DIGITAL TRANSFORMATION OF PLM TO ENABLE INTELLIGENT SYSTEMS & LIFE CYCLE ENGINEERING

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AGENDA

1. PLM Status today – cause for action!

2. What drives product creation process today & tomorrow? Transformation & Innovation in Engineering Activities

3. Selected Engineering Scenarios
   - Scenario 1 – Smart Factory, Digital Twin and Information Factory
   - Scenario 2 – PLM for Digital Factory and Industrie 4.0
   - Scenario 3 – Smart Manufacturing and Virtual Commissioning
   - Scenario 4 – Smart Product Engineering

4. Summary & Outlook
Life Cycle of Long Living Products - Airbus A320 fleet

Introduction

What does this mean for Life Cycle Engineering?

Product Life Cycle ~70 years

1981
Go concept phase

1984
Start of development

1987
1st prototype

1988
Start of use

~26 years of use

2006
Start of refresh

A320neo refresh

~36 years of use

2014
use

2027
End of production

2050
End of life

AIRBUS S.A.S. 2014 – photo by master films / A. DOUMENJOU
Life Cycle of Long Living Products - Life Cycle Phases

Introduction

Begin of Life

Development ~8 years

Start of production

Use Phase

Mid of Life

Production ~40 years

~64% of use phase

End of Life

Runout ~23 years

~36% of use phase

End of production

Product Life Cycle

Long living products need long living parts

Fraunhofer IPK

TU Berlin Informationstechnik
Life Cycle of Long Living Products - Life Cycle Phases

Introduction

Product Life Cycle

<table>
<thead>
<tr>
<th>Begin of Life</th>
<th>Development ~8 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of production</td>
<td>Use Phase</td>
</tr>
<tr>
<td>Mid of Life</td>
<td>End of Life</td>
</tr>
<tr>
<td>parts for production on stock</td>
<td>no guarantee on stock</td>
</tr>
<tr>
<td>Need of parts for MRO</td>
<td></td>
</tr>
<tr>
<td>Few long living parts</td>
<td></td>
</tr>
<tr>
<td>Fuselage / Hull / Body</td>
<td></td>
</tr>
<tr>
<td>Engine</td>
<td></td>
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<tr>
<td>Many exchangeable parts</td>
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<tr>
<td>Sensors</td>
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<tr>
<td>Electronics</td>
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<tr>
<td>Interior</td>
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<tr>
<td>Actuators</td>
<td></td>
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<tr>
<td>Mechanics</td>
<td></td>
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<td>I/Os</td>
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Key Activities in Life Cycle Engineering (LCE)

Introduction

Challenge:
Data & Information exchange between OEM and customer for MRO support and Design changes

- Sustainability
- LCE-based design

PLM Product Lifecycle Management
CAD Computer-Aided Design
CAE Computer-Aided Engineering
CAM Computer-Aided Manufacturing
PDM Product Data Management
ERP Enterprise Ressource Planning
CRM Customer Relationship Management
SCM Supply Chain Management
CMMS Computerized Maintenance Management System
LCA Life Cycle Assessment

Activities within lifecycle:
- Reengineering
- Through-life Engineering Services

Re-Design & new Engineering
Future Lifecycle

Previous Lifecycle
LCE-based design – Holistic consideration of influencing factors

Prospective Activities

- Heterogeneous IT landscape
- Interface problems
- Increasing demand for information
- Process automation
- New technologies
- Traceability
- MRO processes
- Reengineering
- Through-life Engineering Services
- Retrospective activities within lifecycle
- Prospective activities within lifecycle
- Industry 4.0 and Smart Service World Engineering
- Sustainable LCE-based design
- Cyber Physical Systems
- Big Data
- Internet of Things
- Cloud services
- Digital factory
- Individualization
- Product Service Systems
- Platform independency
Evolution of digitalization in engineering

Product to system to lifecycle-thinking

INTEGRATIVE WORK ON THE SHOP-FLOOR

Machine Construction

Technical Design

Methodical Design

NC Programming

Virtual Product Creation & Product Modelling

Digital Factory & global digital Collaboration

Systems Engineering

DIGITAL TRANSFORMATION

Year

1850 1900 1950 2000 2010

Complexity of Product Development

Increasing complexity
Evolution of digitalization in engineering

Yesterday with focus on physical models, today and tomorrow with focus on digital models

Yesterday with focus on physical models, today and tomorrow with focus on digital models.

