VMAP

Virtual Material Modelling in Manufacturing

GENERAL INFORMATION

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If you would like to join the community or know more about the project, send an email to info@vmap.eu.com
For VMAP Standard IO Library Implementation, send an email to support@vmap.eu.com

How to Use This Booklet

This document explains the VMAP Project and provides an overview of the VMAP Use Cases.

Overview of Booklet Structure

This VMAP information is divided into two complimentary documents: VMAP General Information and VMAP Standard Specification Documentation.

VMAP General Information:

- Chapter 1 introduces and explains the VMAP Standard, the guiding idea and the definition.
- Chapter 2 throws light on State of the Art.
- Chapter 3 provides a brief account of the requirement analysis, which led to the inception of VMAP.
- Chapter 4 introduces the Software Architecture of VMAP and the output technology used by VMAP.
- Chapter 5 describes the Use Cases that were used to demonstrate the usefulness and capacity of the VMAP Standards.

VMAP Standard Specification Documentation:

- Chapter 1 introduces the Software Architecture of VMAP and the output technology used by VMAP.
- Chapter 2 shows how to start using the API.
- Chapter 3 describes the relationship among the C++ structures defined in VMAP Standard I/O Library.
- Chapter 4 gives an account of the VMAP Standard I/O Library or VMAP Standard API.
- Chapter 5 contains information on compiling the VMAP Standard API.
- Chapter 6 provides a possibility to implement your own VMAP I/O Library. This chapter should be used carefully, since the `Nomenclature` and structure used by VMAP is explained in detail. It is essential to follow this `Nomenclature` and structure to get the correct VMAP Standard file.
- Chapter 7 shows the snapshots from the HDF5 Viewer of a standard VMAP .h5 file.
- Chapter 8 further elaborates on the specifications. It describes the standard VMAP Element definitions, which are already part of the factory, and how to define one of your own elements.
- Chapter 9 further elaborates on the specifications with standard VMAP Integration Type definitions and how to define one of your own integration types.

- Chapter 10 shows the standardized VMAP variables. These will also be available in the API in the next versions.
- Chapter 11 provides some basic tutorials on how to use the VMAP Standard API.
- Chapter 12 defines simple test cases which could be used by a developer or an end user.
- Chapter 13 shows few of the additional features offered by VMAP.

Target Audience

To be able to use the VMAP Documentation efficiently, prior knowledge of modelling and simulation is required. The user should have hands-on experience of at least one CAE Tool, or at the very least, basic knowledge of Finite Element Analysis. Users and Developers may have different needs so in the table below we have categorized the documentation accordingly.

<table>
<tr><th colspan="2">VMAP Documentation Chapters of Interest</th></tr>
<tr><td colspan="2">CAE Tool End Users to understand the VMAP Standard background, format and testing.</td></tr>
<tr><td>VMAP General Information</td><td>VMAP Standards Document</td></tr>
<tr><td>1
2
3
4
5</td><td>12
10</td></tr>
<tr><td colspan="2">CAE Tool Developers to understand and implement VMAP Standard API within their own software tool.</td></tr>
<tr><td>VMAP General Information</td><td>VMAP Standards Document</td></tr>
<tr><td>1
4</td><td>2
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11
12
13</td></tr>
<tr><td colspan="2">CAE Tool Developers to implement their own VMAP I/O Library instead of using the VMAP Standard I/O Library. These users should check every detail carefully to implement the correct VMAP Standard, especially noting the implementation of element types and integration types.</td></tr>
<tr><td>VMAP General Information</td><td>VMAP Standards Document</td></tr>
<tr><td>1
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Abbreviations

CAE	Computer Aided Engineering
FEM	Finite Element Methods
FEA	Finite Element Analysis
SWIG	Simplified Wrapper and Interface Generator
API	Application Programming Interface

Contents

Chapter 1

VMAP Standard for CAE Interoperability

The ITEA VMAP project, see details in Appendix A, aims to gain a common understanding of, and interoperable definitions for, virtual material models in CAE. Using industrial use cases from major material domains and with representative manufacturing processes, new concepts are being created for a universal material exchange interface for virtual engineering workflows.

1.1 Problem Statement

Computer aided engineering (CAE) departments in industries are using different varieties of software tool for material simulation in parameterisation of virtual manufacturing and machining processes and in product tests. All CAE tools have an internal representation of the material data and in almost all the cases these material representations cannot be used by another CAE tool. Although, the exchange of data is paramount to a successful CAE workflow process, there aren't many standardized formats for data exchange. This leads to a case-basis implementation accounting for huge amount of effort. The standardisation of material interfaces in CAE is therefore vital for all industry segments where material behaviour is central to product and process design.

1.2 Proposed Solution - VMAP Standard

The concepts generated within the VMAP project will be concretised in an open software interface standard and implemented in a number of software tools. The advantages of integrated material handling will be demonstrated by six industrial use cases from different material categories, manufacturing domains and industry segments. In brief, VMAP will:

- generate universal concepts and open software interface specifications for the exchange of material information in CAE workflows.

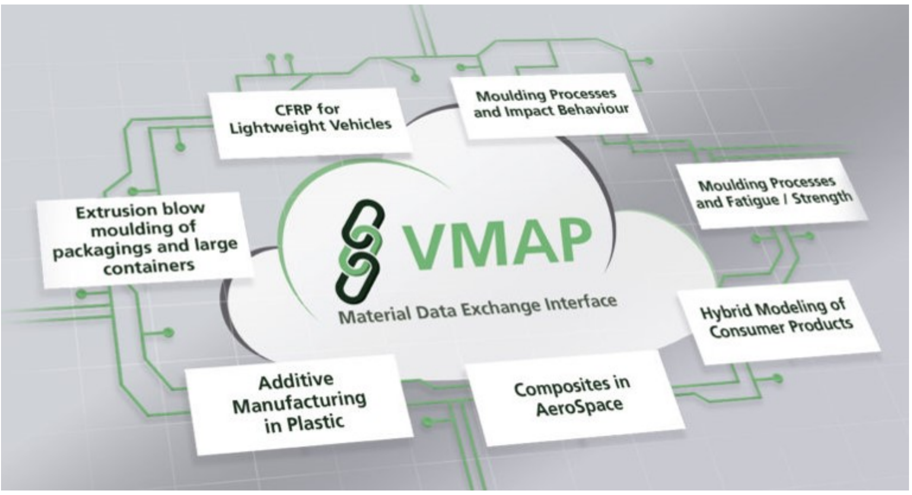

Figure 1.1: Industrial Use Cases will show the need and benefits of a standardised Material Exchange Interface.

- realise (prototype) implementations for extended CAE tool interfaces and – where necessary – translation tools which follow the open interface specification.
- implement virtual industrial demonstrators for relevant material domains and manufacturing processes and provide best-practice guidelines for the community.
- establish an open and vendor-neutral 'Material Data Exchange Interface Standard' community which will carry on the standardisation efforts into the future.

1.3 Challenge

Overall, some efforts have been made in regard to bringing standard file formats or standard specifications to the industry, the penetration of such standards has been limited to a few specific industries, mainly Aero-industry (see Chapter 2). The standardizing of storage formats has been paramount to the Aero-industry because it is essential to use data in the long term. Changing data formats over the years would have been a huge financial and technical blunder for this industry. However, other manufacturing markets might not need data for long term archival, they definitely need it for interoperability among various softwares. With a wide range of application specific CAE tools in the market, the need for a common standard, which allows use of any software the user wishes, has become primary if not indispensable. Hence, VMAP Standard is a step forward in the standardization of output file formats. With multiple partners, it was possible to gather varied use cases from different domains of the manufacturing industry, thus assisting in a comprehensive development of the standard.

Chapter 2

State of the Art

2.1 STEP - STandard for the Exchange of Product model data

ISO 10303 (ISO, 2000) is an International Standard for the computer-interpretable representation of product information and exchange of product data. Its official title is: Industrial automation systems and integration — Product data representation and exchange. It is known informally as **"STEP"**, which stands for " **St**andard for the **E**xchange of **P**roduct Model Data". The objective is to provide a neutral mechanism capable of describing product data throughout the life cycle of a product independent from any system. STEP AP209 ed2 is one such standard for sharing, exchanging and long term archiving of engineering design and multi-disciplinary simulation data (Figure 2.1) [1].

