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SYSTEMS ENGINEERING STUDY IN GERMANY PART 1 – OVERVIEW AND ANALYSIS RESULTS

Dr. Jens Heidrich

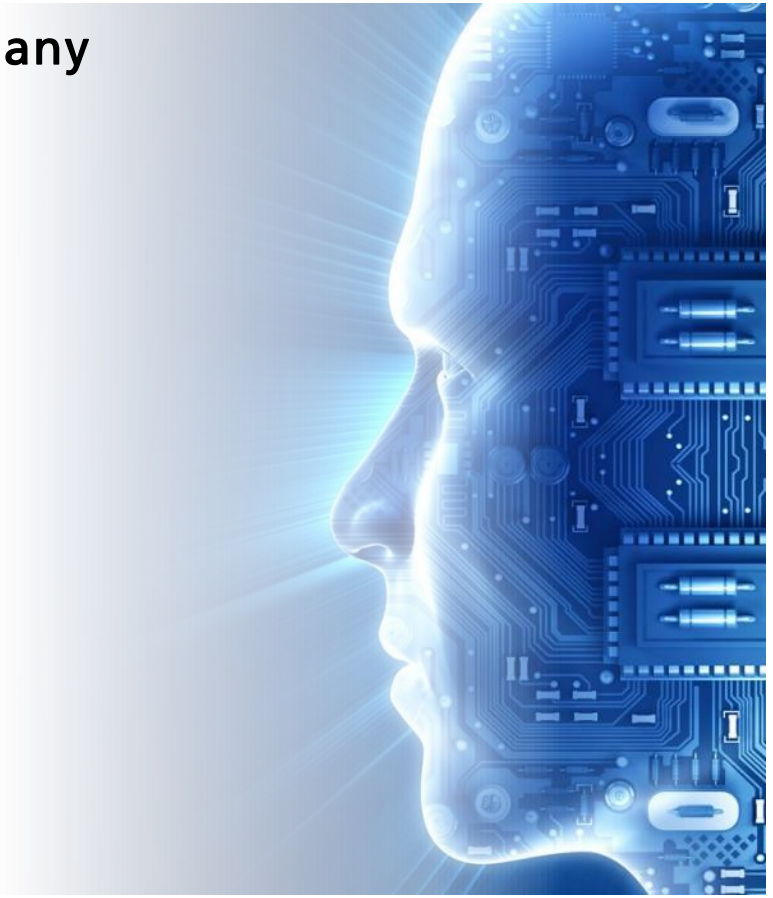
Fraunhofer IESE
Kaiserslautern, Germany

IPA/SEC Special Seminar

Tokyo (Oct 24, 2016) and Osaka (Oct 26, 2016)

SYSTEMS ENGINEERING STUDY IN GERMANY PART 1 – OVERVIEW AND ANALYSIS RESULTS

- **The Fraunhofer-Gesellschaft in Germany**
- Trends towards Systems Engineering
- Systems Engineering Study
- Recommendations and Areas of Activity



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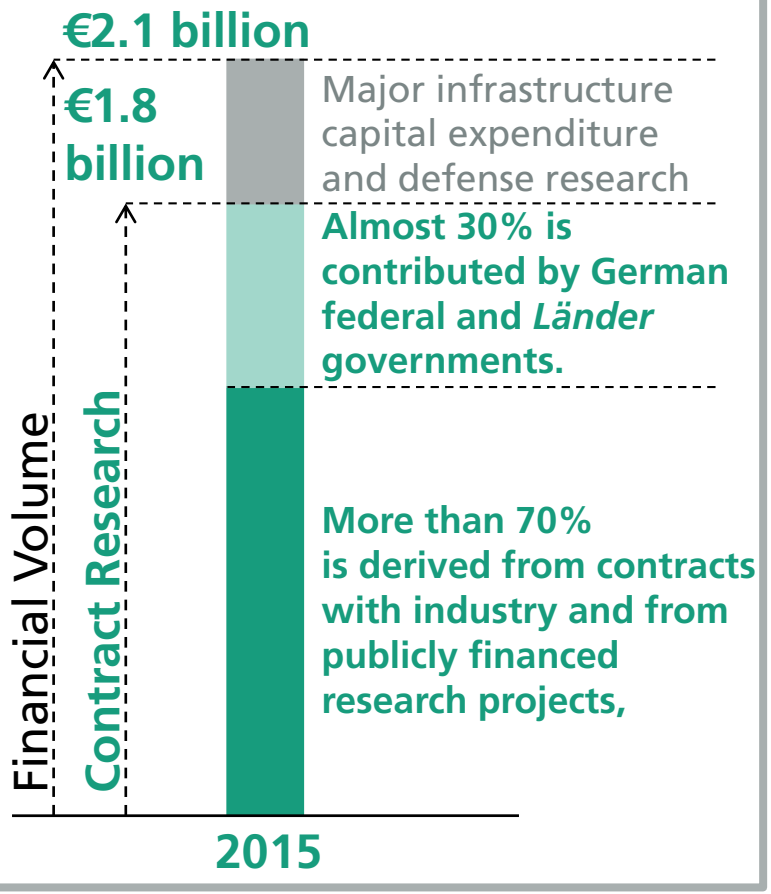
The Fraunhofer-Gesellschaft at a Glance

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society.

Nearly **24,000** staff

67 institutes and research units



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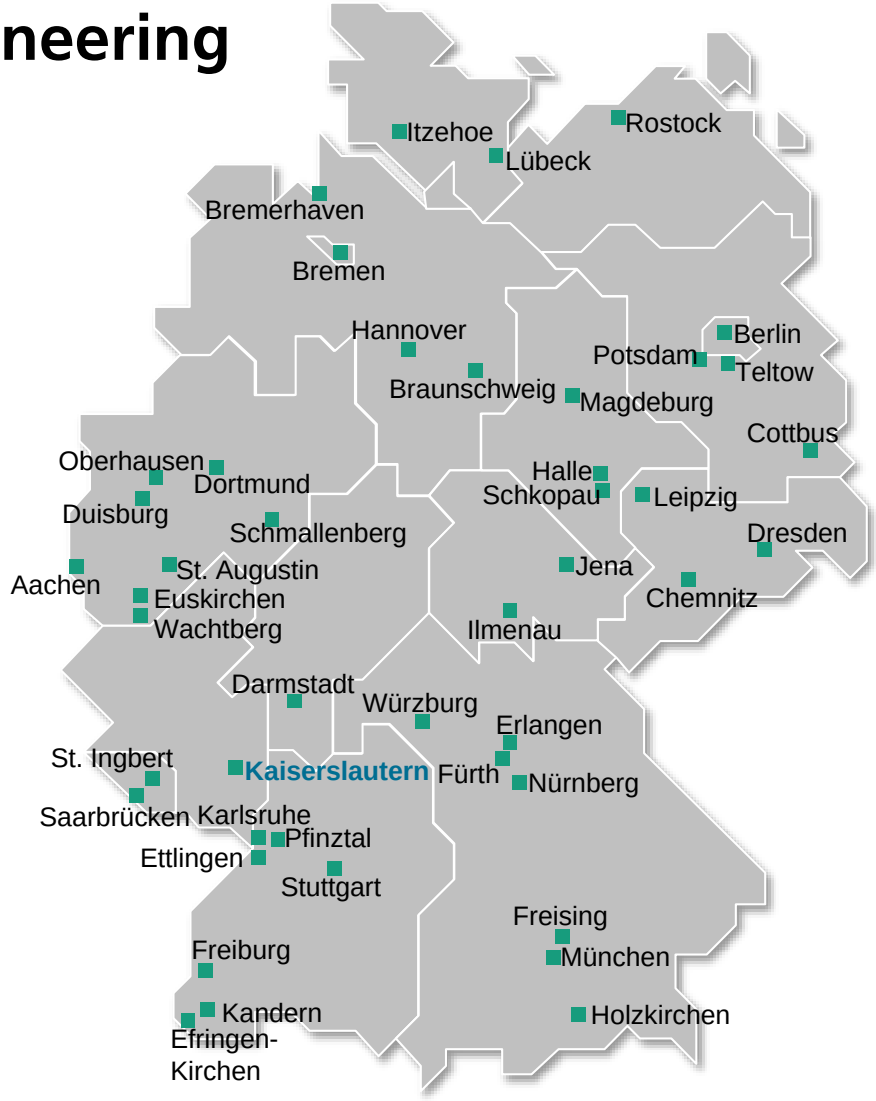
Fraunhofer Institute for Experimental Software Engineering

- Founded in 1996
- One of the leading software and system engineering institutes in Europe and worldwide
- Over 160 full time equivalents



