correspondence, employ whiteboards, or conduct video meetings with the respective designers, where they showcase their screens to highlight areas requiring rework. The interviewees emphasize the significant lack of communication between different teams, which often results in a significant amount of rework.

Efficient file sharing is crucial in the design process of a product, aiming for a seamless and stress-free experience. However, the interviewees express the need for significant improvements in this area and have encountered numerous issues, including missing data during file conversions. Due to teams working in silos, there is a lack of transparency, and it falls upon the interviewees themselves to stay updated on various project components. They emphasize the importance of collaboration among disciplines such as robot simulation, plant layout, and equipment design, and all engineers from different disciplines to effectively complete projects. The interviewees believe that reducing lead time is always advantageous for any company, and initiating certain tasks concurrently with the design phase can contribute to achieving this goal.

Although the interviewees have limited experience with the 3DExperience platform, they possess some knowledge about it. They mention that the ability to switch between applications or software seamlessly, without the need for reloading files and eliminating the necessity for file conversions, would be a game-changer for the design community. Moreover, they emphasize the need for a mindset shift, as individuals tend to be comfortable with legacy software and require significant motivation to embrace change.

3.2.2 Interview with managers

Based on the interviews conducted by the project team, it can be inferred that both interviewees place significant emphasis on concurrent engineering as a vital principle for digital manufacturing. However, it appears that this principle is not widely employed in many companies, and each interviewee expresses their unique interpretation of concurrent engineering principles that effectively function within their respective organizations. Furthermore, one interviewee suggests that organizations are currently grappling with the decision of the appropriate level at which concurrent engineering principles should be adopted. Notably, both interviewees strongly concur on the necessity of collaboration in automation projects, yet lament the lack of recognition and understanding of its value within companies. Additionally, one interviewee highlights that the key to enhancing efficiency in design projects lies in executing faster iterations following the plan, do, check, and adjust approach.

When assessing a company's level of maturity, interviewee D notes that there is no standardized framework for comparison. Instead, it must be evaluated based on an experience index. Key indicators to consider include the extent of cross-functional disciplines within both project and line organizations. Furthermore, the organization's approach to collaboration can provide valuable insights into its maturity level. Similarly, interviewee C acknowledges the significance of a measurement system to gauge collaboration within organizations. In addition, he suggests that the reduction of lead time, man-hours consumption, number of mistakes, and the approach to design projects can serve as effective metrics for assessing the level of collaboration.

Both interviewees are in agreement regarding the necessity for top management to embrace change and comprehend the advantages of collaboration. Only then can others within the organization grasp and accept the concept. They also acknowledge the challenge of shifting individuals' mindsets, as they tend to find comfort in familiar work methods and often champion legacy software. Additionally, the interviewees emphasize the significance of robust security systems for cloud services. While they have not encountered any issues with the current systems based on their experience, they stress the importance of preparedness for future vulnerabilities.

As for the 3D experience, the interviewees elucidate the value of expertise in assisting other organizations or companies in implementing a system that prioritizes collaboration for digital manufacturing. In this regard, Dassault Systèmes proves to be superior in providing such assistance through their product offerings. The systematic and standardized approach, coupled with a wide range of training programs and collaborative tools available within the 3D-Experience platform, facilitates seamless adaptation to changes and reaps the benefits for companies.

3.3 Collaborative tools

In the following section, the collaborative tools for integration of design and simulation environment are discussed. A brief description of each tool is presented along with its derived benefits for the integration.

3.3.1 3D Dashboard

The 3DDashboard service, an integral component of the 3D-Experience web platform, plays a pivotal role in amalgamating diverse information sources into a bespoke web page that fosters collaboration among multiple stakeholders [20]. This versatile tool empowers users to incorporate a plethora of details, ranging from project status updates and pertinent files to task progress and collaborative spaces, all consolidated within a singular interface.

Undeniably, the 3D Dashboard assumes a paramount role throughout the project lifecycle. It serves as an indispensable hub, encapsulating all requisite details and files essential for seamless project execution. Project leaders, in particular, reap the benefits of effortless oversight, as they can effortlessly monitor the status of models and receive regular project updates. The manifold tabs featured on the dashboard afford an organized framework, facilitating easy navigation and content accessibility. Collaboration is enhanced when stakeholders have access to information, fostering continuous information exchange.

During the case project, the team harnessed the power of the dashboard to streamline file organization, harnessing widgets to showcase various project data and expediting the search for specific files. The centralization of all project-related files, from elemental components to top-level nodes, eradicated the need for laborious file searches, effectively saving valuable time and resources. The strategic placement of diverse widgets on the dashboard expedited the decision-making process, empowering the team to make informed choices promptly.

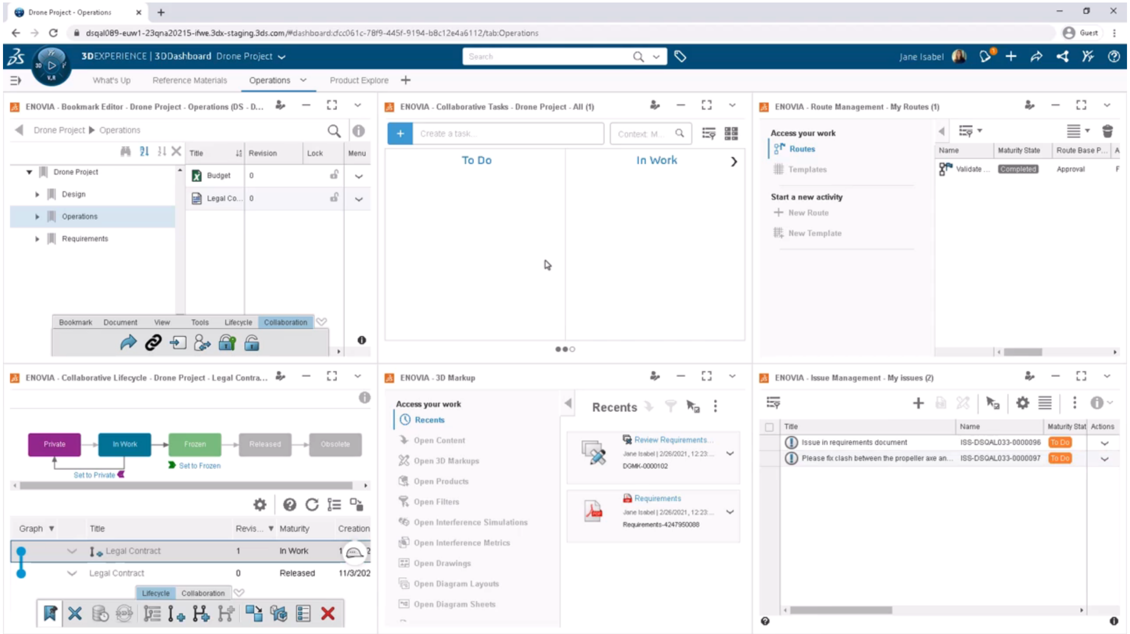

Figure 3.1: Example of a 3D Dashboard window containing several widgets[1]

3.3.2 3D Space

3DSpace is the application that will help the user to manage the collaborative space. A collaborative space is an area where people with different job functions can work together to produce and deliver content. The creator of the collaborative space can give access to other users to collaborate in the space. The content created can be defined into different visibility based on the need.

The 3DSpace application within the 3DEXPERIENCE platform serves as a vital tool for managing collaborative spaces, enabling diverse teams with varying job functions to seamlessly work together in the creation and delivery of content. This collaborative space acts as a virtual hub, fostering a harmonious environment where individuals can synergistically contribute their expertise toward shared goals.

Within the 3DSpace application, the creator of the collaborative space wields the power to grant access and permissions to other users, facilitating seamless collaboration. This means that team members, regardless of their geographical location, can actively participate in the collaborative space, bringing their unique perspectives and skills to the table. By breaking down barriers and bridging gaps, the 3DSpace application empowers teams to achieve remarkable outcomes through collective efforts.

The content generated within the collaborative space can be categorized into different visibility levels, tailored to the specific requirements of the project. This ensures that sensitive information remains secure and accessible only to authorized individuals. By defining content visibility, the 3DSpace application provides a flexible framework that allows for granular control over who can view, edit, or interact with specific elements of the shared content. This not only safeguards sensitive data but also promotes a sense of accountability and transparency within the collaborative space.

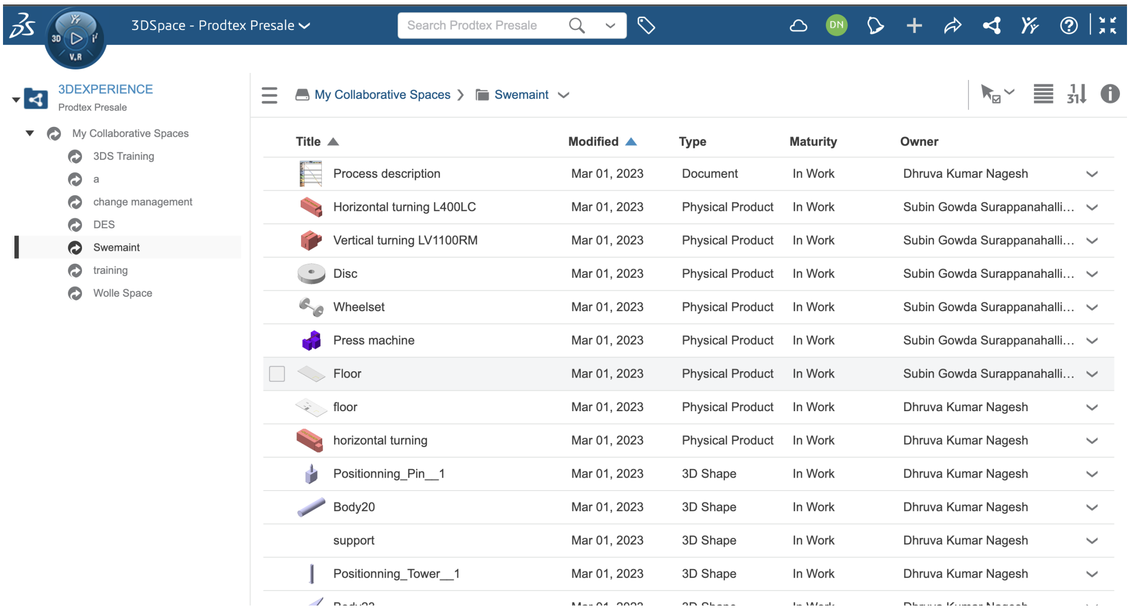

Figure 3.2: Example of a 3D Space window containing the files saved from native application

3.3.3 User groups

User Groups is a service that enhances collaboration and boosts productivity by streamlining the content-sharing process and simplifying the invitation of new users to applications. By granting the team leader exclusive access to the user group, this service empowers them to efficiently manage and allocate team members for new projects. The team leader is afforded the flexibility to assign diverse responsibilities to each team member, ensuring a well-rounded and cohesive approach to project execution.

One of the key advantages of user groups lies in their ability to facilitate seamless communication and coordination among team members. With all members conveniently accessible within the user group, the team leader can effortlessly select and share relevant access with a group of designers simultaneously. This streamlined approach not only saves time but also ensures that the right individuals have the necessary permissions to collaborate effectively on specific projects.

Moreover, user groups prove to be immensely beneficial when it comes to granting permissions to multiple items at once. For instance, they can be utilized to provide individuals with access to collaborative spaces dedicated to specific classes or subjects. This simplifies the process of managing permissions and ensures that relevant individuals have the appropriate level of access to the required resources. By leveraging this service, team leaders can streamline project management processes and foster a more efficient and productive working environment.

