ITEA Smart Systems Engineering workshop

Session I - Complexity of the applications

ITEA Smart Systems Engineering workshop

7 April 2022 | online

Harald Schöning, Software AG

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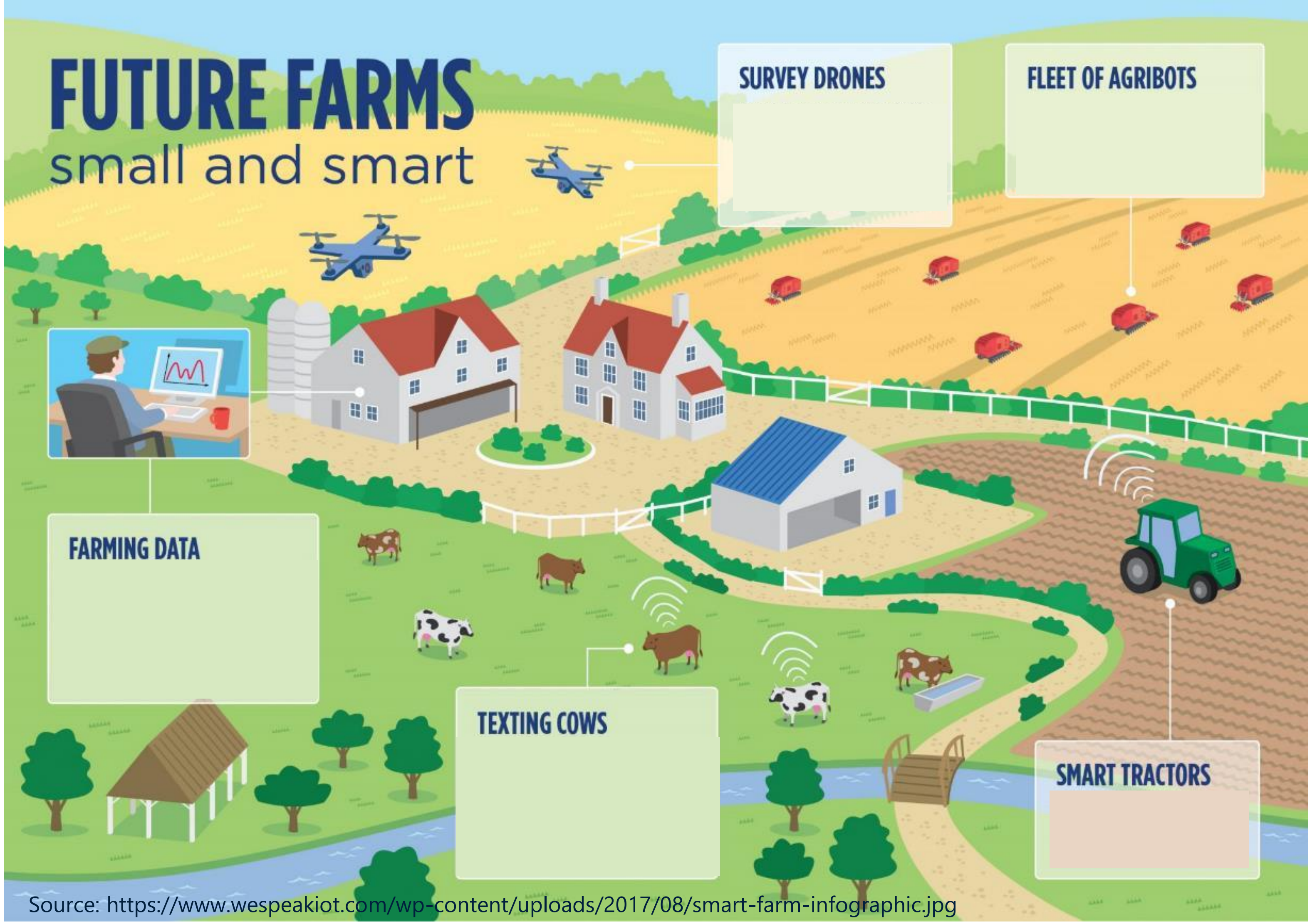
Systems engineering vs. increasing complexity

Harald Schöning, VP Research

software AG

Just an illustration



Source: https://www.wespeakiot.com/wp-content/uploads/2017/08/smart-farm-infographic.jpg

- IoT (lot of heterogeneous devices)
- Cloud
- Edge Computing
- Bandwidth?
- Connectivity?
- Energy efficiency?
- Data Space?
- AI

Functional and non-functional complexity

Functional

- E.g. Distribution optimization
  - Computing Capacity
  - Latency
  - Dealing with load peaks
  - Bandwidth limitations
  - Distributed Learning

Non-Functional

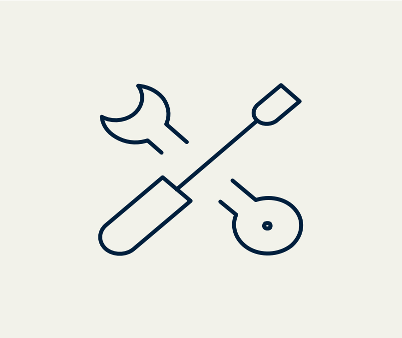
- Energy efficiency
- Ethics
- Security
- Easiness of operation
- …

Combining IT and physical devices

Digital Twins

Safety

What do we need?



