Industrielle Informationstechnik

Transformations in Technical System Development

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Agenda
Transformations in Technical System Development

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Understanding where we are

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Today's situation in automotive

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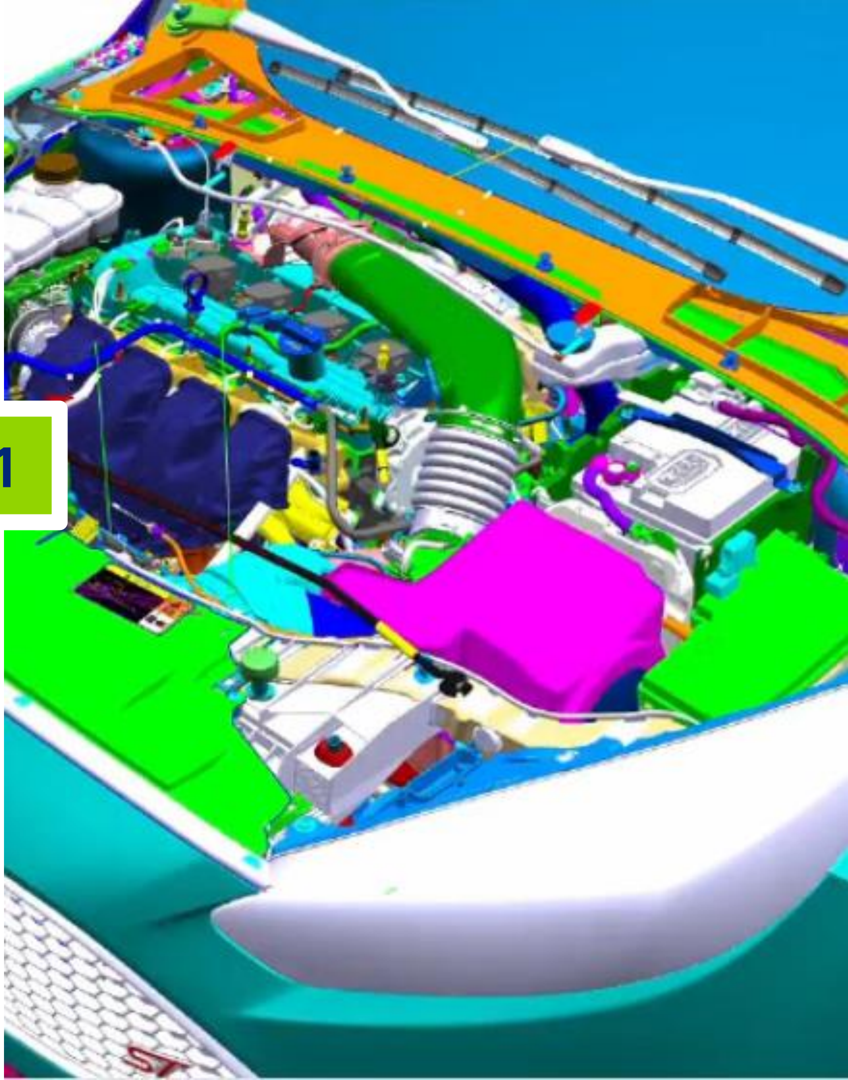


Set-up of CAE in Performance Engineering at European OEMs

- Traditionally, CAE departments have been organized according to the main attribute ownership as part of the main functional activities, e.g.:
  - **Vehicle Crash**: mostly as department in Body Attribute Engineering due to main role of the body shell
    - At some OEMs in Vehicle Engineering or in Advanced Engineering
  - **Vehicle Dynamics, Ride & Handling**: mostly in Vehicle Engineering or in Chassis Engineering
  - **Body/Vehicle NVH:** Body or Vehicle (Attribute) Engineering (due to main role of the body shell)
  - **Driving and ADAS Function:** Chassis and/or Vehicle Engineering (with main support of E/E)
- Recently, OEMs started to revisit this set-up. Porsche e.g., has re-organized the Technical Development (Product Development) according to the V-model areas: e.g., the CAE simulation departments are now together in the *V&V (Validation and Verification)* organization together with the experimental testing areas (incl. proving ground); additional changes are expected over time…
- Vehicle / Platform programs get allocations of CAE / attribute engineering skills according to the PDP
- In addition, CAE and simulation method development are either decentralized within the functional organizations (see above) or are centralized in "Digital Innovation" or "PMTI/O" departments

The Typical *Automotive Partner Eco System* Set-Up in Europe

Automotive OEM

Research & Development (Product Engineering)
Internal OEM
(full ownership versus integration ownership only)

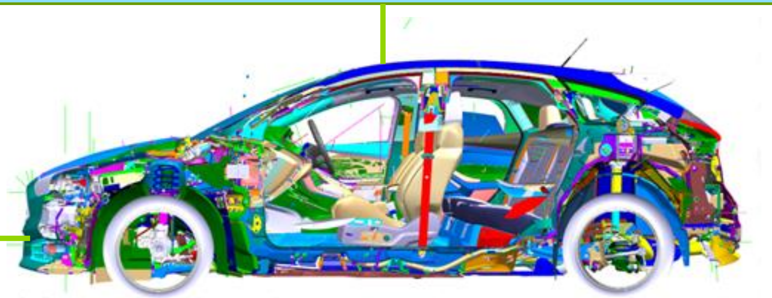
System/Component Delivery (Manufacturing / Production Engineering)
Internal OEM
(component / module manufacturing versus final assembly)

A Engineering Service Provider (ESP)
(on-site OEM)

B Engineering Service Provider (ESP)
(off-site OEM)

C Tier1 resp. Tier2 Supplier
(off-site OEM)

D ESP for Tier1/2
(on-site or off-site OEM)



Note (valid for all OEMs): Increasing importance of in-vehicle **software**: Know-how can be acquired either in-house or through external partners

Note (valid for all OEMs): Per vehicle/powertrain program/project usually 2 – 5 OEM contracted ESP and > 50 Tier 1/2 suppliers are involved.

A Module Tier1 / Component Tier2 Supplier
(off-site OEM Plant)

B Tier1 Full Vehicle Assembler
(off-site OEM Plant)

Top 10 Engineering Service Providers Worldwide

Based on Revenue (1/2) 2020

	Company	Engineering Services	Engineering Tools	Annual revenue worldwide in million euros
1	AVL List GmbH	x	x	1970,0
2	IAV GmbH	x	x	1001,7
3	Bertrandt AG	x	x	950,0
4	EDAG Engineering GmbH	x		781,0
5	FEV Group GmbH	x	x	698,3
6	HORIBA	x	x	669,2
7	Valmet Automotive	x		651,5
8	ALTEN Group	x		640,3
9	AKKA Technologies	x		604,0
10	Altran Deutschland S.A.S. & Co. KG	x	x	590,0

- OEMs increasingly outsourced development tasks (especially in areas such as new powertrains, driving and vehicle safety, connectivity, and ADAS/highly automated driving) to engineering service providers (ESP)
- Integrated, open development platforms play an increasingly important role for OEMs as well as engineering service providers (ESP)

Automotive Engineering Partners. *Ranking 2020 – Neue Auf- und Absteiger* (Aug. 2020). www.emag.springerprofessional.de/atz

Top 10 Engineering Service Providers Worldwide

Based on Revenue (2/2) 2021

Rank	Company	Annual revenue Automotive Worldwide in million euros
1	AVL List GmbH	1975,0
2	IAV GmbH	895,8
3	Bertrandt AG	825,0
4	Capgemini Engineering (vormals Altran)	800,0*
5	Edag Engineering GmbH	650,3
6	FEV Group GmbH	639,9
7	Magna Steyr Fahrzeugtechnik AG & Co. KG	533,3*
8	Akka Technologies	526,2
9	Alten Group	511,0
10	Horiba	503,0

- Trend towards cooperations with IT companies, this is demonstrated for example by the acquisition of ESG Mobility by the U.S. IT service and consulting company Cognizant
- IT service providers benefit from the engineering service providers' business relationships with OEMs

Automotive Engineering Partners. *Ranking 2021* (June 2021).
www.emag.springerprofessional.de/https://www.evafahrzeugtechnik.de/fileadmin/user_upload/AEP-Ranking_2021.pdf

Top 10 Automotive Engineering Service Providers in Germany Based on Revenue

The 10 largest providers of development services in Germany

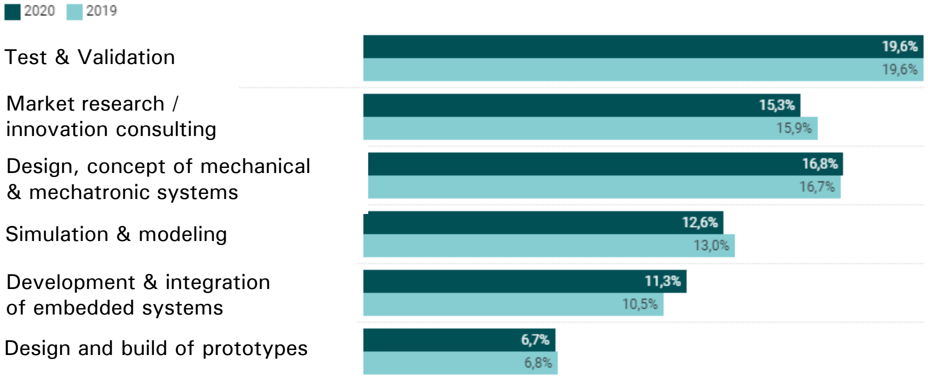
Revenue development in Mio. euros and number of employees – Numbers apply to Germany

