SYSTEMS ENGINEERING AND RESEARCH

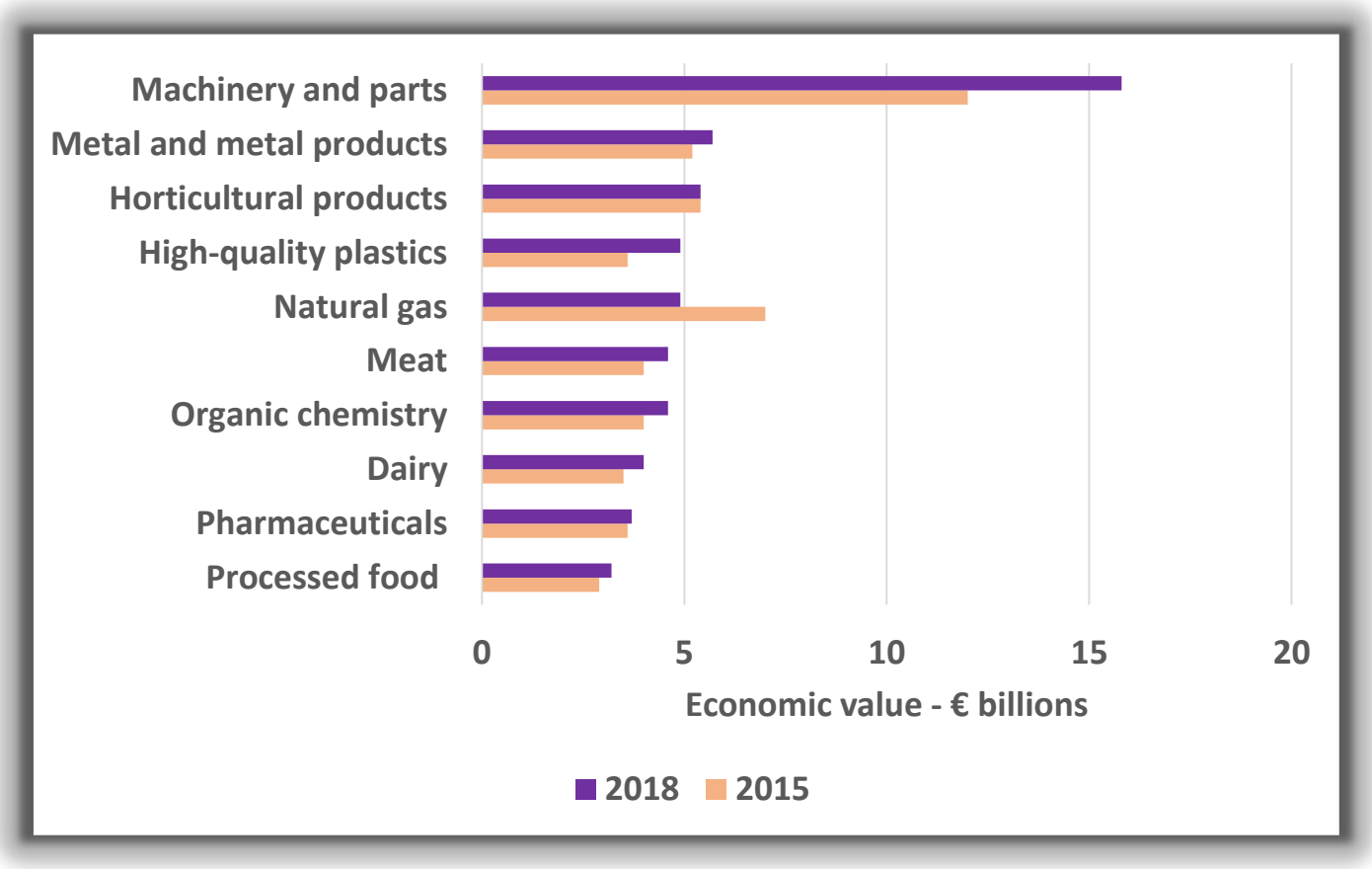
Wouter Leibbrandt
Science and operations director

SERC Research Review
18 November 2019

An initiative of industry, academia and TNO

ESI

Highest earning exports of The Netherlands (released 5 Nov 2019)



ESI at a glance

Mission: ***Embedding leading edge methodologies into the Dutch high-tech systems industry to cope with the ever increasing complexity of their products.***

Synopsis

- Foundation ESI started in 2002
- ESI acquired by TNO per January 2013
- ~55 staff members, many with extensive industrial experience
- 5 Part-time Professors
- Working at industry locations
- From embedded systems innovation to embedding innovation

Focus

Managing complexity of high-tech systems

through

- system architecting,
- system reasoning and
- model-driven engineering

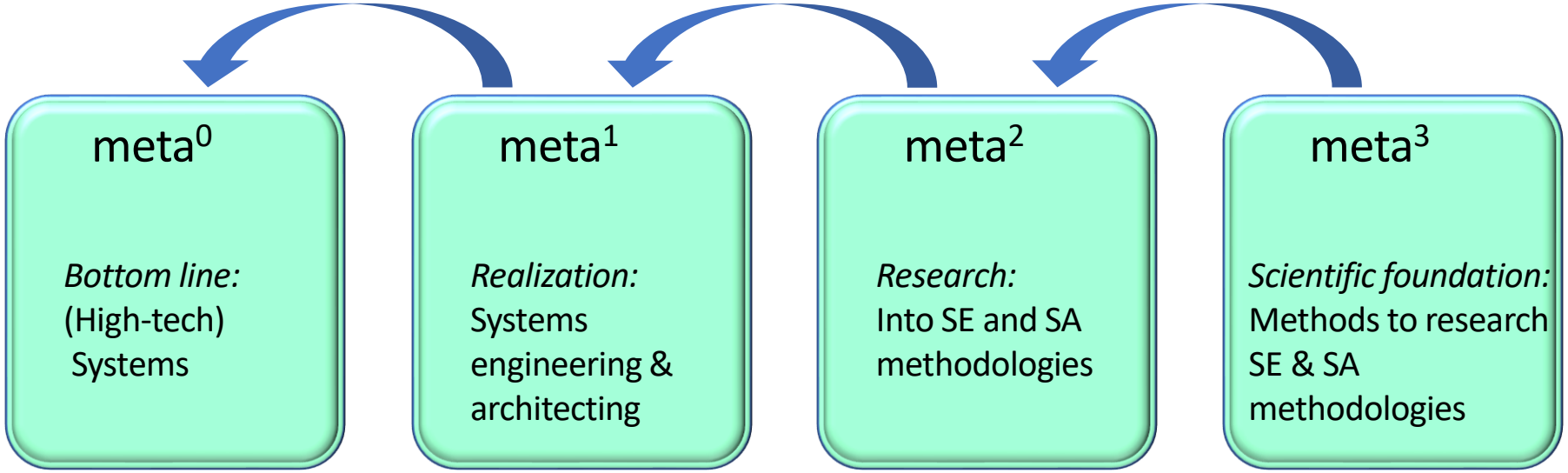
delivering

- methodologies validated in cutting-edge industrial practice

Partner Board

ASML, PHILIPS, nexperia, ThermoFisher SCIENTIFIC, océ, TNO, THALES, TU/e technische universiteit eindhoven, TU Delft Delft University of Technology, UNIVERSITY OF TWENTE., Radboud Universiteit Nijmegen