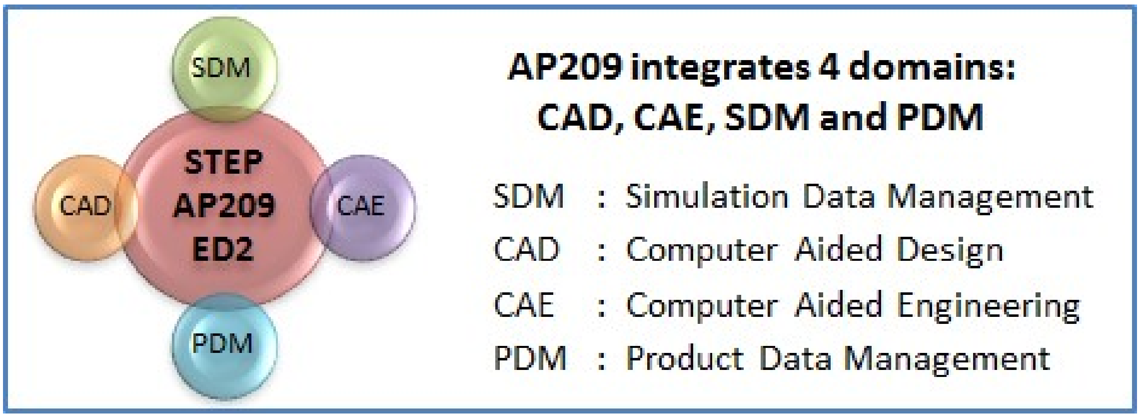

Figure 2.1: AP209 Main concepts [1]

STEP AP209 ed2 – Application Protocol: Multidisciplinary analysis and design Formerly known as Part 209:2001 – Application Protocol: Composite and metallic structural analysis and related design is concerned with sharing, exchange and long term archiving of data between the iterative design and analysis stages of product life cycle. The disciplines covered by AP209 are Structured Finite Element Analysis, Computational Fluid Dynamics and Kinematic Analysis (Figure 2.2) [1]

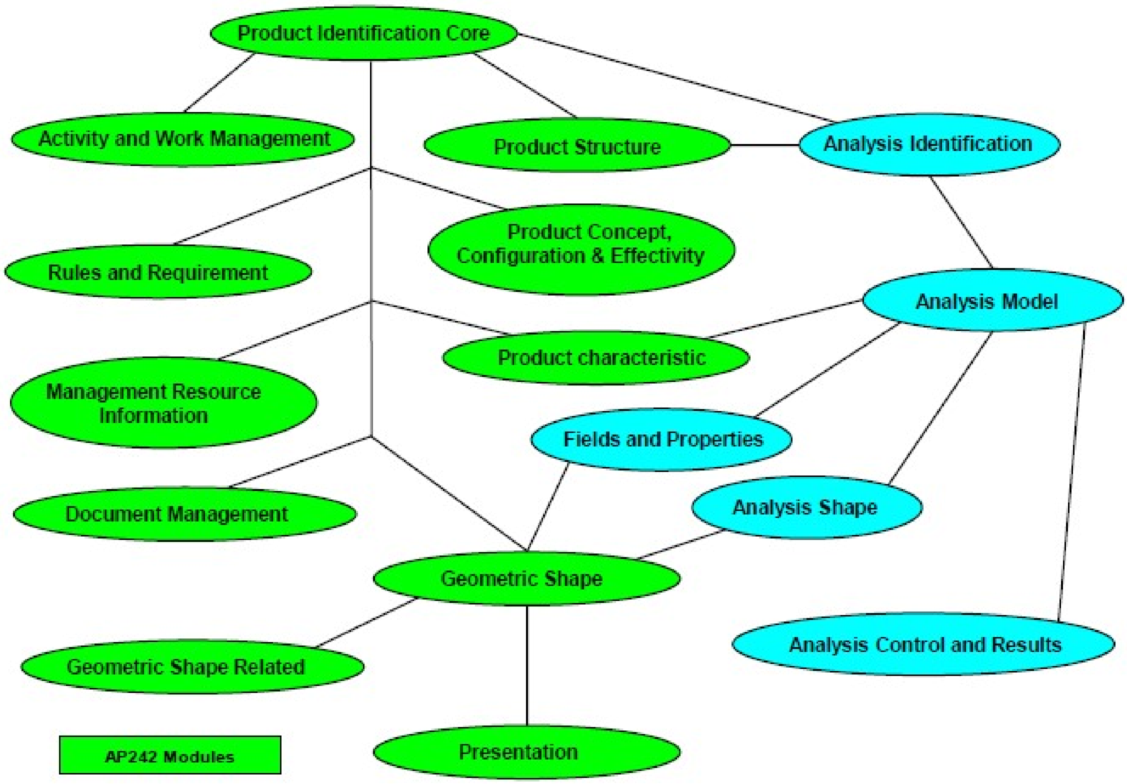

Figure 2.2: AP209E2 High Level Overview – Data Planning Model [1]

2.2 LOTAR – LOng Term Archiving and Retrieval

The objective of LOTAR International is to develop, test, publish and maintain standards for long-term archiving (LTA) of digital data, such as 3D CAD and PDM data. The LOTAR project consortium consists of user companies from around the world. Member companies include Airbus, BAE Systems, Boeing, EADS, Eurocopter, General Dynamics, Lockheed Martin, SAFRAN, Sandia, and others [2].

LOTAR Composites Workgroup

- The objective of the LOTAR Composites Workgroup is to develop, publish and maintain standards designed to provide the capability to archive and retrieve CAD 3D composite structure in a standard neutral form that can be read and reused throughout the product life cycle, independent of changes in the IT application environment originally used for creation. This workgroup has extensively used the ISO 10303 Information models, AP203 "Configuration-controlled design" and AP209 "Composite & metallic structural analysis & related design" standards [2].

LOTAR EAS: Engineering Analysis & Simulation Workgroup

– EAS WG launched in December 2014 is developing capabilities for archiving, retrieval and reuse of valuable engineering simulation and analysis assets. They also rely closely on ISO STEP AP209 ed2 "Multidisciplinary analysis and design" [2].

2.3 EMMC – The European Materials Modelling Council

The EMMC elaborates methodologies and supports the development and implementation of open, widely endorsed metadata schema for interoperability and standards based on the **European Materials Modelling Ontology (EMMO)** framework [3], EMMO covers all aspects of material modelling : behaviour, governing physics law, mathematical representation in a solver and post processing data.

Chapter 3

Requirement Analysis for VMAP

The VMAP consortium involves more than 30 companies from all over Europe and North America. This includes the 10 manufacturing industries and the rest are CAE software developers. All the members of the consortium offer different industrial use cases, hence making VMAP a wholesome standard covering a vast variety of materials used for manufacturing. Based on this vast majority of use cases, some of the critical requirements for VMAP are listed below:

1. VMAP should contain result information in detail.
2. VMAP should contain all data necessary to map the results.
3. VMAP should be capable of storing transient analyses.
4. VMAP should be able to use any of the standard unit systems.
5. VMAP files should be useful for both batch and automatic execution modes.
6. VMAP should be capable of storing custom coordinate systems, both local and global.
7. VMAP should be useful for all known operating systems.
8. VMAP files should be accessible with the help of free/open source tools.
9. A service and support community should exist, even after the project ends.
10. Software maintenance should be carried out on a regular basis.

These are few of the very basic requirements, which form the building blocks of VMAP. These critical requirements and many others formed the basis of VMAP and led to a standard which covers the geometrical and material domain in CAE.

Chapter 4

VMAP Software Architecture

This chapters explains the VMAP software architecture (Figure 4.1), briefly going through all the layers. The further chapters then focus on each layer in detail.