Tools to

- Design
- Build/Generate?
- Test
- Monitor&Operate

Education

Covering complex system handling

- academic
- On the job

Interdisciplinarity

Within computer science disciplines

But also with many other disciplines

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Philippe Dobbelaere, Nokia Bell Labs

ITEA 4

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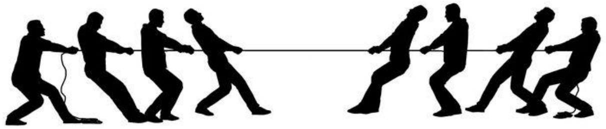
Introduction slide

Background experience

- *Msc engineering and physics*
- *Bell Labs 3y – 5y research on HW, SW and systems problems*
- *15 y of HW and SW product development (DSL, core routers)*
- *15 y of applied research in IoT cooperative projects*
  - *ITEA DiY Smart experiences*
  - *ITEA M2MGrids*
  - *ITEA MOS2S*

Complexity has always been a topic in science / industry…

- “There are two ways of constructing a software design. One way is to make it so simple that there are **obviously no deficiencies**.
  And the other way is to make it so complicated that there are **no obvious deficiencies**.” C.A.R. Hoare
- KISS (airforce engineering)
- Bjarne Stroustrup (C++) "Make Simple Tasks Simple!“
- Einstein paraphrased: "Everything should be made as simple as possible, but not simpler"

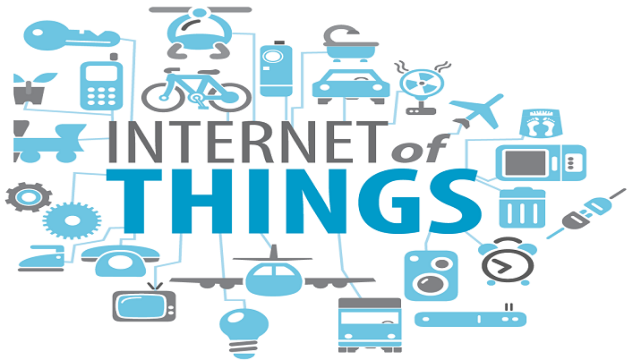


design complexity spawns mistakes ←→ if the problem is complex, a simple solution is probably not going to work (but maybe the subcomponents can be “simple”)

trends…

1980 connecting computers

2000 connecting people



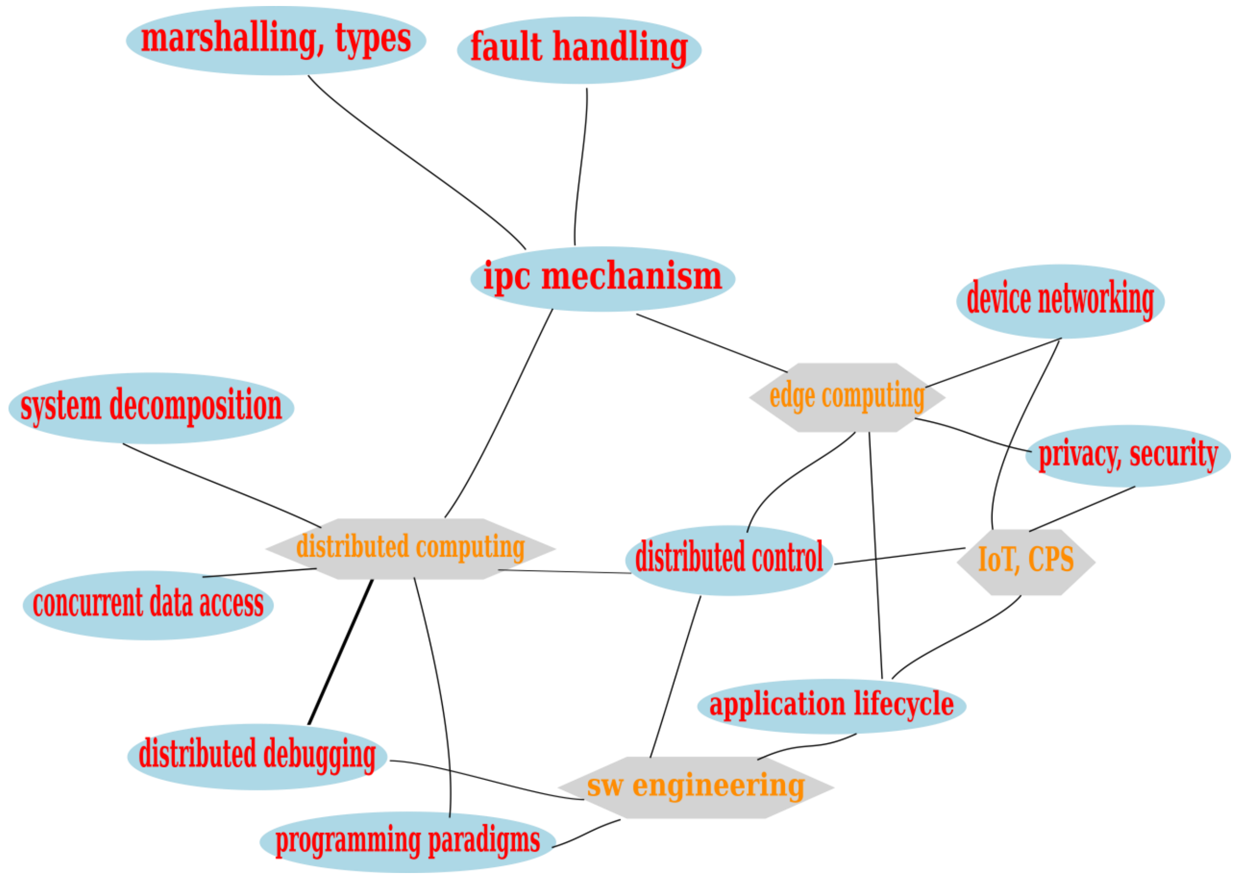
2020 connecting everything

nomadic computing → need to migrate functionality (VM concept helps)
clouds make it cheap/easy to "install" applications that behave as long running "services"
AI/deep learning makes systems autonomous