Systems, Systems Engineering and Research



Based on: Gerrit Muller PhD Thesis, 2004

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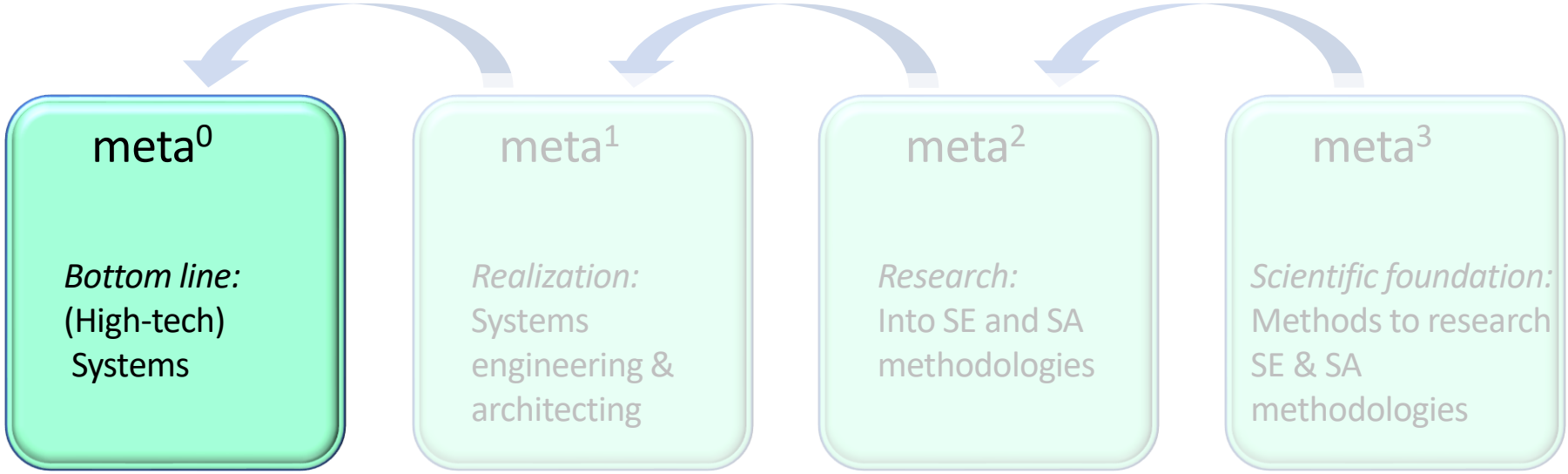

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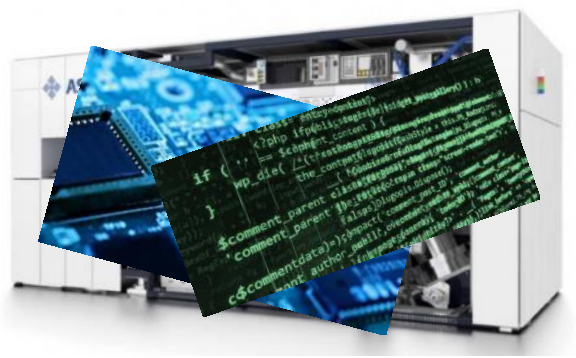
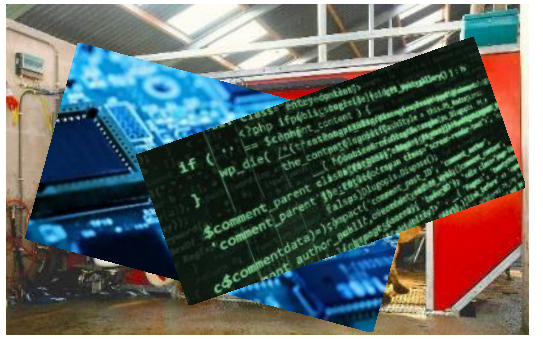
High-tech Systems



Semiconductor manufacturing equipment

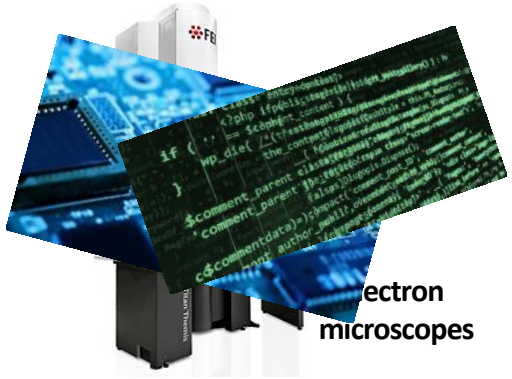
Medical systems

Food processing



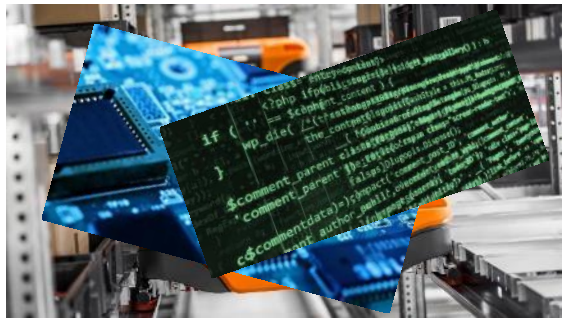
Agricultural robots

Traffic management



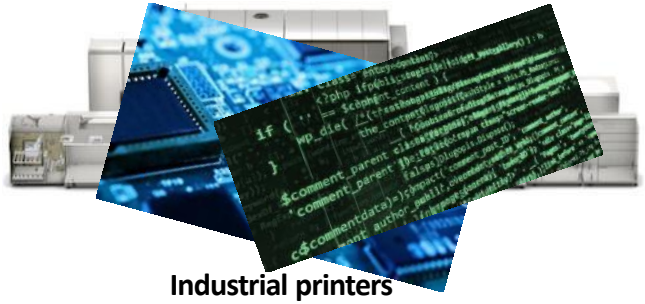
ectron microscopes

Building control



Robotized warehousing

Combat management systems



Industrial printers

Automotive

Residential heating/cooling

Main drivers of complexity into the 2020's

Continuously Evolving Systems

The system has both the capability and the need to evolve over time

Autonomous Systems

System operates without human in the loop, human interaction moves to higher level

X-as-a-Service Systems

Not the machine, but the service it provides is the manufacturer's value proposition

Series-of-one Systems

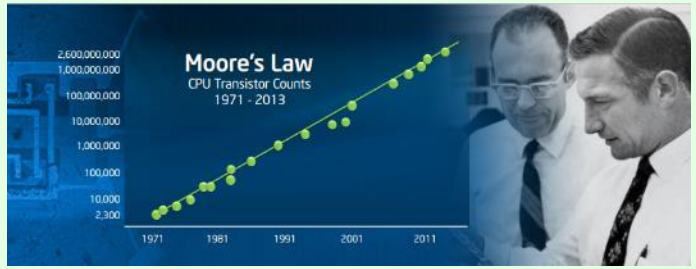
High level of customization of each system delivered, no two systems alike