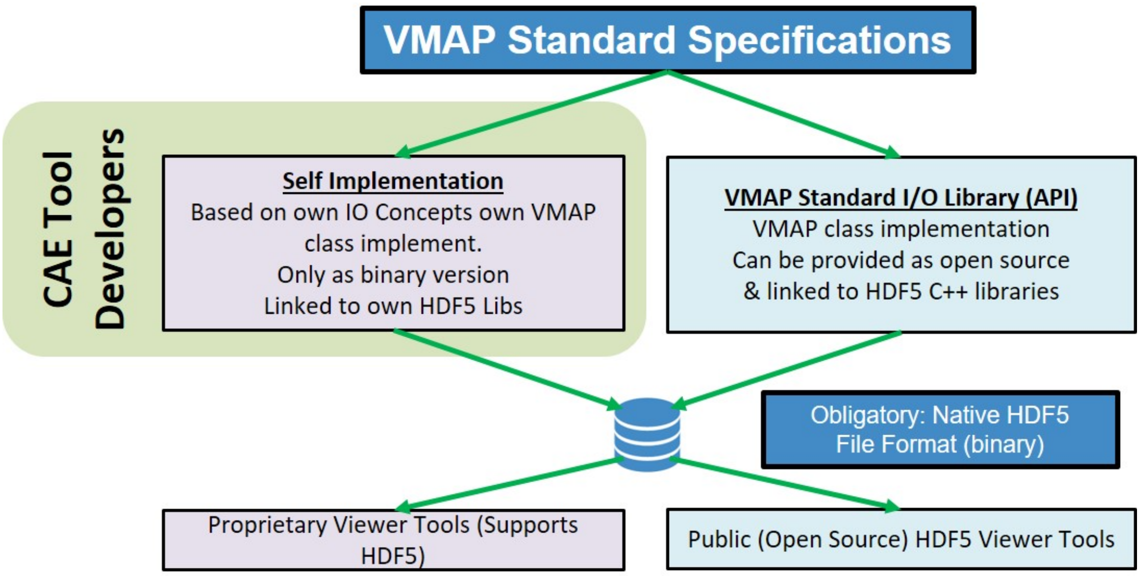

Figure 4.1: VMAP Software Architecture

VMAP Standard Specifications are at the core of the software architecture. VMAP offers two possibilities for any user. First, is to use the VMAP Standard Specifications via the VMAP Standard I/O Library (API) built in C++. The second option is to implement your own VMAP I/O classes using the VMAP Standard Specifications. The only obligation is to use the native HDF5 file format as the output. HDF5 file format is an optimal and apt output option for VMAP because HDF5 Viewer is an open source tool, just like VMAP Standard Specifications are open source. Section 4.3 explains HDF5 Technology in detail.

The VMAP Standard I/O Library or **VMAP Standard API** is explained in detail in chapters 3 & 4 in Standards Document. The option to implement your own VMAP I/O Library is explained with schematic diagrams in chapter 6.

4.1 VMAP Interface to CAE Tools

Almost all CAE tools offer API, these API are used by ISVs to build codes. ISV codes written in C++ can be directly linked to the 'VMAP Standard API'. ISV codes written in Python, Java, C# or FORTRAN utilize the 'VMAP Standard API' through a language specific interface. For Python, Java and C# such a language specific interface can be automatically generated using the **Simplified Wrapper and Interface Generator (SWIG)**(Section 4.2). For FORTRAN the language specific interface is possible but must be written manually. Figure 4.2 shows the extended software architecture.

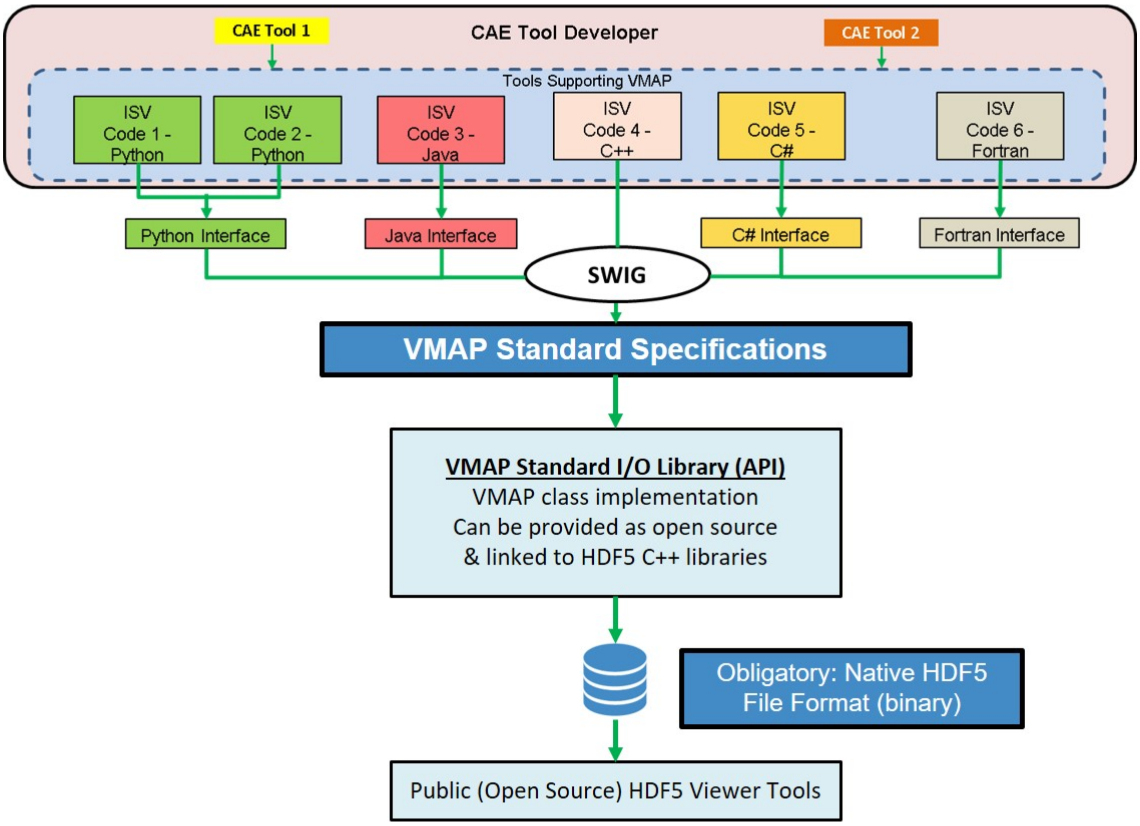

Figure 4.2: Extended VMAP Software Architecture

The VMAP Standard API and its role in a chain CAE simulation process is represented in (Figure 4.3). The image shows two simulations, Blow Moulding simulation carried out using Code A and Cooling simulation carried out using Code B. The cooling simulation requires the output result of the blow moulding simulation. Such a situation arises very often in the industry, where results of one simulation are required to carry out another simulation. Since, there are multiple CAE tools (Codes) available in the market, each time a combination of tools is used a new specific converter needs to be developed. This is where VMAP Standard comes into the picture, with all CAE tools providing VMAP Standard format as one of the output options, the specific converters will become unnecessary. VMAP Standard will facilitate reusability and thus, time saving. Since VMAP Standard is currently in development phase, the converter is replaced by an external

VMAP converter. As the standard is completely formalised, the VMAP Standard API can be directly integrated into the CAE tool.

CAE tools which additionally require a Mapper to map data from Simulation Model A to Simulation Model B, can also have the Mapper integrated with the VMAP Standard API.

