SUMMARY

Session A – PLM / Digital Factory / Simulation / Optimization for the Smart Factory

1. Introduction

The efficient and effective use and handling of data and information within manufacturing enterprises is an essential cornerstone for the next level of manufacturing: At first, interoperable, consistent and timeliness data builds the basis for transparency, collaboration and responsiveness in planning, design and optimization of processes. At second, new capabilities for an extended usage of this data and information can help to reduce time, costs and effort in planning and testing (compare Figure 1), and finally lead to an increase of productivity in manufacturing. The respective methods, such as *Frontloading*, V*irtual Prototyping*, *Simultaneous Engineering* are widely known, but often not entirely applied in the daily practice of manufacturing enterprises – also due to the fact that the reuse of data is too constrained. New ICT-related technologies allow for considerable improvements in data and information handling across the entire product-lifecycle and enable new and improved applications to optimize manufacturing-related processes. Besides promoting the excellence in manufacturing, Europe must claim the leadership in innovative ICT-solutions, capable to support the phases of product design, manufacturing planning and process optimization.

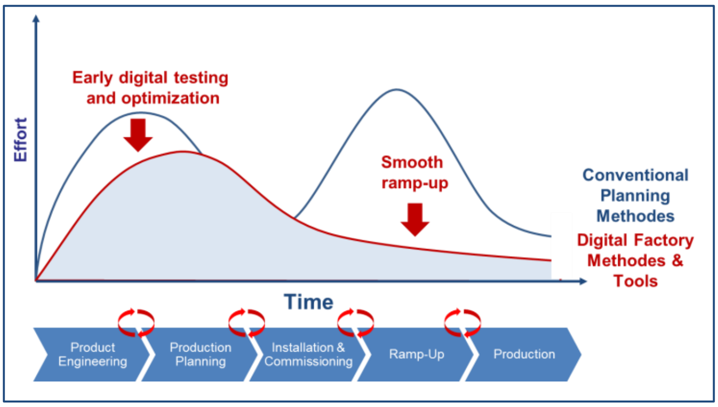

Figure 1: Computer-assisted product and process development and virtual prototyping.

2. Overview about the Session

The aim of the session was to bring together a community of different stakeholders in order to discuss on common long-term goals related to the topics *PLM*, *Digital Factory*, as well as the computer-assisted simulation and optimization of manufacturing-related processes. The outcome of the session should be further sharpened, and then integrated in the "Factories of the Future" vision as part of the "Horizon 2020" research program. Basically, the session has been divided into four main parts:

1. **Introduction** of the session topics and overall goals (→ see below)
2. **Presentations of the projects** (→ see *Chapter 5*) and **success stories** (→ see *Chapter 3*) connected the session topics
3. **Collaboration activities**, which has been initiated/are planned for the future (→ see *Chapter 4*)
4. **Discussion on gaps and needs for future research programs** (→ see *Chapter 4*)

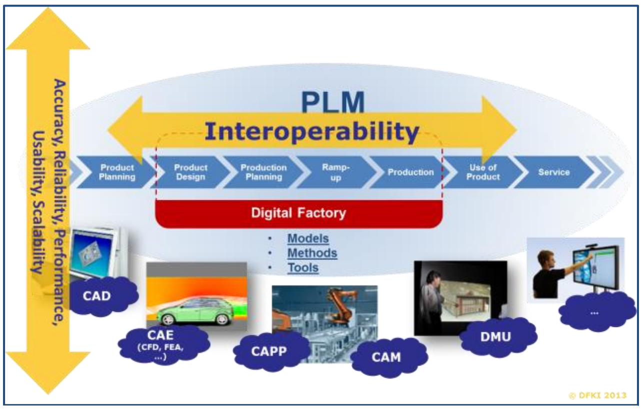

Figure 2: Session topics and their challenges on a horizontal and vertical axis.