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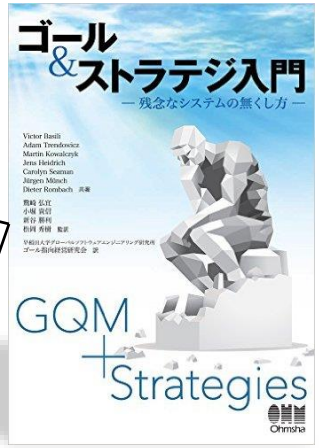
Current Collaborations with Japan



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IPA

FUJITSU

DENSO

WASEDA UNIVERSITY
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L E
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早稲田大学

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Digital Society: Integration Enables Innovation in Private and Business Life

- New **business models**
- **Physical objects** go digital
  - Machinery, things, living objects like plants and animals
  - Usage of Big Data to exploit opportunities
- **Uncertainty** at runtime
- From closed systems to highly **integrated systems of systems**

[Source: Images from https://pixabay.com]

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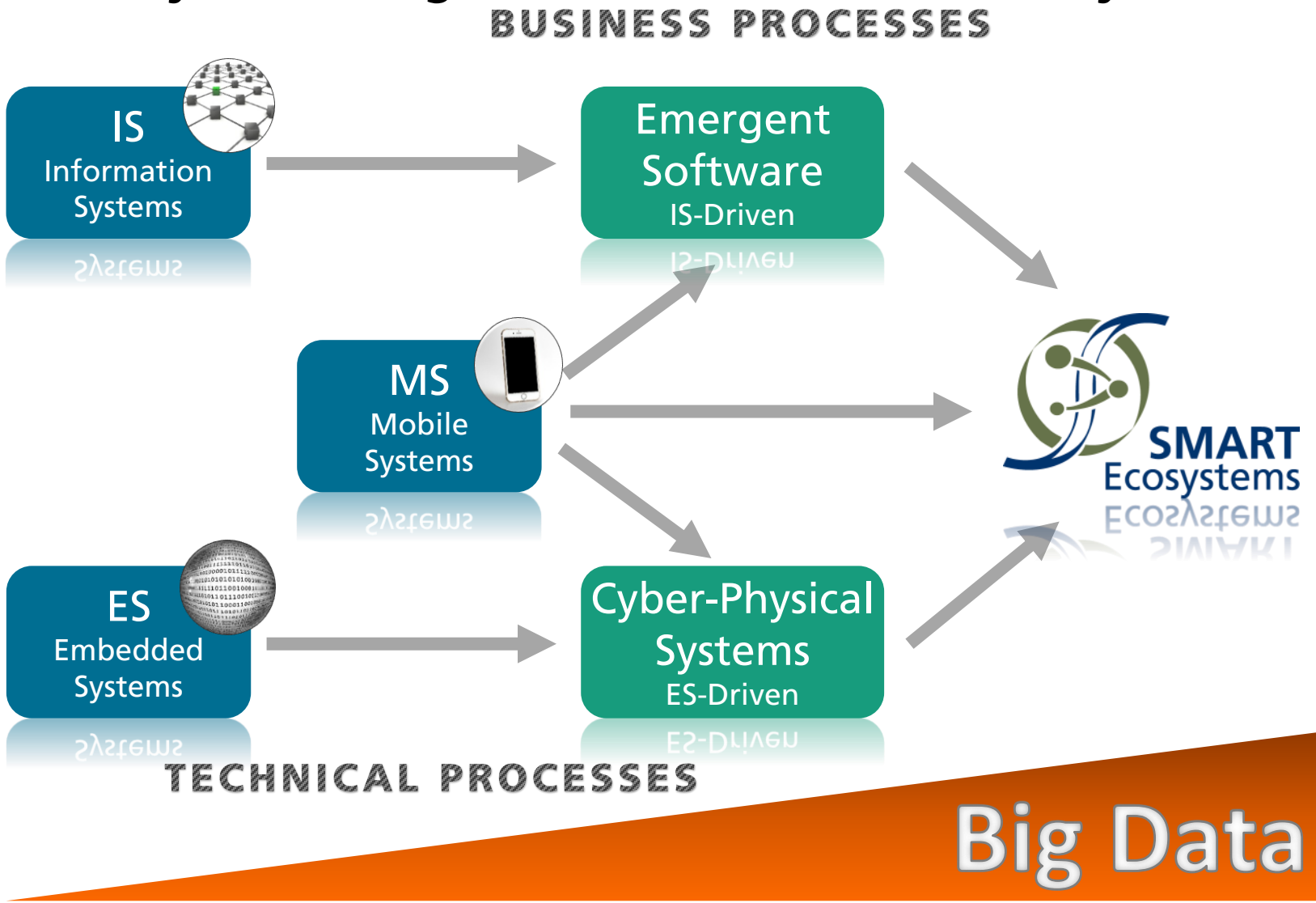
Trend: System Integration towards Smart Ecosystems



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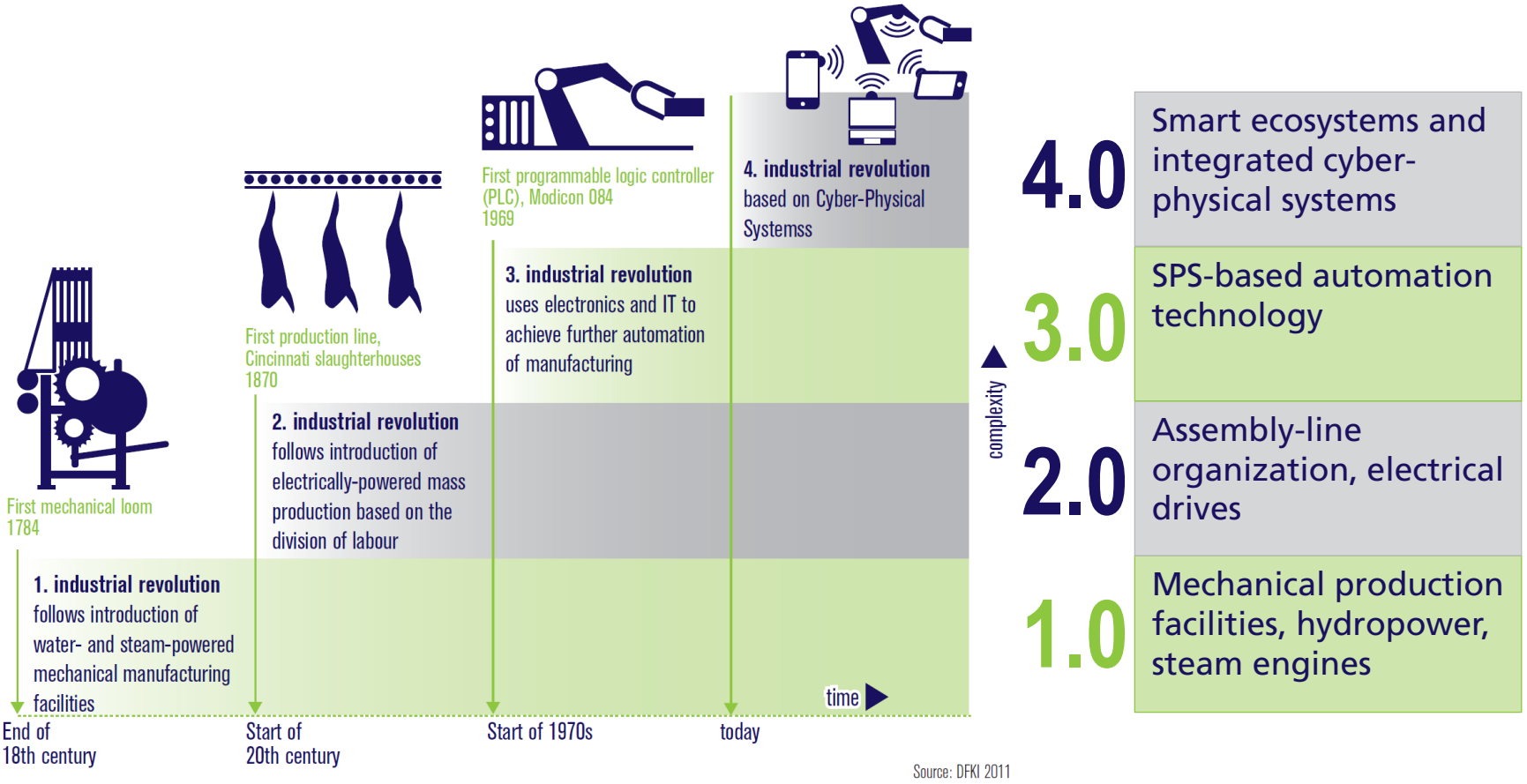
Industrie 4.0
Example for System Integration Trend