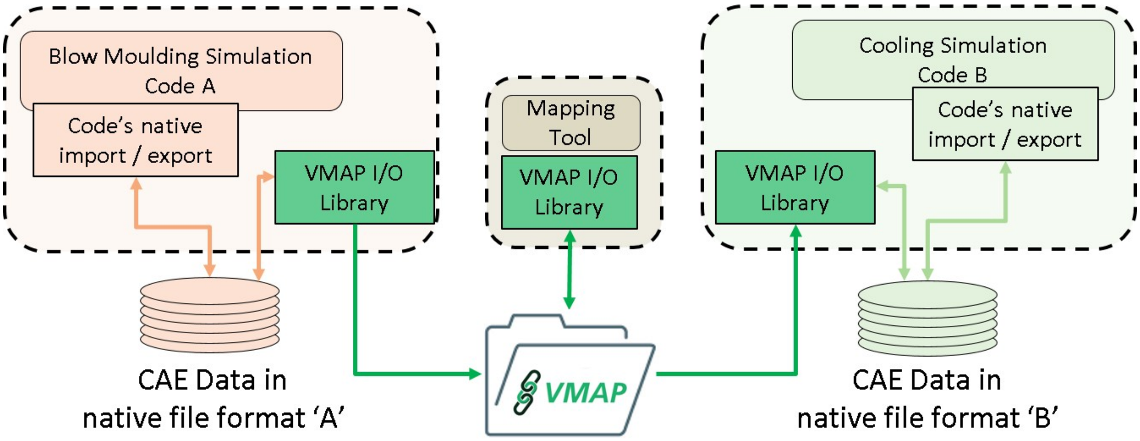

Figure 4.3: VMAP Standard API in CAE chain simulation process

4.2 SWIG

SWIG is a software development tool that connects programs written in C and C++ with a variety of high-level programming languages. SWIG is used with different types of target languages including common scripting languages such as JavaScript, Perl, PHP, Python, Tcl and Ruby. The list of supported languages also includes non-scripting languages such as C#. SWIG is most commonly used to create high-level interpreted or compiled programming environments, user interfaces, and as a tool for testing and prototyping C/C++ software. SWIG is typically used to parse C/C++ interfaces and generate the 'glue code' required for the above target languages to call into the C/C++ code [5]

4.3 HDF5 technology

The VMAP interface and transfer file relies on the HDF5 technology. The Hierarchical Data Format (HDF) implements a model for managing and storing data. The model includes an abstract data model and an abstract storage model (the data format), and libraries to implement the abstract model and to map the storage model to different storage mechanisms. The HDF5 Library provides a programming interface to a concrete implementation of the abstract models. The library also implements a model of data transfer, an efficient movement of data from one stored representation to another stored representation. The figure below illustrates the relationships between the models and implementations. This chapter explains these models in detail.

The Hierarchical Data Format version 5 (HDF5), is an open source file format that supports large, complex, heterogeneous data. HDF5 uses a "file directory" like structure that allows you to organize data within the file in many different structured ways, as you might do with files on your computer. The HDF5 format also allows for embedding of metadata making it self-describing.

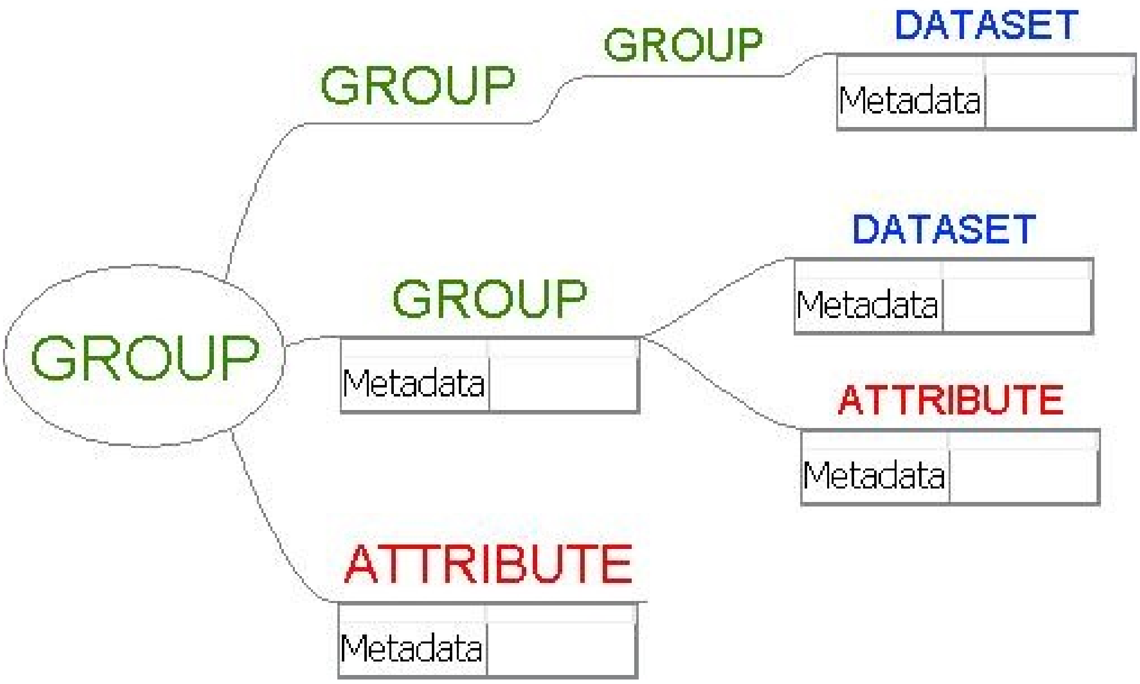

Figure 4.4: HDF5 file format

Chapter 5

VMAP Use Cases

This chapter describes the seven VMAP use cases created to demonstrate the VMAP standards being used within industrial simulation workflows in different sectors.

UC.1	Blow Forming
UC.2	Composite for Lightweight Vehicles
UC.3-1	Injection Moulding – impact
UC.3-2	Injection Moulding – foaming
UC.3-3	Injection Moulding – creep
UC.4	Additive Manufacturing
UC.5	Plastic Metal interaction
UC.6	Composites in Aerospace

Additional input file information is provided in digital form, please contact the VMAP Standards Community via the website.

5.1 Use Case UC.1 Blowforming

Sector: Extrusion blow moulding

5.1.1 Description and Final product

Integrated simulation and optimization workflow for blow moulded plastic parts considering geometry changes because of shrinkage and warpage.

The product range of extrusion blow-moulded plastic parts ranges from thin-walled packaging products like bottles or cans, to highly stressed technical parts like fuel tanks or intermediate bulk containers (IBC), see Figure 5.1.

Figure 5.1: Blow moulded components

5.1.2 Process description

The CAE workflow of blow moulded products cover the manufacturing process, as well as the product behaviour of the final part (structural analysis), see Figure 5.2.

The process simulations give information e.g. about the wall thickness distribution and the shrinkage and warpage, which significantly influences the product properties of the final part. Therefore, all the information regarding the process history (e.g. temperatures, residual stresses, or wall thickness) needs to be stored and transferred between the different simulation steps. In combination with high advanced material models, this integrative simulation approach makes it possible to predict the product properties of blow moulded parts with a very high accuracy.

Simulation Steps	Custom Interface	VMAP Interface
Blow Moulding Simulation		
transfer	yes	yes
Custom Code		
transfer	yes	yes
Cooling Simulation		
transfer	yes	yes
Shrinkage & Warpage		
transfer	no	yes
Product simulation		

Table 5.1: Blow Moulding: Status & Progress

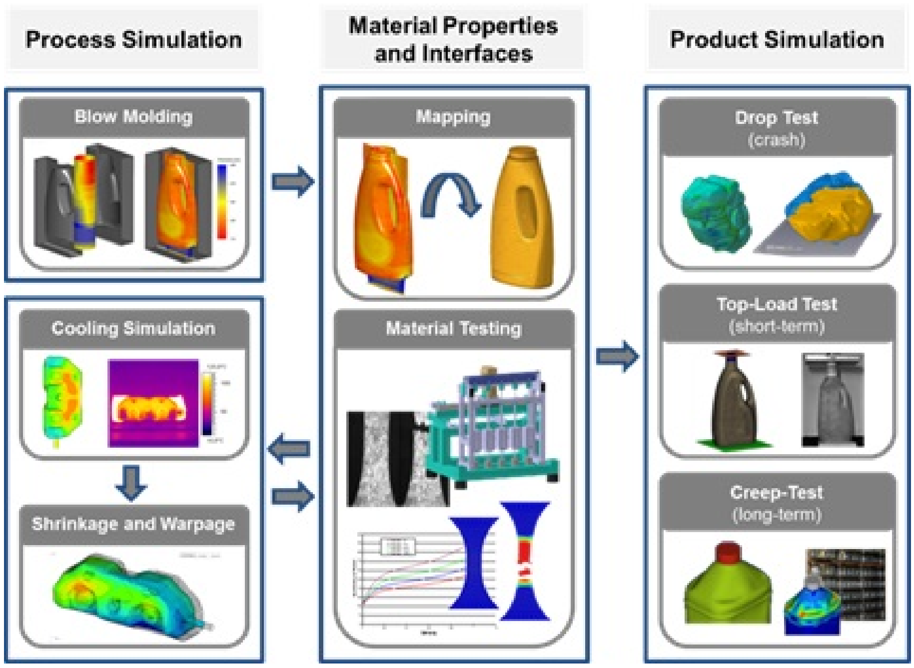

Figure 5.2: Simulation process workflows - Blowforming

5.1.3 Process requirements and advantages

The product performance of blow moulded parts is highly influenced by the process conditions. Therefore, the whole process history (e.g. local wall thickness, temperatures, residuals stresses, principal strain etc.) needs to be transferred between several simulation stages also involving different solvers and meshes.