cyber-physical systems

actuation is the enabler

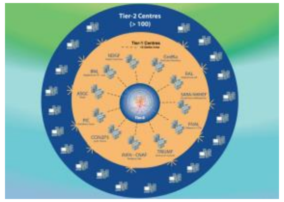
Concerns in contemporary IoT design and engineering



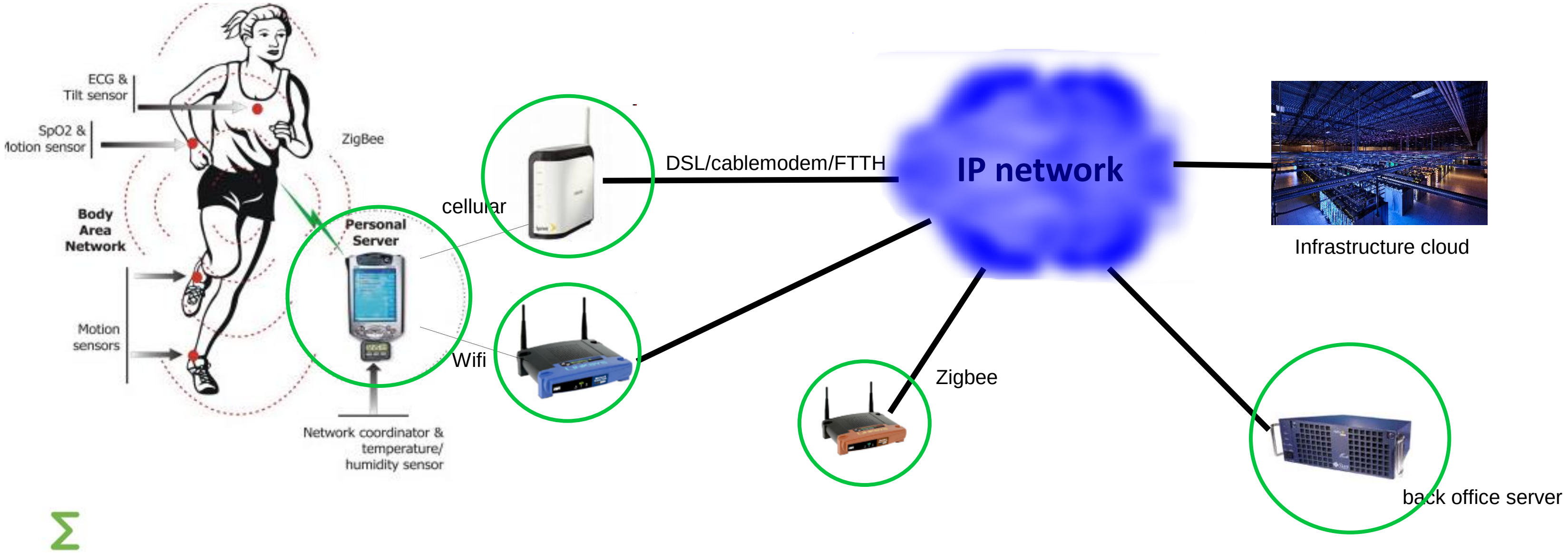
heterogeneous environment

nature of heterogeneity is changing

- used to be single computer → cluster of computers
- (**"pets"** with different capabilities and roles)
- but this has migrated to IaaS cloud based on hypervisors/VM
- (**"cattle"**)



heterogeneity now comes from end-to-end compute architectures, all the way from edge devices, gateways, edge and core routers to SaaS datacenters and public and private IaaS clouds



IoT ?
in real projects today…

- edge devices such as sensors, actuators, gateways with some level of compute resources
  (if not at the sensor / actuator, then on the gateway)
- multiple organisations with their own, underspecified concepts and interfaces ("vendor specific API") for data exchange and control functionality
- a melting pot of (*almost* standard compliant) networking technologies
  - a requirement to connect data sources, data sinks and processing logic together, regardless of network technology ("data broker")
  - less than rock-solid round-trip latencies (~ 2s = no TCP...)
- a mix of communication protocols
- a SW architecture containing legacy components that were created at a time
  where elasticity was a concept of mechanical designers, not SW systems and
  process communication was RPC (or evolutions such as CORBA, SOAP based WS, ...)
- private or public VM based IaaS cloud infrastructure to run the majority of the software functions
  - data brokering
  - data analytics (real-time or offline)
  - backend application
    - actuation support, business logic
    - management layers

