RESEARCH REPORT

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SIMPRO

Simulation Lifecycle and Data Management

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Summary

Use of computational methods with multidisciplinary models and simulation has been identified as one of the key factors for major progress in research and rapid development of advanced products. However, lack of software tools that allow integration and management of the modelling and simulation data from various disciplines has remained a bottleneck in the wide application of computational methods both in research and industry.

The purpose of this task is to identify challenges and problems faced by the design engineer during the modelling and simulation phase of the product development and design process. The objectives of this task are to identify the possibilities for data exchange between simulation tools and accessibility and exchange of data among teams and between tools.

In this report, data exchange between various simulation tools has been stated together with the Simulation Lifecycle Management tools. The report also describes various middleware that plays an important role in the transfer of data between the tools. This document gives the foundations for the SIMPRO project task 4.3, which studies the use of simulations over the product lifecycle using the selected case studies. Tools will be studied and used among different processes and interacting with different software and specialists.

Confidentiality	Public

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Contents

Acronyms

CFD	Computational Fluid Dynamics
DMU	Digital Mock-Up
FEM	Finite Element Method
JTA	Joint Tolerance Analysis
MBS	Multi-Body Simulation
SDM	Simulation Data Management
SLM	Simulation Lifecycle Management
SyS	System Simulation

1. Introduction

Use of computational methods with multidisciplinary models and simulation has been identified as one of the key factors for major progress in research and rapid development of advance products [1]. However, lack of software tools which allow integration and management of the modelling and simulation data from various disciplines has remained a bottleneck in the wide application of computational methods both in research and industry.

In today's competitive market companies are required to bring new products to the customer with innovative and powerful features at a rapid pace. This puts forward new challenges for industries in the product development process. One of the major consequences with the increasing complexity of products is the integration of functionalities from various disciplines, which is a source of innovation [2]. At the same time, companies are looking to decrease the development costs and shortening the time-to-market. Hence, the digital tools are considered essential during the design process and are becoming more and more common within the whole product life-cycle. This means that developing more complex systems, decreasing the number of physical prototypes while increasing the use of digital tools leads to increase likewise the amount and diversity of data. A multitude of data is then generated across the different teams, sometimes even spread worldwide and the transfer of those data is of primary importance. Often they are rather isolated from each other since tools used are generally much specialised [3]. But by reducing the amount of physical prototypes, computational analyses and simulations, and especially multidiscipline simulations, are contrariwise increasing. This is particularly true within the current trend in the industry, the simulation-based product development, which consists of targeting the design process around simulations and computational analyses. Consequently, those computations require collecting data from various fields, in various formats, and they produce a large amount of results data, and therefore efficient data management process is nowadays required by companies.

1.1 About the SIMPRO project

Computational methods in mechanical engineering product development – SIMPRO is a jointly funded Tekes (the Finnish Funding Agency for Technology and Innovation) research project that focuses on the application of computational methods in the product development of mechanical systems and products. The project has the following points of view to the topic: 1) high-performance computing in mechanical engineering, 2) optimisation, design studies and analyses, 3) requirement- and customer-based product development, and 4) modelling and results data management. The SIMPRO project is categorised by Tekes as *public research networked with companies*.

2. Objectives

The background of this project task consists of the report written [4] under the task 4.1 concerning the study of new developments, tools and possibilities for modelling, simulation data management of machines with the availability of parallel computing. The literature review defined the current practices in the Finnish industry. It aimed to identify the industrial needs and highlight potential solutions.

The purpose of this project task 4.2 *Simulation lifecycle and data management* is to identify challenges and problems faced by the design engineer during the modelling and simulation phase of the product development and design process. One of the major issues within the design process is the accessibility of design data directly from simulations. Exchanging data among different computational tools is for some cases a challenging task especially while dealing with complex products. Some Simulation Lifecycle Management (SLM) tools need to be studied in order to point out the existing gap between modelling and simulation tools all along the product lifecycle. To illustrate the research work, different case studies are used combining multidiscipline simulations.

The objectives of this study are:

- selection of simulation and simulation lifecycle management tools
- study the data exchange between simulation tools
- identification of problems faced during the design and simulation process
- study the accessibility and exchange of data among teams and between tools.

This document aims to answer some key questions for a better understanding of the major issues currently faced in the Finnish industry concerning simulation data management. It will lead to propose ways of improvement in the following phase of the project.