- Software is the key to innovation and productivity boost

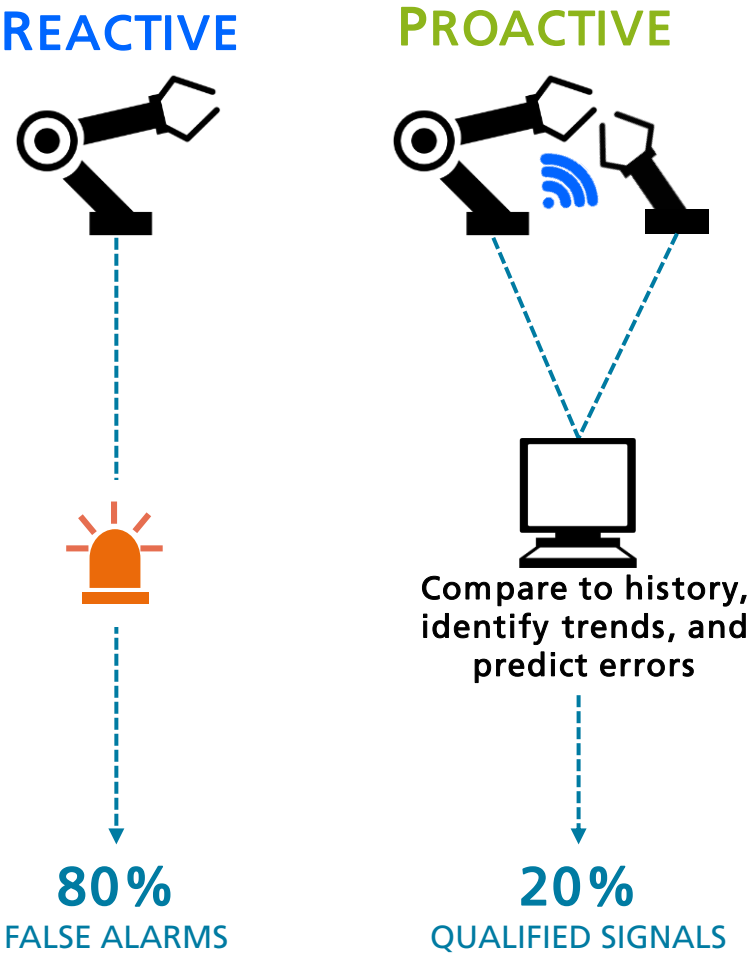


Source: DFKI 2011

Industrie 4.0: Smart Production Example

TODAY

- Which events can be isolated and handled by a service employee?
- Which errors influence the operation of a complete industry plant?
- Is there a correlation between the errors?



FUTURE

- Machine-to-machine communication
- Analysis of machine and surrounding data
- Estimation of machine's condition
- Predict errors & maintain machine
- Avoid downtime
- Avoid unnecessary maintenance

[agendaCPS]

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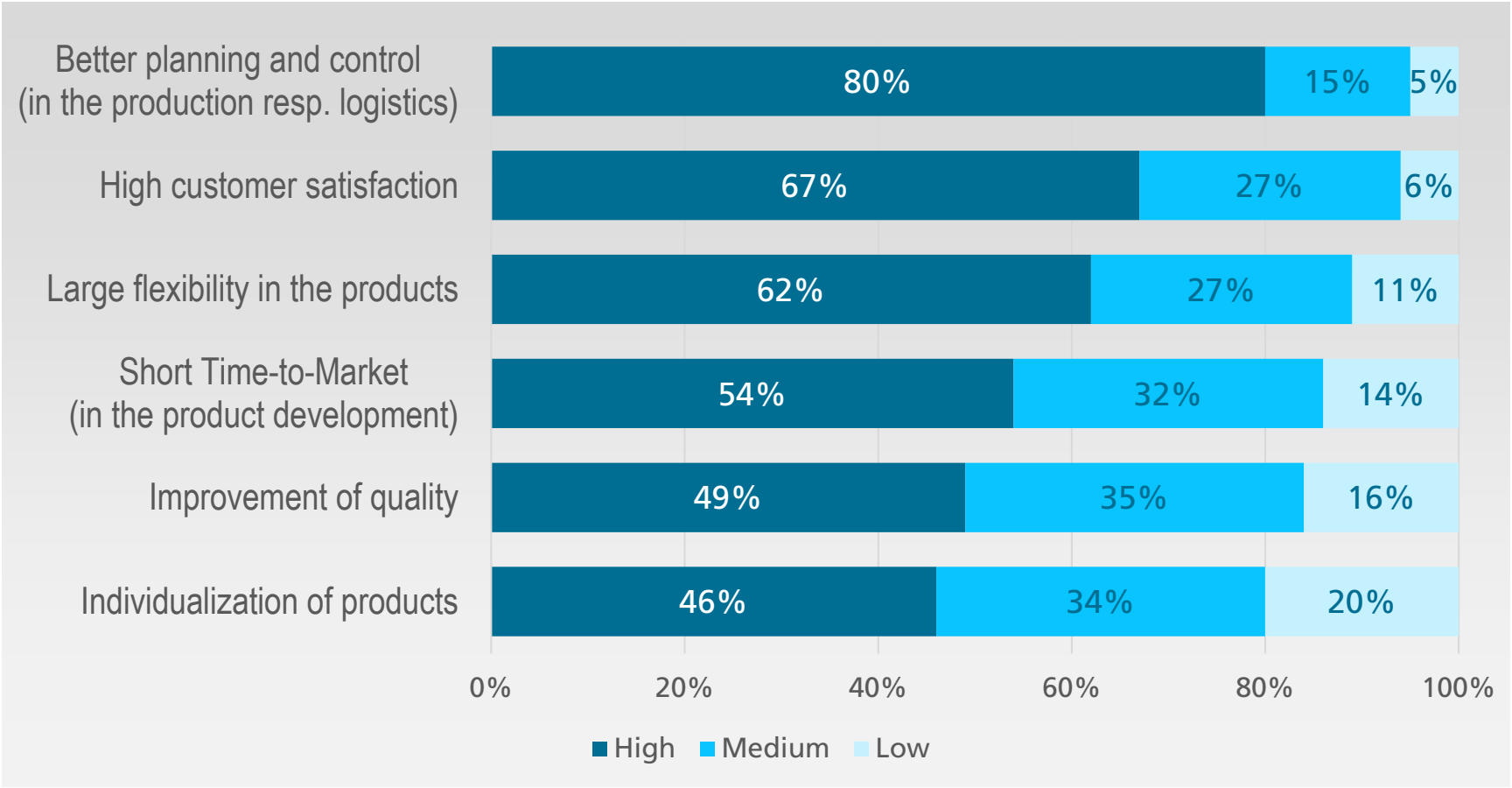
Industrie 4.0: Expected Benefits



[PwC 2014]