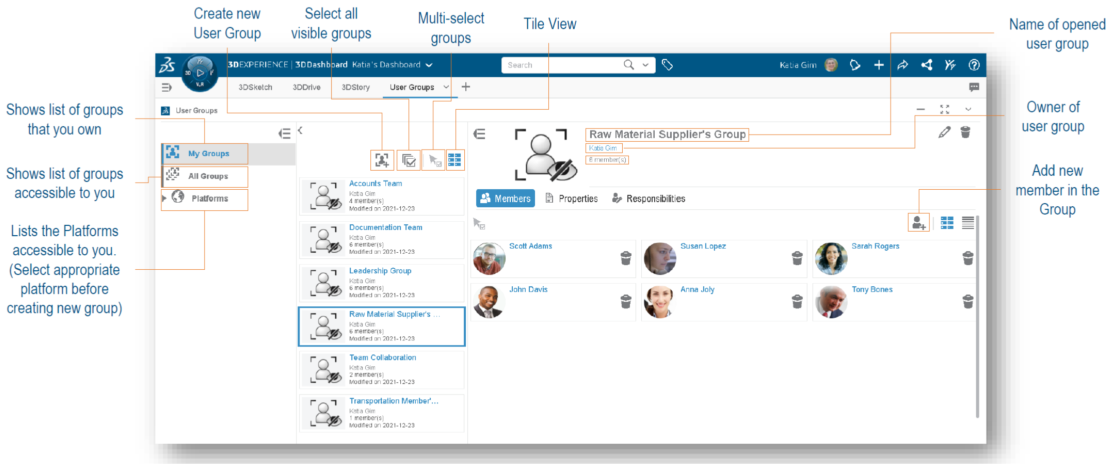

Figure 3.3: Example of a User Groups window with options available to manage users [2]

3.3.4 3D Search

3DSearch, an integral component of the 3DExperience platform, serves as a forefront search service, facilitating users in uncovering pertinent information from diverse sources such as 3DSpace and 3DSwym. This versatile search functionality is accessible both through native applications and the 3D dashboard web interface. To enhance the precision of search results, the 3DExperience platform offers a sophisticated filtering mechanism known as 6WTags. These filters enable users to streamline their search outcomes based on six distinct categories: 'who', 'when', 'what', 'where', 'why', and 'how'.

This invaluable feature proves especially valuable when scouring through a vast repository of files stored in 3DDrive, as it assists in locating the desired model or document amidst the abundance of data. Users frequently rely on 3DSearch to swiftly locate specific files by utilizing their respective file names within the extensive file collection, be it files created by themselves or by other team members. As files are seamlessly saved to the cloud upon the designer's native application, they become readily accessible to other users who can effortlessly retrieve them through the intuitive 3DSearch functionality.

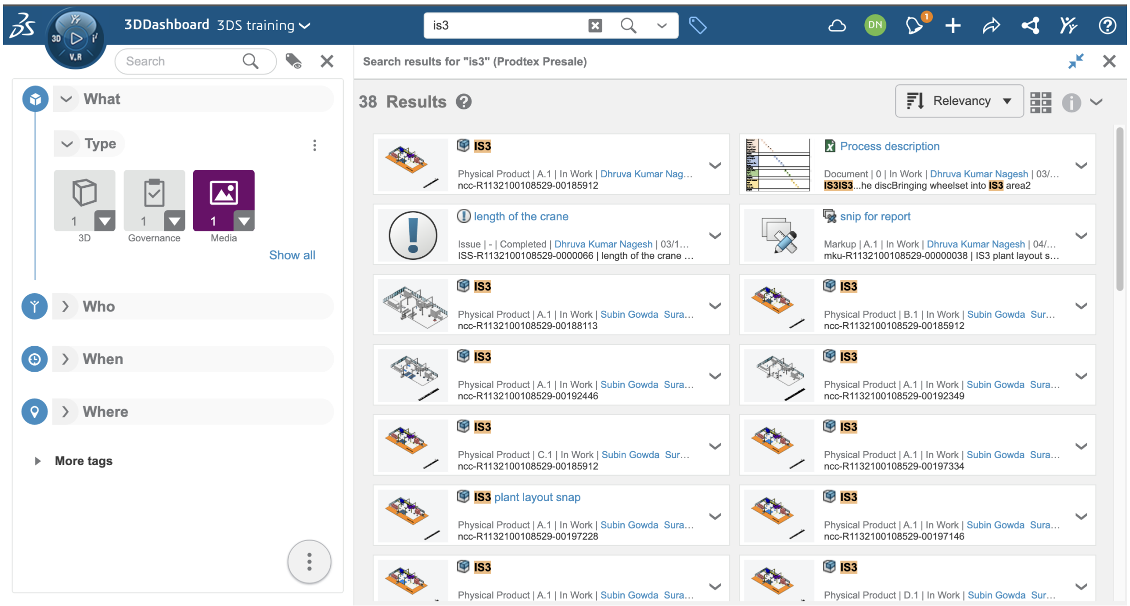

Figure 3.4: Example of 3D Search window with 6W Tags used for filtering the search

3.3.5 Bookmark Editor

Despite all files and 3D models being stored within the 3DSpace, locating specific files can prove to be a daunting task. The 3D models stored in 3DSpace exist as individual elements, resulting in an overwhelming accumulation of files. Identifying the main node amidst this sea of files can be a challenging endeavor. Consequently, the 3D-Experience platform offers a valuable tool known as the Bookmark Editor, which aids in the organization of files based on user preferences. Accessible via both the browser and native application, the Bookmark Editor serves as a facilitator rather than a storage repository, enabling users to arrange and conveniently access content within the collaborative space. Users have the freedom to add revisions and top nodes of models to bookmark folders, ensuring effortless accessibility.

While models created by one user can be accessed by others in 3DSpace, discerning the correct version of a file can pose difficulties. Designers possess the ability to effortlessly modify files, with these changes being instantaneously reflected in the respective files. Consequently, other designers can access the most up-to-date versions without concerns of outdated information impeding their progress.

During the case project, the project team extensively utilized the Bookmark Editor tools. The benefits derived from this tool were manifold, including the consolidation of all top node files in a centralized location, simplifying access for all team members. The ability to store different file versions within a single repository streamlined collaboration, allowing team members to work on the specific files they required. Given that team members worked with diverse applications, the seamless transfer of files and simplified conversion processes alleviated potential complications. Furthermore, the meticulous organization of files from the inception of the creation process effectively eradicated the need for time-consuming file searches.

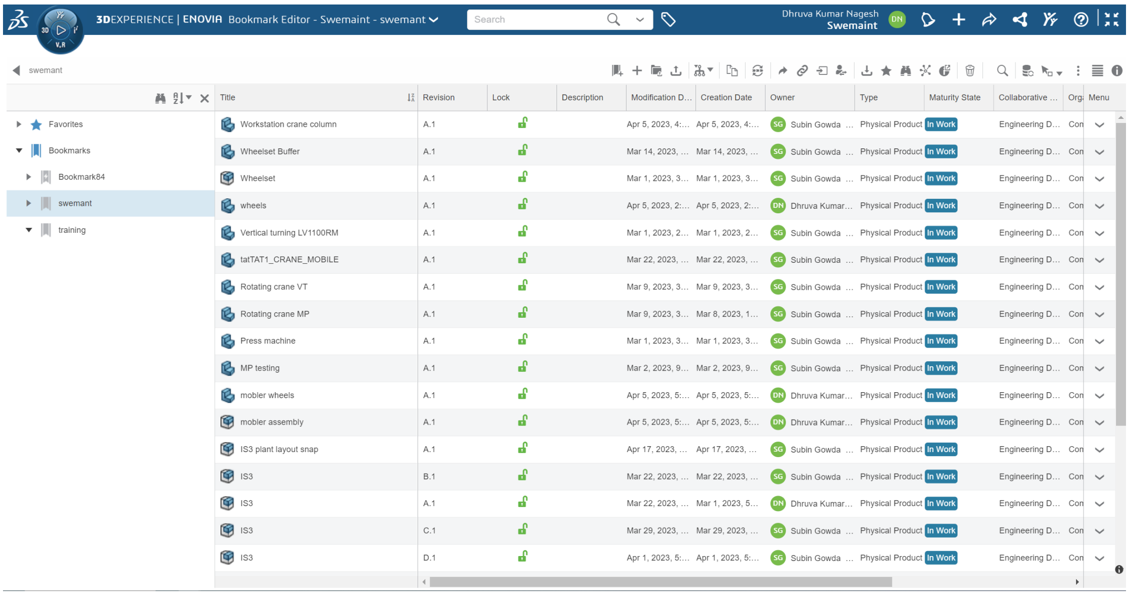

Figure 3.5: Example of a BookMark Editor window used to organize the file needed for case project

3.3.6 3DSwym

In the expansive realm of the 3D-Experience cloud platform, an exceptional option known as 3DSwym unveils itself, bestowing upon users the ability to cultivate a dynamic social innovation environment that engenders the active participation of all stakeholders involved. This remarkable service empowers stakeholders to showcase their work within this nurturing platform, while concurrently receiving real-time updates on content developments. The integration of 3DSwym into the organizational framework augments the company's agility and fosters a culture of innovation, thanks to its provision of cross-disciplinary collaboration avenues and the provision of intuitive content creation tools that facilitate seamless social interactions.

The 3DSwym service serves as an invaluable resource, enabling users to delve deeper into their fields of interest by posing thought-provoking questions to fellow users who possess expertise in the respective domains. Simultaneously, users have the opportunity to peruse the wealth of content already available within the home feed, thereby expanding their knowledge base. Furthermore, this interactive and unstructured service actively nurtures collaboration by affording users the opportunity to contribute and engage with the community. Users can freely post content, articulating their design concepts or ideas in the form of engaging blog entries, while also availing themselves to assist others by responding to their queries. The inherent flexibility and interactivity of 3DSwym serve as catalysts for a vibrant and collaborative ecosystem.

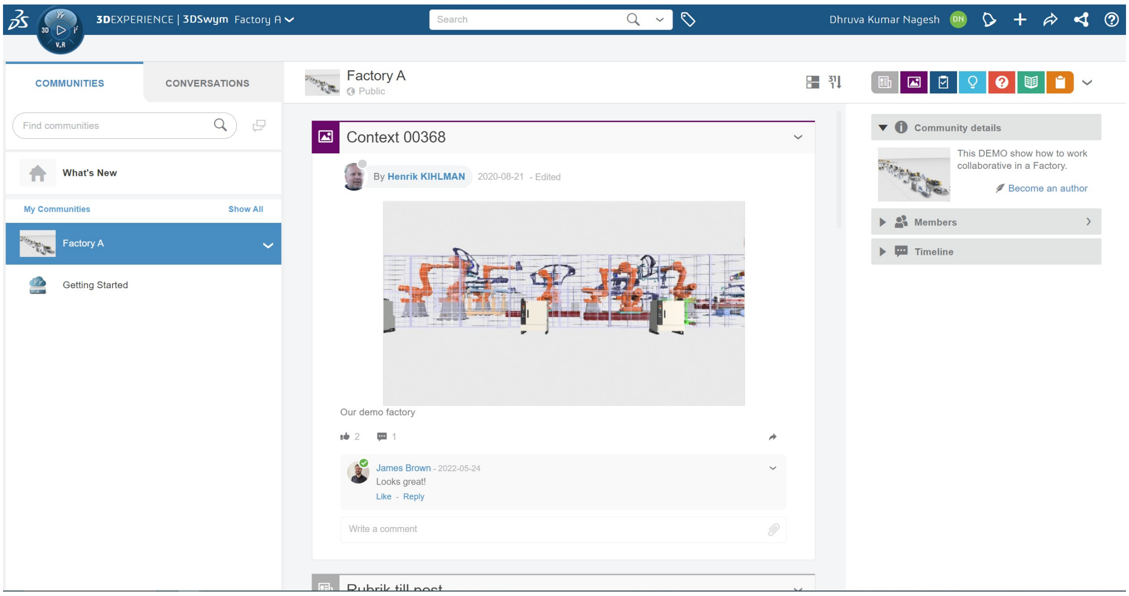

Figure 3.6: Example of a 3D Swym Window with various options available

3.3.7 3D Markup & 3D Play

Within the 3D-Experience web interface platform, resides remarkable applications known as 3D Markup & 3D Play, which empower users to conduct meticulous model reviews without the need to load the main file. This innovative functionality enables reviewers to perform precise measurements, identify areas requiring corrections, delve into intricate details by zooming, and even create visually captivating slides to share with designers.