WiFi Bluetooth Z-WAVE sigfox LoRa 4G LTE 5G

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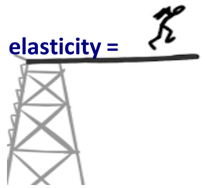
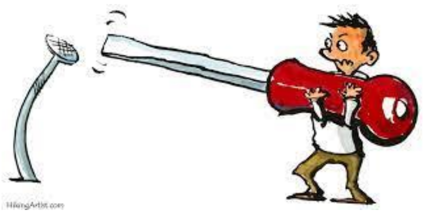
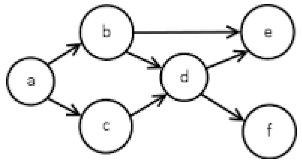


Multiple programming paradigms
when to use them, how to use them together

- imperative
  - C(++), Fortran, Go, Java, lua, perl, python, ruby, matlab, **javascript**, …
- functional
  - Haskell, C++11, **javascript**, erlang, java8, lisp, scala
- declarative
  - prolog
  - table based DB (SQL)
  - document based DB (rethink, mongo)
  - tuple based DB (SPARQL, quadstore)
- rule based
  - prolog, CHR, drools
- linear algebra / array processing
  - torch, matlab, R, fortran (linpack,…)



system decomposition
implies the need for an IPC mechanism



RPC is problematic

- no differentiation between client stub crashing and remote server crashing
- requires argument list construction: one monolithic memory copy at the server (cfr XML DOM/SAX parser)
- typically blocking, synchronous calls - timeout?
- reply always goes back to the requesting client
- difficult to make compatible with transactional semantics (who owns a transaction that started on the client?)
- tightly coupled, sensitive to interface creep (and SW guys like bleeding edge…)

message passing preferred

- typically asynchronous, event driven
- message handling scales extremely well
- inherent point-to-multipoint capability
- offers at least once semantics in a very natural way
- messaging can easily handle transactional semantics (e.g. Kafka: write all messages in batch or drop all of them)
- if something RPC style is needed, trivial to code, with required flexibility and error handling, on top of messaging infrastructure
  - e.g. OTP template for erlang servers on top of actor model
- can do distributed error handling
- typically lightweight protocol stacks, minimalistic state that just fits on IoT devices
- an application becomes a directed dataflow graph (HW guys would call this a ***netlist***)

designing and testing for a 3rd party operated cloud

e.g. C-ITS backend logic by Nokia deployed on AWS WZ datacenter of Vodafone
see https://tv.theiet.org/index.html?videoid=15510

challenges:

- authentication complexity
  - SSO into 3rd party infrastructure (“jumpserver”)
  - SSO into kubernetes control layer (time limit)
- deployment complexity
  - setup pods / services on provided k8s resources
  - setup networking to allow application data communication
  - setup networking to allow application OAM
- OAM complexity
  - wire logging / resource monitors into 3rd party kibana / grafana stack

extremely “hostile” environment to do anything except finalised app deployment

value chain complexity

- makes it difficult for companies to commit design resources, due to "complicated" business plan outcomes
- makes it difficult for stakeholders to invest

e.g. road safety

- Nokia can design SW infrastructure, but who is going to pay for it?
- less people are killed, but people do not directly fund infrastructure
- a road might be "owned" by central government, but local government is suffering the problems

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https://itea4.org

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eureka

https://www.eurekanetwork.org

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Oliver Lenord, Robert Bosch GmbH

Introduction slide
Background experience

today

Reseacher and Project Leader of PFPs
- *Bosch Corporate Research[1] (Renningen , Germany)*
- *<u>Dependable</u> Cyber-physical Systems Engineering, Model-based Development*

2015

CAE Product Manager
- *SISW (Cypress California, USA)*
- *Mechatronics <u>Concept</u> Design and Systems Engineering*

2011

Leader of Simulation Software Development
- *Bosch Rexroth (Lohr a.M., Germany)*
- *<u>Sales</u> enabling Simulation-Tools*

2004

PhD Mechatronics
- *Gerhard-Mercator-University (Duisburg, Germany)*
- *<u>Biologically</u> inspired Virtual Prototype of 4-legged walking machine*

1999

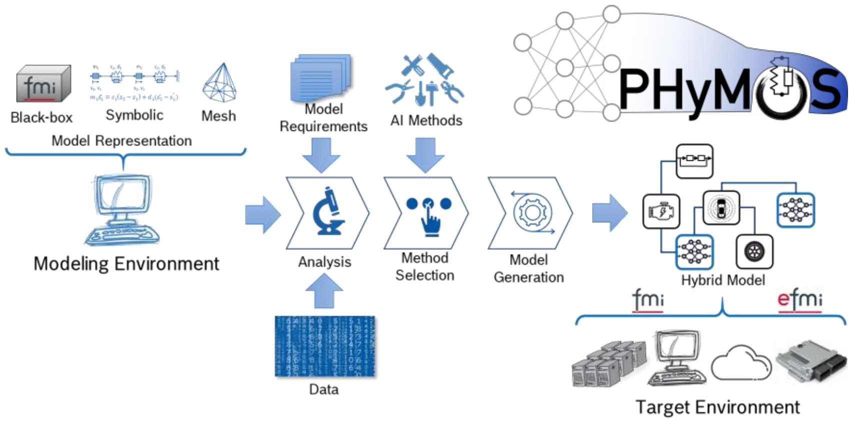
BOSCH
Invented for life

Bosch Research Campus Renningen

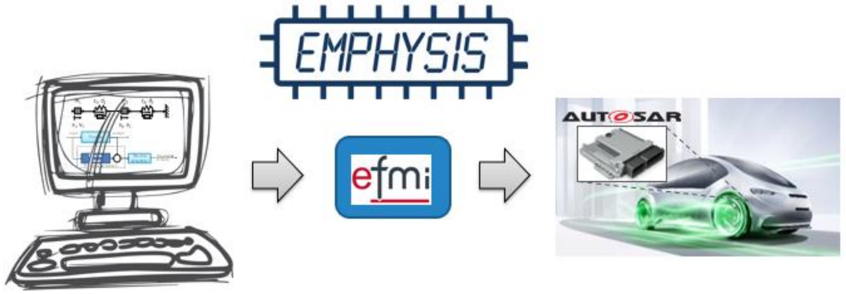
[1] 1740 employees, 90% scientists
PFP: publicly funded project

