Presentation

3D wiring and wire harness automation – an analysis of the digitalization essentials

Graph-based Design Languages and Design Cockpit 43®

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with contributions from our RoboChallenge 2026 partners

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digitalization paradigms

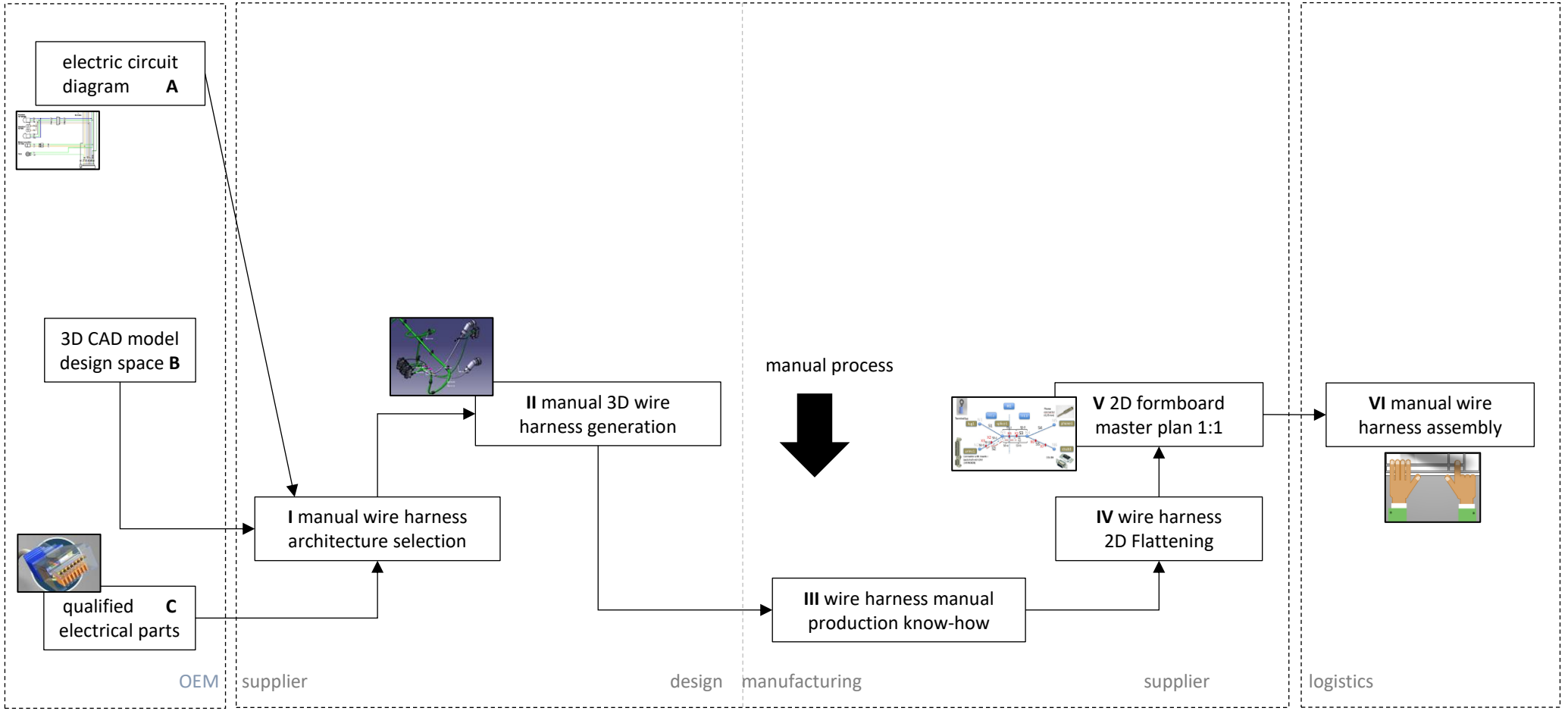
Engineering as Code (EaC)