Undoubtedly, 3D Markup & 3D Play proves to be an invaluable asset during the model review process, streamlining the transfer of essential information. Reviewers are liberated from the burdensome necessity of acquiring dedicated software or converting files to review the models, as the application seamlessly keeps the models up to date with the latest changes. This mode of operation fosters collaboration among team members, effectively mitigating the unnecessary waste of time and resources.

During the case project, the team harnessed the power of 3D Markup & 3D Play to meticulously measure and verify the dimensions of the model, while also leveraging its capabilities to identify and rectify errors present within the models. The plant layout engineer, found great value in the application, employing its functionality to accurately measure the length of cranes and validate their placement. The factory flow simulation engineer utilized the 3D Play application to verify and present the obtained simulation to the reviewers. This approach eliminated the need to load files during discussions, saving valuable time. By leveraging 3D Markup, the team successfully circumvented the complexities associated with installing dedicated applications for model validation. Furthermore, the project team capitalized on the application's capacity to create slides and annotate different areas of the models, proving to be indispensable during meetings with stakeholders, where clear visual communication was paramount.

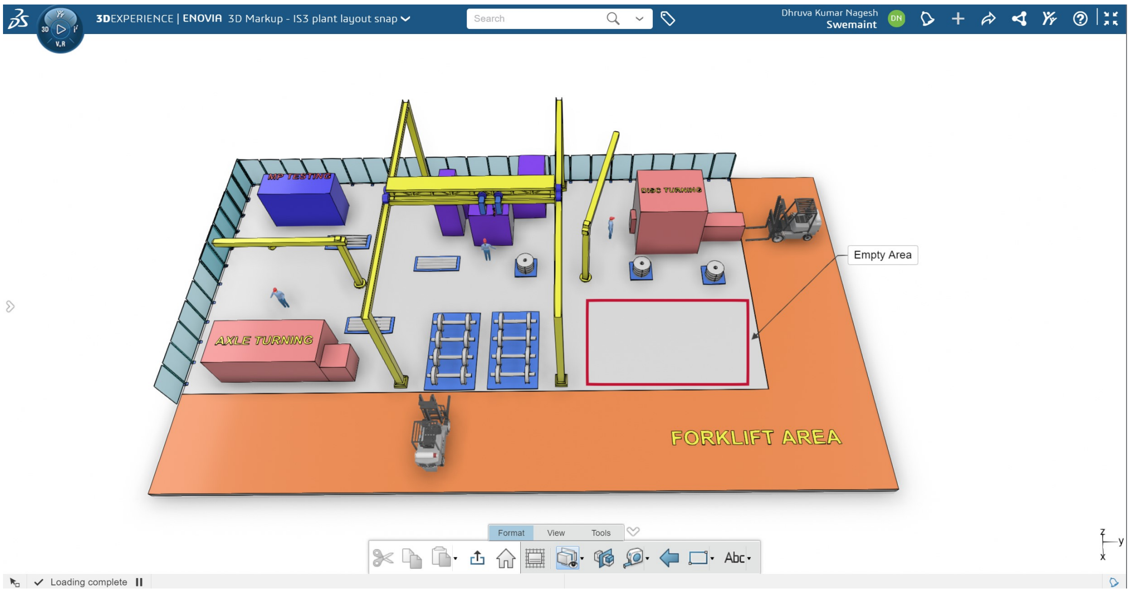

Figure 3.7: Example of a 3D Markup Window used in highlighting and annotating particular area in case project

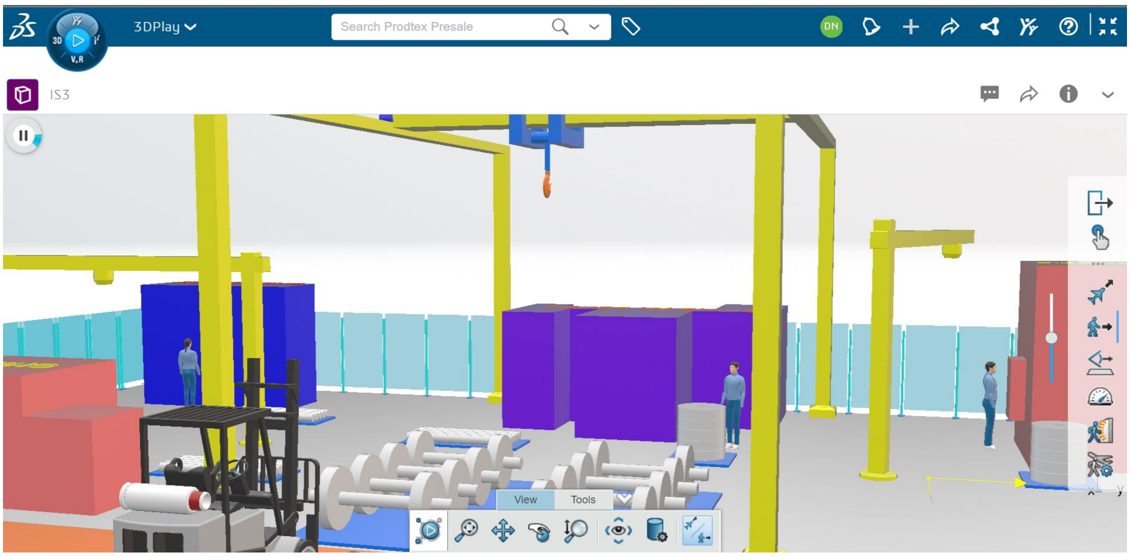

Figure 3.8: Example of a 3D Play Window used for navigating through the case project model

3.3.8 Issue management

Issue management is a valuable service that empowers users to efficiently log and track problems, facilitating effective resolution within project management. While this service bears similarities to traditional issue management practices employed across various industries, its integration within the cloud platform offers distinct advantages. One notable benefit is the seamless accessibility of relevant files, eliminating the cumbersome processes of file conversion and transfer. Users can effortlessly retrieve and work with the necessary documents, streamlining their workflow and saving valuable time.

Moreover, the incorporation of 3D markup within the issue management process enhances the clarity and precision of issue identification. Design flaws and concerns can be visually highlighted, providing a comprehensive and detailed description to the assigned user. This visual representation not only expedites issue comprehension but also ensures that all stakeholders are on the same page, fostering effective collaboration and problem-solving.

Another significant advantage of utilizing a cloud-based issue management service is the creation of a seamless collaboration loop. With all users operating within a single platform, there is no need to switch between different software to address or report issues. This consolidated approach streamlines communication, enabling prompt and efficient issue resolution. The collaborative nature of the platform encourages active participation from team members, facilitating a smooth and synchronized workflow.

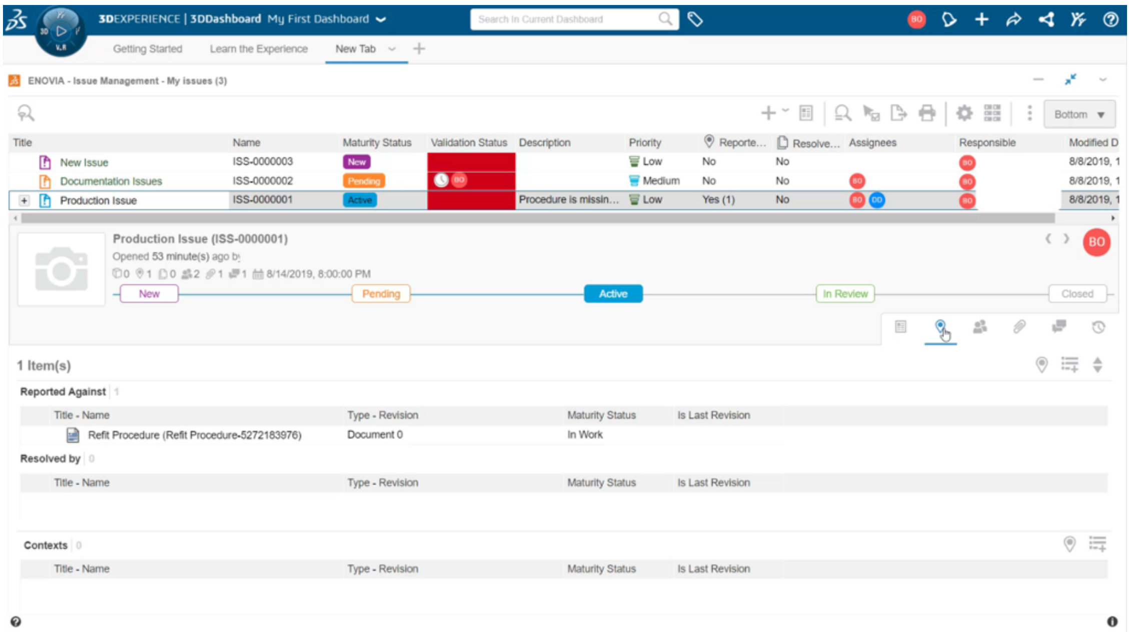

Figure 3.9: Example of an Issue Management window containing issues to be addressed [3]

3.3.9 Change execution

Change execution is a dashboard widget that is used to create and manage change actions. Change actions are the object that specifies a task to carry out change process activities in 3DExperience applications[21]. Using this widget, users get a comprehensive overview of all assigned change actions, thereby streamlining the change management process and providing a centralized platform for processing these tasks. The widget's intuitive interface simplifies the creation, tracking, and definition of requisite changes, allowing users to seamlessly propose modifications or operate within the context of a change action. Moreover, Change Execution can be seamlessly configured to promptly notify users, acting as assignees, of essential alterations to the model or file, as well as any changes in the maturity of change actions. Consequently, this feature ensures that all users remain interconnected, fostering a collaborative environment and facilitating the swift and reliable transfer of critical information.

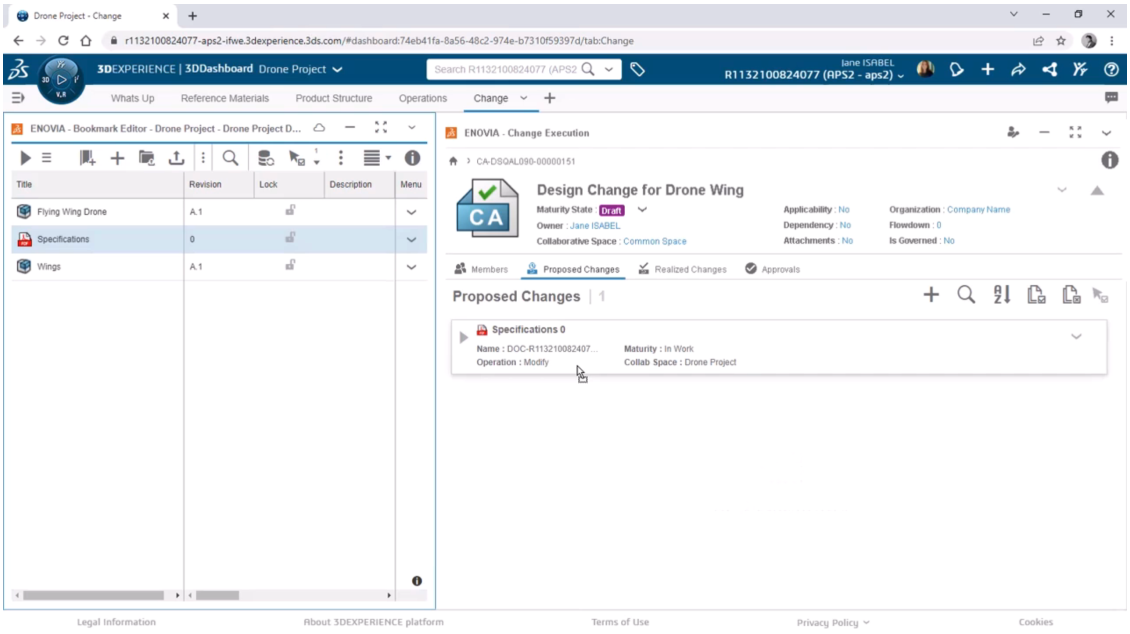

Figure 3.10: Example of a Change Execution window [1]

3.3.10 Collaborative Tasks & 3D Lean

In the qualitative studies, interviewees emphasized the significance of Jira software in monitoring tasks within large organizations. The functionalities of this software bear a striking resemblance to the Collaborative tasks along with 3DLean found in the 3DS platform. As a result, the subsequent paragraphs will provide a concise overview of Jira, followed by an exploration of Collaborative tasks and 3DLean together.