Ranking	Company	Head-quarters	Revenue 2020	Revenue 2019	Employees 2020
1	IAV GmbH Ingenieurgesellschaft Auto und Verkehr*	Berlin	807	882	7.100
2	Bertrandt AG*	Ehningen	791	876	10.300
3	Ferchau GmbH*	Gummersbach	490	661	5.800
4	Akka Deutschland GmbH*²	Sindelfingen	400	600	5.100
5	Edag Engineering GmbH	Wiesbaden	395	534	5.815
6	Capgemini Engineering*³	München	280	295	3.200
7	Alten GmbH⁴	Coburg	225	278	3.000
8	FEV Group GmbH*	Aachen	210	250	4.200
9	Modis GmbH	Düsseldorf	202	242	1.852
10	Brunel GmbH	Bremen	195	242	2.600

*) Umsatz- und/oder Mitarbeiterzahlen teilweise geschätzt, ²Übernahme durch Adecco im Juli 2021, ³Umsatz- und Mitarbeiterangaben 2020 inkl. Altran, ⁴Inklusive Übernahme von OSB im Jahr 2020

Tabelle: Automobil Industrie • Quelle: Lünendonk • Daten herunterladen • Erstellt mit Datawrapper

Services of the development service providers: Share of revenue in percent in case of Engineering Services



Grafik: Automobil Industrie • Quelle: Lünendonk • Daten herunterladen • Erstellt mit Datawrapper

- https://www.automobil-industrie.vogel.de/die-zehn-groessten-deutschen-entwicklungsdienstleister-a-1060113/

> ➢ The German automotive industry has triggered an Engineering Service Provider (ESP) eco system across Germany
> ➢ The tasks and responsibilities of the ESP can be divided into 6 major categories (right figure)

Rules How to Incorporate CAE ESP in EU Automotive Engineering

- CAE Engineering Service Providers are specialized in certain vehicle attributes
  (crash, durability, NVH, driving dynamics, driving comfort, ADAS driving functions, TASE, fuel economy, energy management …)
- CAE ESP often have long standing relations to individual OEMs in order to closely develop mutual CAE methods and operational vehicle project execution
  (CAE model build, CAE simulation, CAE result management, CAE prediction and design proposals etc.)
- CAE ESP are requested to deliver efficiencies (budget, time, add. capabilities) over time (year over year …) – business wise extended offices are executed in East-Europe and/or India
- CAE ESP have unique skills which are offered for different OEMs
- CAE ESP are requested to train personnel in and to prove evidence of OEM like methods skills
- CAE ESP are allowed to use internal OEM compute power and cloud computing in a vehicle project
- OEMs involve CAE ESP in VDA / ACEA, Horizon Europe and BMWK (German Governance) research projects together with research institutes, suppliers, and SMEs.

Cause for action

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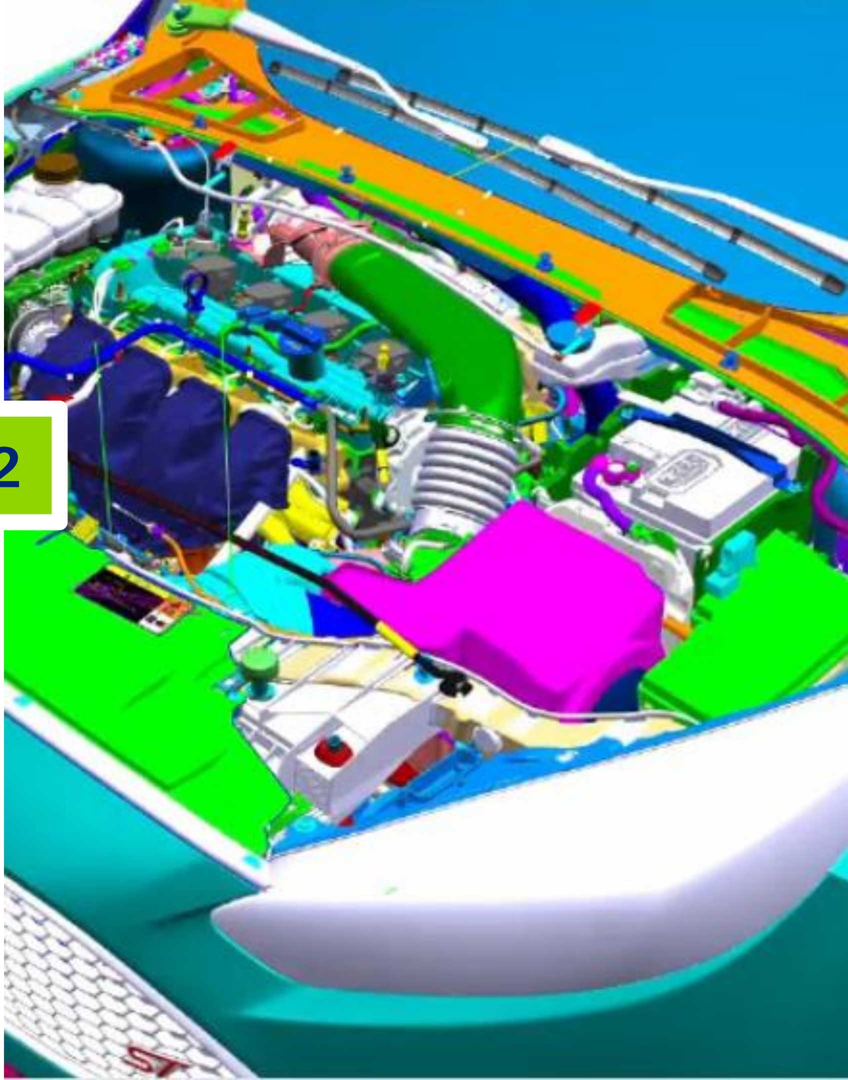


New Mobility Strategy and the Automotive Industry Transformation

c Looking forward

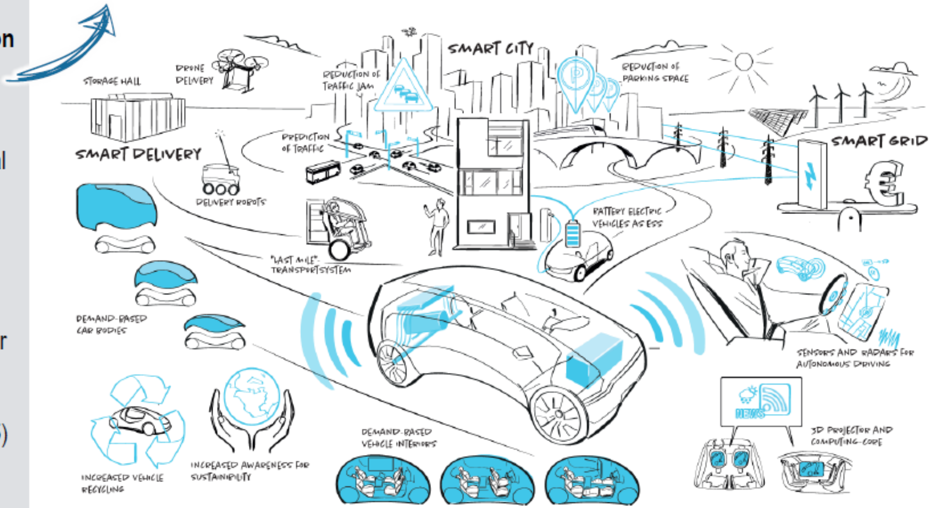
LAZARD Roland Berger

The current pandemic doesn't change the future automotive and mobility ecosystem – R&D remains key to ensure long-term success

Industry transformation 2030 and beyond

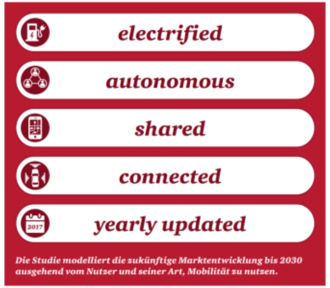
- **High share** of **electric vehicles** (30-50% w/o ICE)
- **AI-based optimization** of "super-systems" (e.g. traffic flow plus grid load)
- Low share of individual car **ownership**
- **MaaS** using purpose-built mobility vehicles (**PMV**'s):
  - Modular
  - Electric (BEV and/or FC)
  - Connected
  - Autonomous (L4/L5)

In the future mobility ecosystem, purpose-built, automated, modular, connected vehicles become part of a "System of Systems"

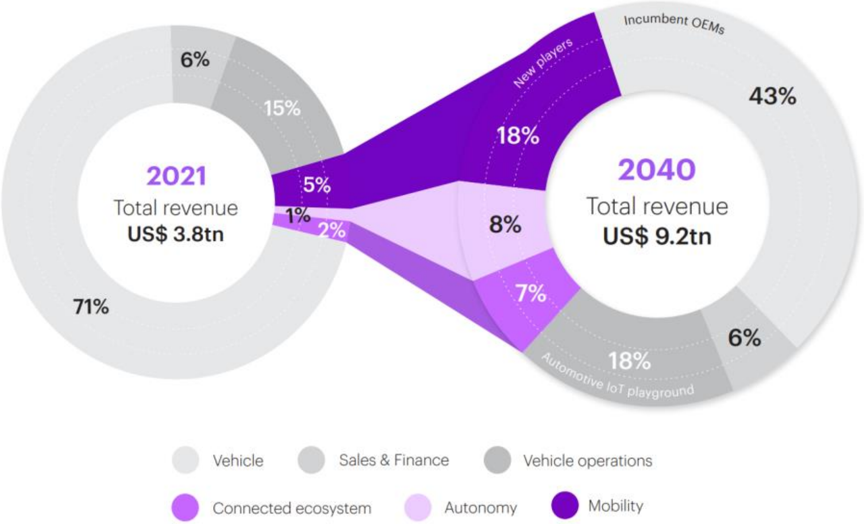


Trends in Automotive Industry

- The vehicle of the future will be **electrified, autonomous, shared, networked** and gets **updated** over the air at least **twice per year**. An overview is given by the market model **EASCY**.
- As a result, future vehicles are **highly mechatronic, cyber-physical** and **intelligent devices**, for which most of the **functions and systems are controlled by software**.
- The concept of **Software Defined Vehicle (SDV)** has, therefore, been introduced already.
- **Software development** and **embedded software intelligence in technical systems** will prevail with **major changes** in the **engineering eco system** and in **value creation chain.**
- **New key players** are arising



Quelle: pwc – eascy – Die 5 Dimensionen der Transformation der Automobilindustrie (2017)



Quelle: Accenture – Moving into the software-defined vehicle fast lane (2022)

VISION

of the future vehicle … between „living digital interaction room“, „autonomous mobility device“ and „driving active and safe vehicle“ with <u>significantly reduced</u> CO_2-footprint“!