Focussing on engineering, testing, validation & verification (time, cost, knowledge, competence, etc.)

Necessity: Replacing physical prototyping will result in experience driven digital validation & verification.
(R)evolution of the „Virtual Product Creation Operating System“
(timeline: lead automotive OEM)

- 2D CAD
- CAM/CNC
- File saving
- Tape exchange
- Analytical calculation

Level 1
1975 - 1985
(R)evolution of the „Virtual Product Creation Operating System“
(timeline: lead automotive OEM)

- 3D CAD
- CAE 1 (MBS/FEA)
- TDM/EDM
- MRP/PPS
- File transfer

Level 2
1985 - 1995

Level 1
1975 - 1985
(R)evolution of the „Virtual Product Creation Operating System“
(timeline: lead automotive OEM)

- 3D Parametric CAD
- CAE 2 (CFD)
- PDM
- Product Structure
- Triggered data exchange
- DMU
- VR
- Manuf. CAE (robot simulation)
- E/E
- KBE

Level 3
1996 - 2003

Level 2
1985 - 1995

Level 1
1975 - 1985
(R)evolution of the „Virtual Product Creation Operating System“
(timeline: lead automotive OEM)

- 3D Template CAD
- Global PLM (ERP link, Manf. PPR)
- Configuration BOM driven DMU
- Design in Context
- Real time ray-tracing
- CAE data management
- Digital Factory set-up (e.g. PPR linkage)
- New global collaborative engineering solutions

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**Level 4**
2004 - 2013

**Level 3**
1996 - 2003

**Level 2**
1985 - 1995

**Level 1**
1975 - 1985
Summary of PLM status today and cause for action!
Code for PLM Openness (CPO): Openness in IoT / Industry 4.0

Smart products continuously provide and consume information within its environment and the Internet via interfaces.

Openness: Assuring that smart products and services can be offered and applied globally!
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4. Summary & Outlook
What is smart?
The difference between general trend and specific approach

**Smart** means the intelligent junction of *technology*, *environment* and *people* to create sustainable growth within a highly global and competitive market.

- **S**: Sustainable + context-Sensitive
- **M**: Multi-disciplined + Model-Based
- **A**: Adaptive + Autonomous
- **R**: Robust + Rewarding
- **T**: Teamplay with Technology
(R)evolution of the „Virtual Product Creation Operating System“
(timeline: lead automotive OEM)

- Immersive modeling & reviewing
- Smart Systems Engineering
- X-discipline Functional Mock-up
- Smart Hybrid Prototyping
- Process enabled PLM
- Real time Functional Product Experience
- Mobile PLM
- Smart Data / Big Data „PLM“
- Industrie 4.0: Digital Twin

Level 5
2014 - 2020

Level 4
2004 - 2013

Level 3
1996 - 2003

Level 2
1985 - 1995

Level 1
1975 - 1985
(R)evolution of the „Virtual Product Creation Operating System“
(timeline: lead automotive OEM)

- Level 6
  2020 - 2025
- Level 5
  2014 - 2020
- Level 4
  2004 - 2013
- Level 3
  1996 - 2003
- Level 2
  1985 - 1995
- Level 1
  1975 - 1985

- Next generation engineering workspace
- Personal digital avatar support
- Product Lifecycle Knowledge Intelligence (PLKI)
- Industrie 4.0 Smart Engineering (incl. semantic engineering analytics & Digital Twin)
- Immersive Engineering Reality (real-time product/plant adaptation)
- Sustainable Engineering and Manufacturing
- Real time Digital Manufacturing Feasibility
Digital Transformation
Areas and challenges

- Cross-company collaboration in distributed locations
- Horizontal integration
- Increasing amount of data
- Data security & safety
- Big Data to Smart Data
- Different file formats
- Compatibility of data
- Reliability of data
- Availability of data everywhere anytime
- Real-time data exchange
Transformation in Engineering Activities
Holistic Model representing the engineering environment

- Management-, Core- and Supporting-Processes
- Organization (roles and responsibilities)
- Processes: who (role) should do what, which tools are used, and which results are expected

- Virtual and Physical Artefacts as well as models (data and information models)
- Are generated or manipulated in the product life cycle by activities

- Actions (activities) carried out by people and IT systems in product life
- Activities are person-specific dynamic or automated instantiations (IT activities) of the processes.