In modern-day large organizations, Jira stands as a formidable software solution, firmly rooted in the principles of Agile methodology. Its widespread utilization can be attributed to its prowess in project monitoring and people management. This software boasts a meticulously designed array of user-friendly tools, tailored to effectively oversee tasks and foster collaboration within organizational settings.

In order to gain a comprehensive understanding of Jira's functionality, it is essential to delve into its organizational structure and the diverse roles within the software. The structure primarily comprises a basic unit known as a Squad, which consists of cross-functional members who are dedicated to a specific area or mission. Multiple squads then come together to form a Group, typically focusing on a specific aspect of a project. Several of these groups collectively constitute a Domain, which is responsible for overseeing a particular project.

To effectively manage this structure, individuals are assigned specific roles. At the foundational level, Scrum masters play a crucial role in facilitating day-to-day collaboration and monitoring activities within their respective squads. Each squad is led by a Product Owner, who determines the squad's priorities and functionalities. The Group is headed by a Group Leader, responsible for resource allocation and the overall management of the squads within the group. Lastly, a Domain Leader assumes the responsibility of overseeing and leading a domain.

Underpinning this structure and the roles within it is a methodology that relies on a series of significant events, known as ceremonies. Among these, the sprint takes center stage, serving as a prominent cornerstone. The use of sprints ensures a continuous loop of task management on the Scrum boards. By incorporating feedback loops within these sprints, tasks are expedited, leading to accelerated completion and the swift alignment of all team members. One of the most invaluable features of this software lies in its ability to facilitate the seamless management of daily tasks and assignments. The Scrum board, adorned with an intuitive interface, elegantly divides tasks into categories such as 'to do', 'doing', 'in review', 'blocked', and 'done'. The daily meetings are conducted to discuss the content on these scrum boards. This streamlined categorization allows for effortless comprehension of requirements and fosters efficient collaboration amongst team members. Additionally, Jira provides an array of key performance indicators (KPIs) that contribute to a comprehensive understanding of task progress, blocked tasks, and pertinent information related to versions and changes. These KPIs include sprint health, sprint burndown, blocked issues, version reports, and more. By leveraging these indicators, users can easily visualize the progress of tasks, identify any obstacles or blocked tasks, and gather valuable insights regarding versions and changes.

1. **Collaborative tasks**

   The 3DExperience platform offers a tool called collaborative task, enabling efficient task management and assignment to users based on their respective areas of expertise. This application bears a resemblance to Jira, a widely adopted task management tool in various industries. The collaborative tasks application facilitates the visualization, organization, and real-time updates of tasks, employing a Kanban-style column layout. By incorporating this feature, the need for external task management services is eliminated, streamlining the overall workflow. The board consists of three columns for 'to-do', 'in-work', and 'completed'. Within the app, users have the ability to create tasks and assign them to either themselves or specific individuals. Furthermore, tasks can be enriched by attaching relevant documents, setting completion levels, assigning priorities, and establishing estimated completion dates. These options, among many others, provide users with comprehensive control over task management, ensuring clarity and facilitating efficient progress tracking.

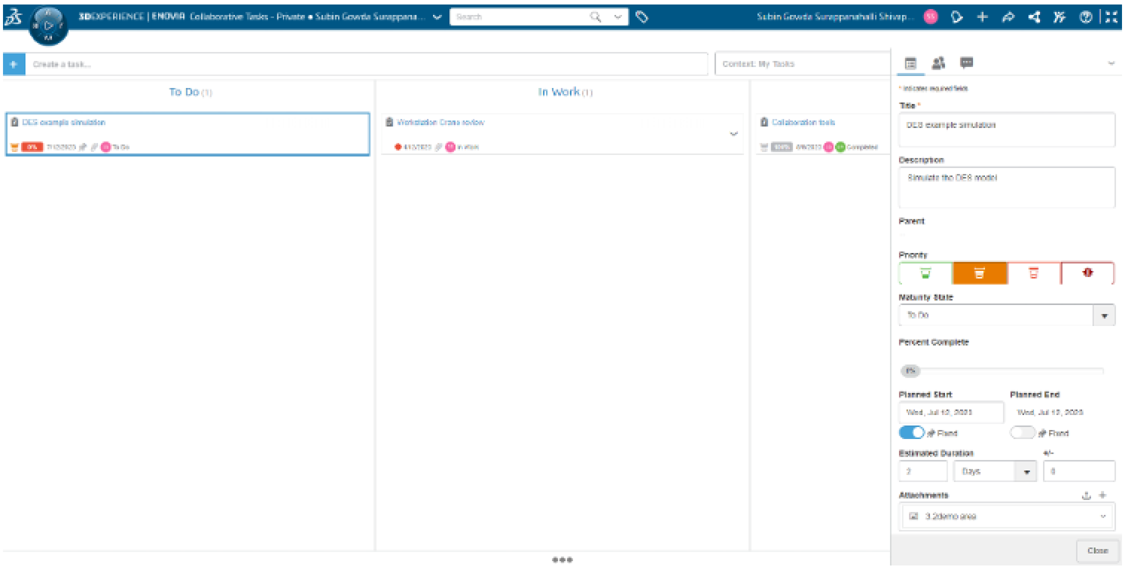

Figure 3.11: Example of a Collaborative task window containing various options to create and manage tasks

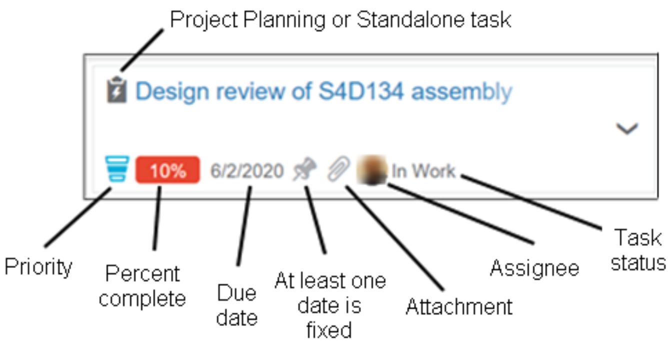

Figure 3.12: Example of different Task options available [4]

2. **3D Lean**
3DLean is an innovative widget app designed to enhance the meeting environment within organizations. Built on the principles of lean teamwork, the app focuses on fostering engagement, revealing insights, and driving continuous improvement. With the aim of enhancing the overall meeting experience, 3DLean offers 10 specialized tools known as "Leangets." Each Leanget serves a specific purpose, covering all essential aspects required for effective meetings of any kind. These Leangets include Team (for the addition and management of team members), Action Log (for displaying and managing actions), Problem Log (for displaying and managing problems), KPI (providing the ability to

define, visualize, and track progress), Web Page (for displaying web content), Sketch (enabling the creation of sketches and annotations), PDF Viewer, Picture Viewer, Player (for playing videos), and 3DPlay (for displaying 3D models).

By utilizing these tools, users can create a virtual "team board" that resembles the traditional whiteboard commonly used in meetings. 3DLean provides lean templates that can be used to create the team board, although customization based on the specific team and meeting type is highly recommended. Each Leanget can be customized as per individual needs. Additionally, the app offers several templates for analysis and organization purposes. Some notable templates include the Ishikawa diagram, 5 Why?, SWOT analysis (assessing strengths, weaknesses, opportunities, and threats), Starfish diagram, Eisenhower matrix, Project charter, Daily meeting, Scrum board, and Work organization, among others. Each template serves a specific application, and users also have the flexibility to create their own templates using the available Lean gets.

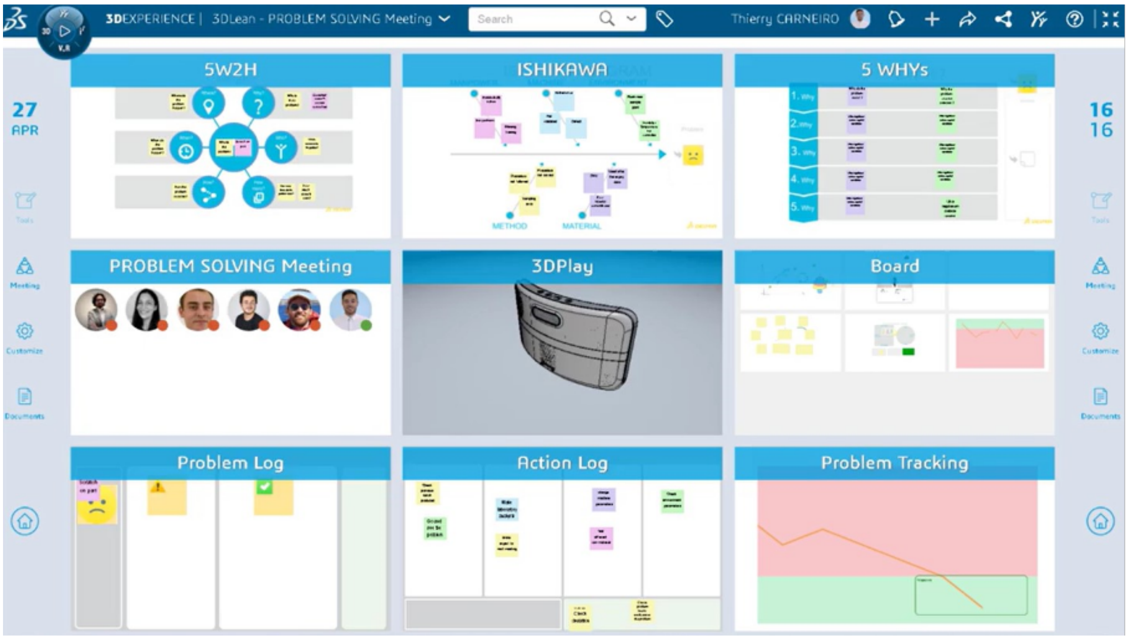

Figure 3.13: Example of a 3D Lean window containing the team board [5]

The seamless and visually appealing interface of the app greatly enhances the effectiveness of meetings, encouraging active participation and robust discussions. Additionally, the utilization of templates enables swift analysis, assignment, and resolution of tasks, leading to a reduction in meeting duration. Certain Leangets, such as 3DPlay, PDF Viewer, Sketch, Action Log, and Problem Log, prove to be particularly valuable in facilitating collaboration between designers and simulation engineers. The 3DPlay tool allows for easy analysis of 3D models within the team board, while the Sketch tool enables annotations to be made seamlessly. Screenshots, sticky notes, and other outcomes generated during meetings are automatically documented, ensuring easy accessibility for future reference and follow-up in subsequent meetings.

When 3DLean is effectively utilized in conjunction with Collaborative tasks, the app fosters enhanced collaboration among cross-functional engineers. This proves especially beneficial in scenarios where designers and simulation engineers collaborate, as the app streamlines communication and promotes efficient information sharing throughout the project lifecycle.

3.3.11 Collaborative lifecycle

Collaborative Lifecycle provides services for managing the content lifecycle within the 3DEXPERIENCE platform, facilitating the global product development process. This dynamic tool, conveniently accessible as a widget, can be effortlessly integrated into the platform's dashboard by means of a simple drag-and-drop action. A Collaborative Lifecycle platform allows one to create, modify, open, save, duplicate, iterate, version, lock/unlock, and delete content with ease.
The collaboration lifecycle in the 3DX platform provides several benefits. to effortlessly monitor the status of CAD models and documents, streamline workflows, enhance project execution efficiency, and improve decision-making processes. This ensures that vital information is readily accessible and utilized effectively. This becomes particularly crucial in large-scale projects where continuous iterations are performed, as even small details hold significant value. By utilizing the collaboration lifecycle, teams can effectively manage and leverage these details, leading to improved project outcomes.