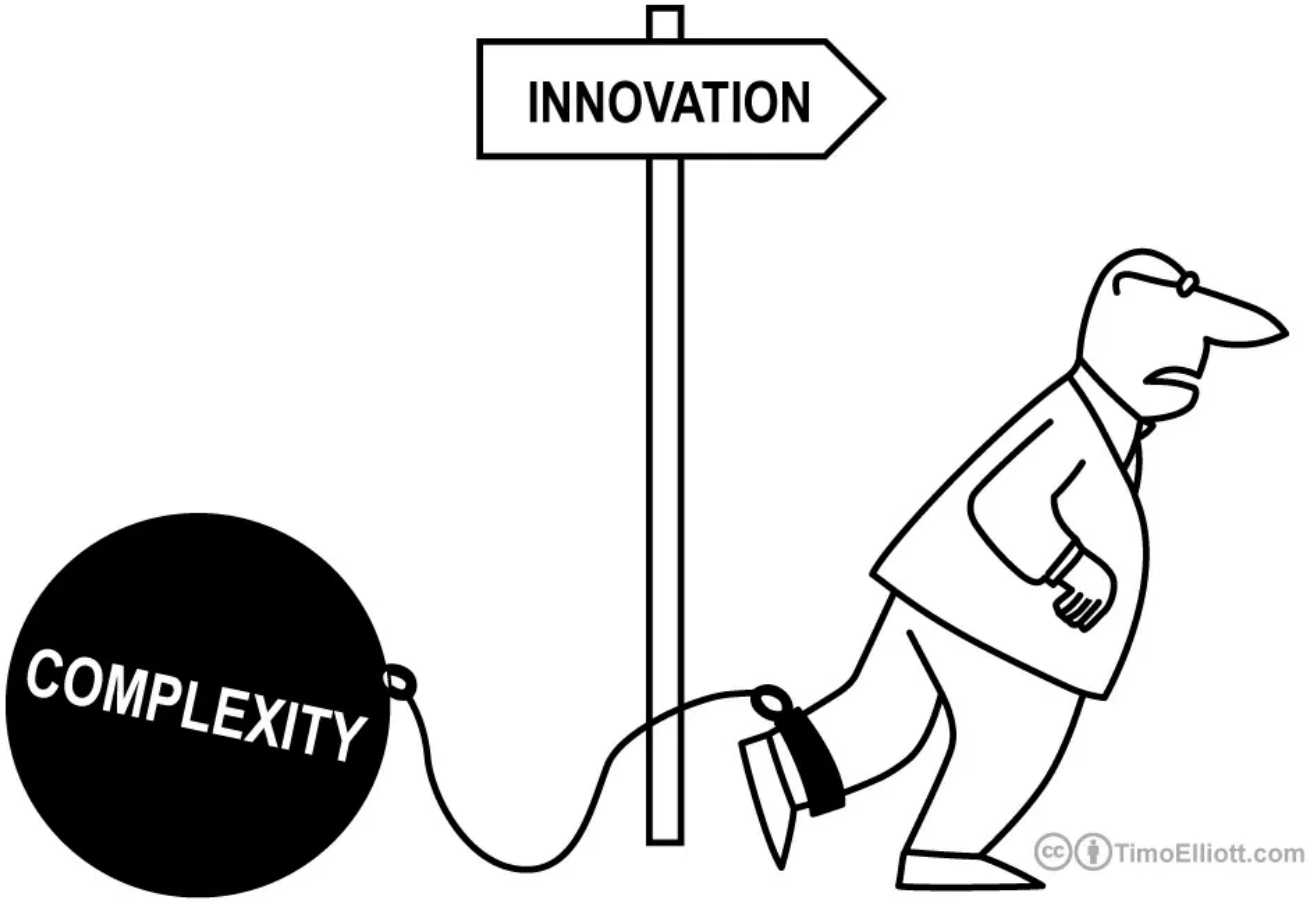
Systems of Systems

The system is an integral part of a larger system without any control of that system

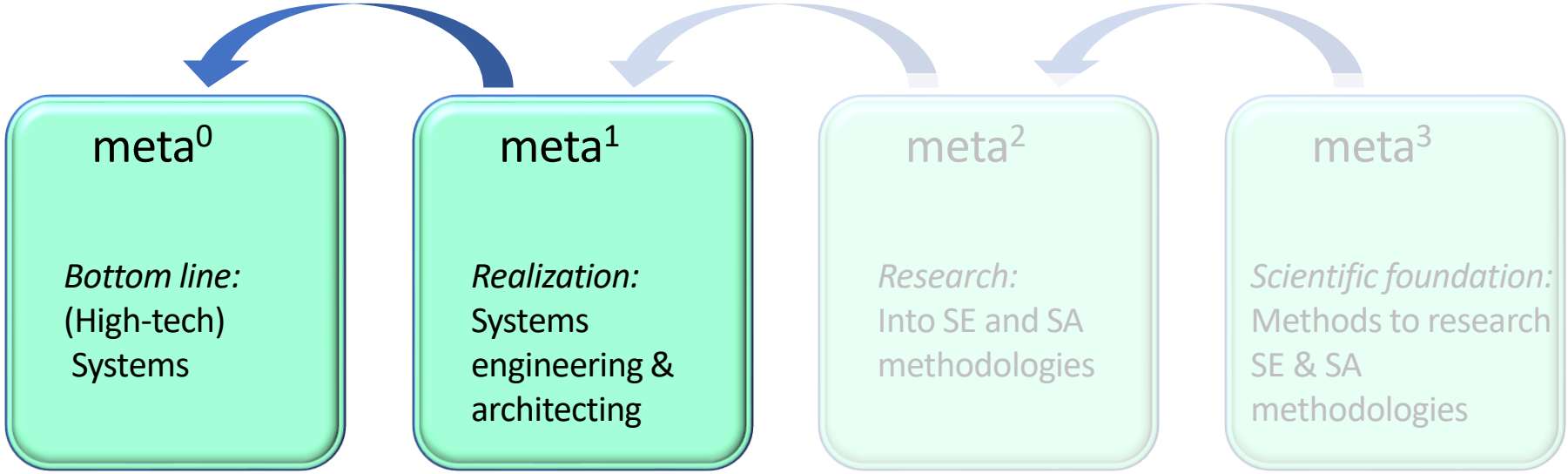
Parameters-times-10 Systems

All design parameters (e.g. interfaces, LoC) get one (or more) orders more demanding