3. Modelling and simulation in product design processes

In the literature, design process of complex systems has been identified as one of the key area for the validation of product requirements during the development phase [5]. Various industries have adopted different processes to meet there product and customer needs. This chapter aims to review most common practices and select important aspects of each approach, as well as clarify evolution trends in the system engineering field.

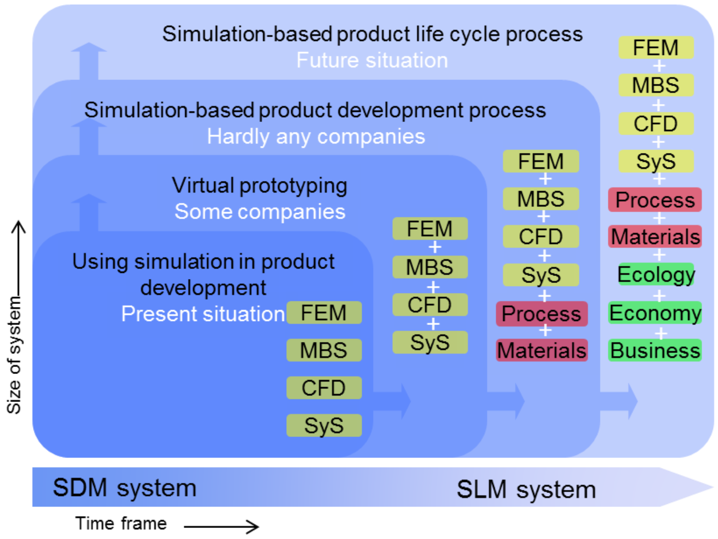

Figure 1: Evolution of application of simulation in product process and the increase of the importance of data management [6].

The current trend in the industry is to go towards simulation-based product lifecycle process [7]. However, current practice in the industry shows that simulations in product development are mostly used without real interactions between the simulation and analysts [8]. The Figure 1 summarizes this section by presenting the evolution of design processes from the present towards the future situation. This process shows the scope of improving design processes throughout the lifecycle by implementing more interactions between simulations tools and between design engineers. Seamless combination of more tools within the same formalized process can lead to enhance the confidence in the developed system. It also leads to reduce the risk of design errors early in the design, which is obviously less costly, then during an advanced phase of the system development.

Any development process, whether the output is a product, service, process, organisation, software etc. consists of the following steps [9]:

- understanding the customers' needs
- defining the problem that must be solved to satisfy these needs
- creating and selecting a solution
- analysing and optimizing the proposed solution as well as verifying the solution against the customers' needs (design validation)
- implementing the solution (either a prototype or a final product)
- checking the resulting product against the customers' needs (implementation validation).

Different practices in design process are commonly used starting from product development to simulation based product life-cycle process by going through intermediate processes such as virtual prototyping and simulation-based product development process. In a similar time frame, data management systems are currently going from simulation data management system to simulation lifecycle systems. Details of various design processes are captured in the following sub-sections.

3.1 Product-based design process

In the industry, the most common practice is to use simulations within the product development to perform simulations on the design independently from each other's, one by one and one after the other (Figure 2).

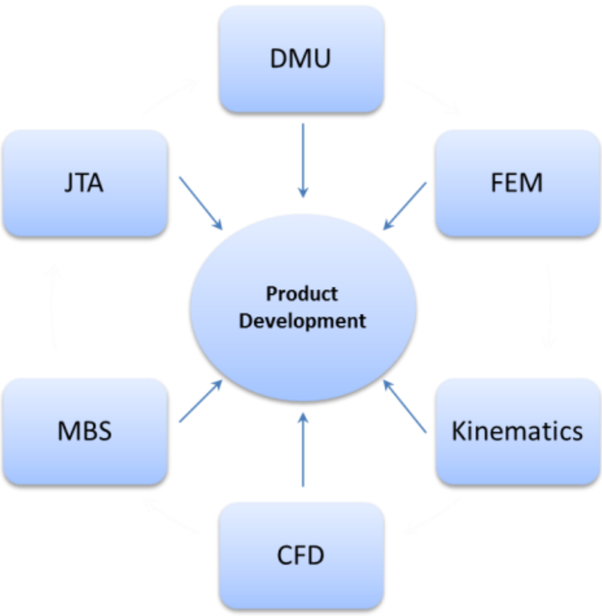

Figure 2: Product-based design process.