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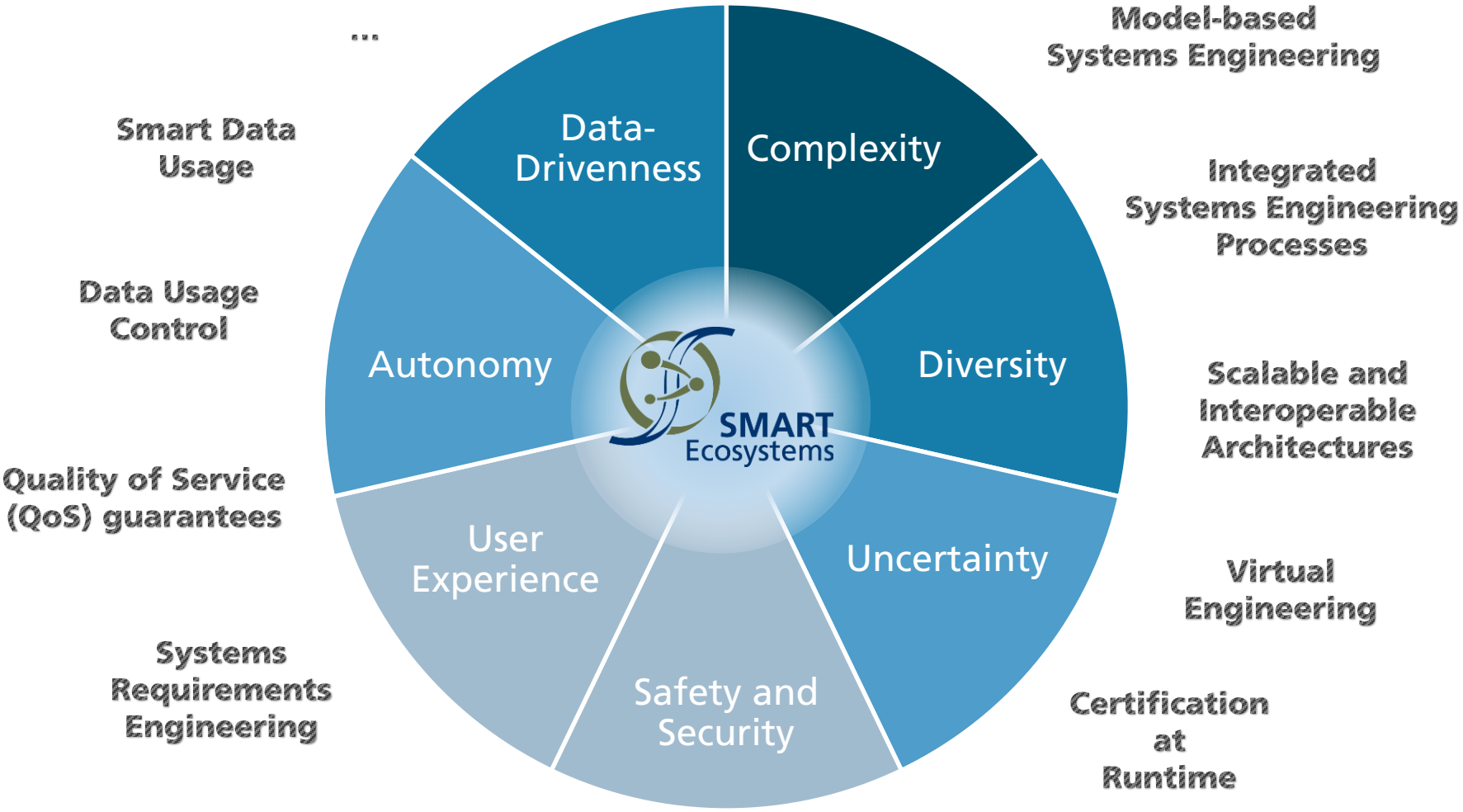
Smart Ecosystems:
A Trend across Domains

- Individual products instead of mass products
- Massive integration of data into technical systems of systems
- Self-organization and re-organization
- Self-optimization: autonomy

⇒ From static solutions designed during development time to dynamic solutions that adapt and optimize autonomously during runtime!

Smart Ecosystems and Needs for Systems Engineering



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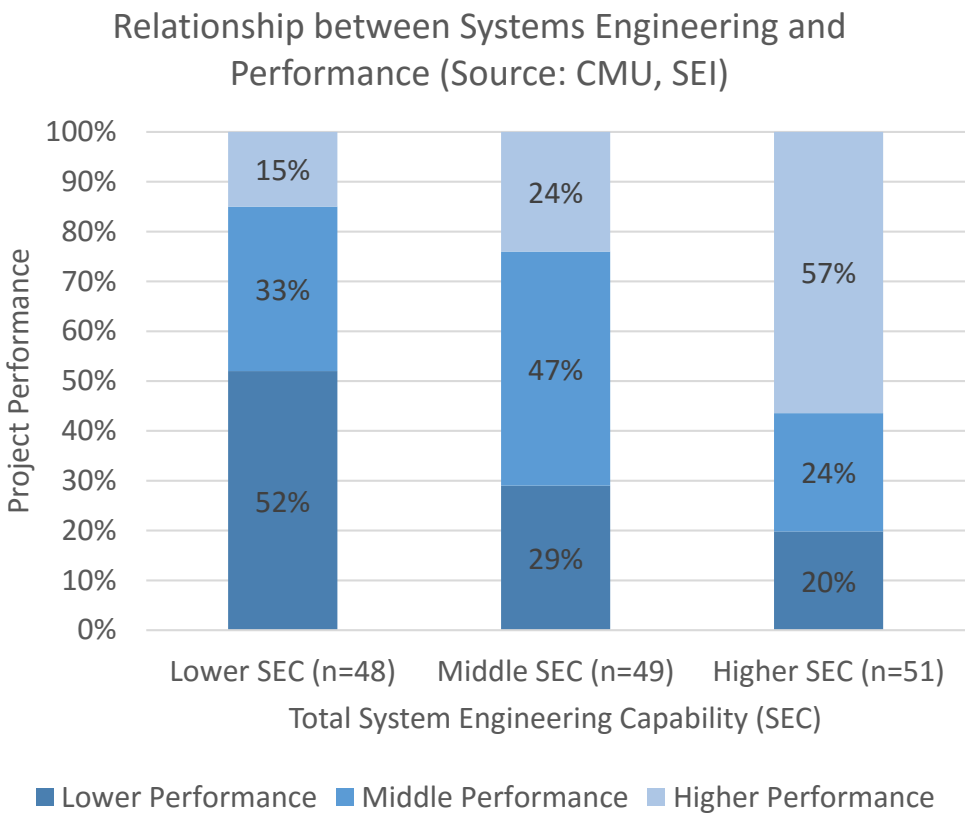
Overview of Related Studies

- Model-Based Systems Engineering Methodologies (by INCOSE MBSE Focus Group, 2007)
- Improving the Integration of Program Management and Systems Engineering (by INCOSE, PMI, 2012)
- Systems Engineering in Industrial Practice (by Unity, Fraunhofer IPT and Heinz Nixdorf Institute, 2013)
- Survey of Systems Engineering Effectiveness (by SEI, 2012)
- Study on Model Driven Development (by Fraunhofer IESE, 2013)



SYSTEMS ENGINEERING STUDY IN GERMANY PART 1 – OVERVIEW AND ANALYSIS RESULTS

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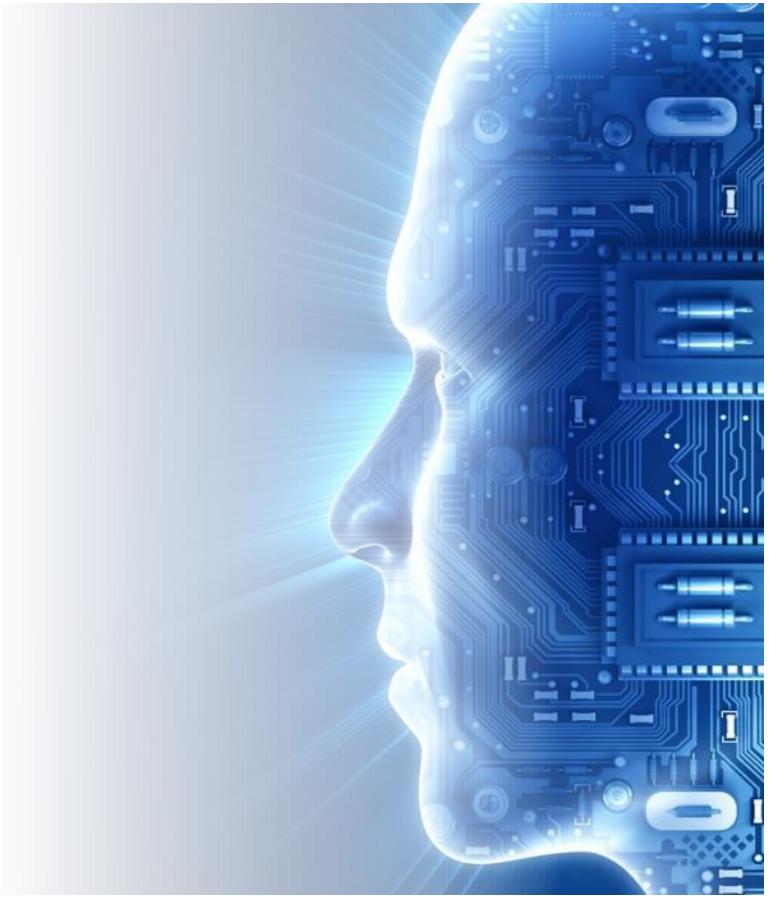
- **Systems Engineering Study**
- Recommendations and Areas of Activity



Study Motivation and Goals

- Amount of software in products is increasing
- Software becomes an enabler for new services and business models
- Systems Engineering is an interdisciplinary approach that considers both business and technical needs (hardware and software)
- Establishing appropriate practices is crucial for developing innovative products on time, within budget, and with a high level of quality
- **Goal: Collect the state of the practice regarding Systems Engineering in the German-speaking region**