Systems, Systems Engineering and Research



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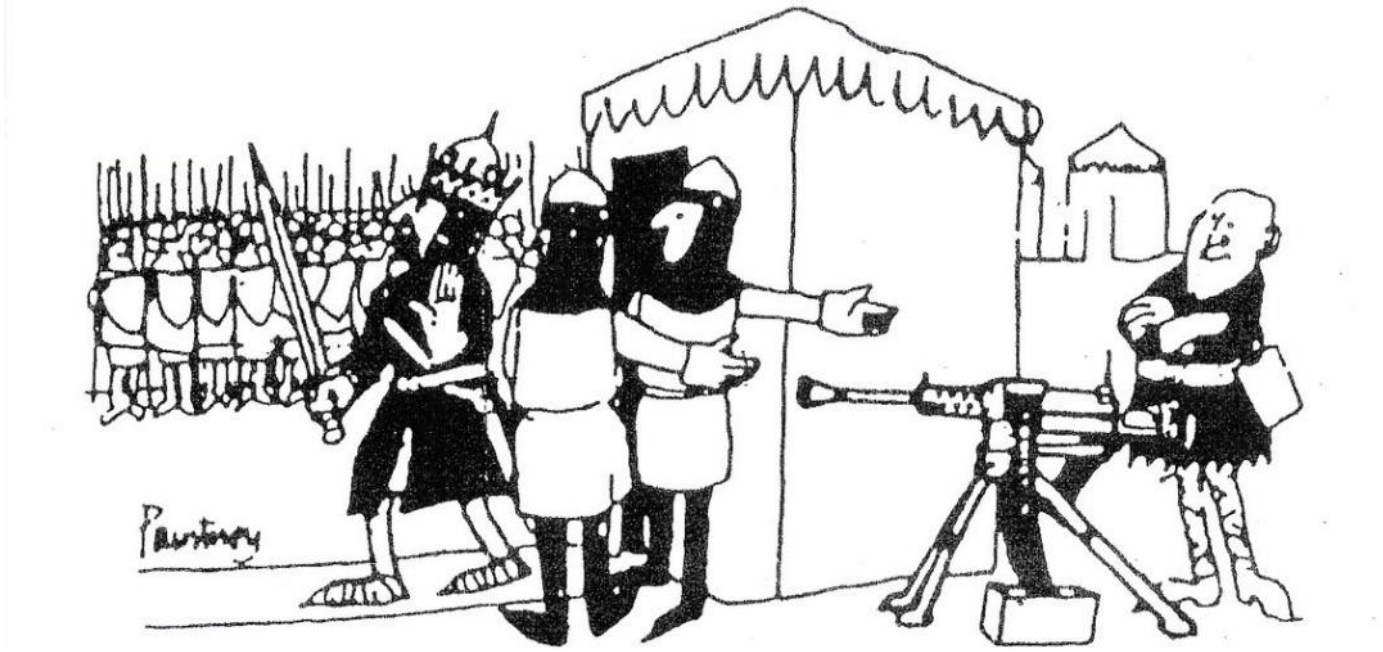
Systems engineering: applying methodologies to better design and realize complex systems



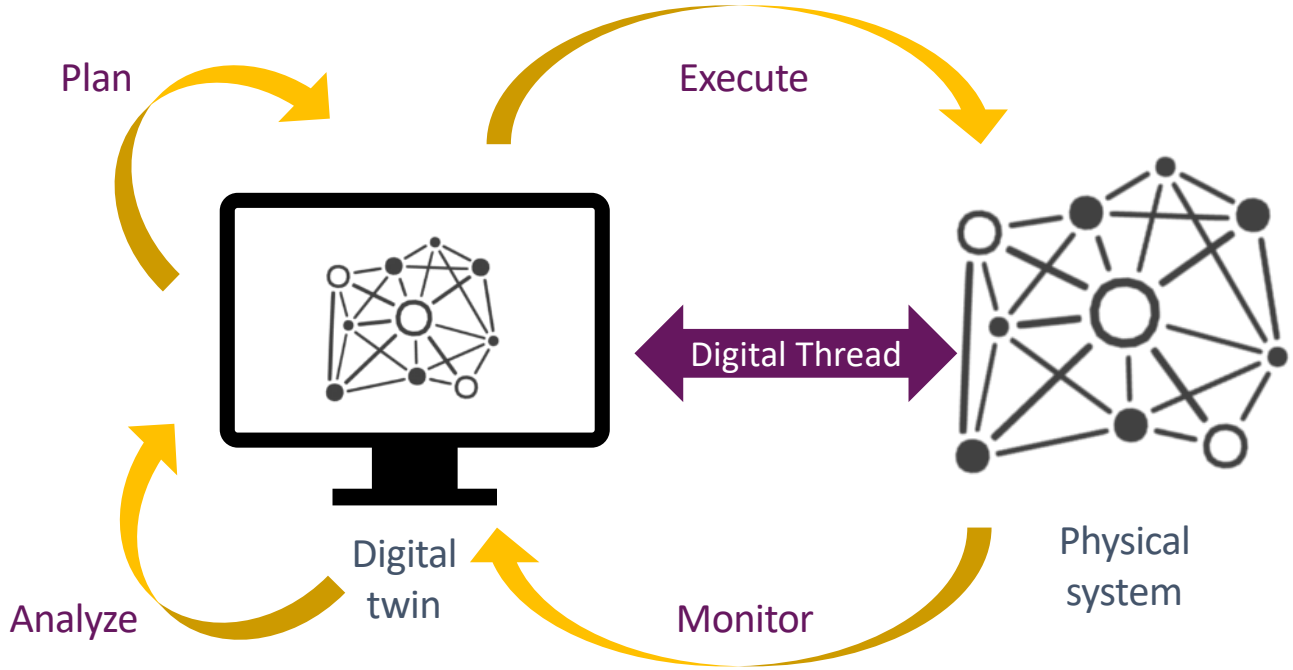
I can't be bothered by some crazy technology idea, I have a war to fight!