- Information technology and physical tools
- The IT infrastructure includes application systems and operating resources (hardware and software).
Transformation in Engineering Activities

Examples

- **Way of working changes,**
  - Agility of organisations
  - e.g. remote mobile work

- **Heterogeneous product life cycles,**
  - Customization of products
  - e.g. customers can track & customize their product during manufacturing

**Trends**

- (Model-based) Systems Engineering
- Industrie 4.0
- Global collaboration
- Data driven Business
- Digital Transformation
- Digital Twin
- Information Factory

The future activities performed by an engineer change:
- e.g. designing parts of an assembly remotely with a mobile device

Emerging new technologies (e.g. 5G)
- IT and internet technologies are optimized e.g. latencies decrease and bandwidth increases
Definition of Industrie 4.0
Interconnection of humans, objects and systems

With the interconnection of humans, objects and systems
dynamic, real-time optimized and self-organizing cross-company value
creation networks emerge.

Intelligent interconnection of material,
products, production technologies and
automation processes

Decentral, self-controlling and flexible
operating products
Definition of smart products

Overall context

Internet of data, humans, services and things

Smart products

\[ \text{Smart products} = \text{CPS} + \text{Internet-based Services} \]

Cyber-Physical Systems (CPS) = IMP + ‘Communication’

Intelligent mechatronic products (IMP) = MP + ‘Intelligence’

Mechatronic products (MP)

E.g.: AIS supported collision avoidance
E.g.: Steer-by-Wire
E.g.: autonomic ship
E.g.: “Parking” assistant with ship to infrastructure communication

‘SMART Products are Cyber Physical Systems with Internet-based Services’

Source: CIRP Encyclopedia of Production Engineering, 2015
Intelligent networking in the factory ICT of the future

Digital Factory
- Management, planning, simulation and development

Living Digital Twin
- Data & Context
- Information & Optimisation
- Vertical integration

Physical Factory
- Control and command level
- Plants, production, processes, products

Horizontal integration

Management software
- enterprise
- Engineering software
- Product design & development
- Information factories: infrastructure, data and services
- Management software
- production, manufacturing
- Control and regulation software
- Machines and plants manufacturing processes

Physical Factory
- Control and command level
- Plants, production, processes, products

Digital Factory
- Management, planning, simulation and development

Living Digital Twin
- Data & Context
- Information & Optimisation
- Vertical integration
Digital Factory Twin
The mission to achieve true Industrie 4.0 factories

Continuous update & augmentation of digital twin with shopfloor data

Usage of information of Digital Twins:
- Product development
- Production planning
- Logistic planning
- Plant and facility development
- Quality assurance
- Virtual validation

Capture of:
- Changes due to commissioning, maintenance, reconfiguration
- Process parameters
- Operating and machine data
- Quality information

Simulation & digital validation of physical equipment
Five disciplines of model-based systems engineering
(to be adapted to product systems, factory production systems and industry branches)

- **Systems Environment Analytics**
  Specifying interacting systems and describing types of interaction

- **System Definition & Derivation**
  Creating models which describe systems from different views

- **Modeling and Simulation**
  Modeling and simulating the behavior of the system in focus

- **Managing and Integrating System Models through the Product Lifecycle**
  Managing and integrating system models through product lifecycle

- **Gaining and Mastering the Necessary MBSE Competencies**
  Gaining and mastering the necessary MBSE competencies

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**Fraunhofer IPK**

**Technische Universität Berlin**

**Fraunhofer Informationstechnik**
Sustainable innovation
Transformation of business models by adaptable architectures and smart services

- Flexibility of new product architectures
  - Cars are evolving to living service platforms with longer usage time by utilizing flexible electronic/software architectures and reconfigurable hardware
  - Individual customization of vehicles, enables new business models (from car manufacturer to service provider)