Potential Threads

Low sample size

Self-reported data

Questionnaire design

Trust and openness

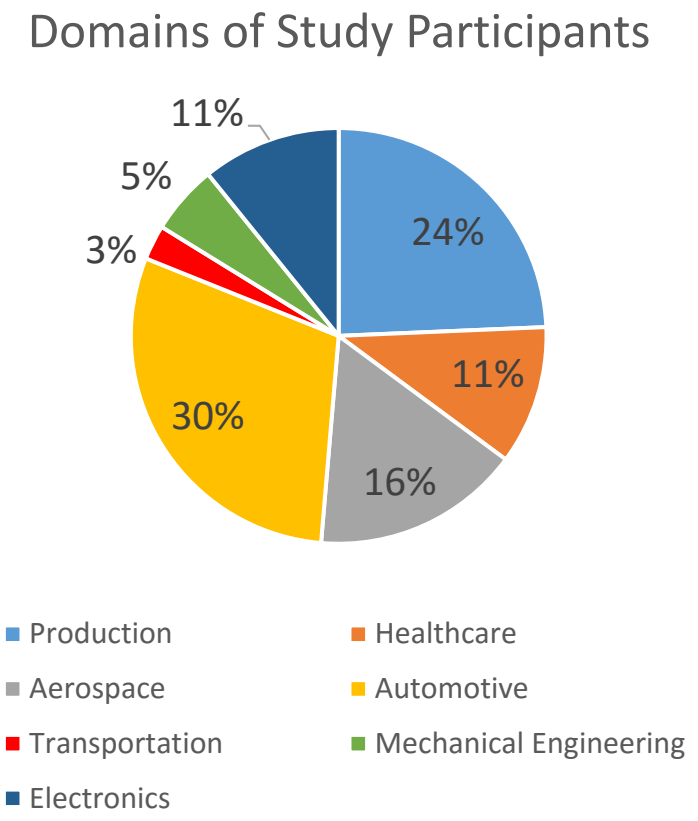
Language issues

Study Context

- 42 invitations to 34 organizations
- 22 agreed to be interviewed
- 20 interviews with 18 companies, such as:

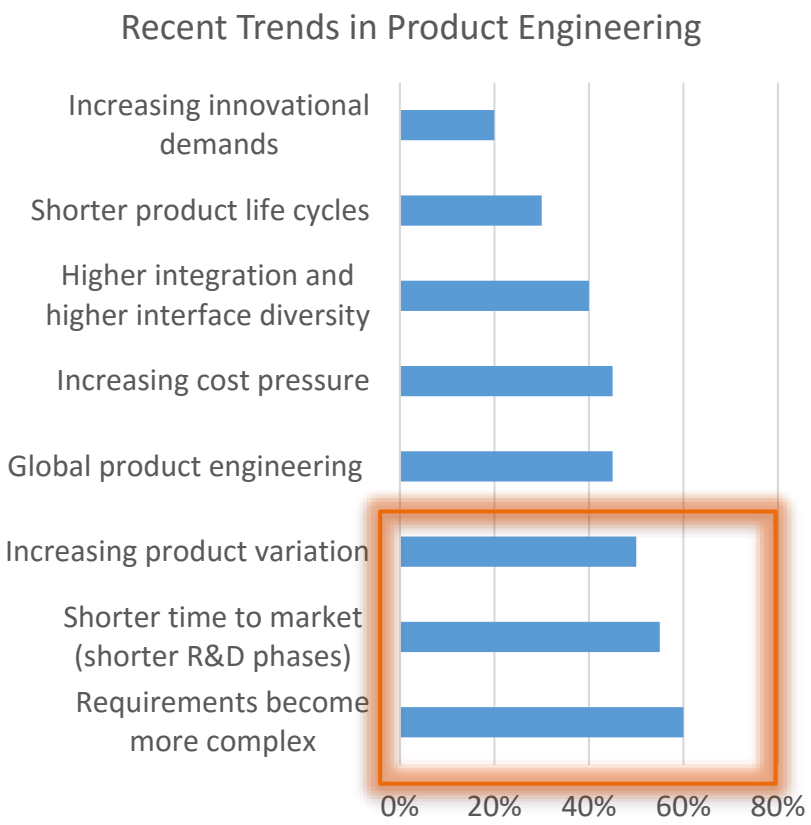
Airbus DS Electronics and Border Security
Art of Technology AG
AVL LIST GmbH
Binder Elektronik GmbH
camLine GmbH
CIBEK technology + trading GmbH
ETAS GmbH
Hella KGaA Hueck & Co.
Robert Bosch GmbH
ZF TRW Automotive Holdings Corp.

- 6 SMEs and 14 LOs
- 29 questions in 12 groups



SME = Small or Medium-sized Enterprise
LO = Large Organization

Product Engineering Trends



Key Outcome #1

- Companies are driven by
  - Increased complexity of system requirements
  - Shorter time to market
  - Larger number of product variations
- In future, in addition more cross-disciplined development is seen (20%)
- This will in turn increase complexity of projects

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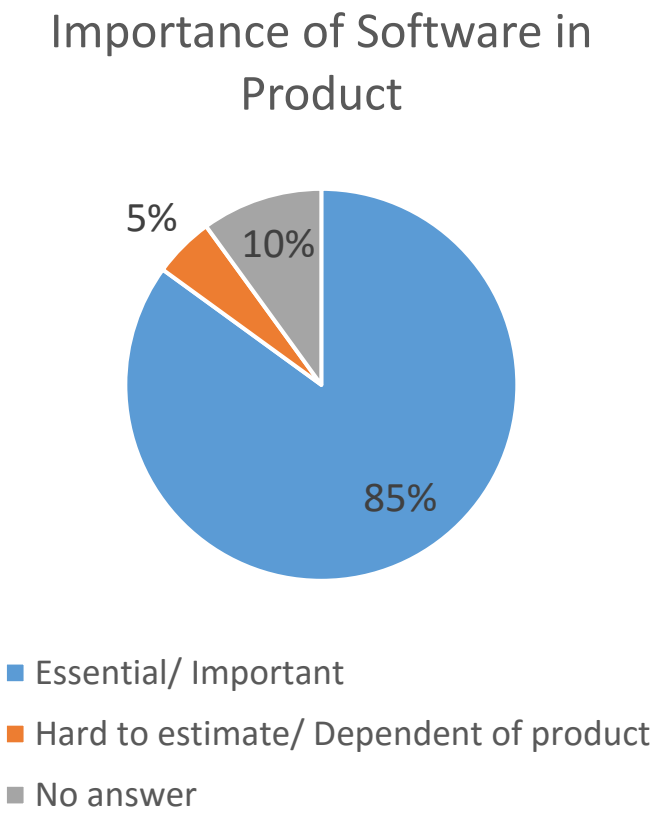
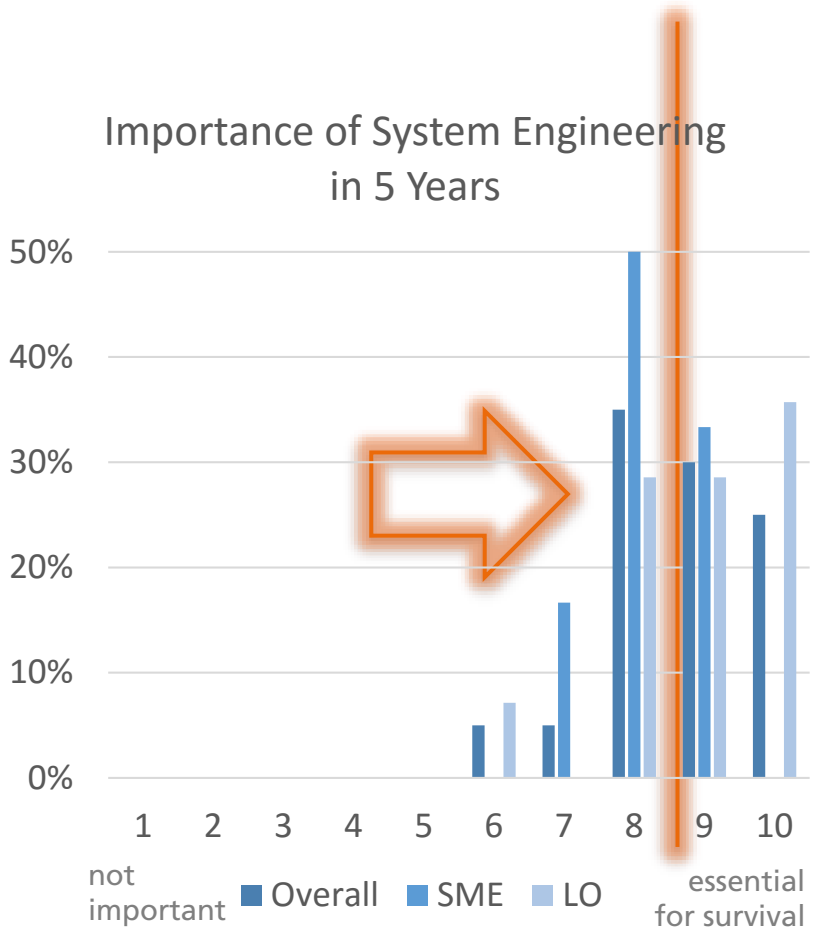
Importance of Software