The benefits of a standardized and self-acting virtual process chain are significant shorter development times and considerably more precise simulation models.

5.1.4 Simulation issues prior to VMAP

The main issue and challenge concerning a more realistic simulation in combination with a less time consuming CAE workflow is the lack of standardized interfaces. So it‘s currently difficult e.g. to use alternative solvers for different simulation.

5.1.5 User benefits/business case

More accurate simulation methods allow higher product performance of blow moulded plastic parts with less material consumption and shorter cycle times. Due to standardization and automation of the CAE-workflow, time consuming data transfer between different simulation stages can be avoided. In addition, the accuracy of the simulation models will be increased because the whole process history is taken into account. Furthermore, the automated data transfer makes the whole simulation process more user-friendly.

5.2 Use Case UC.2 Composites for Lightweight Vehicles

Sector: Automotive lightweight technology

5.2.1 Description and Final product

Integrated simulation and optimization workflow for an automotive composite manufactured by the established Resin Transfer Moulding (RTM) technology to produce complex shaped composite parts.

An automotive underfloor structure made of continuous fiber-reinforced polymers (CFRP) is shown in the Figure 5.3 below.

Figure 5.3: Simulation process workflow - Composites for Lightweight Vehicles

5.2.2 Process description

The CAE workflow is shown in Figure 5.4.

Resin Transfer Moulding (RTM) is an established technology to produce complexly shaped composite parts. The firgure below shows a standardized CAE workflow particularly from the view of high-performance composites in structural relevant automotive applications. The CAE chain shall efficiently combine all essential simulation steps and enable an integrated product development considering all relevant manufacturing effects and finally provide an integrated structural optimization over multiple simulation steps.

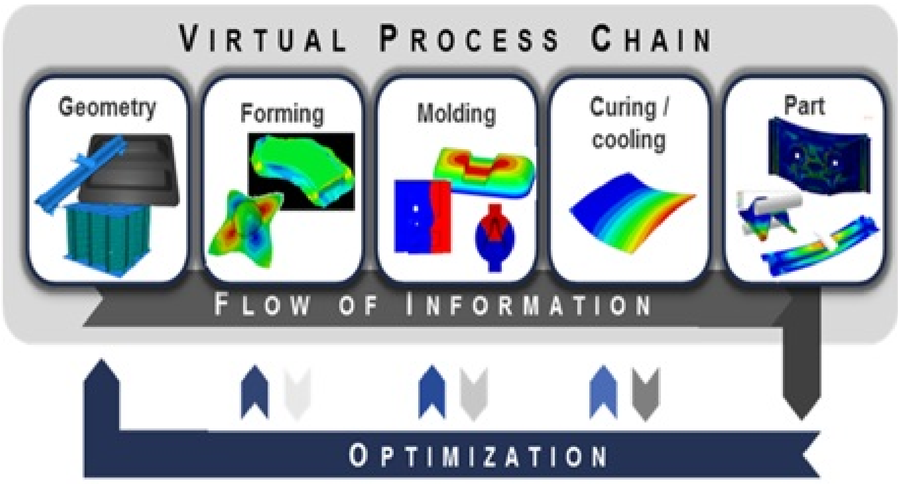

Figure 5.4: Simulation process workflow - Composites for Lightweight Vehicles

Simulation Steps	Custom Interface	VMAP Interface
Draping/Forming		
transfer	yes	yes
Infiltration/Molding		
transfer	yes	yes
Distortion		
transfer	no	yes
Structural		

Table 5.2: Composites for Lightweight Vehicles: Status & Progress

5.2.3 Process requirements and advantages

Results of forming simulation are required as initial conditions for subsequent simulations. This can help in reducing efforts for the development of product and reduce error in the part design evaluation.

5.2.4 Simulation issues prior to VMAP

The main issue and challenge is the mapping of the layered material including the transfer and mapping of fibre orientation, volume and density. The other difficult issue is the stress equilibrium after mapping has been carried out from the solid mesh to the shell mesh.

5.2.5 User benefits/business case

Support the development of a generally applicable, standardized CAE workflow particularly from the view of high-performance composites in structural relevant automotive applications.

The CAE chain shall efficiently combine all essential simulation steps and enable an integrated product development considering all relevant manufacturing effects and finally provide an integrated structural optimization over multiple simulation steps.

5.3 Use Case UC.3-1 Injection Moulding – Impact

Sector: Injection moulding of fibre reinforced materials

5.3.1 Description and Final product

For Short- and Long-Fibre Reinforced Thermoplastics (SFRT and LFRT) an integrative simulation will be performed. The transfer of the process induced fibre orientation as well as of further results of the injection moulding simulation (e.g. melt and weld lines) into structural explicit simulation will be researched. Especially the influence of simple to advanced approaches on prediction of energy consumption will be compared.

Injection moulded parts subjected to impact are shown in Figure 5.5.

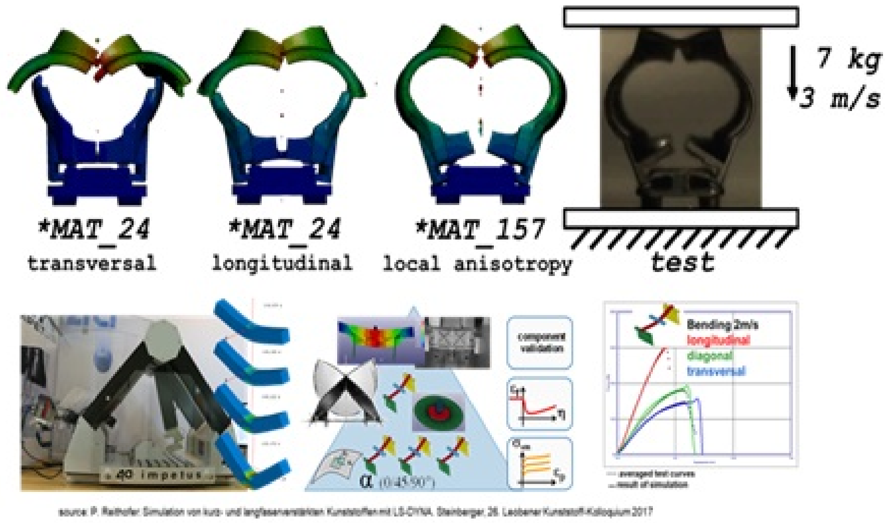

Figure 5.5: Injection Moulded Parts - Impact

5.3.2 Process description

The CAE workflow is shown in Figure 5.6.

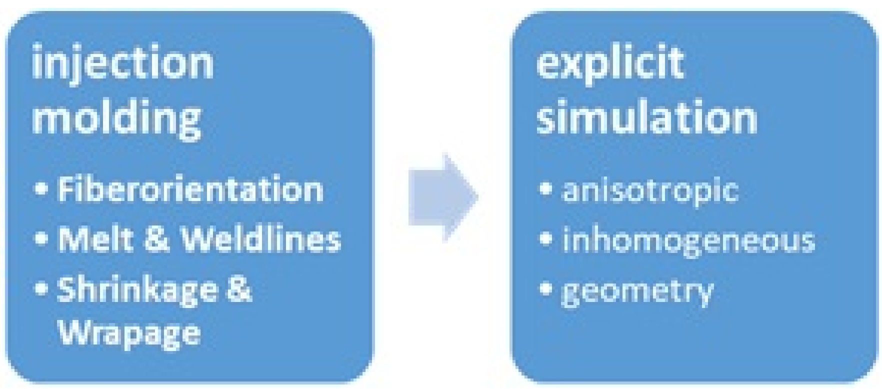

Figure 5.6: Simulation process workflow - Injection Moulding - Impact

Simulation Steps	Custom Interface	VMAP Interface
Injection Moulding		
transfer	yes	yes
Mapping		
transfer	yes	pending
Explicit Simulation		

Table 5.3: Injection Moulding - Impact: Status & Progress

5.3.3 Process requirements and advantages

From the injection moulding simulation (using Moldflow) the following information is required:

- fiber orientation,
- melt and weldlines,
- shrinkage and warpage.