New Strategic Core Capabilities of Future Automotive Engineering

Transformation of Automotive OEM into fully-fledged mobility providers

Vehicle	Environment/costs	Environment/ infrastructure	Smart services
(e.g. packaging, infotainment)	(e.g. CO_2 emissions, cost efficiency)	(e.g. car-to-X, charging infrastructure)	(e.g. mobility networks, use instead of buy)
			

Future development capabilities and need for change

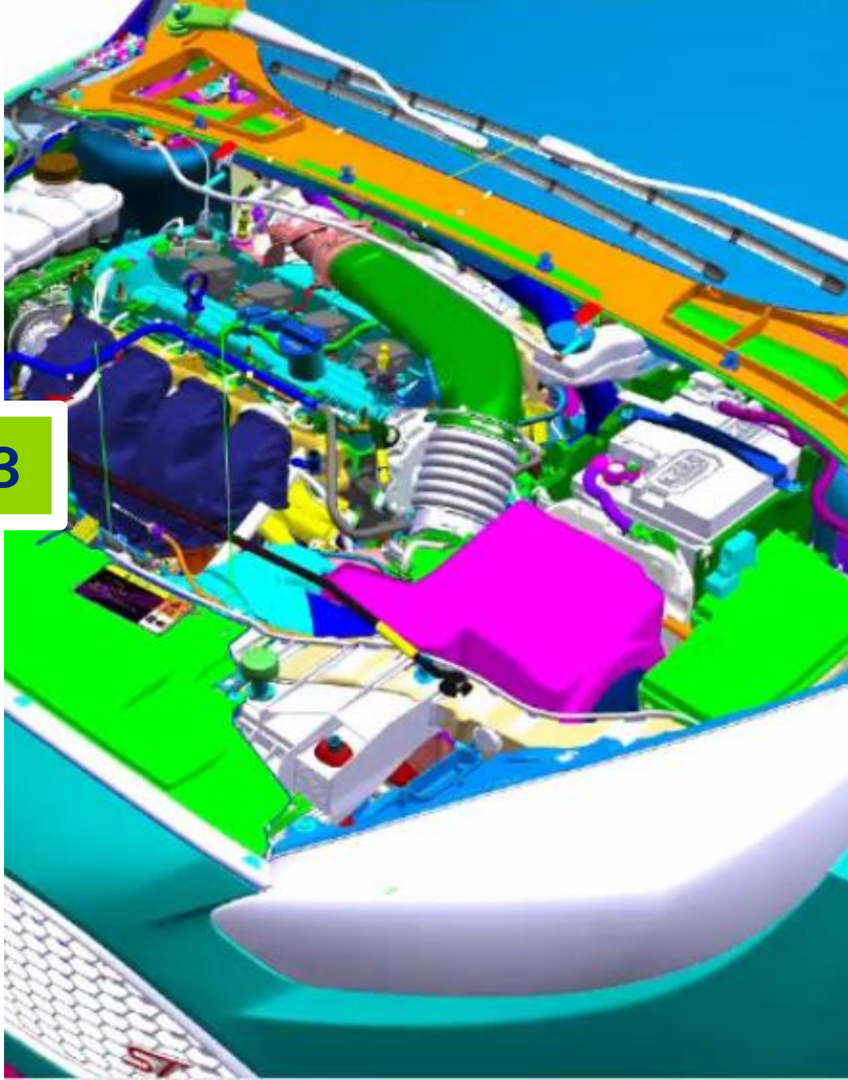
"From weight distribution to functional compatibility" (e.g. model-based systems engineering)	"Actively shaping development for sustainability" (e.g. new drive concepts and architectures)	"Breaking new ground in the design of systems-of-systems" (e.g. use of big data and smart data)	"Selling used to be, operating is the new business model" (e.g. performance sales and maintenance centers)

New digital core competencies needed in technical development

➢ Establishing a model-based and end-to-end digital product development process ➢ Increasing efficiency through intelligence and automation	➢ Battery management, power electronics, charging and discharging simulations ➢ Embedding the environment in product development models	➢ Engineering of systems: Product and enterprise systems ➢ Data-driven validation and verification of systems	➢ Data-driven business models for combined mobility ➢ Development and operational capabilities for product-service systems

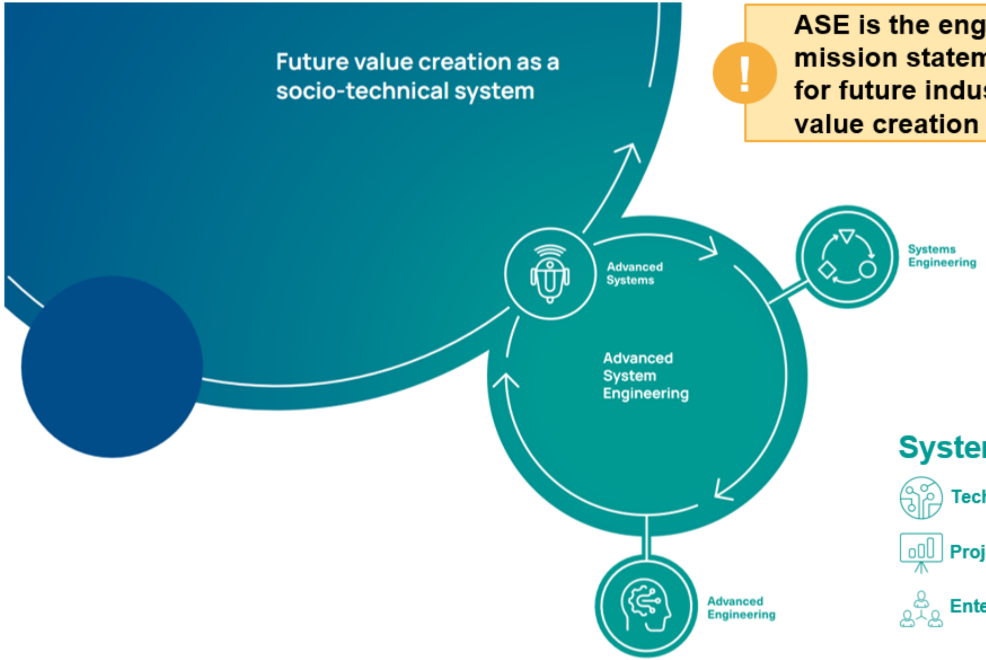
Transformations for the future

3



Transform 1: The strategic project *Advanced Systems Engineering* *(1/3)*

Strategic directions affect future value creation



! **ASE is the engineering mission statement for future industrial value creation**

Advanced Systems

- Autonomous Systems
- Autonomous Systems
- Dynamically networked Systems
- Product Service Systems

Systems Engineering

- Technical System
- Project Management
- Enterprise Organization

Advanced Engineering

- Creativity in engineering
- Agility in engineering
- Digitization in engineering

Transform #1: Education, example Advanced Systems Engineering

(2/3) Role of SE at universities in Germany and Japan

- Publication: "*Engineering in Germany – Status Quo in Business and Science*"
  https://www.advanced-systems-engineering.de/documents/211206_FHI_ASE_Broschuere_web_EN.pdf
  - Systems Engineering (SE) in teaching in **Germany**:
    - Almost all technical universities offer lectures related to SE. The distribution is very heterogeneous, especially outside the TU9 (TU9: alliance of leading Universities of Technology in Germany)
    - In 2019, courses of study and professorships related to SE can be found at all universities in the TU9
    - A total of 206 SE-related courses were identified at the TU9:
      - 50% of these courses are offered by faculties of computer science (25%) and mechanical engineering (25%)
      - The other courses are offered by faculties of natural sciences/mathematics (16%), electrical engineering (13%), economics (10%), construction (7%), and teaching/humanities (3%)
  - Systems Engineering (SE) in teaching in **Japan**:
    - According to the study carried out by the "Japan Student Services Organization", three out of seven universities in the "National Seven" group of top institutions are SE-related
    - A total of 50 out of 729 university institutions in Japan related to the topic of SE

> ➢ Number of universities in Japan with SE-related courses is comparable to the cumulative range of courses in Europe
> ➢ Technical universities in Germany have a larger absolute/relative proportion of SE-related courses/professorships compared to leading technical universities in the United Kingdom, France, the Netherlands, and Scandinavia

Transform #1: Advanced Systems Engineering (ASE)