In this product-based design process, the design team is working on a new product starting from the requirements to design a new system. During the development process, digital mock-ups (DMUs) and simulations are used as tools to verify that the system of interest meets the requirements. After using one of the available tools, a report is edited in order to express the analyst's feedback concerning how the DMUs and simulations have been conducted and what are the main results. The report is then helpful for the decision making process, to increase the confidence in the product development process. After the selected simulation has been performed, the feedback from the analyst is collected and, if needed, corrective measures on the design are carried out. Based on the review the decision can be taken to perform further design changes and simulations.

Thus engineers are often working on individual simulations, and design updates may be performed afterwards by the designers. For different engineering domains, such as mechanical and control systems, the use of simulation can and often is concurrent. The engineering in different domains is often independent, except that the product is the same. In complex systems or products, e.g. mechanics, hydraulics, electrical subsystems, and controls and automation may be involved.

When reaching the validation phase, reports are produced and simulation results have to be individually collected and interpreted often by a third party, who may not have directly collaborated on the simulations. In such a case, loss of information, such as specific simulation parameters or how exactly the simulation has been performed, may happen and affect the final decision. Thus, the product-based design process may lead to some limitations due to a potential lack of accuracy in the final decision statement. The more information is spread around, the more difficult it is to collect them and interpret them in the most relevant way. Moreover, collecting them is often time consuming and especially within long time span project. Validation assessment may be performed years after the entire verification process has been carried out. Sometimes after such time span, required information such as simulation results or other models may be not recovered anymore due for instance to compatibility issues between software updates and some simulations may require to be redone.

In the product-based design process, product data management systems (PDM) may be used to collect, store and trace data, CAD models and other associated documents during the design process. Documentation and PDM become essential tools in case of long time span product development or while sharing within and outside the organization.

3.2 Virtual prototype-based design process

In order to reduce the risk of losing information during the entire design process, the current trend is going towards the virtual prototyping-based design (Figure 3). This process is increasingly used within the industry and many studies have been performed on the topic. In [10], Rooks B. clearly illustrated that using DMU during the development of the Boeing airplanes reduced errors and rework by up to 80%.

However, it remains challenging especially concerning complex products development. As the interaction between computational tools and systems increase compared to the product-based design process, compatibilities between software and simulations are the most faced issues. For instance combining joint tolerance analysis (JTA), FEM and kinematic simulations on the same DMU remains challenging since almost no software can provide such abilities.

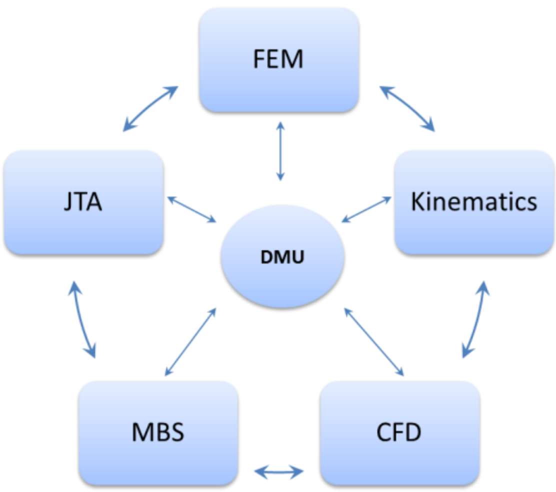

Figure 3: Virtual prototype-based design process.

Virtual prototype (VP) -based design process aims at connecting simulations to each other by providing a common virtual platform to engineers. The DMU of the developed system is the central part of the design process and plays the role of an interactive collaboration platform. Designers, analysts and engineers share data on the same virtual model, by performing simulations, design updates and other measurements. For instance, in case of products designed to work in heavy loading conditions, a common practice is to build a 3D model of the product on which FEA is performed, and resulting deformed models are then used as inputs for the kinematic simulation. It enables, for example, to verify the collision free trajectory of the system under loading conditions.

More complex aspect is to integrate the joint tolerance analysis into the DMU in order to take into consideration the potential deflection due to joint misalignments. Such virtual testing may be very relevant for heavy systems, in which insignificant joint misalignments can happen under loading conditions. As the power density (power/performance of the system compared to the mass) of the systems is increasing, the dynamics (deformation of the structure, vibrations and noise, etc.) of the system are becoming increasingly important. In addition, active control is being increasingly used for increasing the system performance (to e.g. decrease vibrations), and for this, virtual prototypes are an efficient tool for the engineers. Hence virtual prototyping-based design process delivers relevant benefit to reduce design errors and rework from the very early design phases.

In the virtual prototype-based design process, the use of a PDM system is very common especially combined with a simulation data management (SDM) system. Thus data resulting from the simulations can be collected, stored, traced and linked to the data previously located in the PDM system. However, many PDM systems rely on managing documents (files). This sets some limitations in linking the modelling and simulation tools and efficiently managing the data.