Example: Digital Twin

The digital twin as central asset for adaptation and evolution

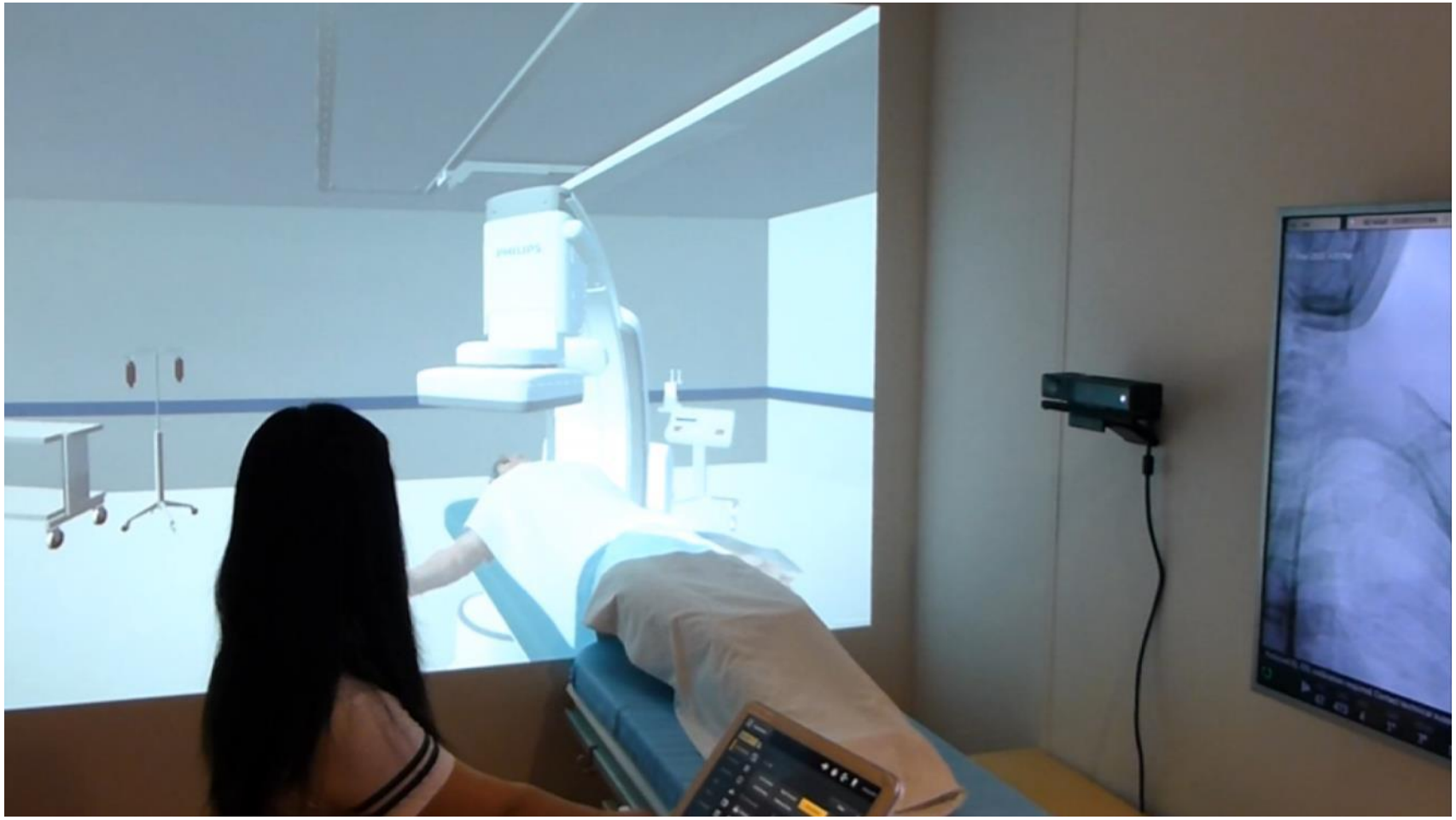
Digital twins are software representations of assets and processes that are used to understand and diagnose systems, and predict and optimize their performance, allowing us to perform the **critical evaluation** and by which the **system becomes better fitted to perform and last in its environment.**

The **digital thread** sets up full traceability across a **whole lifecycle**, addressing the key concern of availability of engineering and system knowledge.




PHILIPS
PHILIPS
PHILIPS

Digital twin – with hardware in the loop

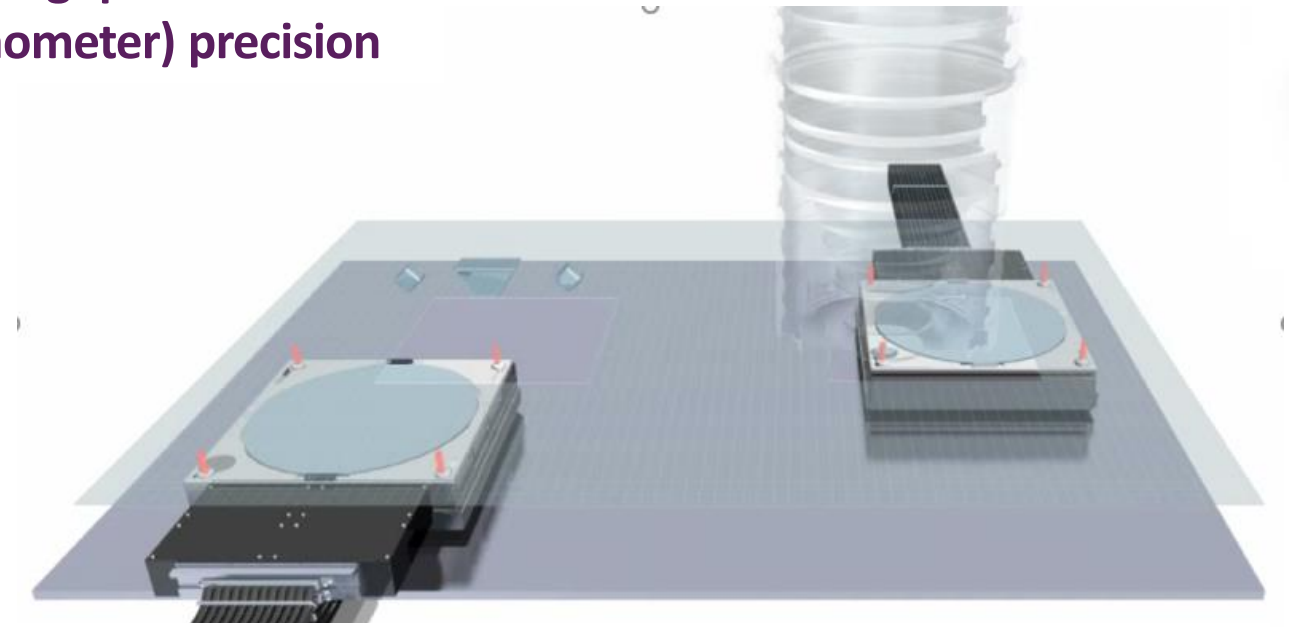


Roland Mathijssen

Case study – ASML lithography scanner

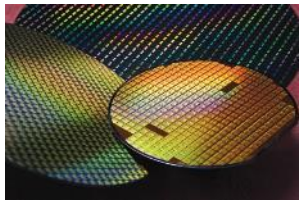
System requirement

- Very high throughput
- Extreme (nanometer) precision



- Requirement: no hiccups
- exposure is carried out as sequence of concatenated Step/Scan actions

Digital Twin to diagnose timing bottlenecks in large-scale component-based software

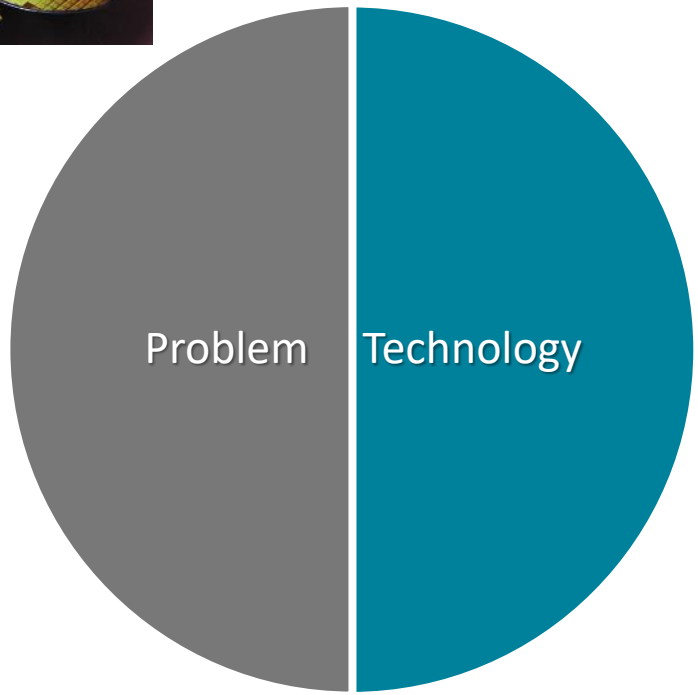


Domain

Lithography scanners

Industrial partners: ASML

How to **measure** and **exploit** the **measured data** to automatically diagnose timing bottleneck in existing large-scale component-based software?