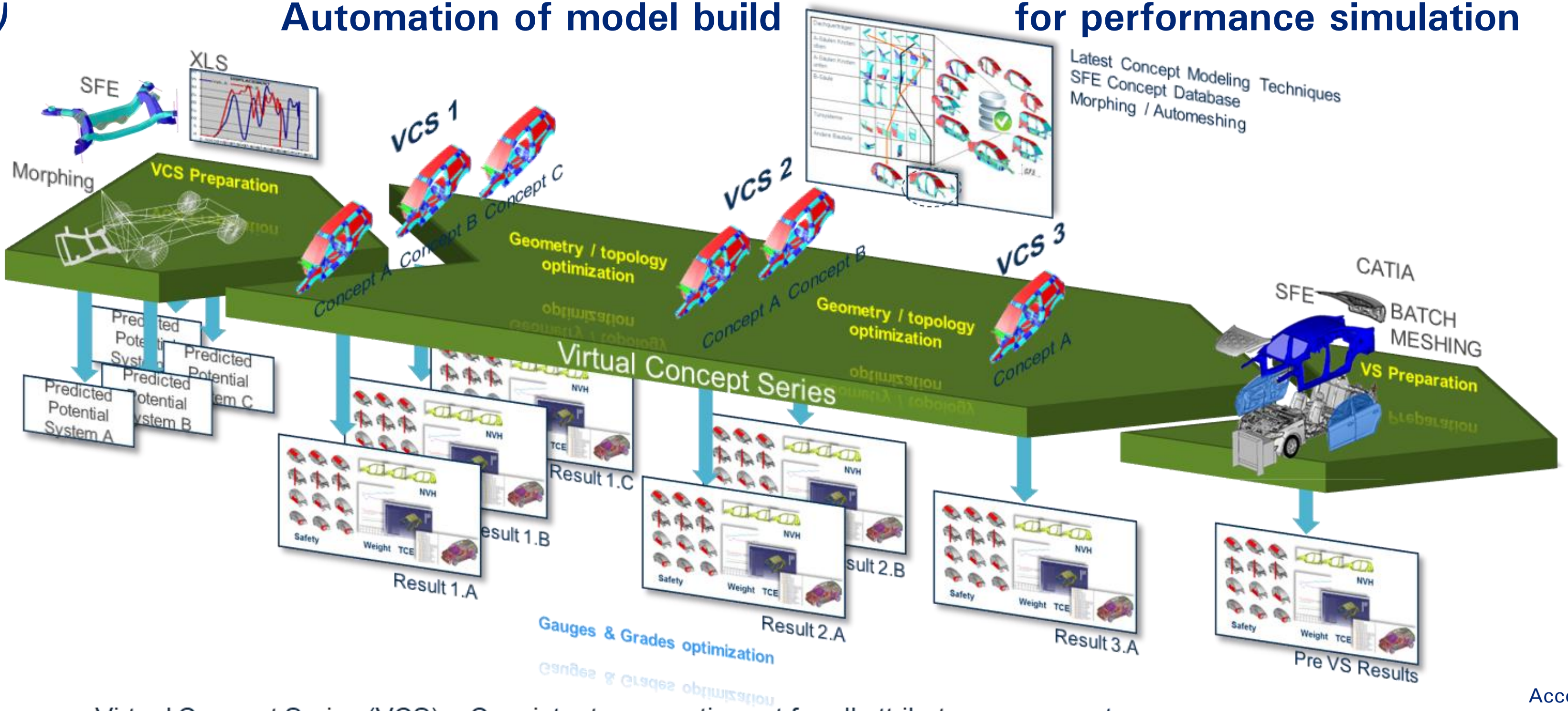
(3/3) Identified action items regarding ASE in Germany

- Publication: *“Flagship initiative on the future of the engineering and innovation location Germany”* (currently only available in German):https://www.acatech.de/publikation/die-advanced-systems-engineering-strategie/
  - **Strengthen strategy competence**, e.g. introduce ASE maturity model, perpetuate competence monitoring
  - **Manage diversity of activities**, e.g. understand ASE as a cross-sectional task, operate platform for ASE
  - **Advance method innovations**, e.g. integrate Systems Engineering with Software Engineering, focus on sustainability of sociotechnical systems, ensure data competence for engineering
  - **Intensify cooperation between business and science**, e.g. integrate transfer as a third pillar in the higher education system (in addition to research and teaching), exploit success potentials of proven cooperation models
  - **Accelerate education and training**, e.g. establish basic degree programs, broadly disseminate further education, mobilize the “Generation 50+”
  - **Realize behavioral innovations on a broad front**, e.g. practice new ways of working, ensure participation of stakeholders, succeed with new business models in the platform economy

➢ Target groups and responsibilities:
  - ➢ Politics: Create framework conditions for social acceptance, dissemination, …
  - ➢ Economics/industry: Key player regarding market performance innovations leading to sustainable value creation, employment, prosperity, and welfare
  - ➢ Science: Development of methods with focus on sustainable and reliable systems, interaction with industry

Transform #2 – Model/Software driven technical system development (1/4)

Automation of model build for performance simulation



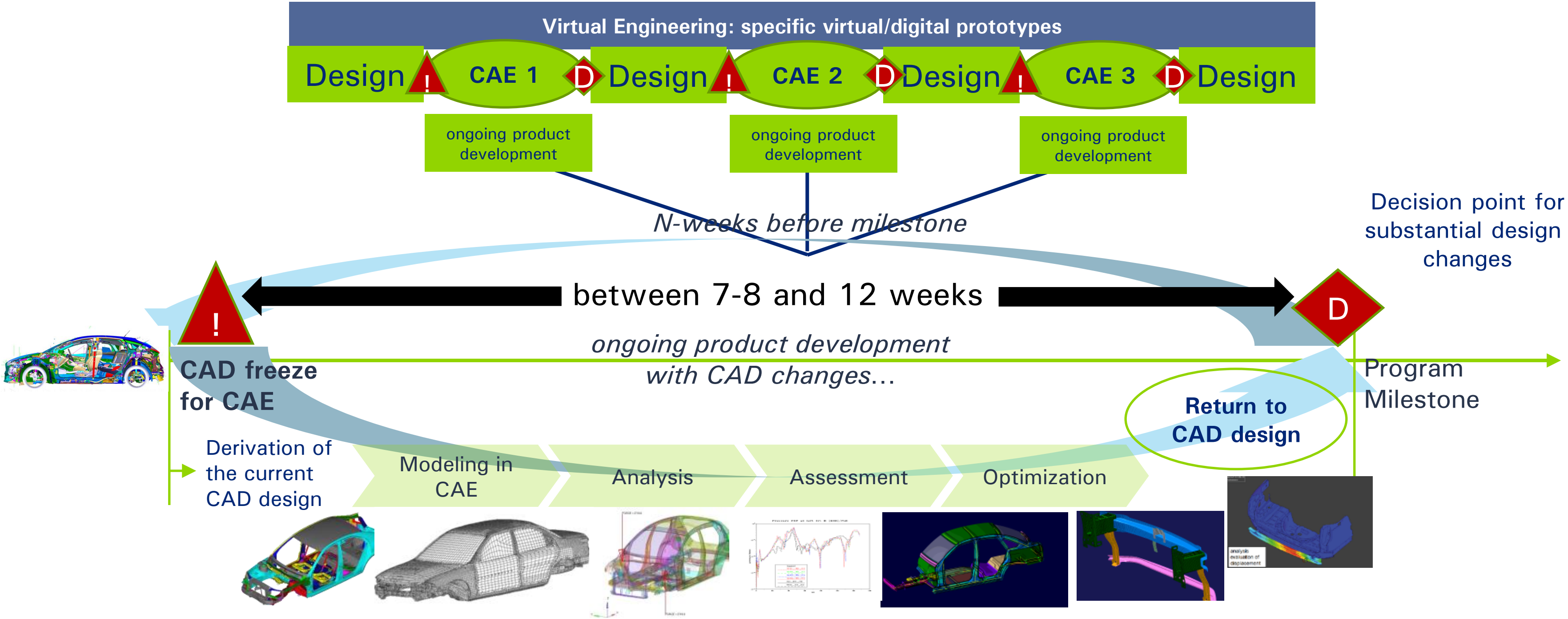
Virtual Concept Series (VCS) – Consistent assumption set for all attribute assessments

According to A. Hänschke

➢ It is core to establish deep dive model expertise, to set-up an efficient digital model generation and to agree on a development logic in order to allow for trade-off decisions based on digital models!

Transform #2 – Model/Software driven technical system development (2/4)

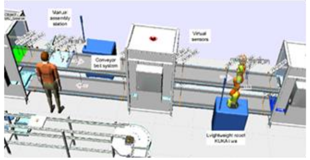
Significant acceleration of virtual series with intelligent automation…

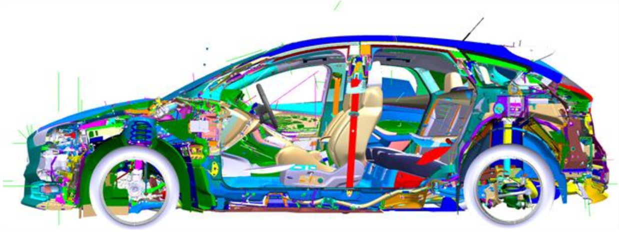


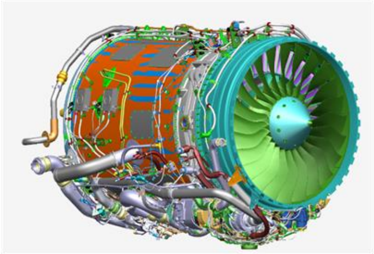
- Virtual prototypes are created and optimized in several iterations between CAD & CAE based on data freeze points, each full vehicle CAE simulation cycle takes between 7-8 weeks (leader) and 12 weeks
- Each overall Design – CAE phase takes between 4 and 6 months, overall PDP time to be reduced to 30 months!