3.3 Simulation-based design process

In the industry, companies are constantly required to provide more innovative and powerful products features, which lead to increase of the complexity of the products. Physical prototyping become then more and more costly and time consuming. On the other hand, simulations enable to decrease the needs toward physical testing, by virtually testing some aspects of the designed product [11]. Many studies point out the fact that finding a design flaw in a later phase of the product process remarkably increase the costs caused by correcting the flaw [12], [13]. By using virtual prototypes proactively in the process for already testing the concepts in the early design phase (conceptual design) is one of the biggest added values of this type of a design process.

Nowadays digital tools for virtual testing are considered essential during the design process and are becoming more and more common during the whole product life-cycle. In order to be able to replace some new physical testing aspects by virtual testing, simulation are becoming more advanced by verifying multiple aspects at a time and combining different areas of expertise. Multi-discipline simulations are not without problems, and many challenges remain.

The research field shows that the current trends are going towards the simulation-based design process. In a simulation-based design process, simulations become the central part of the development of the product. The goal is to verify the virtually prototype in order to avoid costly and time consuming multiple iterations during the validation phase. In such a process, the design model is built according to the simulations unlike in the VP-based design process for instance. Barely few companies are using this type of design process due to the numerous challenges involved in such a process. But on the other hand, when the process is well implemented, it offers new perspectives in a matter of reducing the risk of errors as well as the product time-to-market. In some special cases, full scale physical prototypes are required for part of the validation assessments [14].

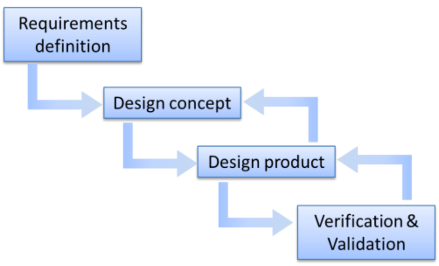

Figure 4: Product design process [15]

The simulation is mainly used in all the four main stages of the product design process shown in Figure 4. Starting from the requirements identification, they are used as input for the next phase. The design concept phase consists of evaluated alternative product concepts, and one concept is then selected for further development. The design product phase consists of the detailed 3D model of the system on which detailed level simulations are performed. The last stage includes the verification of the virtual model as well as the model validation by way of physical prototype. These design phases are described in detail in the following sub-sections.

3.3.1 Concept design phase

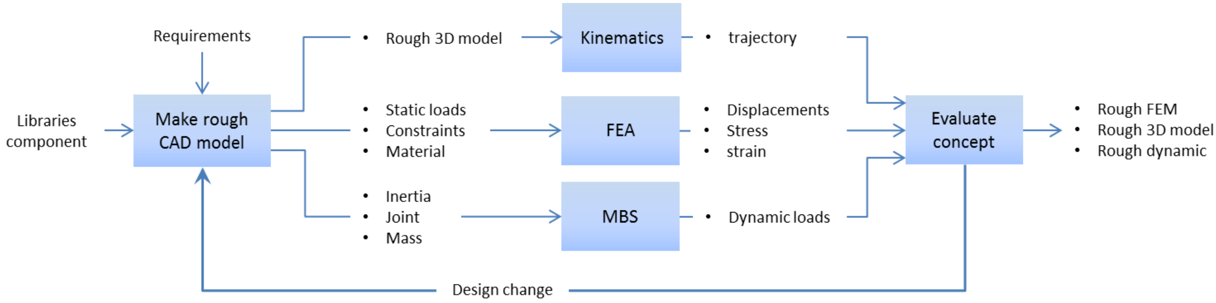

Figure 5: Concept design phase.

The design concept phase (Figure 5) uses the initial requirements previously defined by the customer as inputs. With the help of a component library, the rough CAD model is built and used as a base for the preliminary simulations. For each simulation aspects, alternative concept designs are evaluated according to the simulation results to determine, which concept will be further developed. The evaluation is based on the functional requirements of the system as well as some main features such as the economical aspect of the different concepts.

3.3.2 Design product phase

The third step consists of the second iterative loop of the simulation-based design process, which is represented by the detailed product design phase (Figure 6). The previously built rough 3D model is used as the input to build a more detailed model of the system. Then FEA and MBS are performed to refine the model. An assessment activity closes the loop by evaluating the design and commits design modification requests to the 3D model design phase. In such a process, it is very interesting to use a well-furnished component library, in order to allow the process to pre-select the different component options according to the requirements by performing iteration simulation loops with the concepts selected in the previous phase. Taking cost, reliability and maintenance aspects into consideration from the very early stage of the design leads to reducing the risk of a further development of a non-conformant solution. After the evaluation of the concept design, feedback is sent to the previous design concept phase in case of relevant modification, or to the modelling phase of the detailed 3D model.