First, the **session topics** were introduced and clearly differentiated (compare Figure 2):

The **Product lifecycle management** (**PLM**) is an essential element of the information technology structure of a manufacturing enterprise. It is concerned with managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal. In each of these phases, various data and information is created and consumed. **Here, the challenge is to establish seamless data exchange across the different phases.**

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The **Digital Factory (DF)** represents a cut-out of the PLM. It is a concept to support the planning, implementation, control and continuous improvement of all essential plant processes and resources by methods, tools and models. **Here, the challenge is to integrate innovative DF tools and methods on a technical and organizational level into the existing factory structures, and to provide them with the required data.**

Simulation and Optimization Tools (SO) – as part of the DF – are often summarized by the acronym CAx, which contains CAD, CAE, CAPP, CAM, DMU, etc. **There is a constant need to improve these tools in terms of accuracy, reliability, performance, usability and scalability; but also new and extended functionalities for computer-assisted tools must be investigated.**

Next, the **overall goals** for the PLM / DF / SO have been defined and translated in generic recommendations (based on the input of the EC):

Responding to higher variance, shorter innovation cycles of highly complex products like cars and aircrafts	**Master Complexity / Increase Transparency**
Shorten the time to production during the ramp-up phase of new products by the use of digital tools, make design/re-design more efficient/reliable	**Improve Productivity / Reduce Effort, Time and Costs**
Modelling, reuse and share of manufacturing knowledge…	**Create Interoperability**
…for strategic decision making, flexible responses to varying demands	**Ensure Flexibility**
Boosting the launch of new innovative products through digital design and validation	**Stimulate Innovations**
Enhance innovation through the use of new, intuitive and collaborative design tools.	**Develop new Functionalities / Enhance Usability**
Develop modular, flexible and highly adaptable solutions – suitable from SMEs to major industrial enterprises.	**Enhance Scalability**

The interrelation between the different goals and the enabling technologies is depicted in Figure 3.