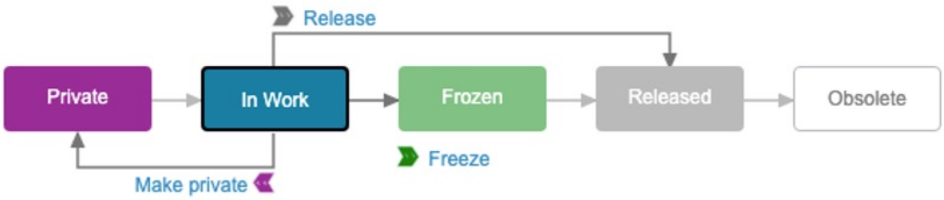

Figure 3.14: Example of a Collaborative lifecycle maturity graph

The above graph is composed of distinct elements, each of which signifies a specific state of maturity. The private state denotes the initial phase in which a designer starts the creation of a model. The "in work" state, on the other hand, represents the ongoing progress of the model. The frozen state, meanwhile, indicates that the model has reached a stage where it necessitates review and subsequent submission to the relevant team member. Should any modifications be deemed necessary during the review process, the file is returned for the required adjustments. Once all the alterations have been successfully implemented, the model can either proceed directly to the release state or be frozen once again for further review. The release state signifies the final stage, wherein all model parameters and definitions have been accepted, and no further changes are either possible or required. Finally, the obsolete state denotes a scenario in which the defined model is no longer relevant to the project and must be eliminated from the entire lifecycle.

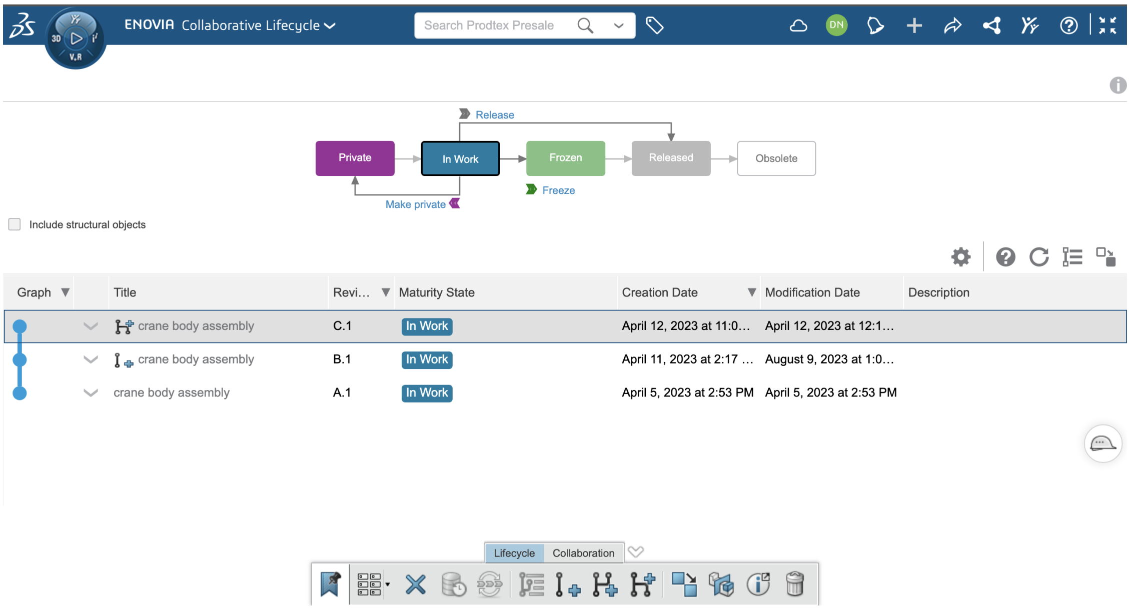

Figure 3.15: Example of a Collaborative lifecycle window containing different options

3.3.12 Collaboration and approvals

The Collaboration and Approval function integrates the functionalities of Business Process Service (BPS), facilitating user interface interaction and object management across various applications. Its primary purpose is to foster collaboration among team members while ensuring controlled access to content. BPS serves as a versatile application that offers customizable user interfaces and schemas, catering to both internal stakeholders and external entities like suppliers, enabling seamless collaboration while maintaining content access controls. Additionally, BPS establishes a comprehensive framework that incorporates a metrics reporting capability, enabling performance assessment based on product content. It encompasses the Application Exchange Framework, Common components, Team, and Business metrics module. This solution proves particularly valuable when outsourcing tasks to external suppliers. For instance, in scenarios where resource limitations hinder in-house robot programming, outsourcing the task can significantly enhance efficiency.

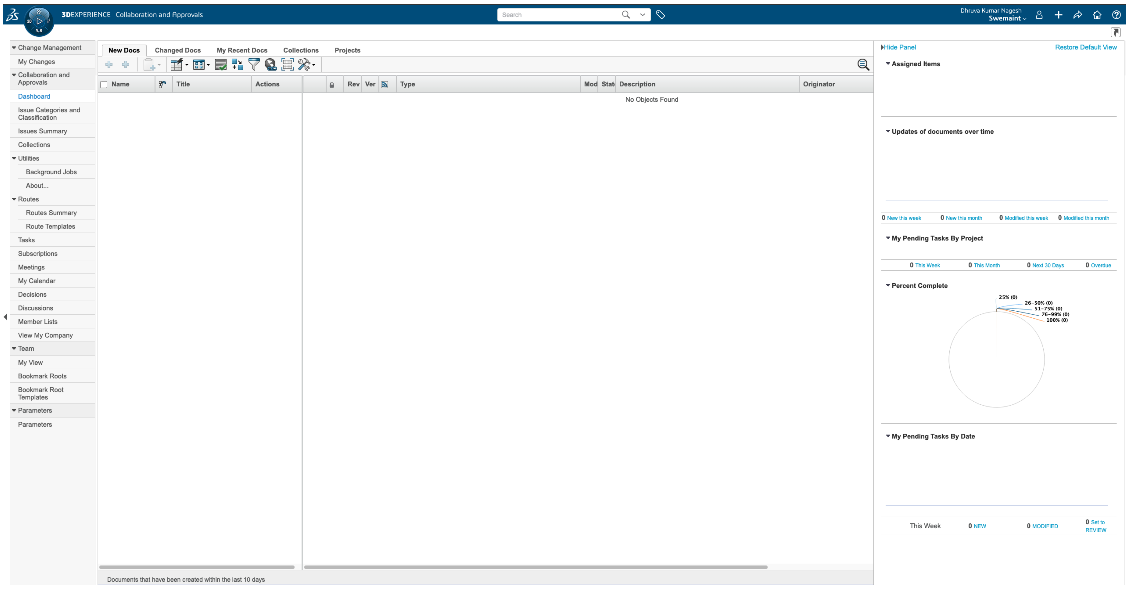

Figure 3.16: Example of a Collaboration and approvals window

3.4 Work Structure

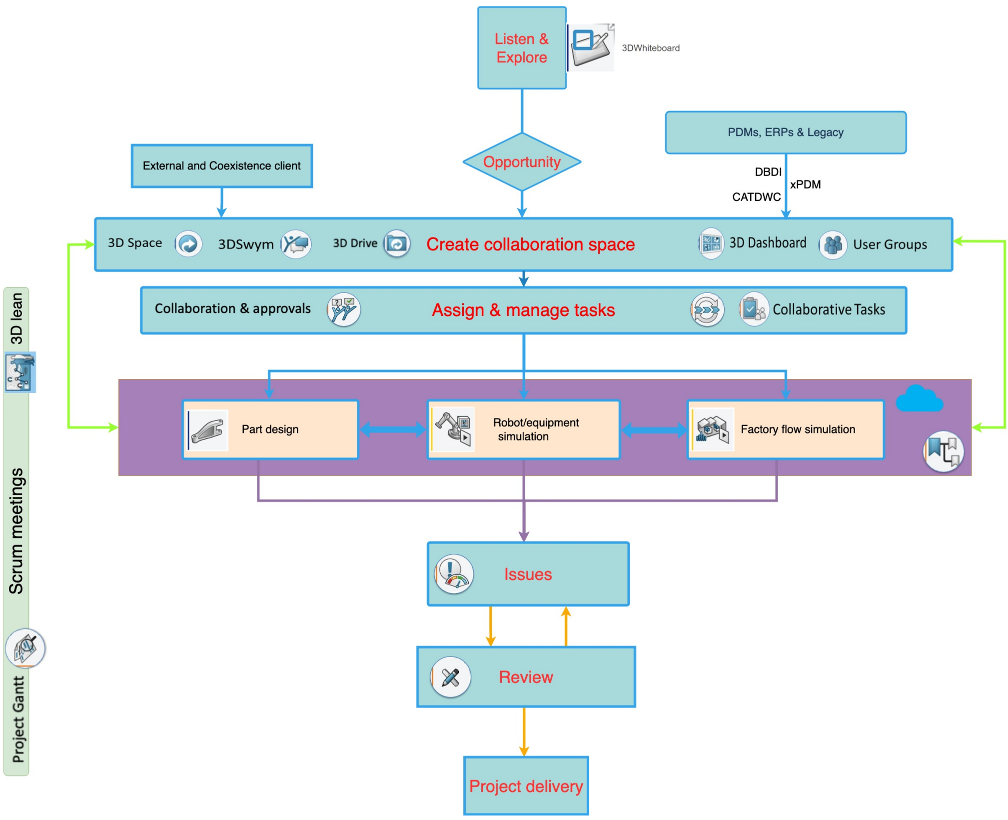

Figure 3.17: Work structure proposed by the thesis team

The work structure outlined above is founded upon an extensive literature review and a series of insightful interviews. This comprehensive investigation enabled a thorough understanding of the current work structure, taking into consideration the distinctive approach adopted by Dassault, which aligns with its core values and leverages key principles. The work structure was further shaped by insights gained from a case study conducted by the project team.

During the formulation of the workflow, certain assumptions were made. Firstly, it was assumed that the projects examined in this study pertain to the domains of robotics, equipment design, and factory layout. Secondly, the team size was estimated to consist of 3 to 4 individuals. It is important to note that the proposed work structure serves as a template and a comprehensive solution, facilitating effective collaboration across these three disciplines.

The initial phase of any project commences with the articulation of a problem statement by the company. This serves as a catalyst for in-depth discussions aimed at exploring the underlying idea and the value that the team can contribute toward resolving the identified challenge. Upon assuming responsibility for problem resolution, the subsequent phase necessitates the delineation of customary prerequisites to be met by both the team and the organization throughout the project.

In scenarios where pre-existing models from customers or suppliers are available, the migration of data to the 3DS platform is facilitated. The 3DS platform offers a range of options for file conversions, ensuring seamless integration during the migration process. Additionally, any required software for the project can be seamlessly integrated with the 3DS platform, further enhancing its functionality and capabilities.

Following this, the formation of a team becomes necessary to propel the project forward. The establishment of a collaborative workspace becomes important in fostering effective teamwork. To facilitate this, obtaining the necessary licensing to access the 3D-Experience platform is essential. Furthermore, specific roles must be defined to ensure seamless coordination among the three disciplines involved. These roles encompass the Equipment & Layout Engineer, Robotics Simulation Engineer, Factory Simulation Engineer, and, crucially, the Team Leader in the capacity of a Platform Manager. These roles serve as the fundamental prerequisites for successfully executing the project. To foster a more collaborative environment, the project leader has the capability to grant varying levels of visibility to all stakeholders. This enables access to be extended to individuals based on their respective roles and responsibilities, ensuring a cohesive and inclusive work environment. 3DS offers the functionality to seamlessly integrate outsourced tasks through the Collaborations and Approvals application. This feature enables efficient monitoring of metrics and tracking of various task aspects. Moreover, it provides restricted access to suppliers, ensuring controlled content access within the 3DS platform.

Upon acquiring all the necessary software requirements, the team leader takes the responsibility of creating a 3D Dashboard on the home page of the 3D Experience

Platform. Simultaneously, a Collaborative Space dedicated exclusively to the project at hand is established using the 3D Space widget, which can be accessed by clicking on the compass. To facilitate smooth collaboration, the Team Leader, with the aid of User groups accessed through the User Groups widget, efficiently manages the team members selected for the project, granting them access to the dashboard and the designated 3D workspace. Subsequently, the Team Leader proceeds to assign tasks to each team member within the collaborative space, utilizing the Collaborative Tasks widget added to the dashboard from the menu.