Transform #2 – Model/Software driven technical system development *(3/4)*

New VPC-SW synchronization – formal notations, extended models …







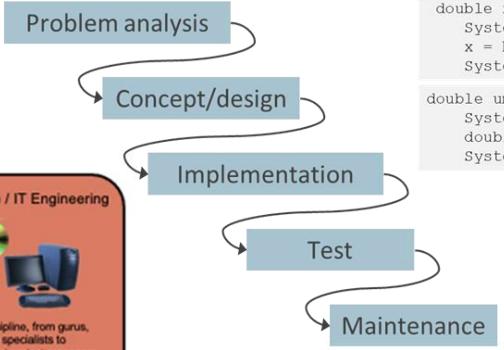
“Factory” of technical systems modeling

Virtual Product Creation

- Multi disciplinary
- Affects process, methods and tools
- Difficult for traditional engineering management to understand and assess
- Turbulent development cycles
- Needs solid understanding of information objects and multi-model representation
- More than 100 different digital models per component within each development project

Software / IT Engineering

- Young discipline, from gurus, artists and specialists to professional project managers (30+ years) and software coders
- Algorithm and modularization driven
- Usually 2-3 test cycles by key users
- Almost standard that not everything is available at Job1 (workaround mentality)




```
double x = 2 * (breite + hoehe);
   System.out.println("Umfang: " + x);
   x = breite * hoehe;
   System.out.println("Fläche: " + x);
```

```
double umfang = 2 * (breite + hoehe);
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```
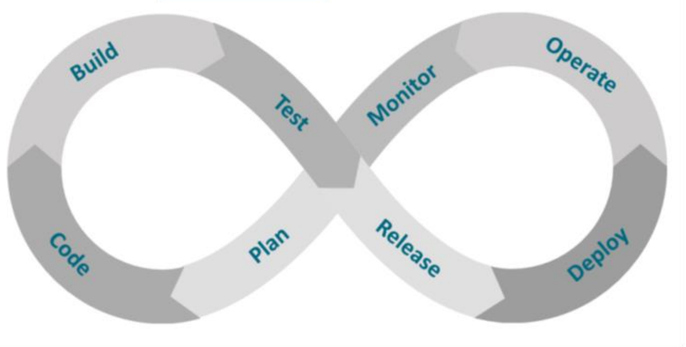



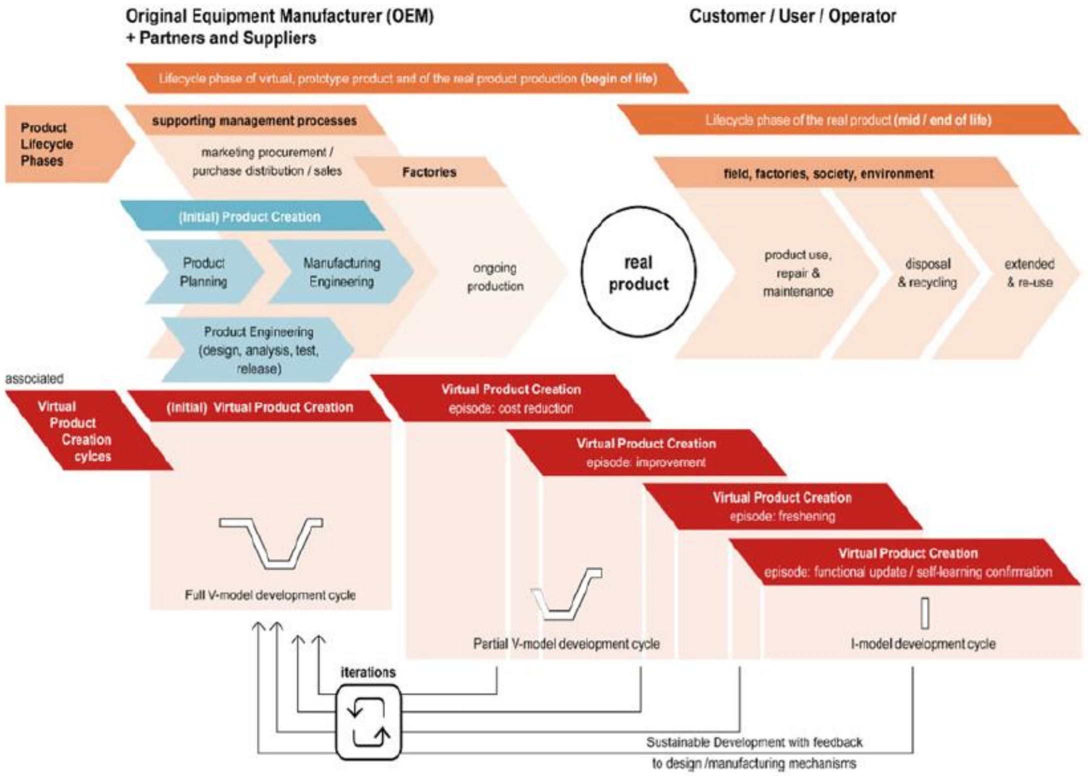
“Factory” of software systems development & operations

Best Practice/recommendation: definition of synchronisation points in PEP

Transform #2 – Model/Software driven technical system development *(4/4)*

Move to continuous Virtual Product Creation (VPC) for ongoing operations

„***Virtual Product Creation*** constitutes of all process steps and engineering activities (and their iterations) that use digital applications, IT tool functions, software algorithms, working methods and assessment and decision capabilities to create, modify, simulate, analyze, test, validate, verify, sign-off, release and exchange *virtual products* and their derivations." (p. 48)

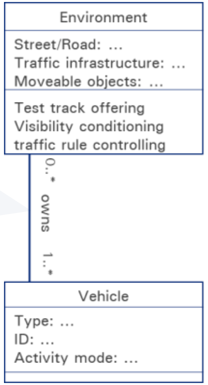


Stark, R. (2022). Virtual Product Creation in Industry. Springer.
https://doi.org/10.1007/978-3-662-64301-3

Transform #3 – Extended Model based Systems Engineering
(1/5) How to link a System Model with 1D & 3D Simulations?

SysML Model:
System Architecture,
Functional Flow;
Solution neutral

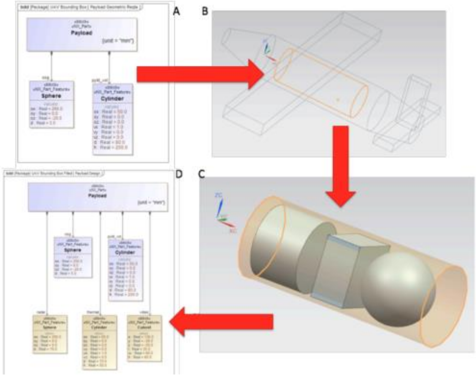
SysML



Logical Design/
Behaviour Model
(1D CAE):
solution defined,
split in domains

Modelica | SimulationX | Dymola

Matlab/ Simulink | SimScap | Stateflo | ...