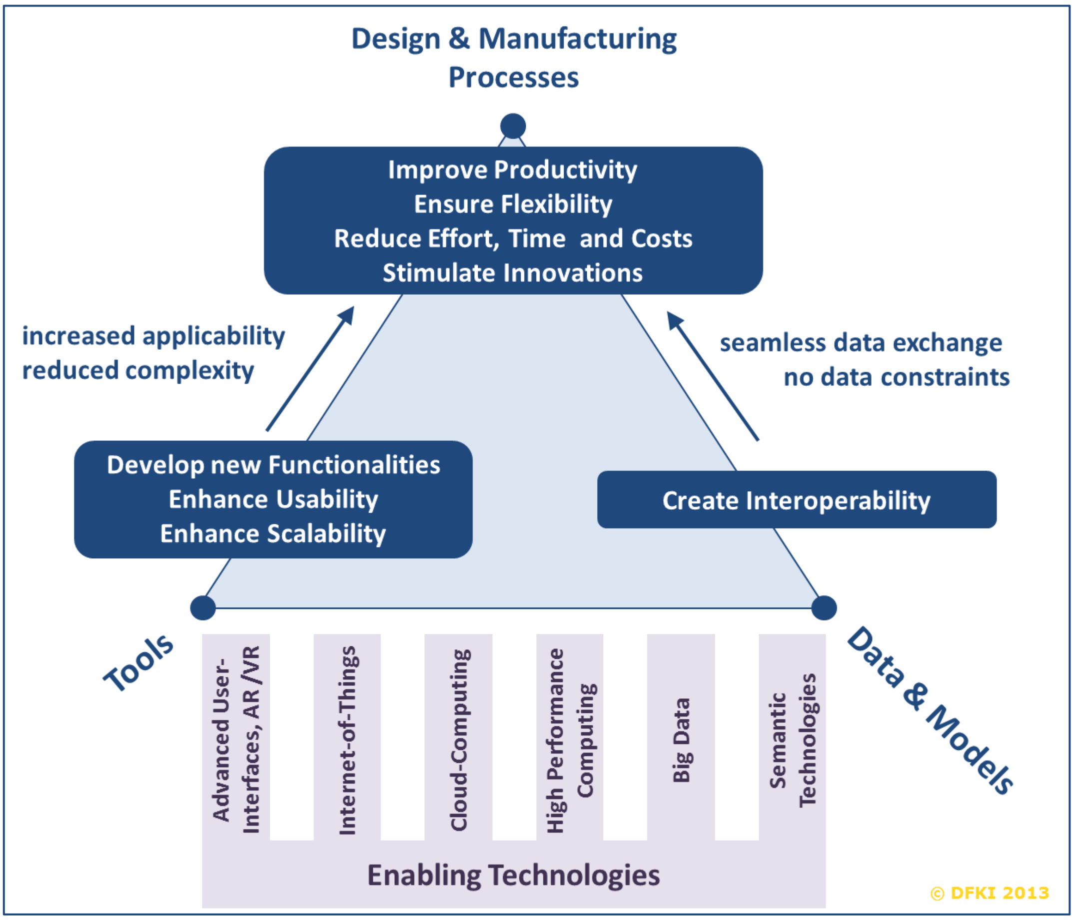

Figure 3: The PLM / DF / SO goals and their interrelationship and enabling base technologies.

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3. Success Stories

VISTRA

The VISTRA project (www.vistra-project.eu) demonstrates how existing product and manufacturing data can be captured, updated, enriched and transferred into an interoperable semantic representation, in order to enable cross-disciplinary knowledge sharing between product design and production engineering. Based on a semantic repository, novel forms of interactive, game-based training of complex manual manufacturing processes will be developed, which allows to improve and speed up ramp-up for new products significantly. The developed system components are depicted in Figure 4.

Figure 4: The three main components developed and evaluated in the VISTRA project.

Industrial field tests, which are currently conducted in the automotive industry with the first, fully functioning system prototype, indicate a great potential for interactive virtual training as a new digital factory tool. Moreover, the VISTRA project has been successfully demonstrated on the CeBIT 2013 and will also participate on up-coming key events. The VISTRA project was also extended by an IMS initiative to investigate the need for computer-based training and assistance tools in manufacturing on a broader level.

SIMPOSIUM

Please provide input

4. Recommendations

In the following recommendations are given to support the before-hand defined overall goals for the PLM / DF / SO. Not only new technologies must be further investigated, but available state-of-art ICT must be aggregated and adapted to address the manufacturing-specific needs. New ICT solutions for manufacturing must then be adopted and tested by forward-thinking enterprises – gaining a competitive advantage, but also stimulating the broader applicability.

A. Application of semantic technologies to increase the interoperability of digital data and models

Interoperability aims at the flexible aggregation, extension and reused of digital data and models in different contexts and applications. An essential prerequisite for an interoperable use of data and models is that they are formalized (→machine readable), explicitly described (→formal semantics of all statements) and at the right level of abstraction (→suitable for the intended use). For the implementation of a semantic factory, where data and models can be shared, combined and reused across application and sector boundaries, the following steps are recommended:

- Enable the reuse and sharing of digital factory models by raising the level of explicit semantics (e.g. by using ontologies).
- To ensure the interoperable character, digital factory models must be developed in a collaborative manner involving domain experts from different phases of the PLM and supported by intuitive modeling tools.
- The development of holistic factory models must be aligned with relevant standardization activities.

- Besides product-, process- and system-related information, holistic factory models should also include organizational and administrative considerations.
- Develop methods and mechanisms to increase the quality of data across the distributed factory in terms of accuracy, completion, currency, non-duplication, etc.
- Interoperability should be studied not only at the level of conceptualization and modeling, but also at the level of organization and maintenance i.e. how the companies IT structures – and the contained data – should be updated and maintained – taking into consideration new more effective models and representations that are constantly developed. In this context also the acceptance and migration path of semantic technology in manufacturing should be considered.
- Improve data mining, filtering and reasoning capabilities to better exploit digital models in dynamic design, validation, optimization and decision making processes.