The execution of these tasks is guided by the discussions conducted during regular stand-up meetings. To facilitate these discussions, the team can leverage the 3D Lean service provided by 3DS, utilizing a digital whiteboard to gather and organize thoughts and ideas. This enables the team to collaboratively brainstorm and strategize during meetings. Additionally, the team leader, in collaboration with team members, can utilize the Project Gantt widget to create a comprehensive timeline overview for the project. This allows for effective project management and ensures a clear understanding of the project's progress and milestones.

By storing all project-generated data within a unified drive, accessibility for all team members is greatly simplified. This eliminates the need for file conversions and reduces the challenges associated with file sharing. The streamlined process ensures that team members can easily access and collaborate on project data, promoting efficient workflow and seamless information exchange. The team members, upon receiving their assigned tasks, commence their work by utilizing the dedicated native application, accessible through the application menu when clicking on the compass. These applications operate on the computer rather than the browser, necessitating installations. During the process of creating models, designers have the option to save their work within the native application, with the data securely stored in the cloud service provided by the 3D Experience platform. The comprehensive accessibility offered by 3DS significantly simplifies the navigation between different applications, making the process seamless and hassle-free. Designers can effortlessly switch between various applications, such as equipment design and part design, by simply selecting the desired file and clicking on the corresponding application from the application menu. This streamlined workflow allows designers to efficiently transition between tasks, enhancing productivity. Additionally, designers can access their saved files from the 3D Drive, conveniently available on the 3DS platform. To streamline the search for relevant files amidst the abundance of data, it is advisable to employ the Bookmark Editor widget from the application menu, facilitating the organization of frequently accessed files.

Upon completion of the assigned tasks, team members possess the capability to update the maturity status of the models using the Collaborative Lifecycle widget or by altering the maturity status of the model or file from the file information, thereby notifying relevant team members of subsequent tasks. This continuous loop of collaboration fosters a transparent working environment, enabling effective communication and coordination. During the review process, the team member shall use the 3D Markup widget to review the models, any identified issues or required corrections are documented by marking and creating slides or by capturing an image from the available options in the 3D Markup widget. This data is then added to the issue management application. The relevant issues, accompanied by detailed descriptions and associated files, are made readily available to the assigned team member responsible for addressing them. Once the necessary corrections have been made, the model undergoes another round of review before reaching the release maturity state.

Upon achieving the desired level of maturity and finalizing all the models, the project is deemed complete. Throughout the entire design process, continuous information transfer occurs among all stakeholders, resulting in a reduction in rework and lead time. This constant flow of information ensures that all stakeholders are well-informed and actively engaged, contributing to the overall success of the project.

3.5 Organizational needs

The acquisition of the software license from Dassault would be a crucial step in the organization's successful transition from a traditional working style to a more collaborative and effective approach. This license covers a wide range of tools and features that are all included in a single, unified platform. The organization can access a broad spectrum of features that cover numerous aspects of their business operations by implementing this program.

Once the license has been obtained, the Dassault team, which is made up of qualified specialists and professionals, will work closely with the business. They would methodically create an outline for the migration procedure known as a requirement specification together. The company's specific demands and goals are outlined in this specification, ensuring a smooth transition to the 3D Experience platform that is suited to their particular needs.

The migration process itself involves transferring the company's existing systems and data to the advanced 3D Experience platform. To do this, the current infrastructure must be carefully analyzed and mapped to the matching features and functionalities of the new platform. The Dassault team would support this transition by utilizing their technical know-how, ensuring that all data is securely and precisely transferred and that the business's operations remain uninterrupted throughout. But the company's path toward digital transformation has only just begun with the acquisition of the software license and the system migration. The business must make a significant investment in thorough training programs if it wants to fully realize the potential of the 3D Experience platform and embrace a collaborative and productive working environment. These training courses are made to give employees the competency, knowledge, and skills they need to make the best use of the platform's features. Employees will obtain a thorough understanding of the platform's features through these training programs, enabling them to cooperate easily, streamline procedures, and promote creativity inside the company.

3.6 Benefits of Collabaoration

Throughout the preceding sections, we have explored the integration of three manufacturing disciplines and the collaboration tools that facilitate this integration. We have highlighted the numerous benefits associated with each collaborative tool. However, it is crucial to delve into the underlying advantages and value that organizations can derive from integrating these three disciplines using the 3DS platform. In this section, we will discuss the underlying benefits identified by the thesis group, shedding light on the comprehensive value that can be achieved through this integration. The benefits presented here highlight the usefulness of the Dassult's approach in comparison with the existing traditional way of working.

We can classify the benefits into three main sections, 1. Flow of information, 2. Decision making & Experimentation, and 3. User Interface

3.6.1 Flow of information

A crucial aspect of integrating different disciplines in any domain is ensuring the seamless flow of information between them. To achieve this integration, a bridge must be established to enable efficient communication and data transfer. In the case of integrating design, equipment/robot simulation, and factory flow, understanding the flow of data between these disciplines is essential. It is evident that the common thread among these three disciplines is the 3D CAD data. The CAD data generated during the design stage serves as a foundation for the subsequent stages of equipment simulation and factory flow domains. Therefore, any software or platform that aims to integrate these disciplines must possess the capability to effectively handle the flow of 3D CAD data across the domains. The platform should empower users to store, organize, share, navigate, and discover CAD data seamlessly across disciplines in a user-friendly manner. This ensures that the CAD data remains easily accessible and facilitates smooth collaboration among the different disciplines. By enabling efficient management of 3D CAD data, the platform enhances the integration process, promoting effective communication and information exchange between the involved disciplines.

The 3DExperience platform effectively addresses this issue by providing a seamless flow of CAD data across all manufacturing streams, including the three disciplines we have been discussing. 3DS adopts a "single source of truth" approach throughout the entire lifecycle, ensuring that the data created in the initial stages remains consistent and accessible to all users in real-time. This capability is made possible through the cloud-based interface of the platform. In this case, the CAD data generated by the designer is subsequently utilized by the equipment simulation and factory flow simulation engineers. Since the same data exists in every domain, users in any discipline have access to continuously updated data at any point in time. This stands in stark contrast to the traditional approach, where each individual works in isolation without collaboration. The 3DExperience platform promotes a collaborative environment where everyone has access to the most up-to-date information, facilitating seamless integration and enhancing overall productivity.

Another significant challenge that arises in the traditional approach is the conversion of CAD data. In the current working method, different software tools from various vendors are employed within an organization for design, robot programming, and simulation. Each software company typically employs its own proprietary CAD file format, leading to complications and hindrances in collaboration. Engineers often find themselves having to convert files into a common format, usually STEP, in order to import them into their respective environments. This results in valuable time being expended on non-value-adding tasks. However, with the comprehensive 3DS platform offering high-quality solutions for all three domains in a unified platform, the issue of file conversion is completely eliminated. The data is stored in the 3dxml file format, which is universally compatible throughout the entire platform. Simulation engineers can effortlessly utilize CAD files from designers without having to worry about file formats, and vice-versa. This streamlined approach ensures swift data transfer between the three disciplines, facilitating quicker iterations and reducing the need for unnecessary rework.

The cloud-based architecture of the 3DS platform enhances knowledge-sharing capabilities significantly. By continuously sharing and making information available within the collaborative environment, it becomes easier for new team members to grasp concepts and understand the project more rapidly. This level of knowledge transfer is not achievable in the traditional approach. Any incidents or issues identified in one discipline can be promptly communicated to engineers in other domains, eliminating the need for them to spend time searching for solutions or potentially repeating the same mistakes. This seamless communication and information exchange foster a more efficient and effective workflow, ultimately leading to improved productivity and minimized errors. Additionally, the platform provides the convenience of accessing information from any device, including mobile phones, as long as there is an internet connection. This accessibility allows users to view the progress of projects, track changes, and actively participate in discussions, regardless of their location. The platform's global reach fosters collaboration on a global scale, enabling teams from different parts of the world to seamlessly work together and contribute their expertise. This level of accessibility and connectivity enhances communication, accelerates decision-making processes, and promotes efficient and effective collaboration across borders and time zones.

3.6.2 User Interface

In the traditional siloed working approach, it is common for designers to use one software while simulation engineers use another. As mentioned earlier, this fragmented approach hampers collaboration and design reviews. However, integrating the three disciplines using the 3DS platform offers a remarkable advantage through its intuitive and groundbreaking user interface. Dassault Systèmes provides all the necessary tools and applications within a single platform, making collaboration an effortless task. Users can seamlessly switch between applications, provided they have the required roles within the platform. For instance, an engineer with the necessary roles can easily transition from performing part design using the widely used CATIA software to utilizing simulation applications such as Robot Simulation or Factory Flow Simulation, without encountering any significant hurdles. The interface provided is so user-friendly that users can open specific CAD data in different applications with just a single click, streamlining their workflow and enhancing productivity. To illustrate this advantage further, consider a scenario where an engineer is working on equipment in the Equipment Simulation application and encounters an issue with a specific part. In the 3DS platform, the engineer can simply double-click on that particular part to seamlessly open it in CATIA. This seamless transition between applications allows for efficient troubleshooting and collaboration, which is simply not possible in the traditional working approach. The integration and interoperability provided by the 3DS platform empower engineers to address issues swiftly and seamlessly.

The 3DS platform offers a wide array of applications that encompass all the necessary tools for the manufacturing industry. This comprehensive suite ensures that designers, equipment/robot simulation engineers, and factory flow simulation engineers have access to all the required applications in one centralized location. To exemplify this benefit, let's consider a scenario that encompasses the three focal disciplines.

In a typical situation, a robot simulation engineer analyses the movements and reachability of a robot within a specific robot cell, taking into account the tools and fixtures involved. If a collision is detected, the engineer raises a concern to the design department, suggesting modifications to the design. Upon receiving the issue, the designer makes the necessary changes and sends the modified design back to the simulation engineer for validation. Finally, once the robot programming is successfully validated, the robot cell process can be further validated using discrete event simulation. In traditional approaches, this entire process usually involves multiple iterations and the use of various software and tools for different tasks. Change actions and issue management are critical in such collaborations, often leading organizations to rely on external tools such as Excel sheets or third-party applications to manage change actions and versions.

However, the 3DS platform provides all the essential tools to streamline these processes. The platform offers a seamless and intuitive interface that fosters enhanced collaboration, surpassing any other solution for integrating the three domains. Figure 3.17 shows the steps and tools provided by the platform for dealing with the scenario discussed. This integration greatly enhances the quality of the output and facilitates efficient change management, ensuring a smooth and effective workflow for all stakeholders involved. The platform's all-inclusive nature eliminates the need for external tools and promotes a comprehensive and streamlined approach to managing the entire process.

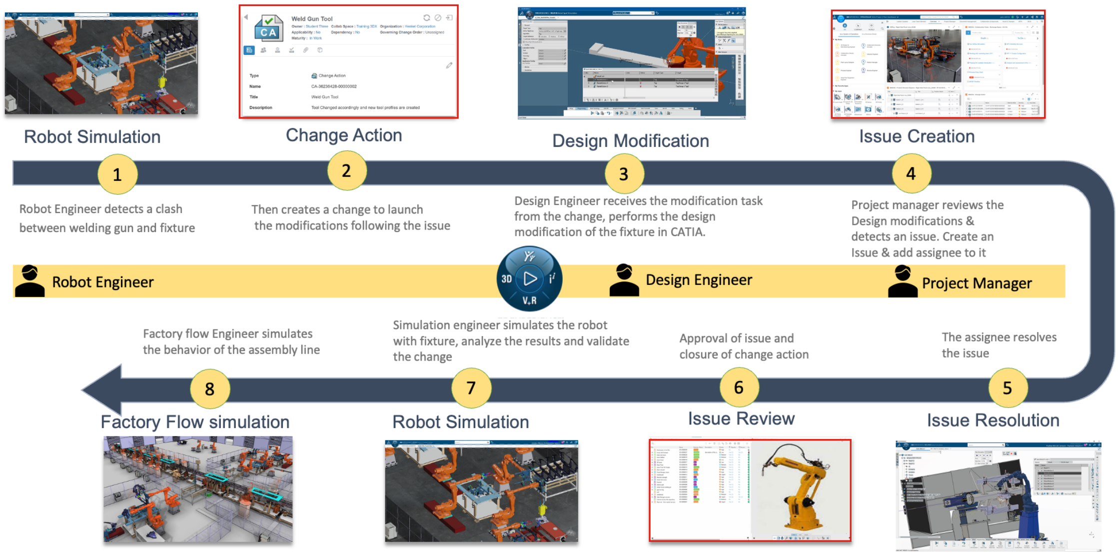

Figure 3.18: Illustration explaining the 3DS approach for the discussed scenario

3.6.3 Decision making & Experimentation

The integration of design and simulation environments using the 3DS platform offers substantial benefits in terms of decision-making and experimentation. Through qualitative studies, it has been evident that the transparency achieved between these two environments enables optimal decision-making with minimal errors. The interplay between design and simulation, which has been lacking in the traditional sequential approach, becomes seamless and efficient with this integration. One of the direct benefits of this integration is the time saved through concurrent engineering. The overlap between the design and simulation domains reduces lead time and, more importantly, facilitates better decision-making and faster iterations. As a result, project resources are utilized more effectively, and unnecessary rework loops are minimized.