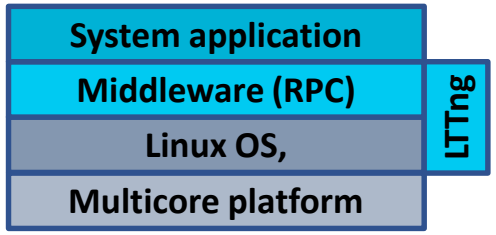
Approach

- Formalization of subset of Message Sequence Charts (based on international standards)
- SW code instrumentation with probes at strategic places in middleware
- Digital twin
- Fully automated Message Sequence Chart inference from measurements
- Fully automated critical path analysis

Automatic diagnosis of timing bottlenecks

Measurement-based approach to get insight in timing bottlenecks based on Timed Message Sequence Charts (TMSCs)

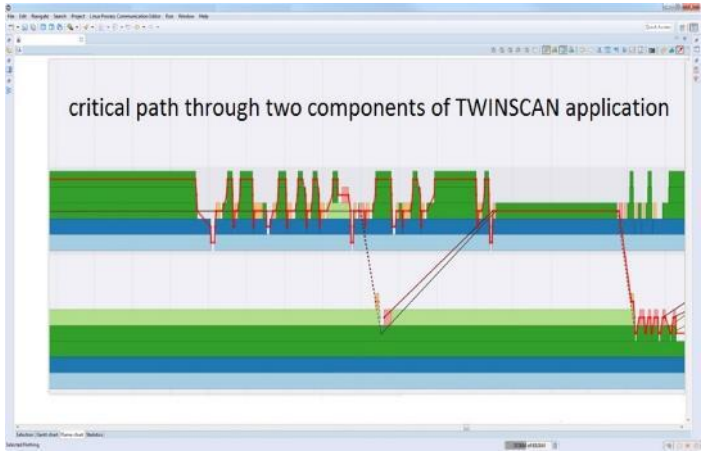
1. **Code instrumentation**
2. **Automated inference of digital representation creating a digital twin in the form of TMSC**
3. **Replay measured sequence: automated critical-path analysis to detect timing bottlenecks**



1. Instrumentation

2. Automated TMSC inference

Digital twin



3. Critical-path analysis

Scalability
- **396 components**
- **48.7 million events**
- **24.3 million function executions**
- **60.4 million timing constraints**
- **11.7 million messages**

Jeroen Voeten

An initiative of industry, academia and TNO

Digital twin research challenges

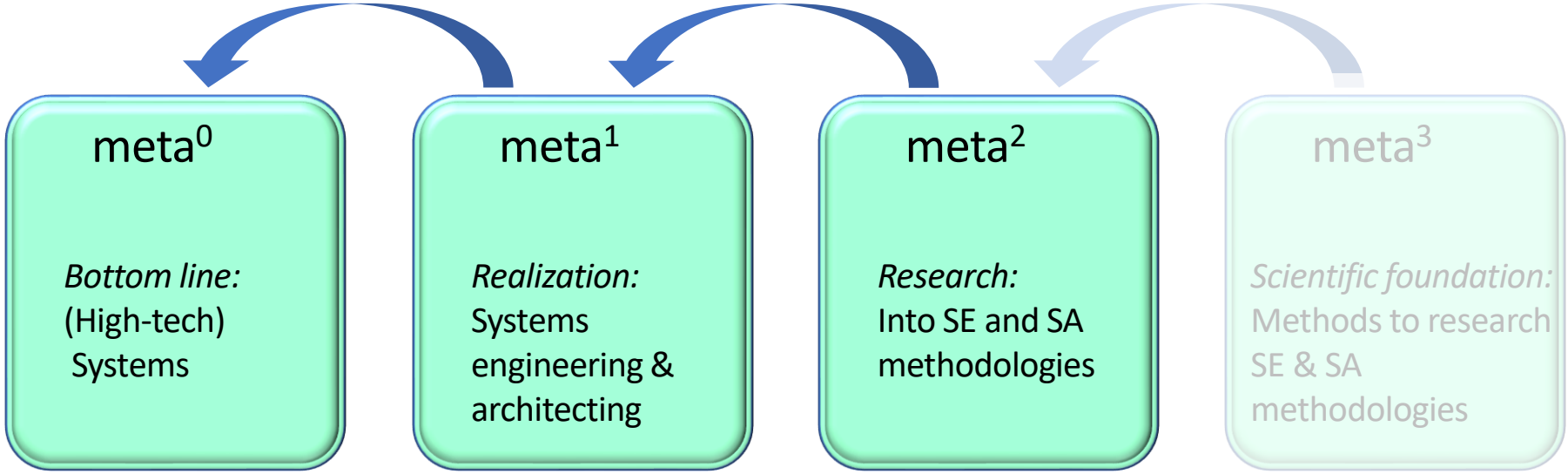
- Digital twin fit for purpose
- Reducing the effort of constructing digital twins
- Use of machine learning and process mining to create models and digital twins
- (much) faster than RT digital twins
- Digital twins for adaptive cyber-physical systems of systems

- ESI position paper: https://www.esi.nl/home/leaflets.dot


Michael Borth


Jacques Verriet

Systems, Systems Engineering and Research



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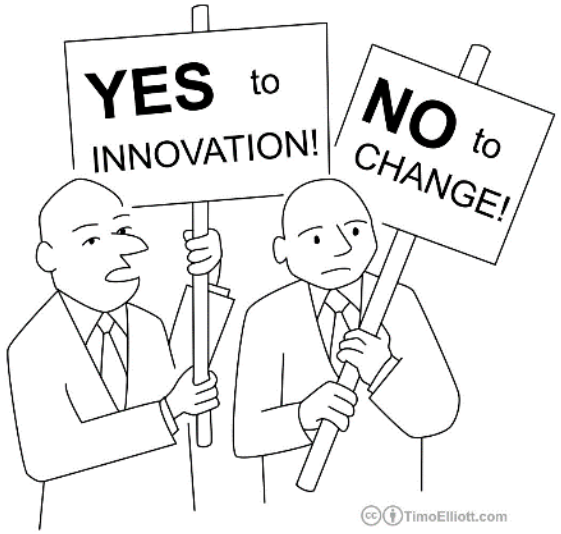
Research into improving the System Engineering Methodologies

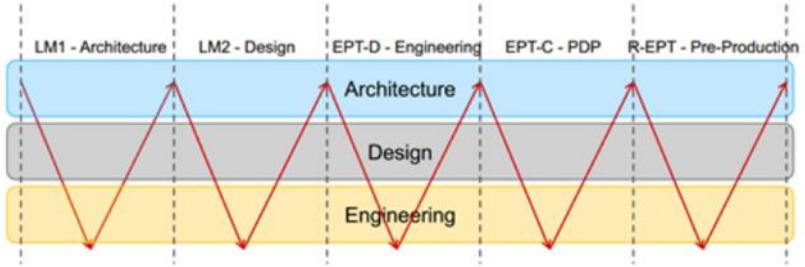


"We only have two demands!
Why don't people just give us what we want?"