Introduction slide
Background experience

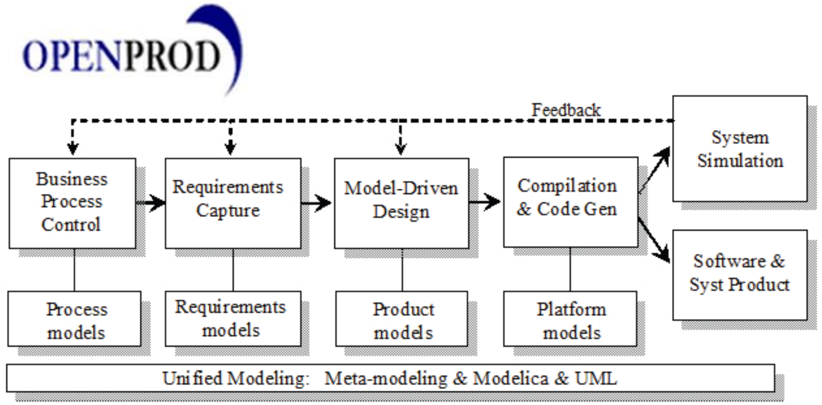
- *BMWi [1)] <u>PHyMoS</u> (2021 – 2024)*
  - *proper hybrid models*



- *ITEA3 15016 <u>EMPHYSIS</u> (2017 – 2021)*
  - *from physics models to embedded software*



- *ITEA2 08021 <u>OPENPROD</u> (2009 – 2012)*
  - *wholistic model-driven product development*



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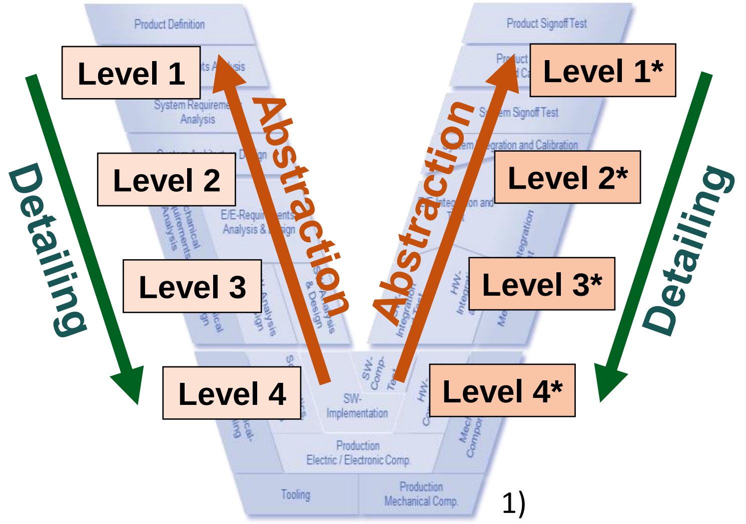
[1)] BMWi: German Federal Ministry for Economic Affairs and Climate Action

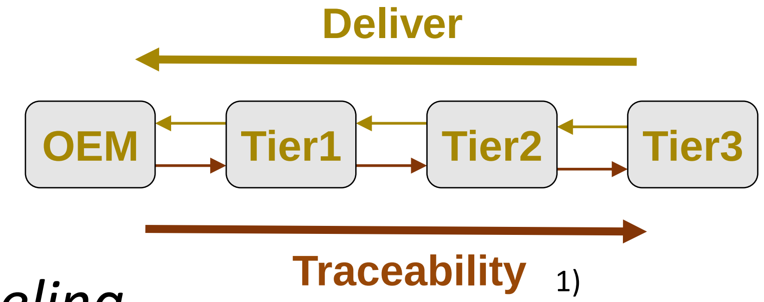
Session topic…

Key challenges

- *Manage Complexity*
  - *by abstraction*
  - *by graphical representations*
  - *by modeling languages*



- *Support the Engineering Process*
  - *from idea to concept to functional models to physical design*
  - *from whole system to subsystem to component*
  - *from behavior to algorithms to target code*