CAD/3D CAE
Simulation
MBS, FEA

Source: IAMTS MathWorks, Siemens, Syndea, TASS, BMW, IPG Carmaker, Altair, VW, Dassault

Transform #3 – Extended Model based Systems Engineering (2/5)

How to link a System Model with 1D & 3D Simulations?

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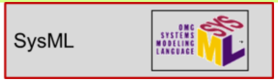

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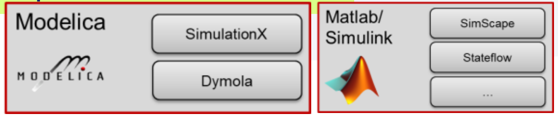

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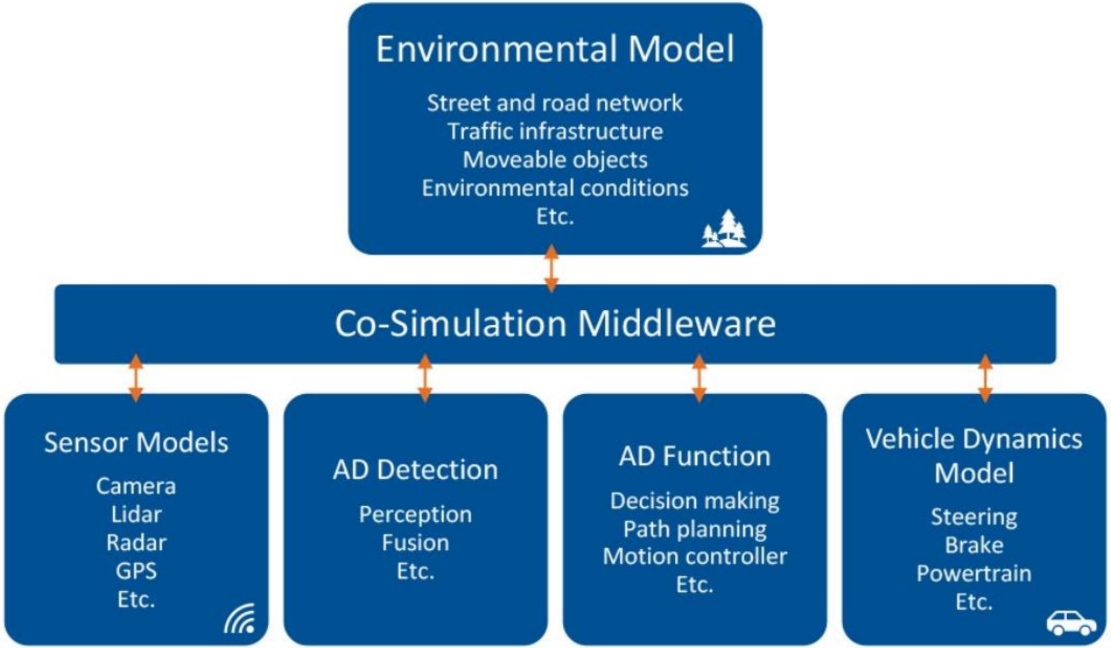

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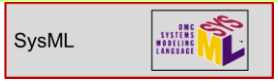

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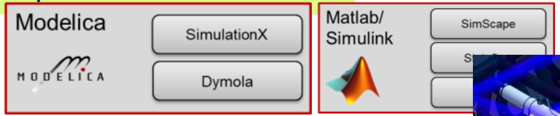

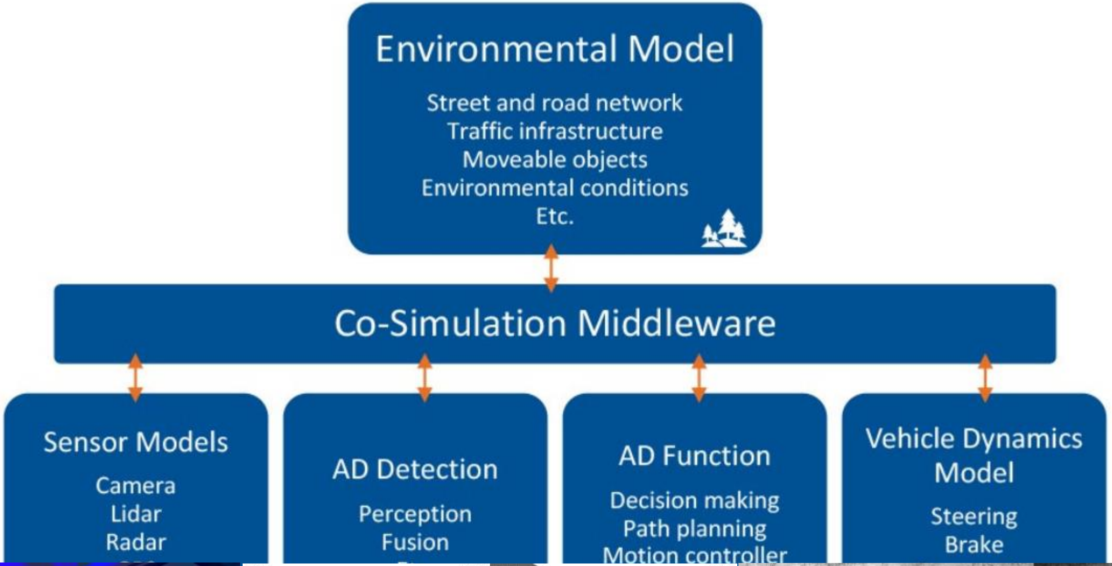

CAD/3D CAE
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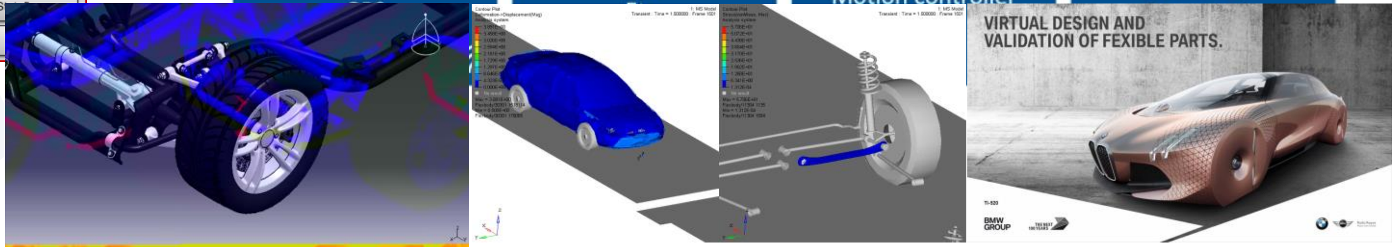
MBS, FEA



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Transform #3 – Extended Model based Systems Engineering
(4/5) How to link a System Model with 1D & 3D Simulations?

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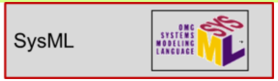

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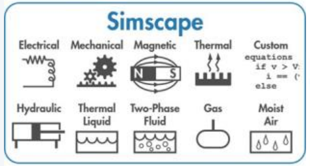
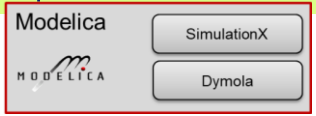
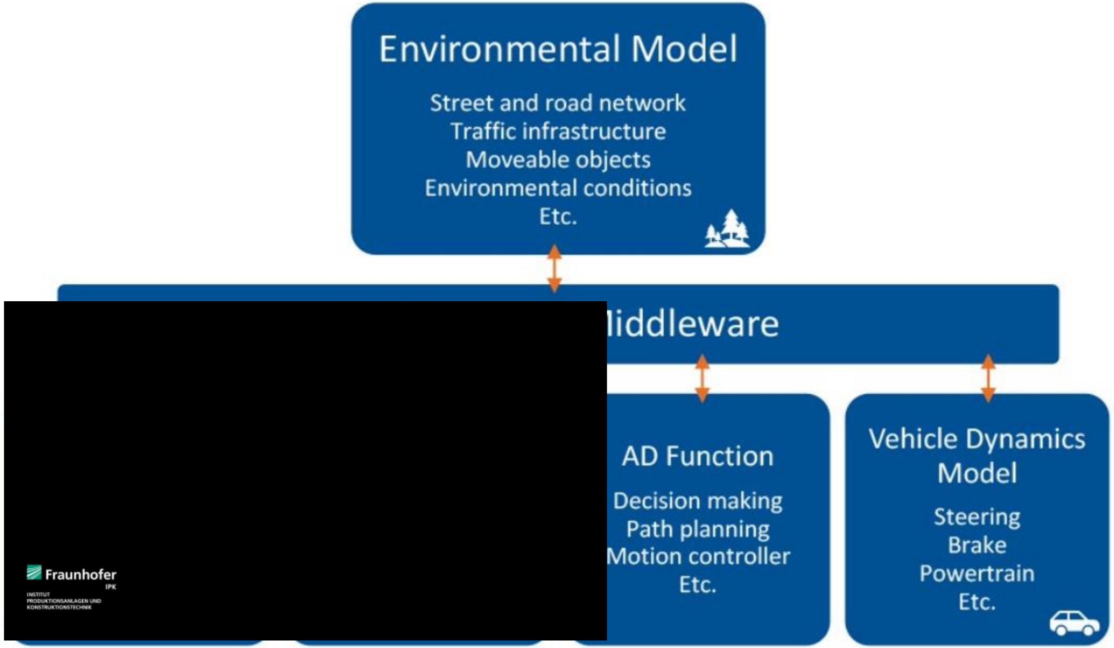






CAD/3D CAE Simulation
MBS, FEA

Source: IAMTS MathWorks, Siemens, Syndea, TASS, BMW, IPG Carmaker, Altair, VW, Dassault

Transform #3 – Extended Model based Systems Engineering (5/5)

How to link a System Model with 1D & 3D Simulations?

SysML Model:
System Architecture, Functional Flow; Solution neutral

SysML

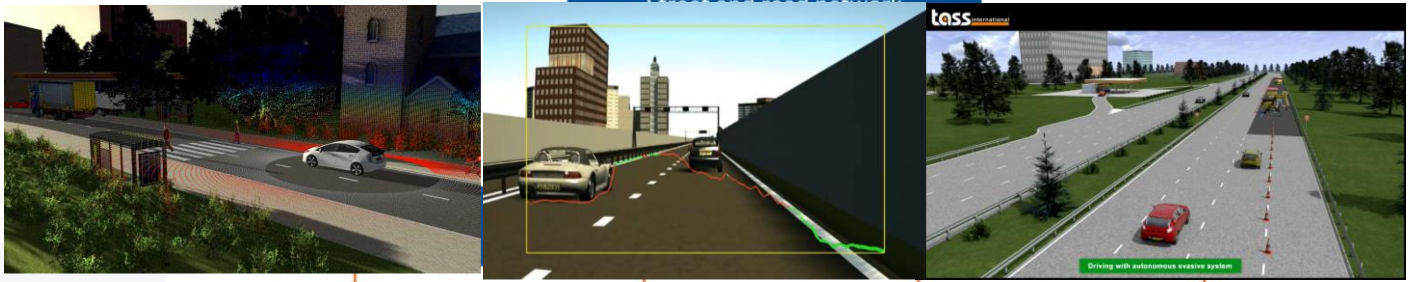
Logical Design/ Behaviour Model
(1D CAE):
solution defined, split in domains

Modelica: SimulationX, Dymola

Matlab/ Simulink: SimScape, Stateflow, ...

CAD/3D CAE Simulation
MBS, FEA

Environmental Model

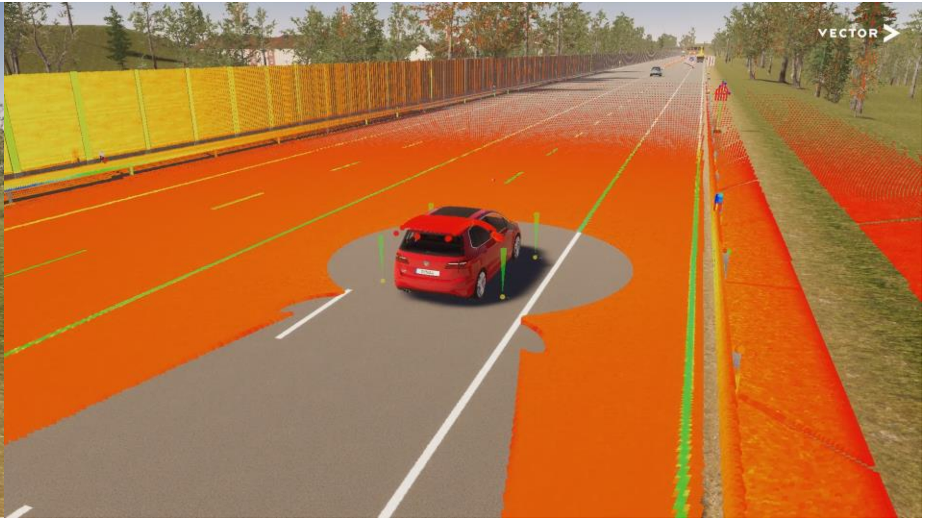


Sensor Models	AD Detection	AD Function	Vehicle Dynamics Model
Camera Lidar Radar GPS Etc.	Perception Fusion Etc.	Decision making Path planning Motion controller Etc.	Steering Brake Powertrain Etc.

Source: IAMTS MathWorks, Siemens, Syndea, TASS, BMW, IPG Carmaker, Altair, VW, Dassault

Transform #4 – AI support for Model based Systems Engineering
(1/2) *New types of digital models to be connected via data analytics*

A Camera based sensor to achieve ***moving object detection***