Key Outcome #2

- 85% stated that software plays a major role in their products
- Even though 70% stated that they come from a pure hardware development world
- 85% stated that they spent 30% or more (up to 90%) of the development budget on software development
- More than half agreed that this will further increase within the next five years

Importance of Systems Engineering



Key Outcome #3

- Average importance of Systems Engineering is 7.6
- Will increase to 8.7 within the next five years
- Reasons for increase:
  - Customer demand for higher quality
  - Increased product complexity
  - Requirements related to system platforms and integration
- Large organizations generally estimate a higher importance within 5 years

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Systems Engineering Challenges

Key Outcome #4

- 80% stated that organizational change management is top challenge
- Followed by:
  - Managing complex requirements and interfaces
  - Modeling and simulation
- Future challenges include in addition:
  - Human Resources Management
  - Data- and information management

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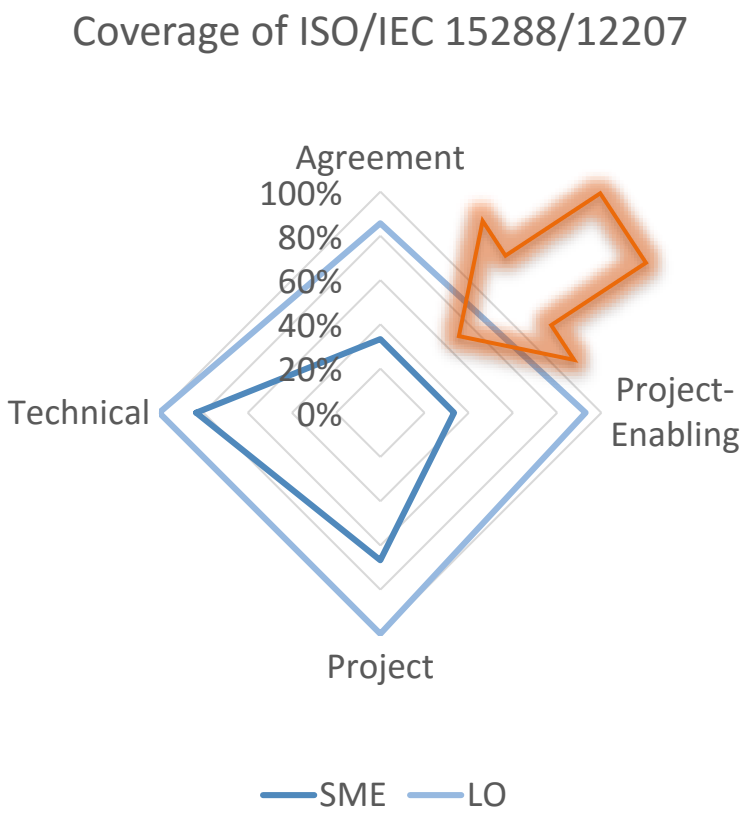
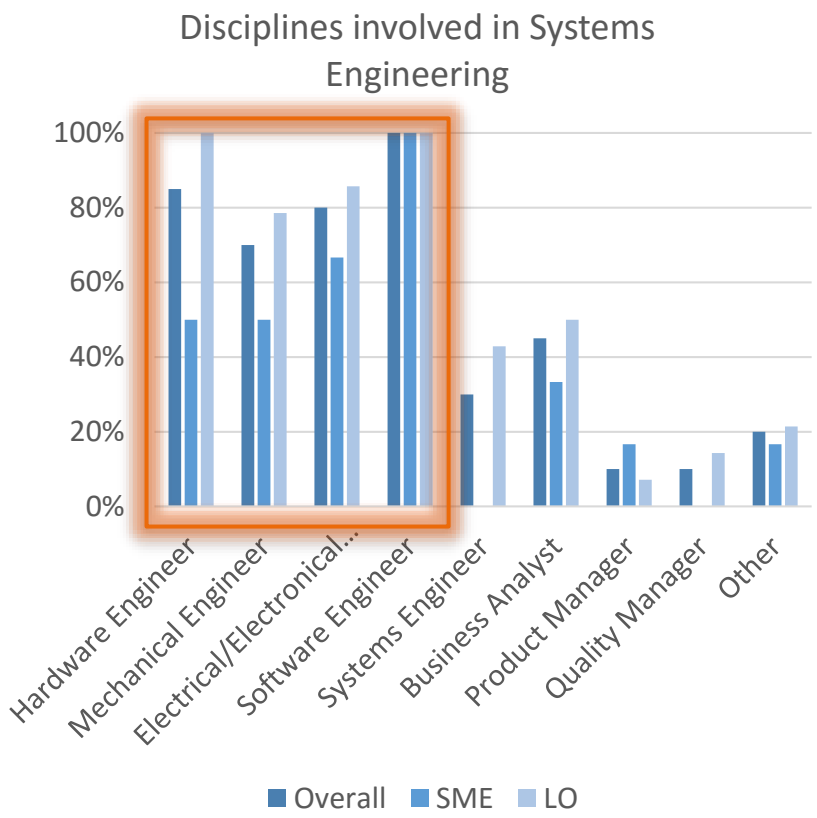
Systems Engineering Process



Key Outcome #5

- LOs basically cover whole ISO/IEC 15288/12207, whereas SMEs focus on technical and implementation processes
- Standards used are quite domain-specific, except for quite general approaches, e.g., ISO 9001
- 40% of LOs explicitly referred to ISO/IEC 15288
- 45% of LOs and SMEs follow an agile model whereas 50% of LOs follow a waterfall model
- 80% of LOs provide different variants of a standard process

Multiple Disciplines/Stakeholders



Key Outcome #6

- Many different disciplines and stakeholders involved in Systems Engineering
- Hardware Engineers or Software Engineers are still viewed as "isolated" disciplines within some organizations
- Role of "Systems Engineer" is only defined in larger organizations
- Coordination of stakeholders takes place by a defined process by 85% of LOs, but only 20% of SMEs
- Between 60% and 70% of the companies create joint teams and perform joint workshops and meetings for coordination

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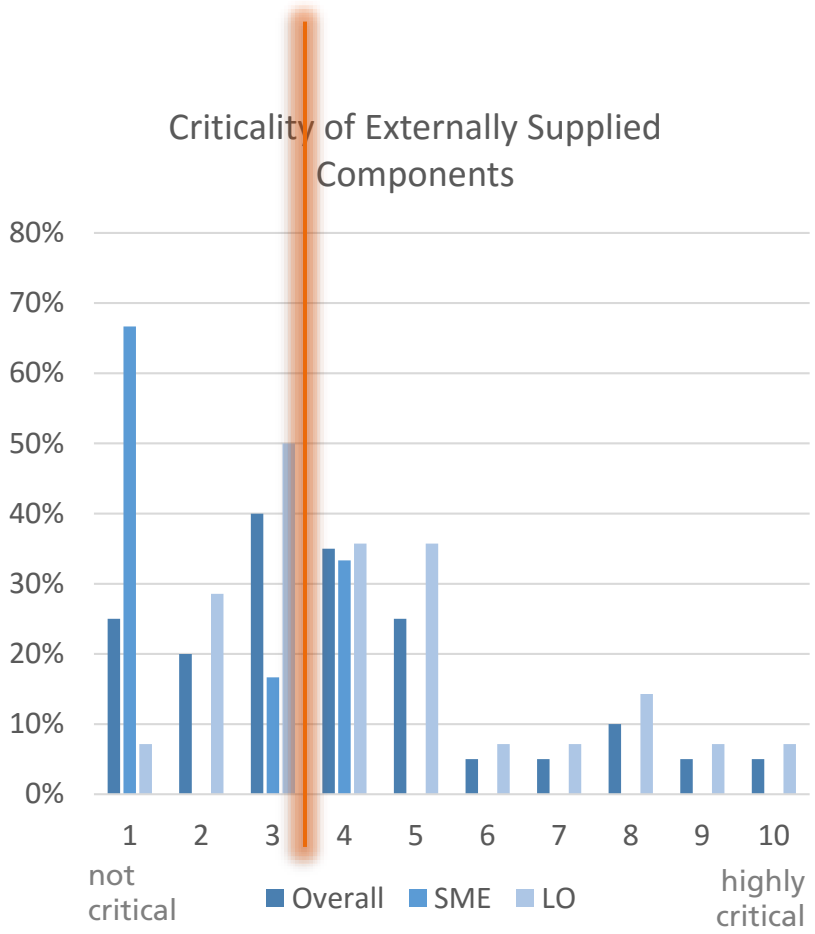
External Suppliers