Example: Research into effective design methodologies

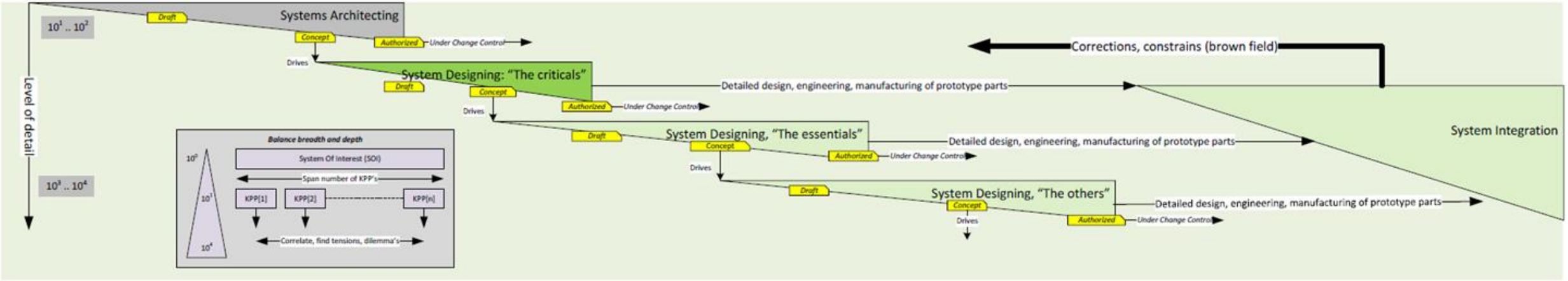
Example: Ongoing research in more effective and robust system design methods

- **Traditional V-model:**
  - **Presupposes completing design and spec in all details**
  - **Only then engineering can start**
  - **Leads to many iterations – (hardware) prototypes**



- **System architecting approach of decomposition (divide and conquer) allows concurrent work on components**
  - **Individual parallel Vs**
  - **Followed by integration**
  - **In complex systems requires super-hero architect**
  - **Often goes foul**

Desired: a way to do team-based phased engineering



Elements

- Determining criticals, essentials and others
- Keep track of decision impact at all levels
- Team-based decision and sharing

Benefits

- Shorter engineering cycles
- Less physical iterations
- Improved quality and better fit to market

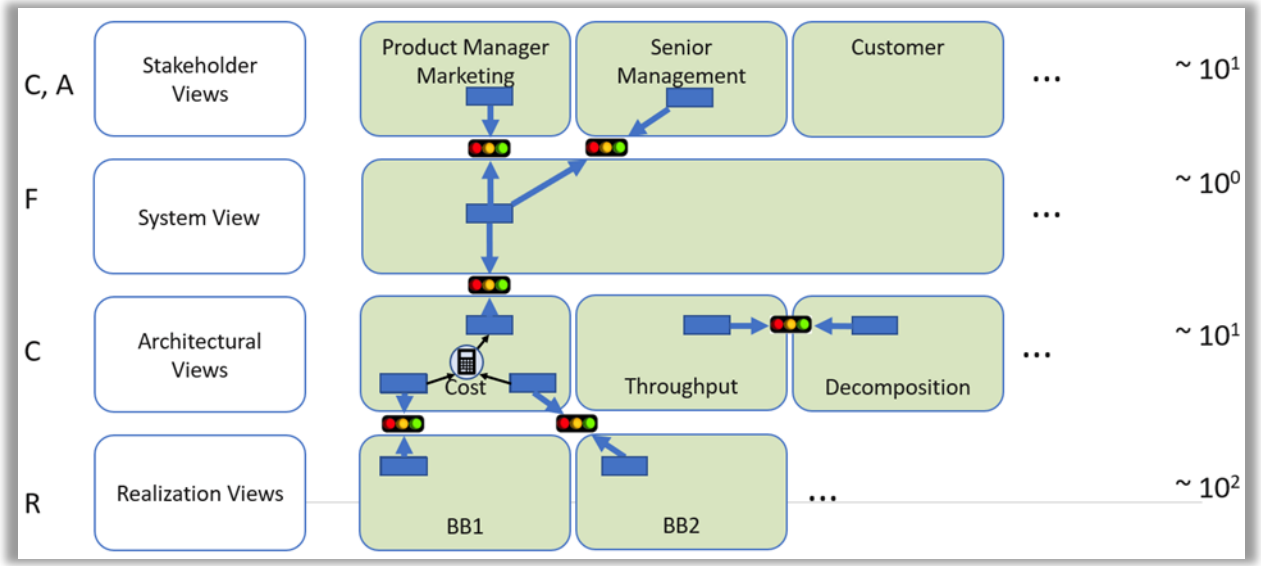
Daarius methodology


Wouter Tabing Suermondt


Tjerk Bijlsma


Richard Doornbos

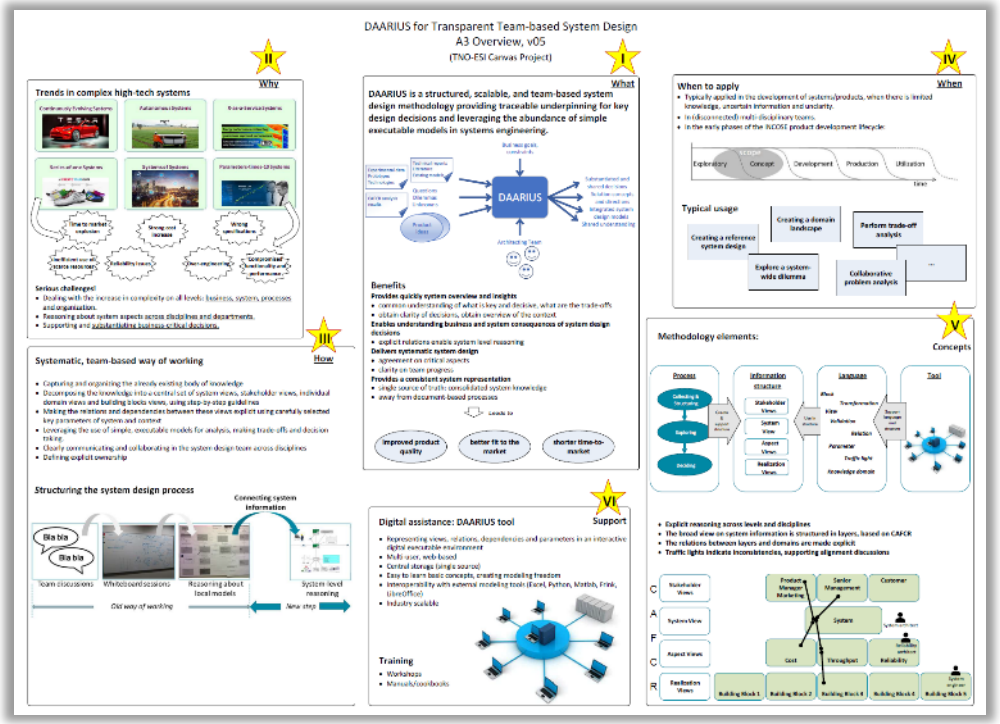
- Daarius is a structured, scalable, and team-based system design methodology providing traceable underpinning for key design decisions and leveraging the abundance of simple executable models in systems engineering.
  - Team-architecting (replacing super-hero architect)
  - Dilemma handling
  - Trade-off handling
- CAFCR based solution space analysis
- Allows to stepwise fill and track solution space
  - First: criticals
  - Then: essentials
  - Finally: others