(use of 2D based AI analysis of graphics)



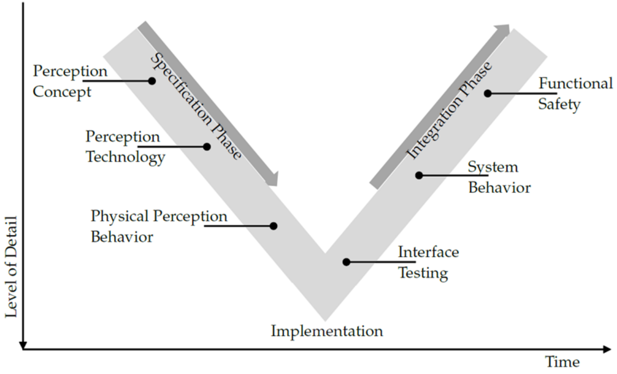
B Lidar based sensor to achieve ***complete environment detection***
(use of 3D based graphical radiosity / raytracing / raycasting analysis
+ subsequent 2D/3D AI analysis)

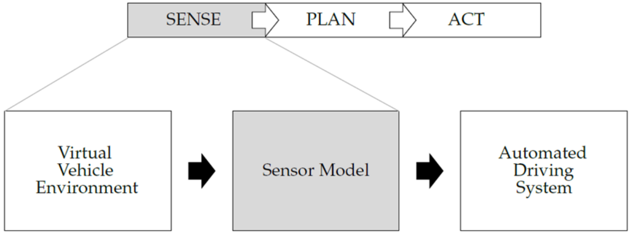
Transform #4 – AI support for Model based Systems Engineering (2/2)

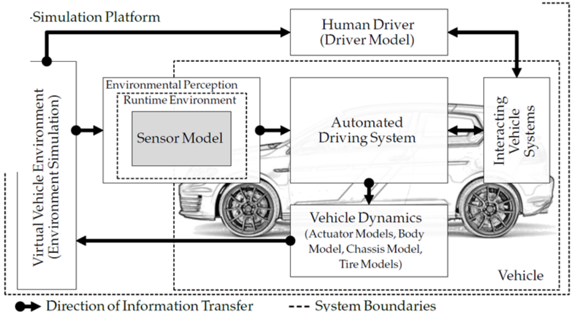
New types of digital models to be connected via data analytics

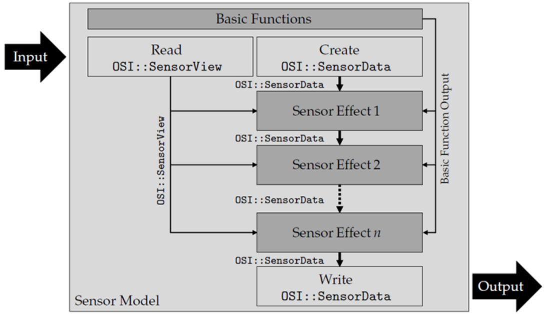
Configurable Sensor Model Architecture for the Development of Automated Driving Systems

Simon Schmidt [1,*], Birgit Schlager [2,3], Stefan Muckenhuber [2,4] and Rainer Stark [5]



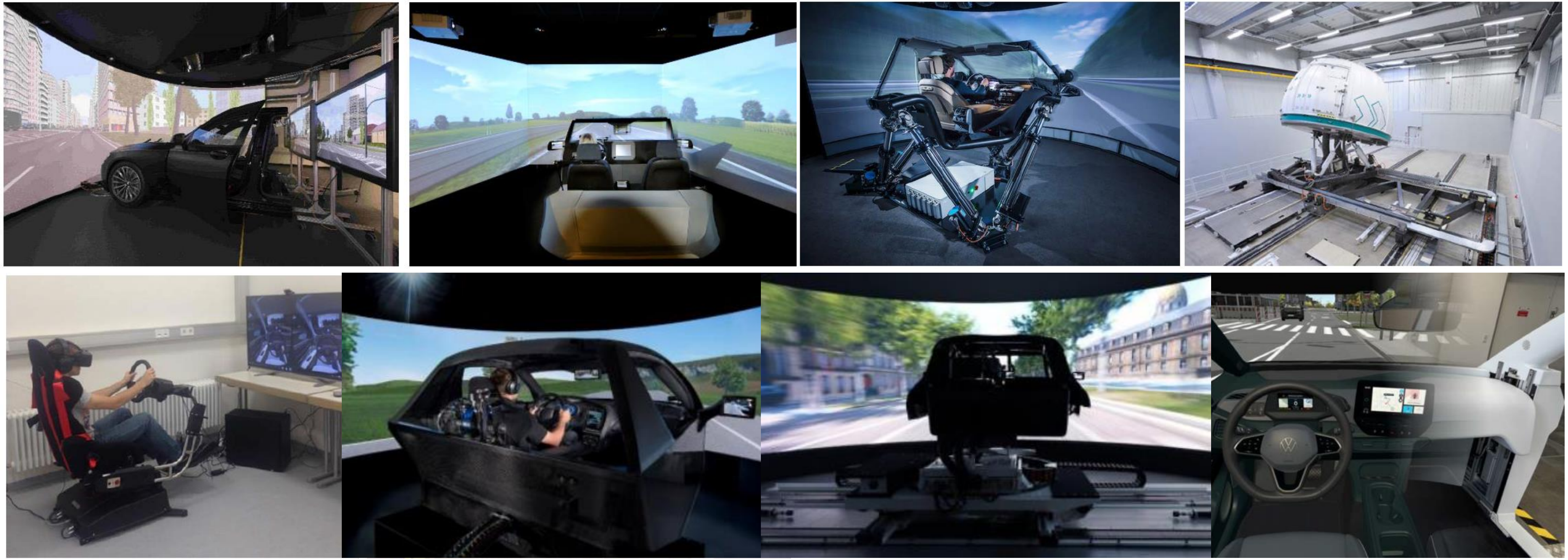






Transform #5 – Simulator environments for new model testing

(1/4) Experience the Digital Twins of the future – driving simulators



- There exist different types of driving simulators, depending on the driving function analysis…

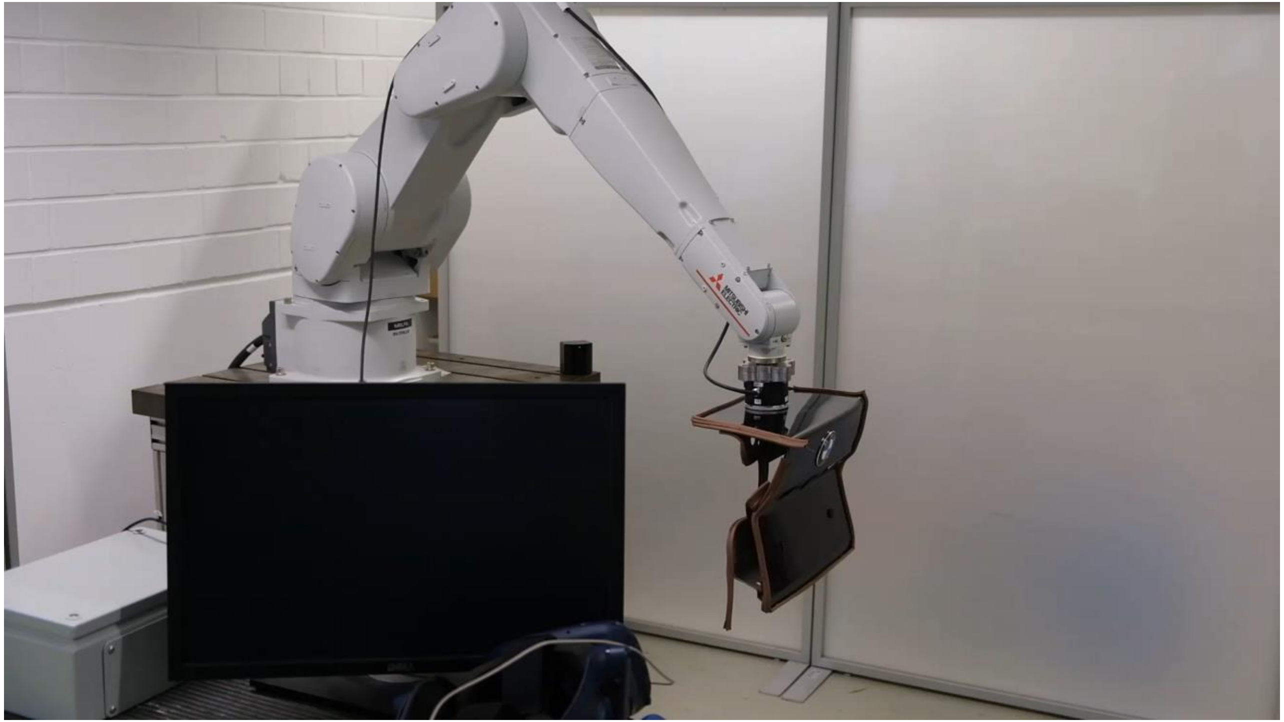
Transform #5 – Simulator environments for new model testing

(2/4) Mixed Reality driving simulator @ TUB – Human in the loop

Description of this unique DCTC (Digital Cube Test Center):

- With the help of two inertia motion platforms, a sound system and mixed reality environments (screen, headset, cockpit etc.) the human driver is immersed into a physical, kinesthetic, visual driving environment
- Engineers and probands can use different types of model intelligence for vehicle prototypes in order to test various types of attributes and functions long before the existence of costly hardware prototypes:
  - ADAS, autonomous driving
  - Future cockpits and human control interactions
  - Dynamic viewing analysis (e.g. pillar obscuration) under specific traffic/environmental conditions

Transform #5 – Simulator environments for new model testing
(3/4) Mixed Reality decklid simulator @ TUB – Human in the loop



Description of this Smart Hybrid Prototyping test installation:

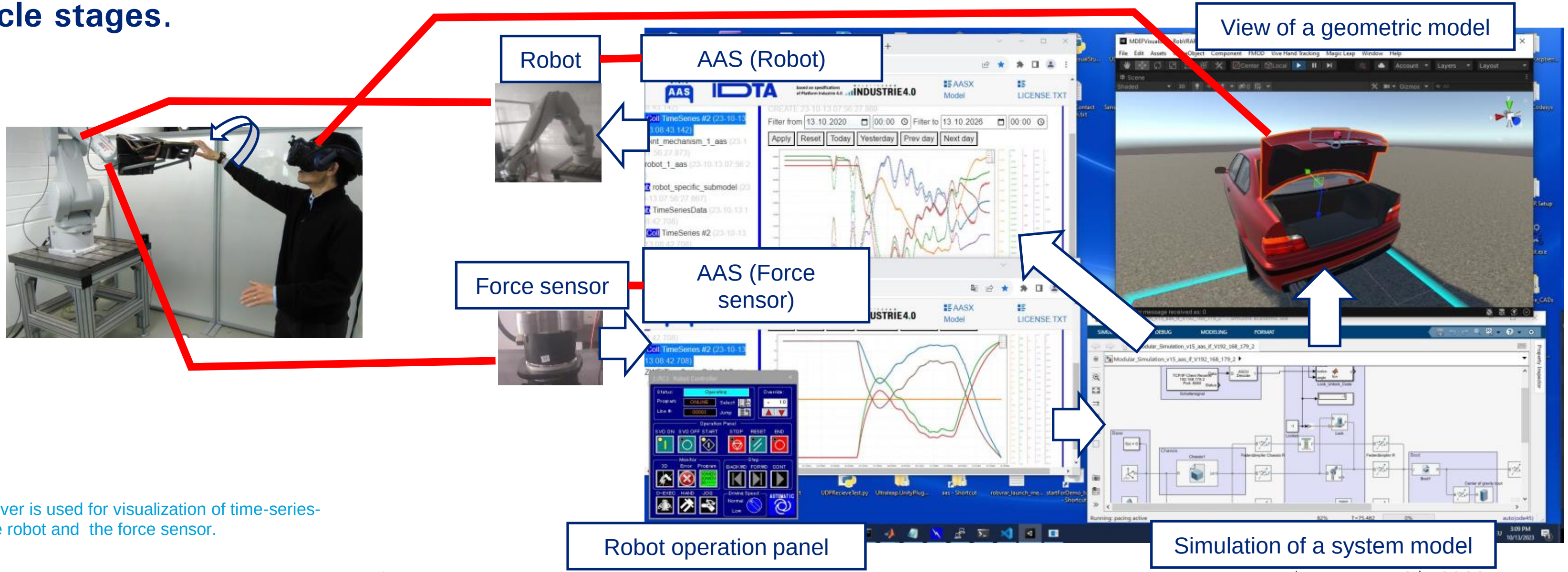
- With the help of physical elements:
  - industrial robot, physical portion of the sheet metal of the decklid, a force sensor, an opening switch, 3D glasses + computer hardware and network
- together with 5 concurrent digital model simulations:
  - digital 3D master / VR Unity
  - multi-body /matlab simulink
  - robot control
  - IoT data digital switch