Key Outcome #7

- Almost 60% get less than 25% of their product parts supplied from external sources
- Nevertheless, one third obtain up to 50% from external suppliers
- Average criticality in terms of intellectual property of externally supplied components is 3.5

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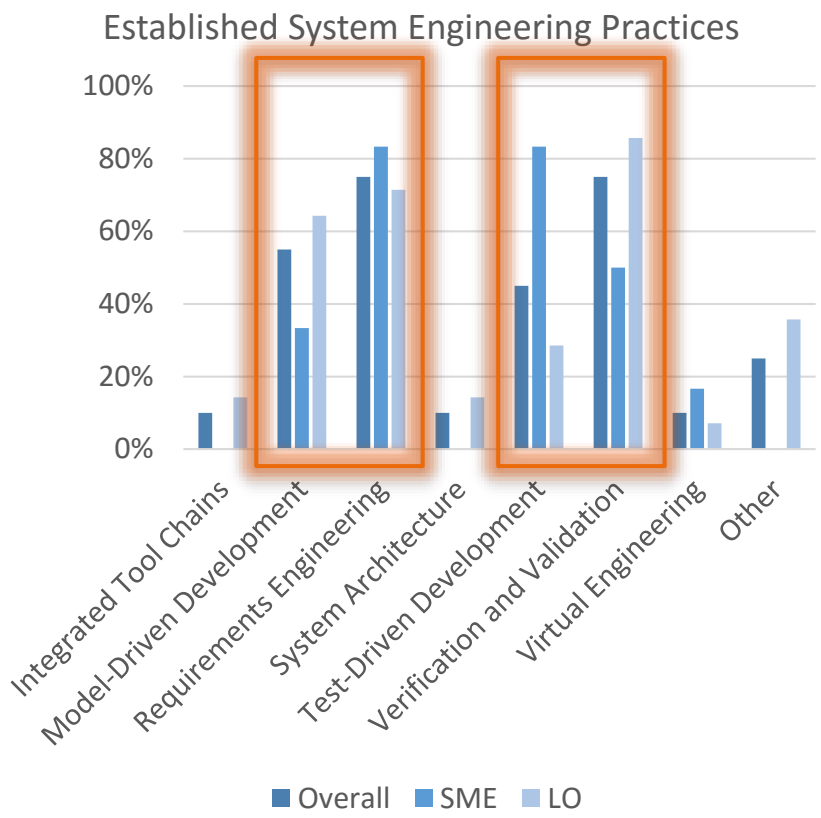
Systems Engineering Practices



Key Outcome #8

- Companies largely established methods, techniques, and approaches related to
  - Model-driven development
  - Requirements engineering
  - Test-driven development
  - Verification and validation
- LOs focus on model-driven development as well as system verification and validation
- SMEs more focus on test-driven development

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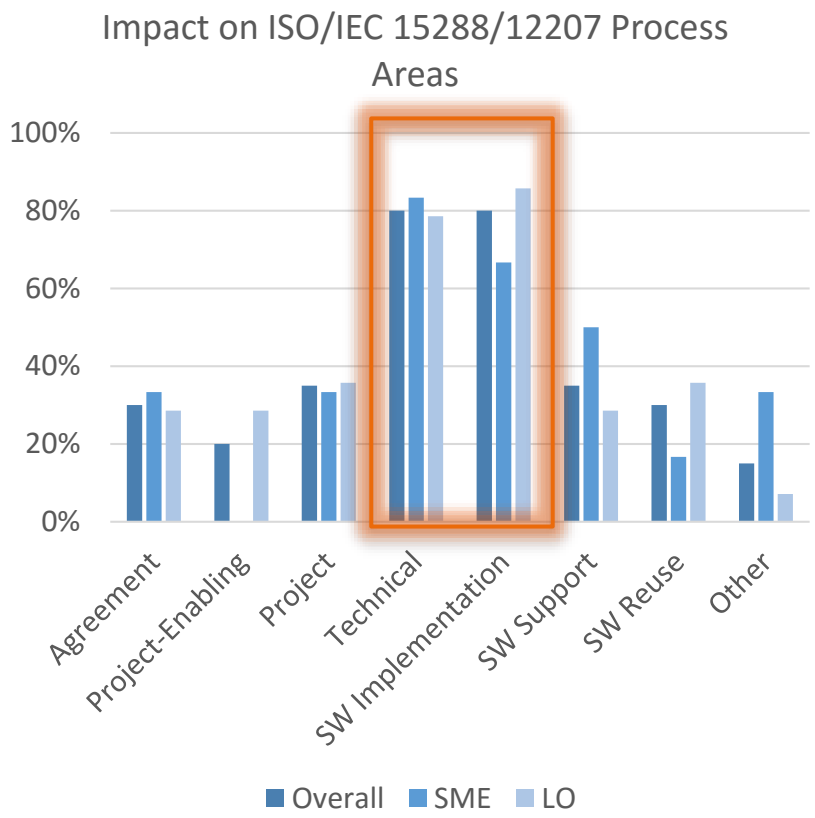
Impacted Processes



Key Outcome #9

- Engineering process areas (ISO/IEC 15288/12207) mostly impacted by Systems Engineering practices are:
  - Technical processes
  - Software implementation processes

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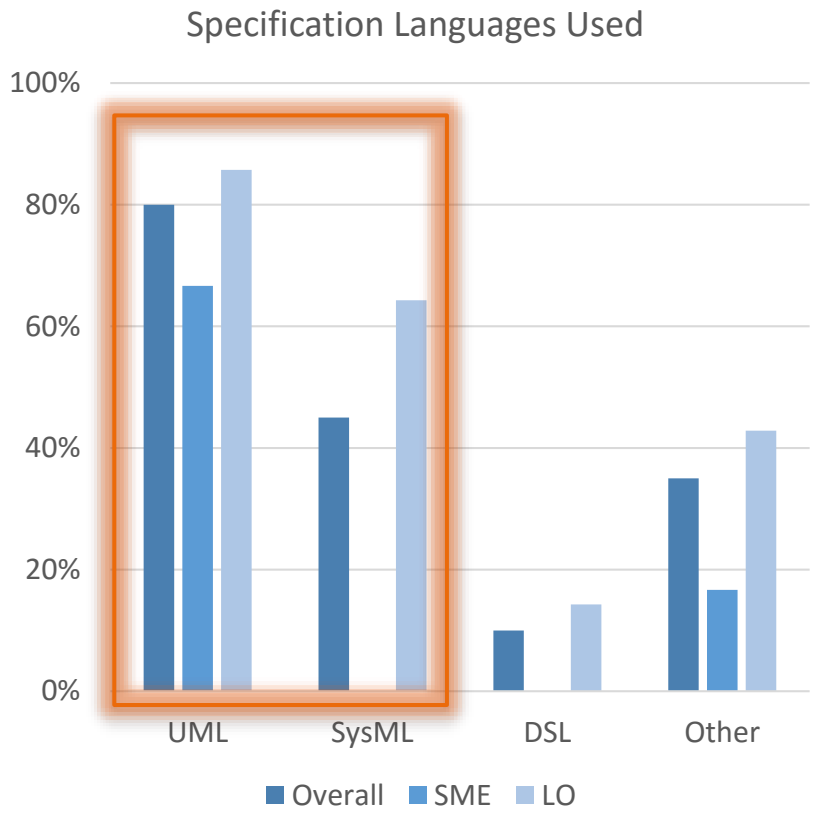
Specification Languages and Tools



Key Outcome #10

- 80% of the participants referred to UML as the major specification language
- LOs tend to use SysML for system modeling
- More than 50% of the tools mentioned were related to modeling different aspects of the overall system
- 30% mentioned requirements and 40% simulation tools as being relevant
- As a future topic, close to 40% mentioned the adoption of formal methods and model-based approaches instead of informal/textual specifications