B. Synchronisation of digital models with the real world behaviour

The still-existing gap between the state of the real world and its digital representation proves to be an obstacle to parallel-operation and predictive simulation and optimization of the factory. The connection to and synchronize with cyber-physical systems allow for a direct insight into the current status of the products, processes and systems on real-time basis. The factory of the future needs to be complemented by holistic, digital models and tools that enable concurrent simulation and optimization of manufacturing processes on the basis of fine-grained real-time information. This will lead to greater transparency of processes and allows operating factories at the optimal operating point from the first product manufactured. To achieve this vision, the following topics of research are proposed:

- Define the interface between digital models and smart objects with embedded intelligence in order to bridge the gap between the virtual and the real world, i.e.:
  - Digital models will automatically be adjusted – triggered by real-world events (compare Figure 5).
  - Sensor data will be contextualized by directly linking it with the corresponding digital model.
- Integration of mechatronic process models, describing physical behavior of factory equipment, into the existing digital models in order to run analyses and simulations on the captured real-world data (Example: energy consumption model + real-world energy data = dynamic optimization of energy consumption).
- Investigate the appropriate level of accuracy and timeliness of real-word data to reflect the requirements of simulation and optimization.

C. Multi-disciplinary collaboration and enrichment of digital models through the social communication processes

Today's digital models in engineering and manufacturing are inhibiting multi-disciplinary collaboration offered by social media and advanced user-interfaces. This is so since digital tools usually have implicit semantics with only one level of abstraction geared towards experts; furthermore the corresponding model navigation, visualization and interaction mechanisms are limited to domain specialists. Additionally, computer support for co-located multi-media, multi-disciplinary collaboration is rather scarce. As a result of this lack of appropriate methods and tools for mobile, web-based multi-disciplinary collaboration, interactions of cross-functional teams are rather cumbersome or close to impossible with major barriers to the smooth flow of knowledge across disciplines. To remedy this situation methods and tools need to be developed to raise the level of explicit semantics of digital models at different levels of abstraction while providing mechanisms for web-based digital model navigation, visualization and interaction from different points of view and expertise. To achieve this vision, the following topics of research are proposed:

- Make the digital models and data extensively available for collaboration and social communication processes.
- Provide interactive mechanisms to enrich and adjust the digital models and data through reflection, dialogue and group decision making.

- Develop co-located, multi-media enriched consistent digital model interfaces at different levels of abstraction.
- Develop web-based navigation, visualization and interaction tools, which allow intuitive collaboration in design, validation, optimization and decision making processes from different points of view, expertise, etc. This includes:
  - Context-based retrieval, provision, adjustment, use and annotation of information based on semantic factory models.
  - Advanced user-interface, including virtual and augmented reality technologies.