From the impact simulation (using LS-DYNA) the following information is required:

- anisotropy,
- inhomogeneousness,
- geometry.

5.3.4 Simulation issues prior to VMAP

The main issue and challenge is the transfer and mapping of fibre orientation, volume and density and the transfer of custom result types such as porosity, bubble distribution, etc.

5.3.5 User benefits/business case

More accurate simulation methods allow higher product performance with reduced product development times.

5.4 Use Case UC.3-2 Injection Moulding – Foaming

Sector: Injection moulding of foamed components

5.4.1 Description and Final product

For foamed parts an integrative simulation will be performed. The transfer of the process induced bubble distribution and dimension into structural simulation will be researched. Some examples of injection moulded parts subjected to foaming are shown in Figure 5.7.

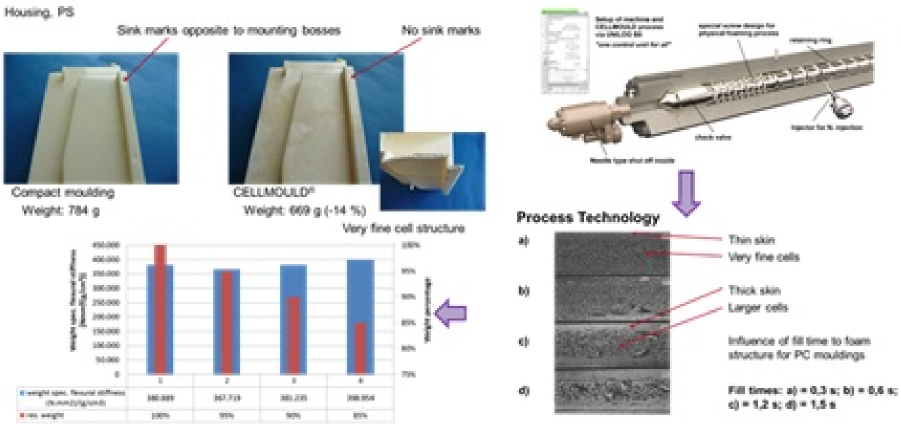

Figure 5.7: Injection Moulded Parts - Foaming

5.4.2 Process description

The CAE workflow is similar to that shown in Figure 5.8.

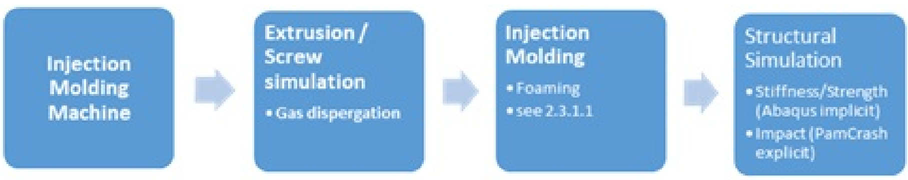

Figure 5.8: Simulation process workflow - Injection Moulding - Foaming

Simulation Steps	Custom Interface	VMAP Interface
Injection Moulding Machine		
transfer	yes	yes
Mapping		
transfer	yes	pending
Structural Analysis		
transfer	yes	pending
Strength Computation		

Table 5.4: Injection Moulding - Foaming: Status & Progress

5.4.3 Process requirements and advantages

Description to be included.

5.4.4 Simulation issues prior to VMAP

Description to be included.

5.4.5 User benefits/business case

More accurate simulation methods enable lighter products due to better exploitation of material capabilities. A major benefit is the reduced product development time.

5.5 Use Case UC.3-3 Injection Moulding – Fatigue

Sector: Injection moulding of fibre reinforced materials

5.5.1 Description and Final product

As for the previous fibre-reinforced thermoplastics an integrative simulation will be done. The simulation chain will be validated on two fibre-reinforced parts, see 5.9

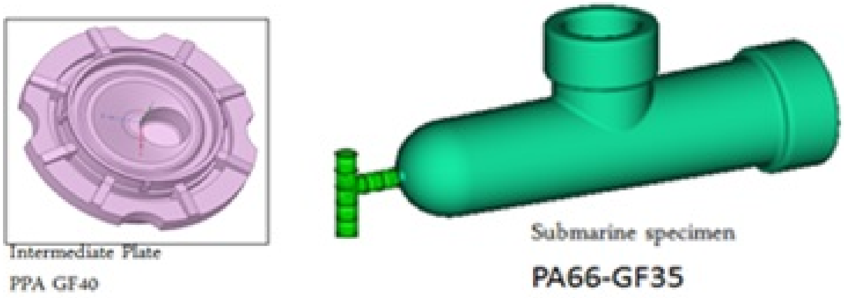

Figure 5.9: Injection moulded Components - Fatigue

5.5.2 Process description

The CAE workflow is similar to that shown in Figure 5.10.

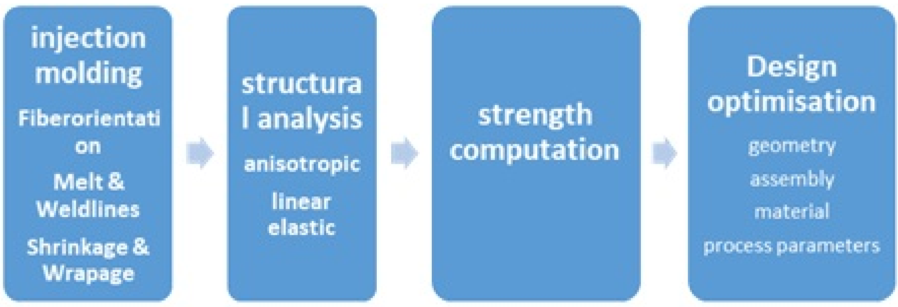

Figure 5.10: Simulation process workflow - Injection Moulding - Fatigue

Simulation Steps	Custom Interface	VMAP Interface
Injection Moulding		
transfer	yes	yes
Mapping		
transfer	yes	pending
Structural Analysis		
transfer	yes	pending
Strength Computation		
transfer	yes	pending
Design Optimization		

Table 5.5: Injection Moulding - Fatigue: Status & Progress

5.5.3 Process requirements and advantages

From the injection moulding simulation (using Moldflow) the following information is required:

- fiber orientation,
- melt and weldlines,
- shrinkage and warpage.

From the structural analysis simulation the following information is required:

- stresses/strains,
- energy field,
- element/integration point volume,
- element/integration point coordinates.

From the fatigue simulation (using FEMAT) the following information is required:

- lifetime,
- damage,
- safety factor.

5.5.4 Simulation issues prior to VMAP

The main issue and challenge is the transfer and mapping of fibre orientation, volume and density and the transfer of custom result types such as porosity, bubble distribution, etc.

5.5.5 User benefits/business case

Increased efficiency in product design process of injection moulded plastic parts due to increased simulation results quality and reduced design optimization cycle times.

5.6 Use Case UC.3-4 Injection Moulding – Creep

Sector: Injection moulding of fibre reinforced materials

5.6.1 Description and Final product

Establish an integrated simulation and optimization workflow for injection moulded plastic parts to consider deformation dependent design optimizations.

5.6.2 Process description

The CAE workflow is similar to that shown in Figure 5.11.