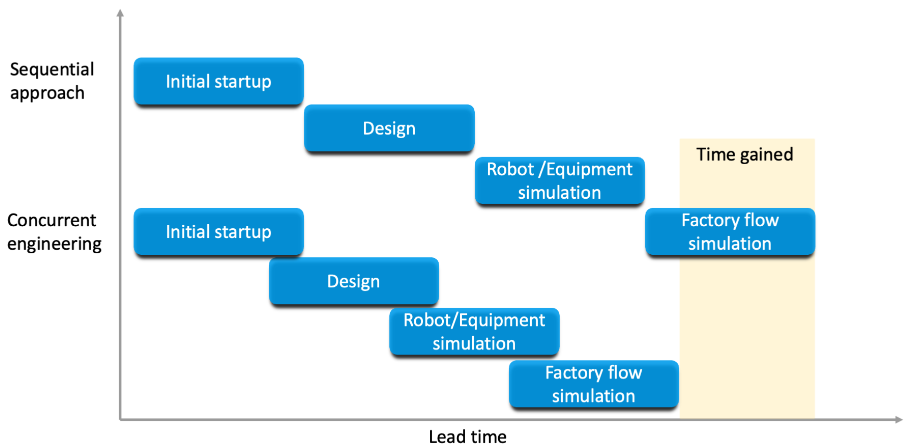

Figure 3.19: Comparision of Concurrent engineering with sequential approach

Additionally, the integration of design and simulation environments contributes to improved product quality. In typical projects involving design and simulation, iterations and rework loops are often persistent. These iterations can drain project resources in the traditional working approach. However, with the 3DS platform's integration, these loops are performed in parallel, leading to improved overall product quality and more efficient utilization of resources.

Furthermore, the 3DS platform enables seamless collaboration with external suppliers and customers, involving them in the process from start to finish. Stakeholders can be invited into the collaborative space, ensuring their continuous engagement throughout the project lifecycle. This inclusive approach ensures that decisions made at the outset are agreed upon by all parties involved, minimizing the need for significant changes later in the process. In the specific domain of focus, stakeholders within the collaborative space can access and view simulations and designs using intuitive 3D visualization tools like 3DPlay. This empowers them to actively contribute to the review process, providing valuable insights and feedback. This streamlined collaboration and real-time feedback process save a significant amount of time compared to the traditional approach, where stakeholders may have limited visibility or input until later stages. By involving external suppliers and customers in the collaborative space and providing them with intuitive visualization tools, the 3DS platform fosters efficient decision-making, reduces the likelihood of errors, and enables effective project execution.

In a typical scenario where equipment design and robot/equipment simulation are carried out in the traditional way, the approach is often sequential. Initially, a design is created based on the given inputs, and subsequently, it is validated by conducting a robot simulation to assess reachability and constraints. However, in this sequential workflow, issues regarding file conversion and data transfer arise during each review step. These challenges typically occur when transferring data between two engineers or between different software applications. These conversions and transfers introduce complexities and potential errors that can hinder the overall efficiency of the project. As a result, multiple iterations and review cycles are often required to complete the design project, further elongating the overall timeline. This sequential approach not only consumes valuable time but also increases the likelihood of errors or miscommunications between the design and simulation stages. Figure 3.19 shows how such a process would look when carried out in a traditional way.

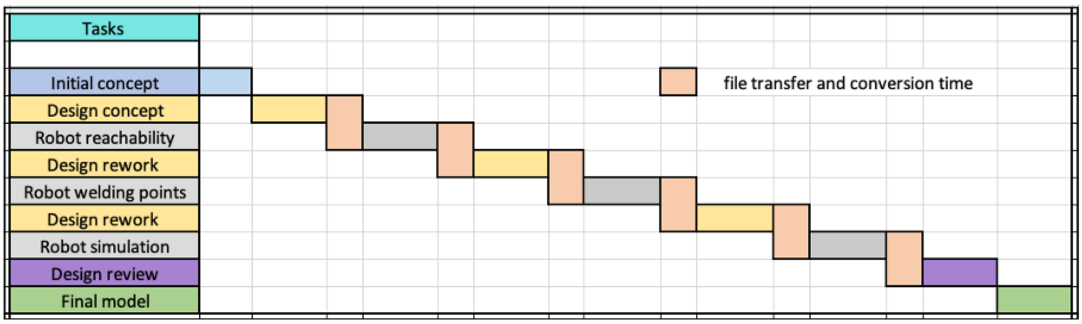

Figure 3.20: Traditional approach involving design and subsequent simulation reviews

To overcome these limitations and streamline the workflow, the integration of design and simulation environments using the 3DS platform proves highly beneficial. Working with the 3DS platform eliminates the cumbersome process of file conversion that is typically associated with the traditional approach. Since both the design and simulation applications are performed within the same platform, there is no need for file conversion between different software. Moreover, the 3DS platform enables parallel task execution with a slight overlap, significantly reducing lead time. Instead of following a strictly sequential approach, where the design is completed before the simulation begins, the platform allows for concurrent engineering. This means that design and simulation tasks can be performed simultaneously, with the output from one task being used as input for the other in a collaborative manner. This parallel execution and overlap of tasks further accelerate the overall project timeline, allowing for faster iterations and decision-making.

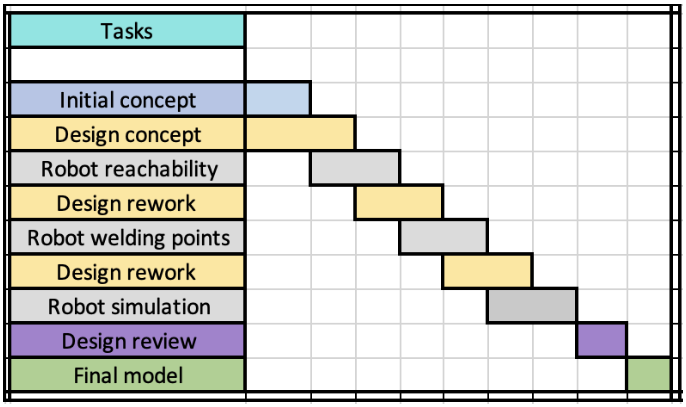

Figure 3.21: 3DS approach for projects involving design and robot programming

To gain further insight into the value of integrating the design and simulation environments, let's examine a specific use case from Prodtex. Prodtex successfully delivered a project for Jonsson & Paulsson Industri AB, focusing on fixture design in a robot application. In this project, the fixture was designed to securely hold a part for welding using a robot. The design of the fixture was crucial to ensure efficient movement of the robot weld gun and its manipulator. By utilizing the 3DS platform, Prodtex was able to perform this project, highlighting the advantages of integrating the design and simulation environments. Within the 3DS platform, the engineer could seamlessly switch between tabs to perform robot programming tasks such as analyzing reachability and determining weld spots, as well as designing the fixtures. This unified environment allowed for efficient workflow, as both tasks could be performed within the same platform. One notable advantage of this integration is the synchronization of CAD data between the design software and the robot simulation environment. Any changes made in the design software are automatically reflected in real-time within the robot simulation environment. This real-time synchronization ensured that the design and simulation were always aligned, eliminating the need for manual data transfer or file conversion. This process enhanced collaboration and facilitated faster iteration cycles, resulting in more efficient and accurate project execution.

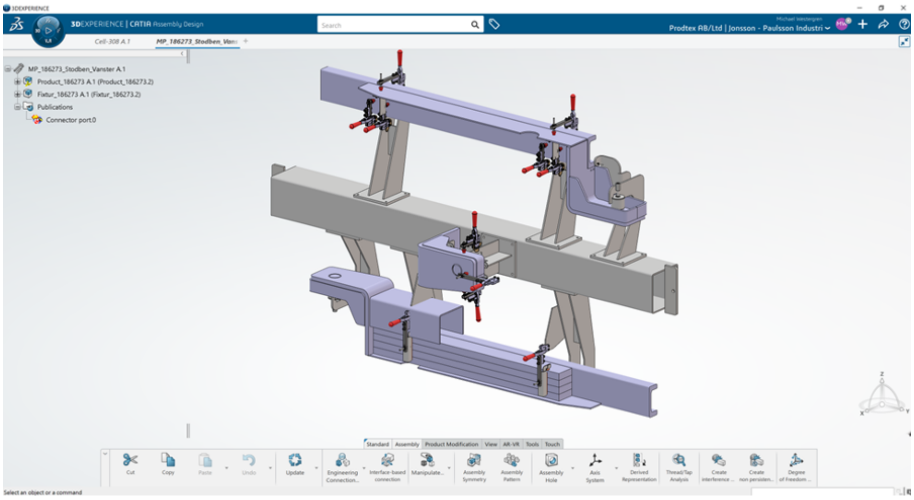

Figure 3.22: Fixture design in CATIA environment (Jonsson & Paulsson case)

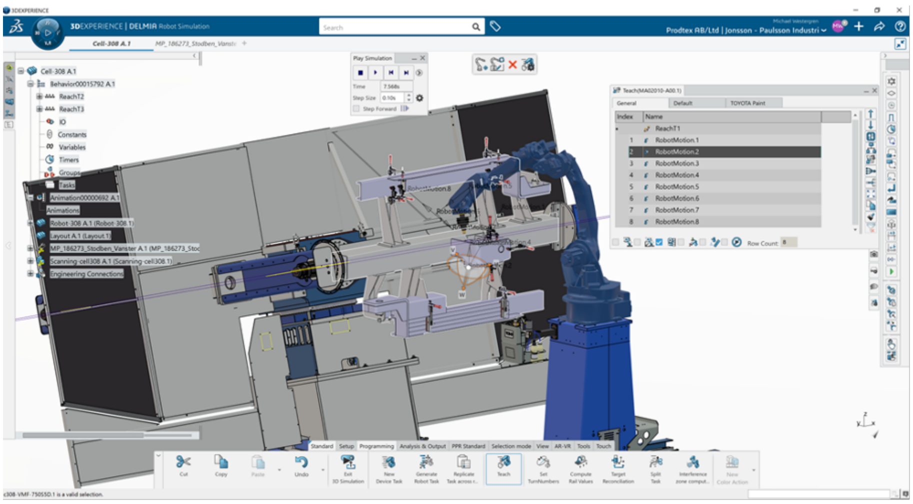

Figure 3.23: Simulation of robot reachability in Robot Simulation app (Jonsson & Paulsson case)

The availability of early inputs from the robot programs played a crucial role in facilitating effective decision-making during the design process. By having access to these inputs, the designer was able to gain a better understanding of the specific requirements and constraints of the scenario. This enhanced understanding allowed for more informed design choices, reducing the likelihood of reworks and minimizing the need for design and validation loops. The integration of design and simulation environments within the 3DS platform enabled the designer to have a comprehensive understanding of the equipment to be designed through 3D simulation. This immersive simulation experience provided a visual representation of the equipment in action, allowing the designer to evaluate its functionality and performance in a virtual environment. With this enhanced understanding, the designer could make more accurate design decisions from the start. Ultimately, this enhanced approach led to improved design quality and reduced project timelines.