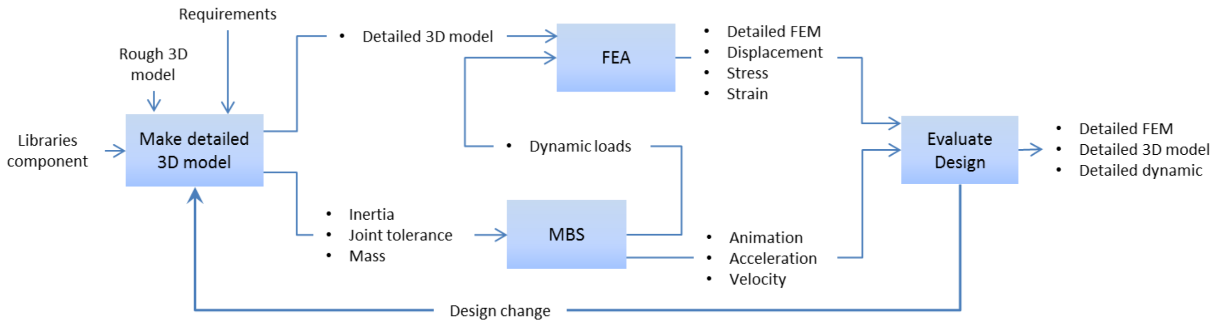

Figure 6: Product design phase

3.3.3 Product Verification & Validation phase

The use of physical prototypes aims to verify the system in the very last stages of the development process. Multiple iterations of the physical prototypes have to be as few as possible due to the cost of such prototypes. Figure 7 illustrates the last phase of the simulation-based design process, the verification and validation (V&V) phase. The digital model of the system is virtually tested within its virtual operational environment. The testing phase allows operating the system as if it was in the reality [16]. The virtual tests may consist of using a virtual reality (VR) platform, involving human interaction for e.g. human-operated systems [17]. The final validation assessment aims to provide evidences that the developed system meets the requirements. Virtual and physical tests are typically subjected to uncertainties which have to be quantified before reaching the validation assessment in order to be able to perform the comparison between the virtual and physical results. After the V&V phase, the product is either validated in case it meets the requirements or are sent back to the design concept or product phase for design updates.

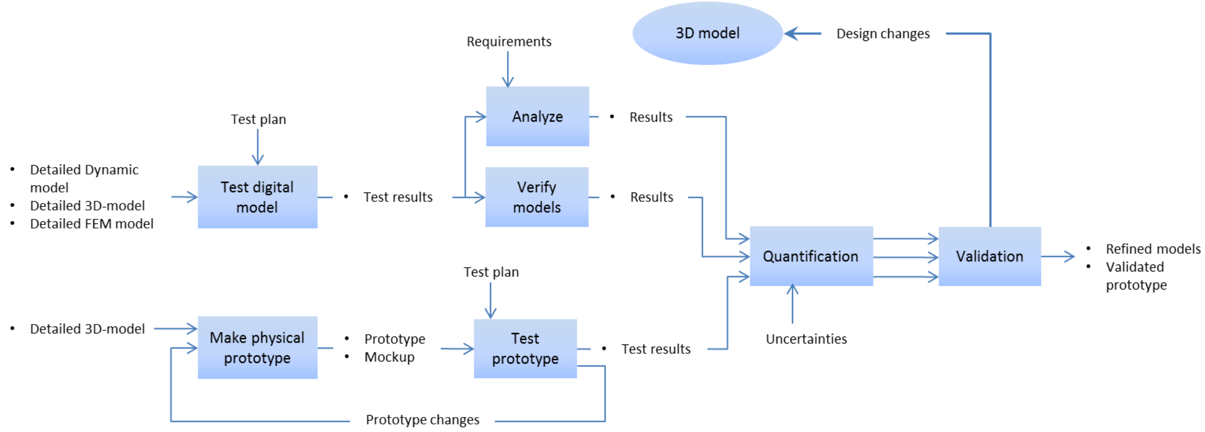

Figure 7: Product verification and validation phase.