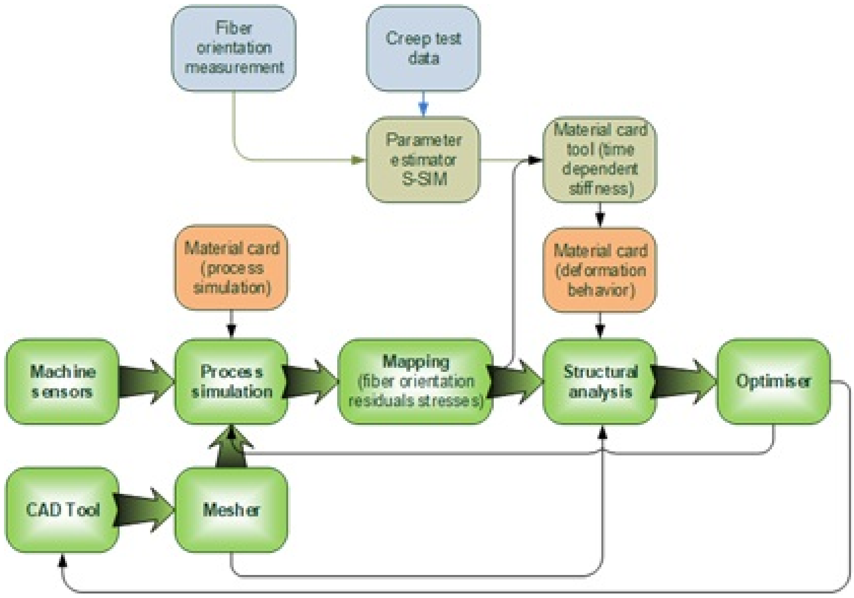

Figure 5.11: Simulation process workflow - Injection Moulding - Creep

Simulation Steps	Custom Interface	VMAP Interface
Injection Moulding		
transfer	yes	yes
Mapping		
transfer	yes	pending
Structural Analysis		

Table 5.6: Injection Moulding - Creep: Status & Progress

5.6.3 Process requirements and advantages

From the injection moulding simulation (using Moldflow) the following information is required:

- fiber orientation,
- melt and weldlines,
- shrinkage and warpage.

From the impact simulation (using LS-DYNA) the following information is required:

- anisotropy,
- inhomogeneousness,
- geometry.

5.6.4 Simulation issues prior to VMAP

The main issue and challenge is the transfer and mapping of fibre orientation, volume and density and the transfer of custom result types such as porosity, bubble distribution, etc.

5.6.5 User benefits/business case

Increased efficiency in product design process of injection moulded plastic parts due to increased simulation results quality and reduced design optimization cycle times.

5.7 Use Case UC.4 Additive Manufacturing Plastics

Sector: Additive Manufacturing of plastics parts

5.7.1 Description and Final product

Establish an integrated simulation and optimization workflow for additive manufactured plastic parts (exemplified for SLS process) to optimize the building process, the part design and the parts function. Ensure first time right production. An example of an additive manufacturing part is shown in Figure 5.12 as represented in the Digimat-AM software-

Figure 5.12: Additive Manufacturing - Plastics

5.7.2 Process description

The CAE workflow is shown in Figure 5.13.

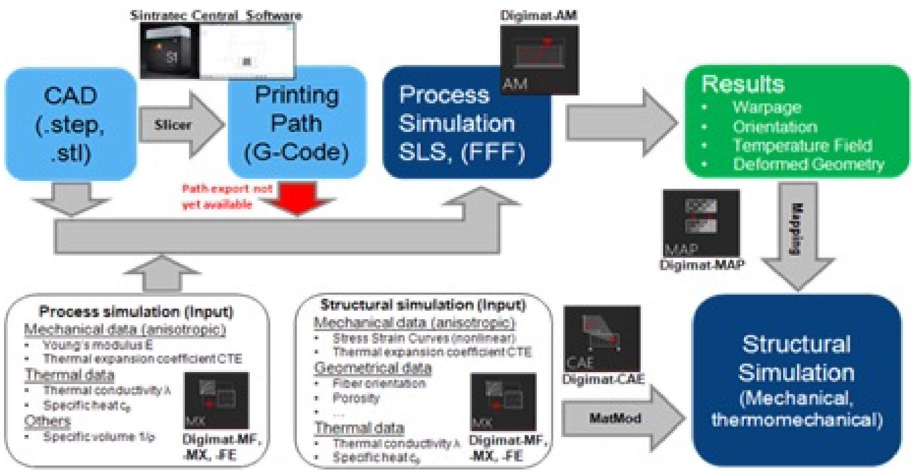

Figure 5.13: Simulation process workflow - Additive Manufacturing

Simulation Steps	Custom Interface	VMAP Interface
Printer Pre-processing		
transfer	yes	pending
Process Simulation		
transfer	yes	yes
Structural Simulation		

Table 5.7: Additive Manufacturing: Status & Progress

5.7.3 Process requirements and advantages

The product performance of blow moulded parts is highly influenced by the process conditions. Therefore, the whole process history (e.g. local wall thickness, temperatures, residuals stresses, principal strain etc.) needs to be transferred between several simulation stages also involving different solvers and meshes.

The Benefits of a standardized and self-acting virtual process chain are significant shorten development times and considerably more precise simulation models

5.7.4 Simulation issues prior to VMAP

The main challenge is the transfer of time dependent boundary conditions from printer to simulation.

5.7.5 User benefits/business case

Users have an effective compatible interface to communicate between the process simulation, other CAE tools and the printer software. Reduce effort and costs during the product development process. Reduce time to market.

5.8 Use Case UC.4 Hybrid Modelling of Consumer Products

Sector: Additive Manufacturing of plastic parts

5.8.1 Description and Final product

Philips seeks to further improve its production processes and the performance of its products.The product considered is the shaver shown in Figure 5.14.

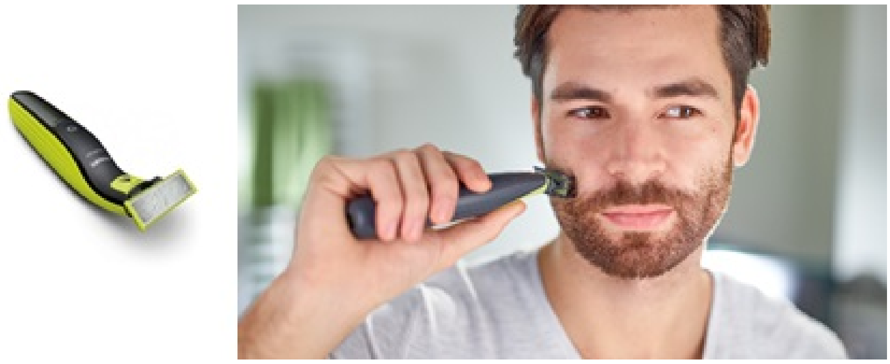

Figure 5.14: Shaver product and use.

5.8.2 Process description

The CAE workflow is shown schematically in Figure 5.15.

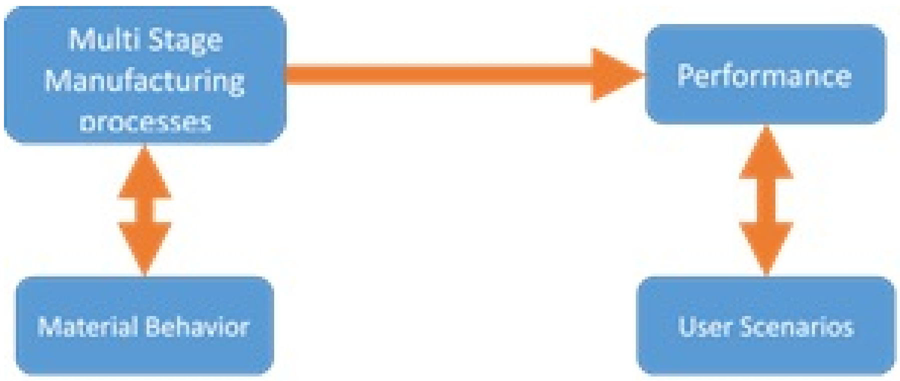

Figure 5.15: Simulation process workflow - Hybrid Modelling of Consumer Products

Simulation Steps	Custom Interface	VMAP Interface
Step 1		
transfer	yes	yes
Step 2		
transfer	yes	yes
Step 3		
transfer	no	yes
Step 4		

Table 5.8: Consumer Products: Status & Progress

5.8.3 Process requirements and advantages

To cut time-to-market and increase the speed of innovation, Philips and its partners aim to achieve a virtual process chain. Each partner in the consortium brings its unique knowledge and expertise to achieve the separate steps along the virtual development chain.

5.8.4 Simulation issues prior to VMAP

Currently a complete virtual process chain is not realized due to difficulties in transferring results from solution A to B.

5.8.5 User benefits/business case

VMAP will provide the links between the different virtual domains enabling seamless virtual product development.