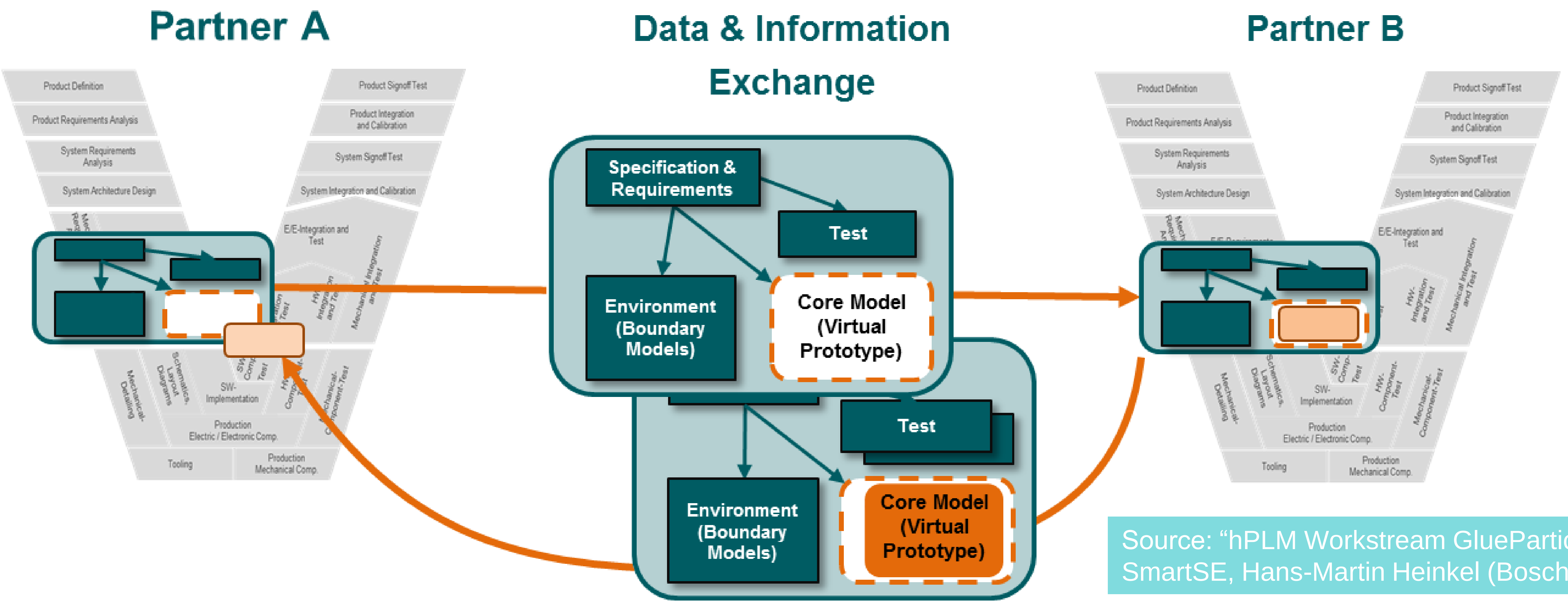


- *Enable Collaboration*
  - *virtualization: hybrid (physics + data) driven modeling*
  - *heterogeneous environments: model exchange, traceability, meta data*
  - *confidence and trust in simulation: model quality considering uncertainties*

[1] Source: "hPLM Workstream GlueParticle" by SmartSE, Hans-Martin Heinkel (Bosch)

Collaborative System Development Between Partners

SmartSE Vision	Establish best practices for distributed collaborative system development between partners using Systems Engineering methods and standards



Source: "hPLM Workstream GlueParticle" by SmartSE, Hans-Martin Heinkel (Bosch)

Mission Statement Phase 5	Enabling collaborative development and validation of complex products by simulation along a multi tier supply chain.

Session topic…
Key challenges

- *Methods to enable Transition between Levels of Abstraction*
  - *“Model on demand”*
    - *define requirements on a “proper” model*
    - *automate model transformation to generate “proper” models*
    - *empower V&V to assess model quality*

- *Bring the Pieces Together*
  - *“Credible Simulation Process” (SmartSE [1])*
    - *develop standards and tools*
    - *connect/enhance existing standards (FMI, eFMI, SSP,…)*

[1] *Smart Systems Engineering: Project of the ProStep IVIP since 2012*

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- *Oliver Lenord, Robert Bosch GmbH,*
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Jonathan Menu, Siemens Industry Software NV

Introduction slide Jonathan Menu

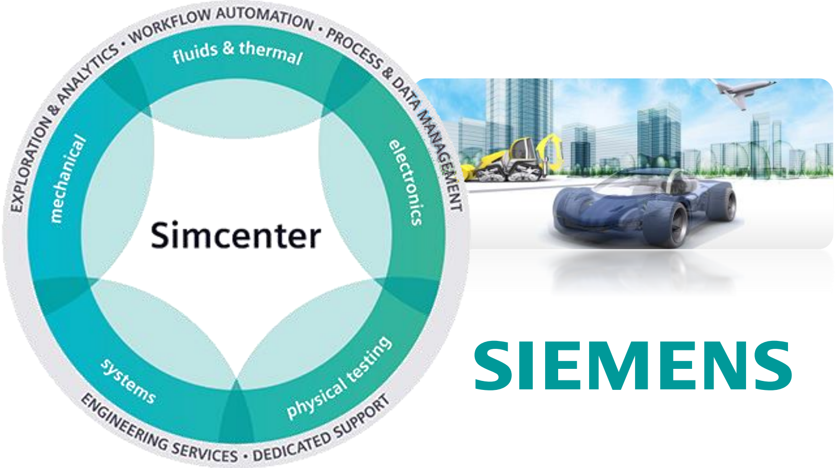
Background experience

Research manager for Simcenter MBSE @Siemens

Background: MSc + PhD in (astro)physics; at Siemens since 2015

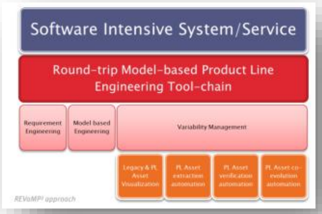
Personal involvement in ITEA projects:

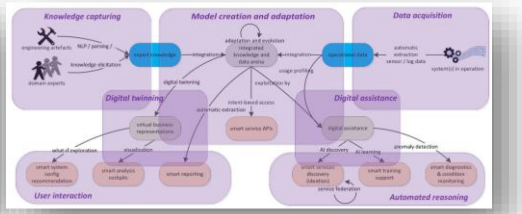
- Reflexion (2015-2019): React to effects fast by learning, evaluation, and extracted information
- REVaMP^2 (2016-2019): Round-trip engineering and variability management platform and process
- EMBrACE (2019-2022): Environment for model-based rigorous adaptive co-design and operation of CPS
- OXILATE (2020-2023): Operational excellence by integrating learned information into actionable expertise



Siemens Industry Software NV

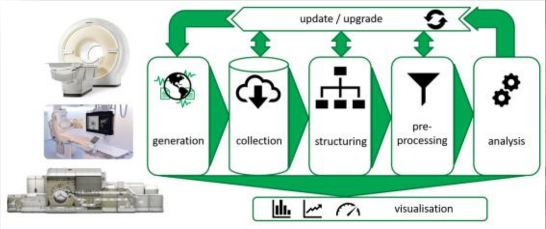
- Engineering innovation partner
- Simulation & test tool provider
- 450 employees in Leuven
- ITEA founding company





REVaMP^2, EMBrACE, OXILATE

Reflexion
(ITEA Award of Excellence 2019)



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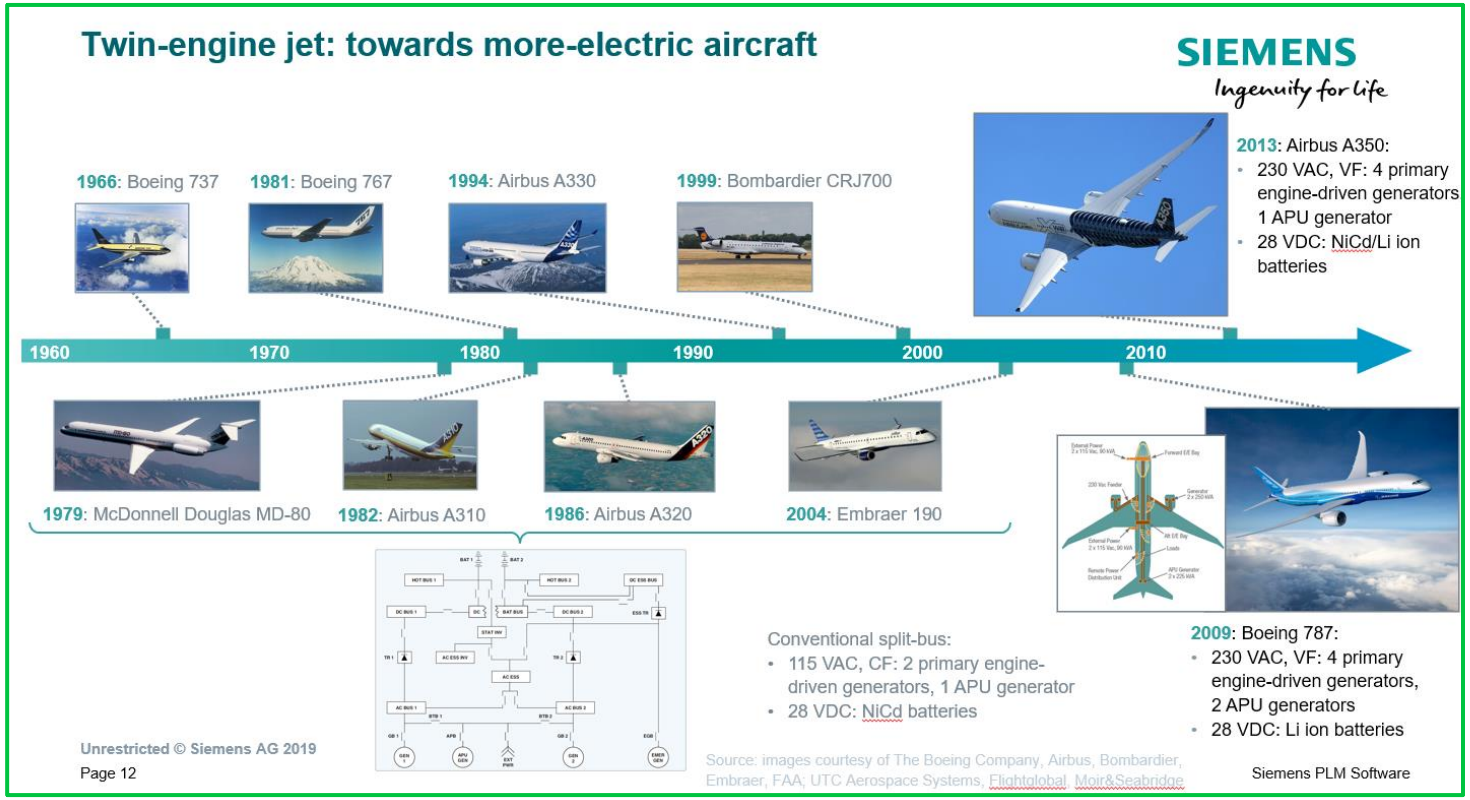
Session I - Complexity of the applications