In such a process, it is essential to use a simulation lifecycle management (SLM) system, since simulations become the fundamental part of the product development. SLM provides the platform needed to transform simulations from a specialty operation to an enterprise product development.

4. A sharable format for multi-disciplinary simulation data

The sharing of finite element analysis (FEA) data during the design process is a key requirement for success in collaborative design environments [18]. However, compared to other fields like computer-aided design (CAD), sharing FEA data using a standardized neutral format remains relatively inefficient because format must accommodate a wide range of data types produced from multidisciplinary analysis applications. The same challenge applies to at least computational fluid dynamics (CFD), general system simulation (such as control, hydraulic, electrical and thermodynamic system simulation), multi-body system (MBS) simulation.

Companies are transcending the traditional design paradigm of in-house production. Instead, collaborative design is practiced in distributed development environments to improve product quality, reduce development costs and shorten the time-to-market. Multidisciplinary stakeholders participate in decision-making and share design information across domain boundaries in a distributed environment. In these collaborative design networks, exchanging product data is the one of the main requirements for success. Thus, extensive research efforts and development work have recently been carried out to meet this need, especially in the field of CAD.

However, the exchange of finite element analysis (FEA) data produced in computer-aided engineering (CAE) processes remains relatively inefficient. This is because that a wide variety of analysis systems are used for virtual product verification, while only a few CAD systems are used in the design process. There are currently two standard formats for CAD data, ISO 10303 (STEP) and IGES (becoming obsolete). These formats do not maintain e.g. parametric information of the design model. The formats have been designed mainly for archiving purposes (the store the final design information) and to share the geometry information, but not the design model. The concentration of the technical solutions in CAD, i.e. the geometry kernels used in the CAD systems, has improved the data exchange between the leading CAD systems. Currently the market leading geometry kernels are ACIS and Parasolid.

Large amount of data resulting from simulations is another bottleneck for sharing the data across network. For instance, aircraft dimensioning and verification are performed on static strength, fatigue strength, damage tolerance, composite materials analysis, thermal analysis, and other criteria. As a consequence, the variety of FEA data formats is of the same order of magnitude as the number of analysis systems. This leads to an unacceptably high level of information redundancy. Moreover, the large file sizes of FEA data make it difficult to exchange data. In the case of a fluid simulation, the native analysis data can occupy dozens of gigabytes even though the analysis is only one small solid part. In these CAE applications, only limited analytical information with 2D captured images and numeric data are shared with the other stakeholders. The original analysis data can be replicated in several places in each local repository of the simulation machines. As a consequence of this lack of exchanging full analytical information, CAD engineers and managers sometimes make incorrect design changes causing additional and unintended iterations of the redesign.

5. SLM tools

Due to the novelty of concepts associated with Simulation Lifecycle Management there is a limited availability of the commercial tools. At the start of the project, a short survey was carried out to select the SLM tools for evaluation during the project. After careful consideration of project resources and discussion with industrial partners in SIMPRO, Simulia from Dassault Systèmes and EKM from ANSYS were selected for practical evaluation. The following subsections provide short details of the SLM tools, which were surveyed during the task.

5.1 Dassault Systèmes – Simulia

Simulia from Dassault Systèmes is an engineering simulation software (CAE). It offers an advanced simulation product portfolio, including Abaqus FEA, Multiphysics, Isight and Sim-Simulia SLM. The package enables realistic simulation for designers and analysts. The integrated analysis solutions eliminate the transfer and translation issues of data and allow users to perform analysis directly on their reference model in CATIA.

Dassault Systèmes offers the possibility to design plugins upon request in case communication between Simulia and other third party software is needed.

Simulia from Dassault Systèmes was selected to be the first SLM tool for evaluation. The evaluation licenses and training material was provided by Dassault Systèmes within the SIMPRO project. Two days training about Abaqus CAE/Simulia was also organized on 26-27.9.2013 in Espoo.

5.2 ANSYS – ANSYS EKM

ANSYS Engineering Knowledge Management (EKM) software is a web-based multi-user collaborative solution aimed at meeting the simulation process and data management challenges faced by ANSYS customers. ANSYS EKM is integrated with other ANSYS simulation tools. Multiple users in a workgroup environment can use the ANSYS EKM solution to automate simulation processes and workflows as well as perform project management tasks. Thus it helps to improve communication and collaboration among various group members.

ANSYS EKM enables to extract simulation properties and other metadata from files to ease the management process. These attributes can be used to search and retrieve files based on key words or complex search criteria. Reports can be generated that compare property similarities and differences between multiple files.