- Impact on product design
  - Future mobility requirements need to be anticipated for current products already
  - Feeding back usage data into product design will become a core competence imposing strong demands on mechanisms for data acquisition and analysis
  - New product architectures needs to reflect heterogenous innovation and technical lifecycles of product parts and embedded technologies

[1] BMW Bordnetz der Zukunft (autonews-123.de)
Summary of drivers for future PLM

(compare PLM 2014 paper „Intelligent information technologies to enable next generation PLM“)
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4. Summary & Outlook
Scenario 1 – Smart Factory, Digital Twin and Information Factory
Demonstration Cell „Smart Factory 4.0“

Living Digital Factory Twin

- Industry compatible
- Industrial IT standards
- IoT & Cloud-ready
- Self-organisation
- Smart data analyses
- Hybrid prototyping

Real time convergence from reality and virtuality
Scenario 1 - Smart Factory 4.0 (Video)
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Scenario 2 – PLM for Digital Factory and Industrie 4.0

PLM as an enabler for Digital Twin Solutions

Shell model from Digital Factory (center) towards business value (outer)

Digitization (e.g. Digital Twins solutions) as potential driver along all levels

The levels of the shell model represent the different views for PLM digitization and address the necessary change dimensions

Digital Twin solutions and their potential have to be evaluated; PLM solution strategy for digitization has to be developed and executed
Scenario 2 – PLM for Digital Factory and Industrie 4.0
PLM as an enabler for Digital Twin Solutions
Integration of Automation pyramid and RAMI into the shell model

Automation pyramid covers the levels from the center to processes and procedures of the shell model

RAMI covers all levels of the shell model
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4. Summary & Outlook
Challenges in plant manufacturing today:

- Mainly sequential development processes are executed in plant manufacturing
- Commissioning represents the first true integration of discipline-specific design and construction drafts during physical assembly and physical implementation of manufacturing system
- Resulting in late and costly change requests and unnecessary requirements discussion during the late phases of the manufacturing system development process

Objectives for future improvements:

- Definition of development processes for virtual prototypes of manufacturing systems (context: Internet of Things)
- Definition of an architecture for a software framework for virtual prototypes of manufacturing systems (Functional Mock-Up with interactive Virtual Reality (iVR), virtualization of plants for early virtual commissioning)
- Definition of a construction kit: provision of design models for geometry, function (kinematics and behavior model) and logic (PLC-code)
Scenario 3 – Smart Manufacturing and Virtual Commissioning

Engineering disciplines and additional design models for virtual commissioning
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Scenario 4 – Smart Product Engineering

Degrees of Virtuality in Prototyping

Prototypes have different degrees of virtuality

<table>
<thead>
<tr>
<th>Degree of virtuality</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Physical Prototyping</td>
</tr>
<tr>
<td>1</td>
<td>Virtual Prototyping</td>
</tr>
</tbody>
</table>

*Virtuality is the share of virtual representation of a prototype (Milgram, 1994)
Scenario 4 – Smart Product Engineering
Hybrid Prototyping to Enhance User Experience

Smart Hybrid Prototyping
to combine the advantages of physical and digital models

High costs
High user experience

Low costs
Low user experience

Degree of virtuality

0
Physical Prototyping

1
Virtual Prototyping

Source: www.autoplenum.de
Source: www.autoblog.com
Source: Volkswagen
Source: Fraunhofer
Scenario 4 – Smart Product Engineering
Architecture of Smart Hybrid Prototyping

Virtual Prototype
DMU

Simulation Model

Haptic User-Interface

Smart Hybrid Prototyping

Main Advantage:
Realistic interaction with the prototype while being able to modify and analyze design parameters within the digital model
Scenario 4 – Smart Product Engineering
Driving Simulator at Digital Cube Test Center Berlin
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4. Summary & Outlook
Outlook and challenges

Digital Transformation

- PLM solution for digital continuity in engineering
- Limitless data exchange between all IT systems
- Collaboration in Multi-User Virtual Reality environment
- Digital validation and Smart data analytics using digital factory twins
- Assembly validation through hybrid prototyping with haptic devices
- Know-How in Model-based Systems Engineering

Funkschau.de
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Thank you for your attention!