Daarius: research in progress

Research questions:

- **Methods to determine criticals, essentials and others**
- **How much detail is needed for taking decision at specific levels**
- **How to determine the right levels**
- **Inclusion of quantified degrees of uncertainty and unknowns in method**



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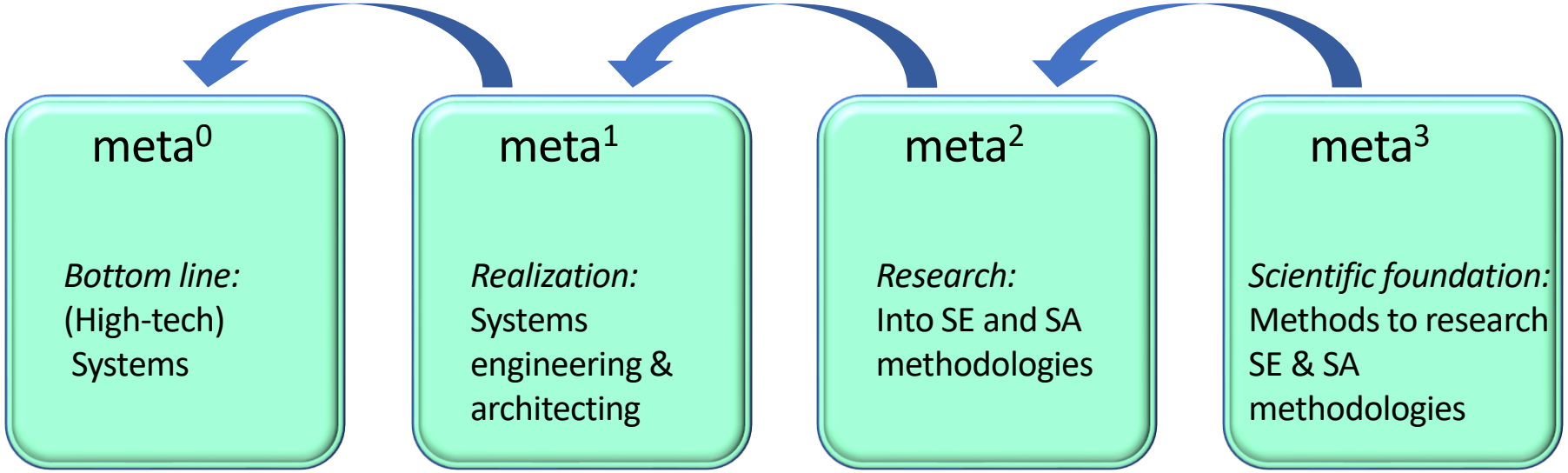

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Meta^3: reflecting on the way to do SE research

An approach to SE Research: Industry-as-a-Lab

ASML - Veldhoven

DAF - Eindhoven

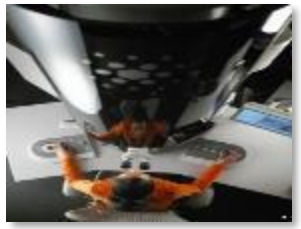
Océ - Venlo

Philips - Best

Full access to industry background

NXP - Eindhoven

Thermo Fisher - Acht



Vanderlande - Veghel

Signify- Eindhoven

Nexperia - Nijmegen

Thales - Hengelo

Industry specific validation results

Learning from each other

ESI industrial network

ESI Eindhoven, Netherlands

SERC industrial network

SYSTEMS ENGINEERING RESEARCH CENTER USA

Fraunhofer IESE Kaiserslautern, Germany

IESE industrial network

OFFIS industrial network

OFFIS Oldenburg, Germany

ices KTH Stockholm, Sweden

ICES industrial network

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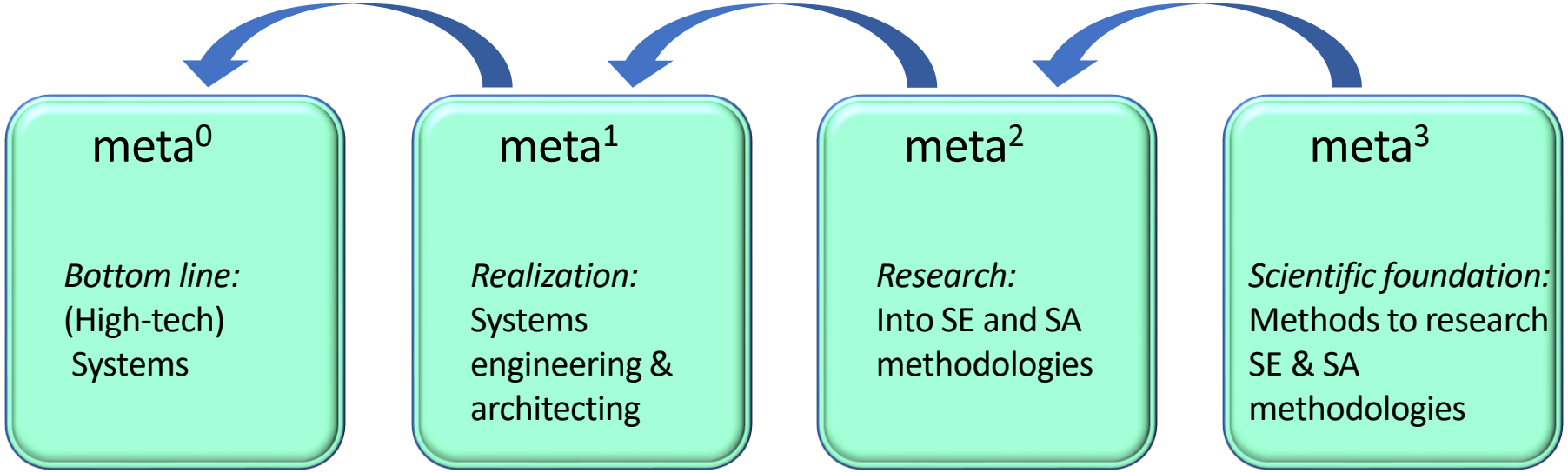

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THANK YOU!

An initiative of industry, academia and TNO

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