EKM from ANSYS was selected to be the second SLM tool for evaluation. The evaluation licenses and training material were provided by EDR&Medeso. A focused training workshop related to SIMPRO topics was also organized on 21.5.2015.

5.3 MSC Software – SimManager

SimManager from MSC Software is a complete solution that brings together people, process and technology. It is a Simulation Process and Data Management System that manages all aspects of performing CAE simulation. It offers the possibility to manage the simulation data and processes for product development. It is a web-based simulation data and process management system from project initiation to the final report generation. SimManager helps to address some important issues for a higher simulation throughput and efficiency at lower cost. It enables to reduce the time spent in repeatable tasks by the process automation which reduces the manual execution of repetitive simulation tasks and processes.

The MSC software for evaluating the SimManager was not pursued due to lack of resources in the task.

5.4 Simantics

Simantics is a software platform for modelling and simulation. The system has client-server architecture with a semantic ontology-based modelling database and Eclipse framework -based client software with plug-in interface. The Simantics platform and many of its components are open source under Eclipse Public License EPL.

The Simantics platform offers an open, high-level application platform on which different computational tools can be integrated to form a common environment for modelling and simulation. The platform includes several modelling tools, so-called editors, for e.g. 2D graph-like hierarchical model composition and semantic graph browsing.

One of the biggest innovations in the Simantics platform is the semantic modelling approach itself and the high-level ontology tools. The data triple engine on the server side enables high performance data management and arbitrary mapping of data. This enables e.g. efficient mapping of simulation and measurement data to the model configuration and its visualisation.

The Simantics platform is still in research and development phase and its focus has been on modelling, simulation and data management tools for process industry. The platform has been successfully utilized to develop APROS [19] which is a process simulation tool for nuclear and thermal power plant applications. However, currently the platform does not provide any solutions for mechanical engineering. The vision of Simantics platform is to create a virtual product model that includes the design model but also the functional models (FEA, CFD, MBS, ...) all linked together. This concept is very big and complex, and requires lots of further research and development.

Although Simantics platform has a potential to be utilized as SLM tool however, implementation of SLM features is a big challenge and SIMPRO project do not have enough resources or knowhow to implement an SLM system on the Simantics Platform.

6. Middleware

Middleware may have an essential role within a company that uses different modelling or simulation software providers. It enables to uniform data from one simulation tool to the other, from the designer to the analyst but as well for extracting/reading data from a file. It also enables to reconstruct a solid 3D model from a surface-based model such as a step file.

6.1 SpaceClaim

SpaceClaim is a powerful middleware allowing the integration of a large variety of CAD formats and simulation tools. SpaceClaim has been acquired by ANSYS. The integrations are provided by SpaceClaim or by Esteco and/or by Noesis Solutions. It integrates with the following CAE Packages [20] (see Table 1).

Table 1: CAE packages for SpaceClaim

CAE Product	SpaceClaim	Esteco (modeFRONTIER)	Noesis Solutions (Optimus)
ANSA by BETA CAE Systems		X	X
ANSYS WORKBENCH	X	X	X
AVLAST by AVL		X	X
CFdesign by Autodesk	X		
COMSOL	X		
CST Studio Suite		X	
Enmesh	X		
FLOWMASTER V7		X	
GT-SUITE by Gamma Technologies		X	X
JMAG by JSOL Simulation Technology		X	X
LMS Imagine.Lab AMESim		X	X
LMS Virtuai.Lab		X	X
LS-Dyna		X	X
MADYMO by Tass		X	X
MoldFlow by Autodesk		X	X
MSC Adams		X	X
MSC Nastran			X
Resources Management system			X
Ricardo Wave			X
Samcef			X
SFE CONCEPT		X	X
SIMULIA (AbaQus) by Dassault Systemes		X	X
Simulation-X by ITI		X	
Thermal DesKtop by C&R Technologies		X	
µETAPost by Beta CAE Systems		X	X

SpaceClaim supports the following formats for Import/Export (see Table 2):

Table 2: Import/export formats supported by SpaceClaim

Module	Import	Export
SpaceClaim Engineer	ACIS, AMF, DXF, DWG, IDF, IGES, OBJ, Rhino, SKetch-Up, STEP, STL, Bitmaps, Videos	ACIS, Acrobat 2D & 3D (lightweight), AMF, DXF, DWG, IGES, KeyShot, Pow-erPoint, Rhino, SKetchUp, STEP, STL, VRML, OBJ, XAML, XPS, Bitmaps, Videos
Data Exchange I	CATIA v4, Inventor, Pro/ENGINEER, VDA-FS	VDA-FS
Data Exchange II	NX, Parasolid, Solid Edge, SolidWorks	Parasolid
CATIA v5 Data Exchange	CATIA v5	CATIA v5
JT Open Data Exchange	JT	JT
3D PDF Data Exchange	3D PDF	3D PDF