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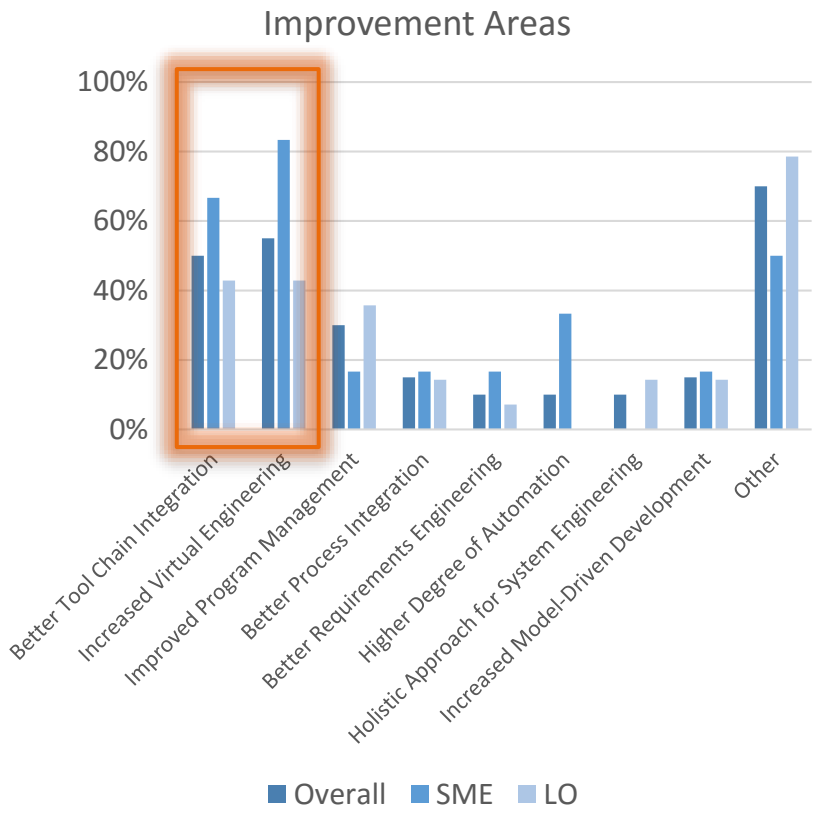
Improvement Potential



Key Outcome #11

- Greatest improvement potential for Systems Engineering lies in:
  - Increased virtual engineering
  - Better integration of the tool chains used
- Demand seems to be bigger for SMEs
- Approx. 40% of LOs mentioned improved program management (aka. project portfolio management)
- Approx. 40% of the SMEs mentioned higher degree of automation

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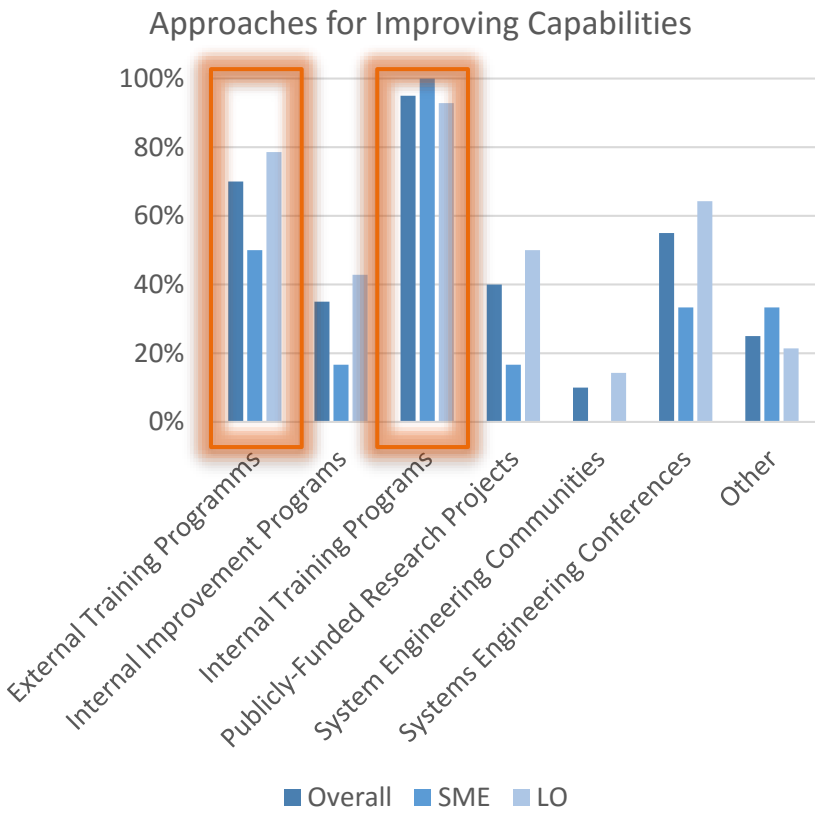
Systems Engineering Capabilities



Key Outcome #12

- Majority of organizations/units rely on internal and external training programs to improve the capabilities related to Systems Engineering
- Participation in Systems Engineering conferences was also mentioned as being beneficial

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Organizational Recommendations

O1: Change Management Strategy

- 80% stated that organizational change management is the key challenge (see outcome #4)
- It is important to openly think about which organizational structure and processes are best suited
- In particular, it is important to include all stakeholders (see outcome #6) in that process

O2: Systems Engineering Competencies

- Creating internal and buying-in external training programs on different topics is obligatory (see outcome #12)
- We would also recommend to:
  - Participate in Systems Engineering conferences
  - Become an active members of communities for experience exchange

Organizational Recommendations

O3: Software Engineering Competencies

- 85% stated that software plays a major role (see outcome #2)
- Companies should build up / maintain Software Engineering competencies depending on:
  - Amount of software in product
  - Major IP and USP of company
- If IP/USP is in software, companies should build up own resources
- If software is only a means, companies should build up competencies for managing software suppliers (see outcome #7)

O4: Project Portfolio Management

- LOs should place special focus on
  - Management of the overall portfolio of projects
  - Interconnections and dependencies among projects (see outcome #11)

IP = Intellectual Property
USP = Unique Selling Point

Technical Recommendations

T1: Integrated Systems Engineering Approach

- Time to market is getting shorter and product complexity is increasing (see outcome #1)
- It is important to efficiently and effectively deliver value to the customers
- This requires a well-integrated and aligned approach across all disciplines involved (see outcome #6)
- Companies should carefully think about what impact Systems Engineering has and what a custom-tailored process should look like (see outcome #5)

T2: System Requirements Engineering

- Complexity of requirements and number of product variants has increased (see outcome #1)
- Cross-disciplined development will come into play
- Companies need to deal with (see outcome #2):
  - How to elicit/develop requirements on the system level and break them down
  - How to manage them systematically over time

Technical Recommendations

T3: Model-driven Systems Development

- Model-driven development of systems is seen as a key practice
- LOs have implemented it at least partially (see outcome #8)
- An organization should evaluate:
  - Which aspects of the system specification should be modelled
  - What appropriate language and tool support is available
- Tool selection should be influenced by the degree of integration (see outcomes #10 and #11)

T4: System Verification and Validation

- Companies should think about establishing proper techniques and methods (see outcome #8) for:
  - System verification and validation in general
  - Test-driven system development specifically
- Additionally, an integrated development process should ensure that system verification and validation is properly linked to other engineering processes

Technical Recommendations

T5: Virtual Systems Engineering

- Complexity of products increases (see outcome #1) and development is becoming more multi-disciplined (see outcome #6)
- It becomes more difficult/costly to compose the system physically
- Companies should think about virtual engineering of systems based on sound models
- This is seen as a major improvement potential for speeding up (see outcome #11)

T6: Integrated Systems Engineering Tool Chains

- Companies have developed their own tools for particular tasks and overcoming shortages of existing tools (see outcome #10)
- One major point for improvement is better integration of the tool chains (see outcome #11)
- Especially when starting to do Systems Engineering, companies should therefore put special emphasis on the interoperability of their tools

System Engineering is required for Coping with Trends related to Increased Digitization and System Integration

Study Outcome Summary

- Increased system complexity and product variations are drivers
- Systems Engineering is considered to be of outmost importance for companies
- Change management is challenging
- Model-driven development, requirements engineering, test-driven development, and verification and validation are key areas to establish
- Improvement potential lies in increased virtual engineering and better integration of the tool chains
- Internal and external training programs are key for improving capabilities

Recommendations Summary

- Establish change management strategy
- Build up competencies in Systems and Software Engineering as well as portfolio management (for LOs)
- Work on an integrated Systems Engineering approach including all stakeholders
- Establish practices in the areas of System Requirements Engineering, Model-Driven Systems Development, and System Verification and Validation
- Mature companies should invest into practices for Virtual Systems Engineering and integrated tool chains

Part 2

Thanks!

どうもありがとう

Dōmo arigatō

Dr. Jens Heidrich

Division Manager
Process Management PM

Fraunhofer IESE
Fraunhofer-Platz 1
67663 Kaiserslautern
Germany

Phone: +49 (0) 631-6800-2193
Fax: +49 (0) 631-6800-9-2193

jens.heidrich@iese.fraunhofer.de

Japanischer Garten Kaiserslautern

[Picture from http://www.japanischergarten.de]

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