5.9 Use Case UC.5 Composites in Aerospace

Sector: Composite manufacturing for commercial aerospace

5.9.1 Description and Final product

Virtual autoclave manufacturing for commercial aerospace parts. End-to-end simulations, design, and optimizations including material characterization, process simulation, shape optimization due to process-induced deformations, and process optimization for thermal compliance and processing defects.

The product considered ia a large, one-piece aircraft wing skin made from polymer matrix composites (carbon-fibre reinforced plastic), see Figure 5.16.

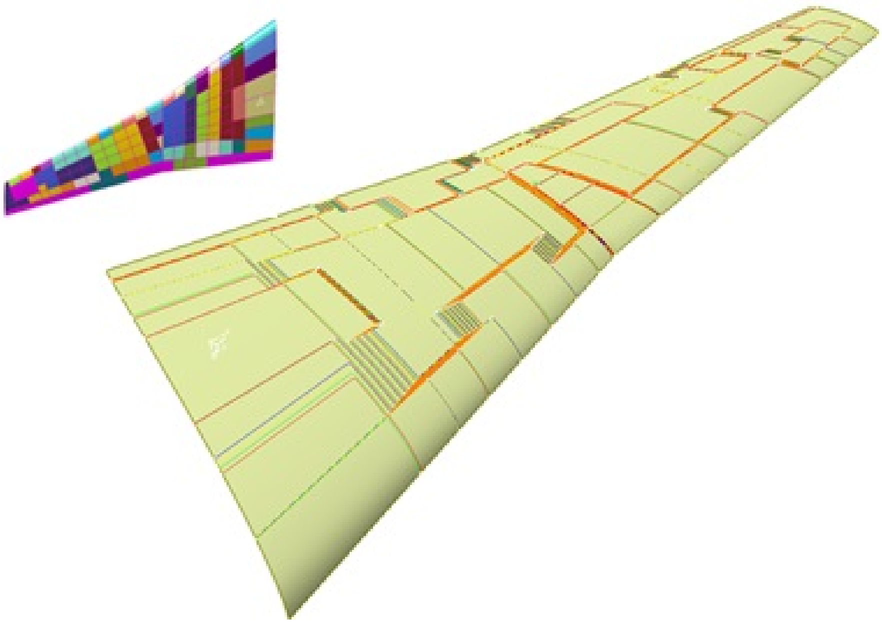

Figure 5.16: One-piece aircraft wing.

5.9.2 Process description

Virtual autoclave manufacturing for commercial aerospace parts, see workflow schematic Figure 5.17. End-to-end simulations, design, and optimizations including material characterization, process simulation, shape optimization due to process-induced deformations, and process optimization for thermal compliance and processing defects, see process chain in 5.17.

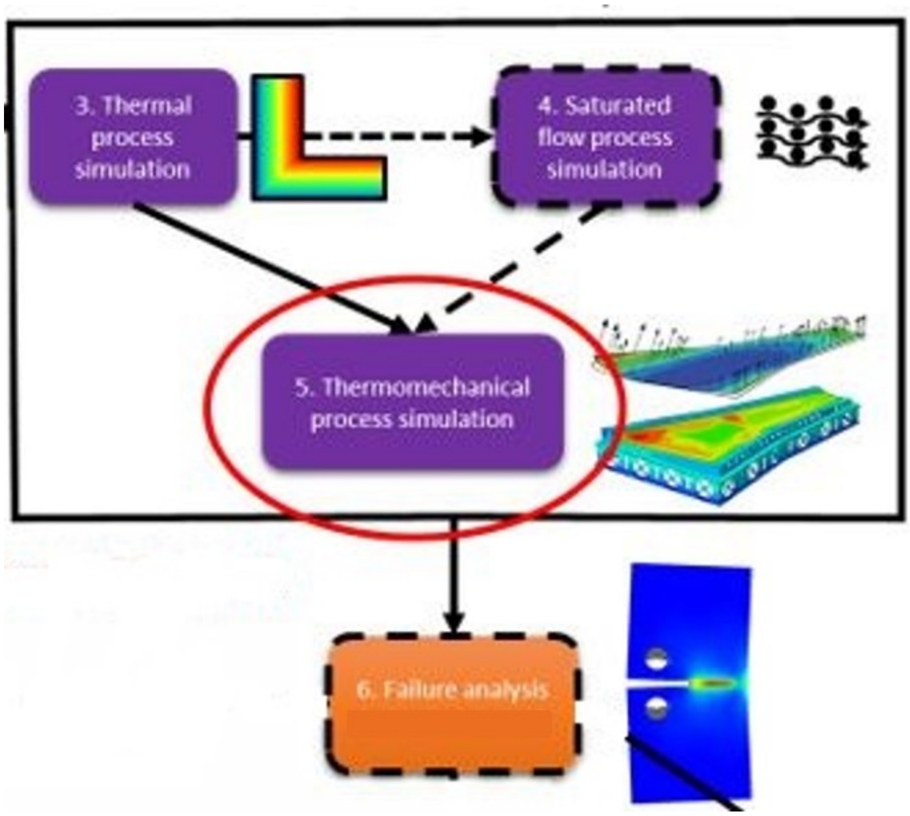

Figure 5.17: Simulation process workflow - Composites in Aerospace

Simulation Steps	Custom Interface	VMAP Interface
Thermal Analysis & Cure Simulation		
transfer	yes	yes
Saturated Flow Simulation		
transfer	no	yes
Thermo-mechanical Simulation		
transfer	no	yes
Failure Analysis		

Table 5.9: Composites for Aerospace: Status & Progress

5.9.3 Process requirements and advantages

The product performance of blow moulded parts is highly influenced by the process conditions. Therefore, the whole process history (e.g. local wall thickness, temperatures, residuals stresses, principal strain etc.) needs to be transferred between several simulation stages also involving different solvers and meshes.

The Benefits of a standardized and self-acting virtual process chain are significant shorten development times and considerably more precise simulation models

5.9.4 Simulation issues prior to VMAP

Many different physics are considered in the process chain, and the simulation requirements for each step are quite different. The computational fluid dynamics simulation requires a different mesh and boundary conditions than the thermo-chemical simulation, saturated flow, and stress/deformation simulations. The mesh required by the failure simulation is different again. Throughout the whole virtual process chain, boundary conditions, deformations, material state, and other process variables change in time. These changes must be communicated to each of the simulation stages. At the moment, there is no easy way to do this.

5.9.5 User benefits/business case

Develop the underlying capability in terms of standardized material models to enable process simulation. This will significantly accelerate and optimize the many steps of an aerospace composite component development program: from material selection, to factory definition, to tooling design, to part conceptual design, then detailed design, production insertion, and finally combining production data back with the original simulation.

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Appendix A

Project Funding

The project is organized via the ITEA programme and funded by national regional agencies and companies over the period from October 2017 to September 2020. The total budget is about 16M€ for the 30 project partners from Austria, Belgium, Canada, Germany (including NAFEMS), Netherlands and Switzerland.

ITEA is the EUREKA Cluster programme supporting innovative, industry-driven, pre-competitive R& D projects in the area of Software-intensive Systems & Services (SiSS). ITEA stimulates projects in an open community of large industry, SMEs, universities, research institutes and user organisations.

As ITEA is a EUREKA Cluster, the community is founded in Europe based on the EUREKA principles and is open to participants worldwide.

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ACRONYM and full-length title

16010	VMAP
Program Call	ITEA 3 Call 3
Full-length Title	A new interface Standard for Integrated Virtual Material Modelling in Manufacturing Industry
Roadmap Challenge	Smart Industry

Project duration & size

Size	Effort:119.62 PY Costs: 14.9M€
Time frame	Start: 2019-09-01 End: 2020-09-30 (37 months)

Coordinator

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Consortium

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Belgium	MSC Software Belgium S.A.
Canada	Convergent Manufacturing Technologies Inc.
Germany	Audi AG, Dr.Reinold Hagen Stiftung, DYNAmore GmbH, EDAG Engineering GmbH, ESI Software Germany GmbH, Fraunhofer SCAI, Hagen Engineering GmbH, inuTech GmbH, Karlsruhe Institute of Technology (KIT), Kautex Maschinenbau GmbH, NAFEMS Deutschland, Österreich, Schweiz GmbH, RIKUTEC Richter Kunststofftechnik GmbH & Co. KG, Robert Bosch GmbH, Simcon kunststofftechnische Software GmbH
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