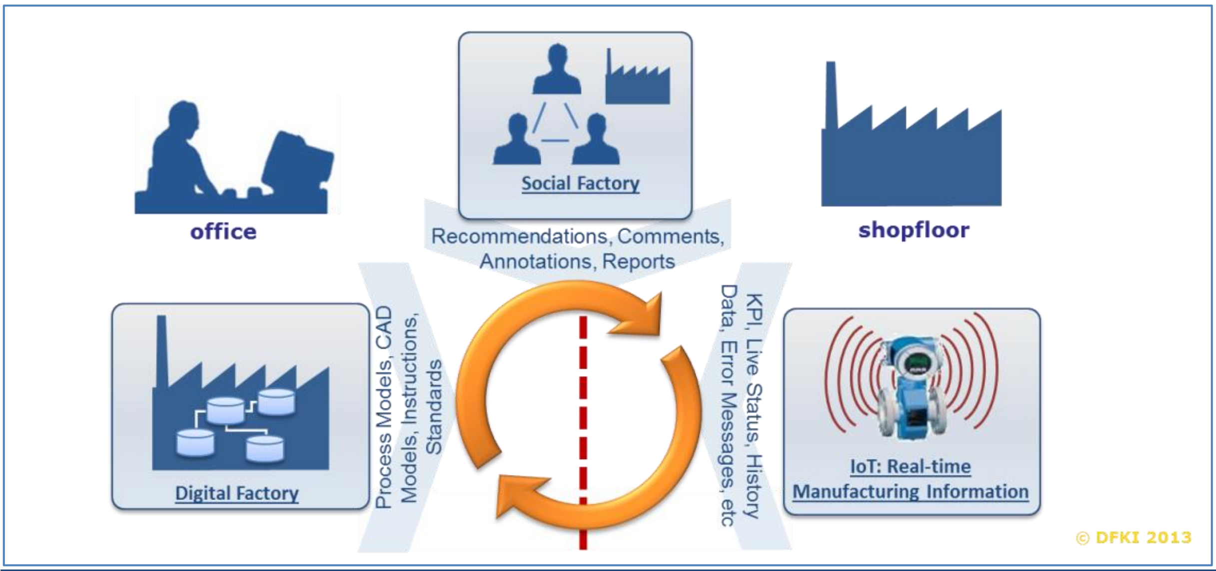

Figure 5: Extending the digital factory by social communication processes and real-world data acquisition.

5. Next Steps

The next key event is the **ICT Conference 2013**, which takes place in Vilnius on 6-8 November 2013. Here several, topic-related workshops will be organized by the group members.

Besides, some group member will also be present at the **World Manufacturing Forum** in Washington DC on 22-23 October and the **MANUFUTURE 2013** in Vilnius on 6-8 October 2013.

The group is open for other research projects or individuals to join.

6. Overview about the Group and Session Organizers

The session was prepared and presented by a group of connected EU-FP7-projects in the "Factories of the Future" initiative. Although each project follows very specifics goals, they shares overlapping research challenges and application areas in the PLM / DF / SO field (compare Figure 5).

	Interoperability in PLM	Semantic Technologies	VR / AR	Simulation (FE, NDE)	Multi-Agent Systems	Engineering	Manufacturing	Use-Cases	Goal
VISTRA	●	●	●				●	Automotive	Virtual training reduces the need for physical training in product assembly.
Know4Car	●	●	●		●	●	●	Automotive	Efficient knowledge management and collaboration, through revolutionized UIs.
amePLM	●	●	●			●		Electronics, Automotive and Medical Devices Industries	Semantics to minimize the efforts for information transfer and retrieval in engineering
TERRIFIC	●			●		●	●	Automotive, Railway, aircraft and machining tools	Interoperability of CAD and FEA/CFD through isogeometric technologies.
SIMPOSIUM	●			●		●	●	Steel Production	Interoperable Simulation tools for non destructive testing and material characterizations
FFD	●		●			●	●	Textile and Garment Industry	New business and production workflow to represent the whole development process
ARUM		●			●	●	●	Aerospace (Airbus A350 Ramp-up + Aircraft system supplier),	Novel, agent-based, distributed scheduling will improve production ramp-up
ENEPLAN				●			●	Aeronautics, Household, Automotive	Energy-efficient multi-process manufacturing & optimum process planning.

Figure 5: Overview about the group of projects.

Project Contacts:

VISTRA: www.vistra-project.eu
TERRIFIC: www.terrific-project.eu
Know4Car: www.know4car.eu
amePLM: www.ameplm.eu
SIMPOSIUM: www.simposium.eu
FFD: www.future-fashion-design.eu
ARUM: www.arum-project.eu
ENEPLAN: www.eneplan.eu

Session Organizers:

Chair: Dominic Gorecky, DFKI
Co-Chair: Nikos Papakostas, LMS
Co-Chair: Arnd Schirrmann, EADS
Rapporteur: Paul Xirouchakis, EPFL

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