4

Discussion

This chapter provides an overview of the methodology employed by the team and presents the results obtained from the research. It will also incorporate the author's opinions and interpretations of the findings. Additionally, the chapter highlights potential areas for future research within the same field or topic, suggesting directions for further exploration.

4.1 Methodology

The methodology employed in conducting this study adheres to the general methodology commonly utilized in scientific research projects [22]. This encompasses a thorough examination of the existing literature, with a particular emphasis on the collaborative aspects of 3D Experience. It is worth noting that a scarcity of academic research specifically centered on the 3DExperience platform was identified. Consequently, the thesis team endeavored to analyze the limited information available and derive meaningful implications from it. It is plausible to assert that a more abundant availability of information could have potentially facilitated a more comprehensive understanding of the research question, thereby resulting in a better outcome of the results.

To comprehend the current methodologies employed in the manufacturing industries, a series of semi-structured interviews were conducted. The interviewees possess extensive expertise in the domains of design and simulation, rendering their insights particularly noteworthy. Notably, these individuals have garnered substantial experience working with many design and robot simulation software from different vendors and for different OEMs. This diverse knowledge base has proven invaluable to the thesis team, facilitating a discerning approach in drawing implications regarding the 3DS platform.

The interviews conducted with industry experts proved instrumental in illuminating the prevailing methodologies employed within the manufacturing industries. Furthermore, the thesis team acquired a comprehensive understanding of Dassault's operational procedures through the completion of pertinent courses and certifications available on Dassault's learning portal. However, given the limitations imposed by time constraints and the project's scope, only a select few courses that directly pertained to the three primary disciplines of the research were completed. It is worth noting that further enhancements to the research findings could have been achieved through a more extensive exploration of Dassault's collaborative approach and by conducting additional interviews with experts from a broader engineering background.

The SweMaint case project played a pivotal role in facilitating a comprehensive understanding of the intricacies of the 3DS platform. This project encompassed various facets, such as equipment design and simulation, plant layout design, and factory flow simulation. It served as an exemplary illustration, allowing for a thorough comprehension of the collaborative capabilities of the 3DS platform and Dassault's approach in similar design and simulation endeavors. Nevertheless, it would have been advantageous had the case project incorporated elements related to robot simulation or robot programming. To compensate for this omission, a use case scenario focusing on the design of fixtures and robot simulation was studied. This particular use case, effectively executed using the 3DS platform by Prodtex, helped bridge the aforementioned gap.

Mindful of the limitations of the traditional manufacturing approach, the project team focused their efforts on devising innovative solutions within the proposed new approach. This approach prioritized addressing the inherent challenges of the traditional methodology. Dassault's approach to virtual manufacturing offers a comprehensive solution that spans the entire manufacturing process. This encompasses a comprehensive product description in the form of an EBOM (Engineering Bill of Materials), a detailed description of the manufacturing process encapsulated in an MBOM (Manufacturing Bill of Materials), and meticulous process planning that incorporates crucial production decisions along the supply chain. The exploration of these disciplines had it been undertaken, would have undoubtedly provided a comprehensive perspective on the realm of virtual manufacturing.

4.2 Results

The results derived from the thesis work serve as a compelling testament to the advantages of utilizing the 3DS platform for the integration of design and simulation environments in the realm of manufacturing engineering. A fundamental element prevalent in projects involving design and simulation is the iterative nature of design review and rework processes. These cycles of rework consume resources and impede the efficiency of the product realization process. The adoption of concurrent engineering in such scenarios facilitates swifter rework, cost reduction, minimized lead times, and ultimately enhances the overall quality of the end product [9]. It is noteworthy that collaboration between these domains empowers designers to make well-informed decisions based on simultaneous simulations, thereby reducing the need for subsequent rework [10]. The thesis work echoes similar findings, underscoring the necessity of concurrent engineering within the design and simulation field. Additionally, it was discovered that having potential solution scenarios readily available before the final design is released empowers designers to make optimal choices during the initial iteration itself [10]. As the manufacturing industry rapidly transitions towards virtual manufacturing, the integration of design and simulation environments and the implementation of an effective data management system that fosters collaboration between them becomes imperative [13]. The 3DS platform, with its diverse collaborative tools and interface, serves as the conduit for such collaboration and boasts a robust cloud-based architecture for efficient data management.

The extensive array of tools and sophisticated software embedded within the 3DS platform serves as a catalyst for business transformation, propelling enterprises towards digitalization. This platform fosters the creation of social enterprises, wherein customers and external stakeholders actively participate in the process of product realization [16][17]. This functionality, which plays a pivotal role in reducing reworks and enhancing product quality, has been observed in both the case project and the Prodtex use case. The platform enables seamless integration between various domains, ensuring the existence of a unified dataset throughout the product lifecycle across all engineering disciplines. The ability to effortlessly switch between different applications, such as design and simulation software, facilitates smooth collaboration during the phases of product development and innovation [15]. With the possibilities afforded by the 3DS platform, there is a seamless flow of information, thereby facilitating faster and more effective experimentation, all while providing an intuitive interface for the collaboration of design and simulation environments.

4.3 Sustainability Aspect

The 3D Experience platform offers significant sustainability benefits, particularly through virtual manufacturing and digitalization of systems. Virtual manufacturing allows for the creation and analysis of designs and factory layouts before physical installation, leading to reduced resource utilization and investment. This approach facilitates better decision-making, as demonstrated by a case project where virtual plant design and analysis informed the implementation of a new process in the workshop.

Digitalizing systems within the supply chain of manufacturing plants provides advantages such as accurate material requirement planning, and efficient resource allocation based on data obtained from virtual designs. This optimization minimizes the need for transportation, packaging, and associated carbon emissions.

Furthermore, by promoting collaboration, the 3D Experience platform reduces the need for excessive iterations and email exchanges to clarify issues. The platform provides tools for efficient communication and information sharing, streamlining the decision-making process and reducing resource waste.

4.4 Future Scope

During the project, the team worked with three disciplines: Design of Equipment, Equipment/Robot simulation, and Factory Flow Simulation. However, due to limitations, the focus of the thesis was solely on these three disciplines, excluding process planning. The team also underwent various courses where Dassault consistently emphasized the importance of process planning in conjunction with the three disciplines studied. According to Dassault's standard way of working, it is recommended to follow a systematic approach that covers all the different disciplines involved in the manufacturing process. This step-by-step methodology ensures comprehensive coverage and integration of all relevant aspects for effective manufacturing operations. In the future, there is potential to include process planning and examine how collaboration would function with all four disciplines integrated.

While the thesis primarily concentrated on the integration and identification of collaboration benefits, it did not address the drawbacks of collaboration. This could be an area of future research, exploring any potential limitations or challenges that may arise from collaborative efforts.

Furthermore, the team attempted to assess the level of collaboration within companies but found a lack of standardized systems or checklists to evaluate the presence and effectiveness of information and data management systems. Developing a standard structure or checklist could be a valuable aspect of future research, enabling companies to gauge their collaborative environment and identify areas for improvement.

5

Conclusion

The thesis team, with the support of Prodtex, conducted a detailed study on the use of the 3DExperience platform for production engineering. This study involved an extensive literature review to understand the concept of concurrent engineering and the academic research conducted on the 3DExperience platform. Additionally, interviews were conducted with industry experts to gain insights into the current working approaches in manufacturing organizations. To gain a deeper understanding of the three disciplines of focus, namely design of equipment, equipment/robot simulation, and factory flow simulation, numerous courses and certifications offered by Dassault Systèmes were completed. These courses provided practical knowledge and expertise in utilizing the 3DExperience platform for these disciplines. To gain practical experience, an industry project provided was executed by Prodtex. This project served as a powerful example to understand Dassault Systèmes' approach to collaboration in the manufacturing industry and the solutions they offer for the focal disciplines.

A rigorous qualitative and quantitative analysis has been performed, with findings interpreted to address the thesis' objectives. The focus was on studying the collaborative tools available in the 3DExperience platform and their utilization and advantages in integrating the three disciplines of design, equipment/robot simulation, and factory flow simulation. The findings of the studies have been presented in a comprehensive manner, highlighting the usage and benefits of collaborative tools for the integration of these disciplines. The thesis provides insights into how these tools can facilitate seamless collaboration and enhance the overall manufacturing process. In addition, a proposed work structure has been outlined, serving as a useful template or guide for organizations seeking to integrate design and simulation environments in their manufacturing processes. This structure serves as a practical framework for implementing the 3DExperience platform and streamlining collaboration between the three disciplines. Furthermore, the thesis delves into a detailed description of the underlying benefits and value that can be expected when utilizing the 3DExperience platform to collaborate across these three disciplines. It highlights the potential improvements in efficiency, decision-making, and overall project outcomes that can be achieved by leveraging the platform's collaborative capabilities. By providing an in-depth analysis of the collaborative tools, proposing a work structure, and presenting the expected benefits, the thesis offers valuable insights and guidance for organizations interested in harnessing the power of the 3DExperience platform to enhance collaboration among the design, equipment/robot simulation, and factory flow simulation disciplines.

The study highlights the benefits of integrating the design and simulation domains using the 3DExperience platform. By fostering collaboration, this approach proves advantageous in many aspects. The interdependent domains, such as equipment design, robot simulation, and factory flow simulation, all benefit from integration and collaborative approaches. This results in reduced project completion time and cost savings. However, despite these advantages, the majority of the industry has not yet embraced this new way of working as there exists resistance within the organization to change.

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A

Appendix 1

A.1 Interview Questions

1. **Interview questions to Designers**
   (a) General introduction of the interviewee. About the Company, Designation, and Experience
   (b) What will be the general work procedure from concept development to deployment in a typical automation project?
   (c) Is there a standard work structure defined by the organization or does it change depending on the project?
   (d) How are teams formed for the projects and what drives the allocation of roles in the team? Who will be responsible for managing the project?
   (e) To what extent do you think the collaboration between the various disciplines exists in present-day working in your company?
   (f) How do you manage/store and share all the data and documents?
   (g) How is knowledge management carried out in such projects?
   (h) How is an issue raised when there is something to be changed in the design/robot simulation/factory flow?
   (i) When a rework is given to make certain changes how does the team communicate?
   (j) When working on a design/robot simulation/factory flow, is communication between teams necessary?
   (k) Are there any issues with file formats when collaborating and reviewing concepts and how do you work around this?
   (l) In such automation projects, how are interdependent/overlapping tasks handled?
   (m) Do collaboration projects require a certain level of transparency?
   (n) Which area do you think requires more collaboration in a project?
   (o) What is your opinion on concurrent engineering?
   (p) Do you think collaboration is needed for improved efficiency in automation projects? And do you feel a unified platform like 3DX will be beneficial in such cases?
   (q) What are the key changes required in your work for collaboration?
   (r) Do you currently use a PLM system? If so, what are the challenges you are facing?
2. **Interview questions to Managers**

(a) General introduction of the interviewee. About the Company, Designation, and Experience
(b) What is your opinion on concurrent engineering?
(c) Do you think collaboration is needed for improved efficiency in automation projects? And how do you feel a unified platform like 3DS will be beneficial in such cases?
(d) How do you rate or measure the maturity level of collaboration in the companies?
(e) What actual value do the organizations gain using the 3DS platform?
(f) What are the key changes required in the present organizations for collaboration?
(g) What are the security issues that can be faced by a company using a cloud platform?
(h) What is the procedure for training people to use 3DS?
(i) What makes 3DS ahead of its competitors in concern with collaboration?
(j) Are there any key features of competitors' software that 3DS does not include?
(k) Does Dassault provide and insists on a standard work structure for organizations to work in a collaborative manner using the 3DS platform?
(l) How does Dassault help with the inconvenience caused during the usage of the software/platform?
(m) What are the challenges faced by Dassault in captivating customers to use the 3DS platform?

A.2 Theory

The 3DX platform comprises three types of applications: widgets, web applications, and native applications. Widgets are pinned onto the dashboard for convenient access to various information. Web applications are opened as new tabs in browsers and offer all functionalities within that tab. Native applications are dedicated design software that is installed on users' computers and cannot be run on the browser. All these applications store data in the same cloud space within the selected collaborative space. Navigation between these applications is seamless as they are unified under the 3D Experience platform.

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