Key challenges

Radical changes to designs required:

- *Regulations (e.g., climate neutrality, environmental footprint)*
- *User expectations: automation, adaptability, performance, availability, response time*
- *Other “ilities” and/or constraints: cost, security, safety*



Tool provider:
what **we want to design**
impacts ***how*** **we design**

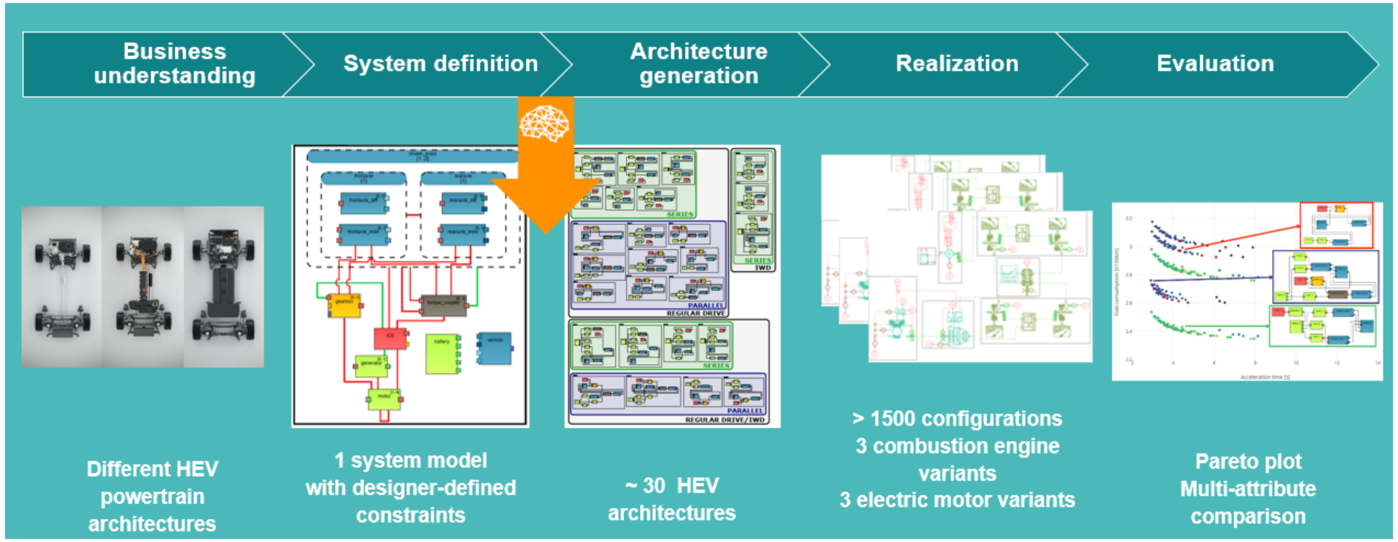
Session I - Complexity of the applications

Key challenges

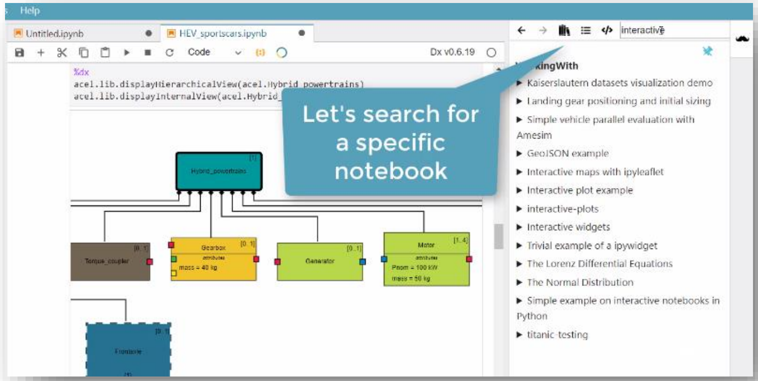
Pathways to solutions:

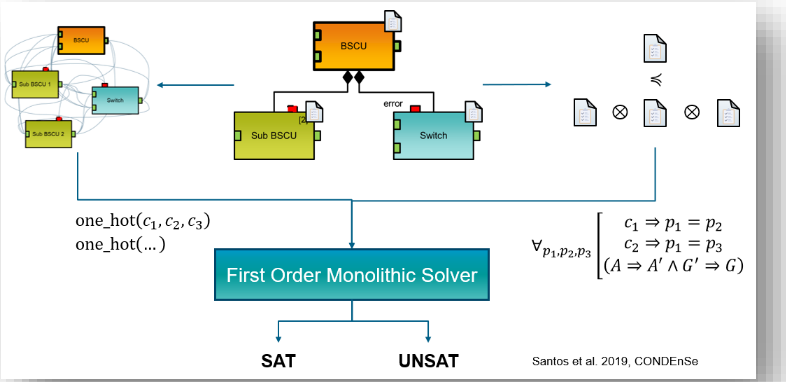
- ✓ Generative techniques
- ✓ Correctness-by-design
- ✓ Usability & decision support

Generative engineering:
using reasoning and ML techniques
to create conceptual alternatives



User assistance built into engineering tools (**OXILATE** ITEA project)





Formal requirements linking with design and V&V (**EMBrACE** ITEA project)

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