6.2 PolyTrans

PolyTrans from Okino Computer Graphics is a middleware for comprehensive visualisation and data translation of 3D Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM). It enables to visualise 3D models and translate them into other formats. It is a stand-alone program which aims to produce more accurate, error free and robust conversions between CAD file formats among others. PolyTrans supported formats [21] are listed in Table 3.

Table 3: Supported graphics formats by PolyTrans

3D Import File Formats	3dsMax, Maya, ACIS SAT, Apple 3D Metafile, Adobe Illustrator, Autodesk Inventor, Biovision, CATIA v5, DirectX, DXF/DWG, DWF-3D, IGES, FACT, ESRI, FBX, HOOPS HSF, JT, Light-wave, OpenFlight, Parasolid, PDB, Rhino-3D/OpenNURBS, Pro/Engineer, SGI-Inventor2 & VRML1, Solid Edge, SolidWorks, STEP; STL; VRML2; Wavefront OBJ; X3D; XGL, VDA-FS, and others…
3D Export File Formats	3dsMax, Maya, Apple Metafile, Cinema-4D, DirectX, DXF/DGW, DWF-3D, FBX, HOOPS HSF, IGES 5.x, JT, Lightscape, Light-wave, NGRAIN 3KO, OpenFlight, OpenGL, OSG/IVE, PLY, Renderman RIB, Rhino-3D/OpenNURBS, SGI-Inventor2, Soft-image dotXSI, STL, Shockwave-3D, U3D (3D-PDF), VRML1+2, XAML, X3D, XGL, Wavefront OBJ, and others…
2D Bitmap File Formats	TIFF, JPEG, BMP, SGI, GIF, IFF Lightwave, IFF Maya, PIC (Softimage), PIX (Maya), PNG, PPM, PSD (photoshop) and Targa. Additional LeadTools supported bitmap file formats: AFP, BMP, CMP, CUT, EPS, EXIF, FLC, GEM, ICO, IFF, ITG, FPX, MAC, MSP, PCD, PCT, CLP, PCX, PSD, PBM, PNG, PTK, SCT, SGI, SMP, RAS, TIFF, TGA, WBMP, XWD and XPM. Vid-eo formats supported for viewing: AVI, MPEG-1, 2, 4, Quick-Time Movies (.qt, .mov, .mtv) and Macromedia Flash (SWF).

6.3 Compatibility Matrix between Abaqus and CATIA V5

The version management of software is also an important requirement of SLM tools. For instance, the following table shows the compatibility matrix between the Abaqus versions and CATIA V5 versions [22]. It shows that depending on which version of CATIA is used, only some version of Abaqus can be used and vice versa. It shows that is not so straight forward to manage old data with new software, and can be sometimes a challenging issue. In this kind of a situation, middleware has an important role in the data management process.

Table 4: Abaqus and CATIA V5 compatibility matrix [22]

Compatibility Matrix		Abaqus for CATIA V5							
		R20	*R20 SP4*[1]	*R21*	*V5-6R2012*	*V5-6R2012 SP2*	*V5-6R2013*	*V5-6R2013 SP1*	*V5-6R2014*
Abaqus	6.13								To be qualified Q4 2013
	6.12						✓	✓	
	6.11						✓	✓	
	6.10			✓	✓	✓			
	6.9-EF		✓	✓	✓	✓			
	6.9	✓	✓	✓	✓	✓			

7. Conclusions

The report identifies the challenges and problems faced by the design engineers during the modelling and simulation phase of the product development and design process. Exchanging data among different computational tools is for some cases a challenging task, especially while dealing with complex products. With this perspective, some Simulation Lifecycle Management (SLM) tools have been surveyed and reported, which will be studied in order to point out the existing gap between modelling and simulation tools all along the product lifecycle. To illustrate the research work, we have described various product development processes, which require the combination of multidisciplinary simulations along with the processes and simulation tools that are going to be used. Data exchange between various simulation tools has been discussed stated, and middleware that plays an important role in the transfer of data have been listed.

This document gives the foundations for the task 4.3, which consists of using simulations over the product lifecycle using the selected case studies. Tools will be studied and used among different processes and interacting with different software and specialists.

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