  - Position / force detection
- it is possible to dynamically and inter-actively experience the damper/spring characteristics of the decklid system in various *relative human to decklid positions*

Transform #5 – Simulator environments for new model testing (4/4)

Mixed Reality decklid simulator via AAS based Digital Twin operation

- An application of **AAS*** to **smart product development** requiring the **synchronization** of **system behavior simulation** and **data transfer** across AASs and physical system components.

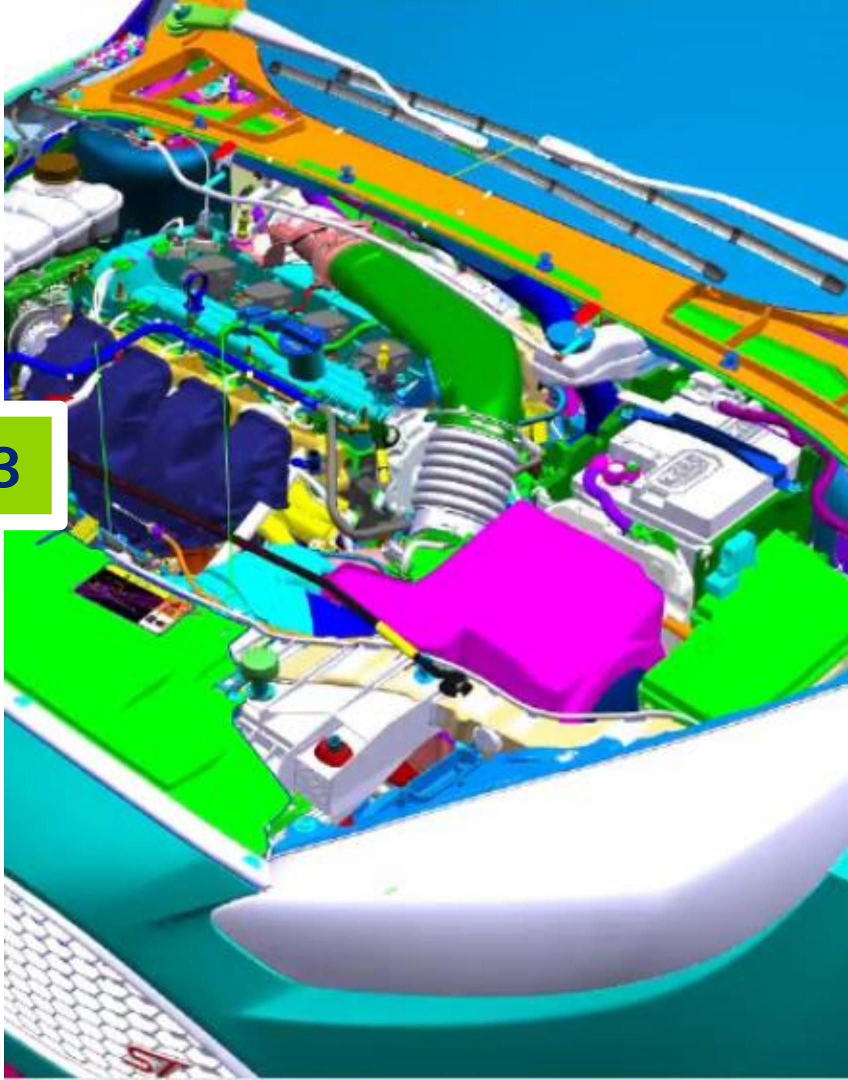
- **AAS-based product models** can be used to create **new services** with combination of **diverse functions of information factory** (such as data analysis, visualization and simulation) across the **life cycle stages**.



*AASX Server is used for visualization of time-series-data of the robot and the force sensor.

Summary & conclusions

3



Conclusions, call for actions and outlook

Conclusions

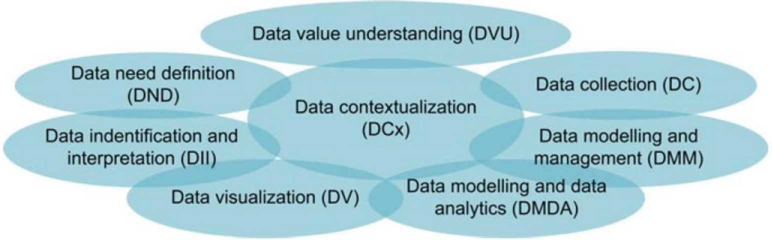
- Engineering gets under increasing pressure due to limitations in developing smart/networked technical systems
- New digital model types to be researched, tested, qualified and disseminated
- Model based Systems Engineering (MBSE) approaches are still immature and not yet sufficient – research to be intensified in close cooperation between academia, digital tool venders (DTV) and industry (see prostep ivip project smart systems engineering)
- Today, there still exist a wide gap between V-model based *Technical System Development (TSD)* with embedded software and *Software System Engineering (SSE)* and associated DevsOps approaches
- The new *Engineering Intelligence* need to be established as a new core field in design & engineering research

Call for actions

- Be confident enough to establish new international formats and projects for *New Engineering Intelligence* for Virtual Product Creation of the Future to bridge the gap between TSD and SSE

Future research outlook

- *Data Engineering (DE)* with its disciplines will get high attention
- *MBSE* needs staggered proficiency levels with the help of AI
- *Digital Twin Engineering (DTE)* becomes indispensable to ensure readiness to deliver sustainable solutions and CO_2 reductions
- *Digital Platform Engineering (DPE)* needs *anti lock-in* mechanisms



Thanks for your attention

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