coding of an engineering task makes it to a service

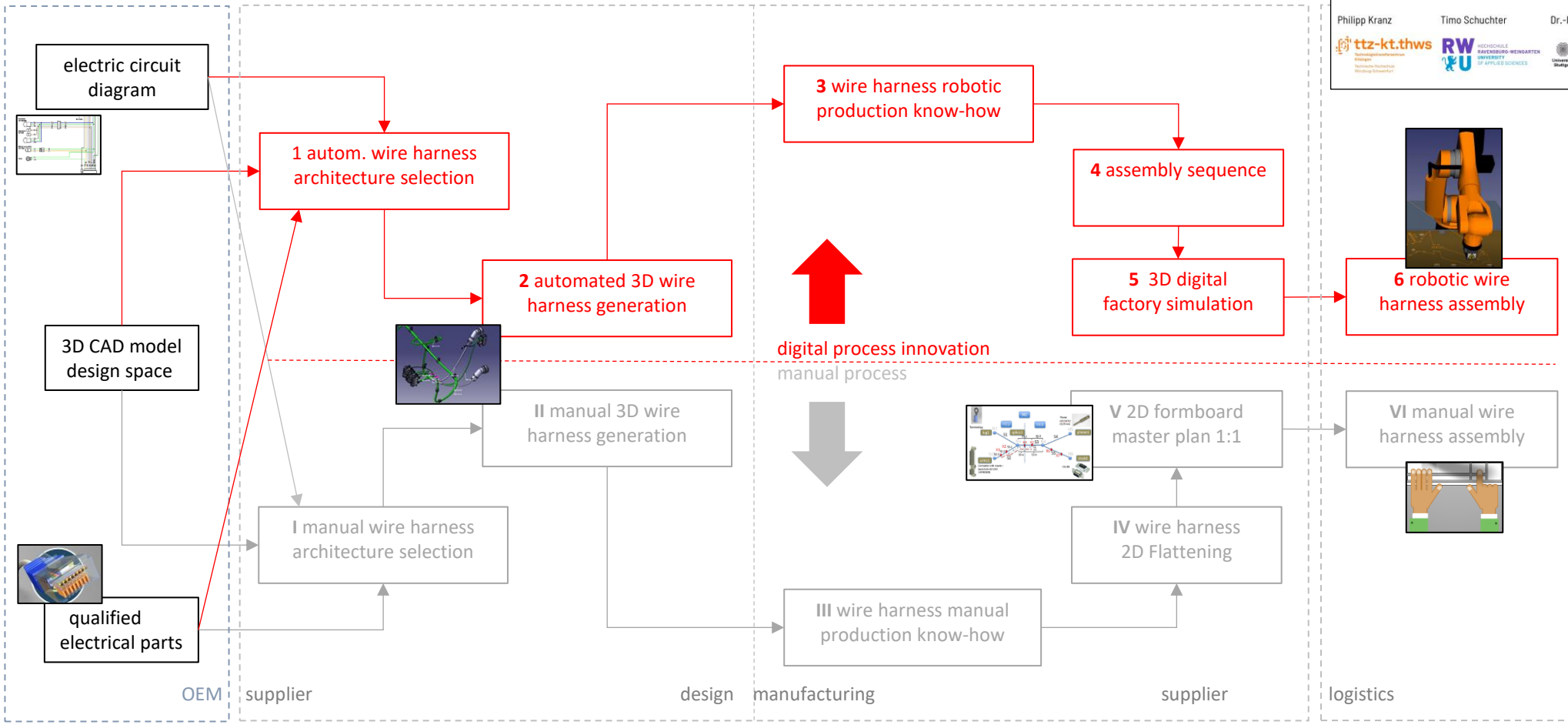
Engineering as a Service (EaaS)

combining services in a platform creates process chains

wire harness manual process (schematic)



wire harness digital process innovation

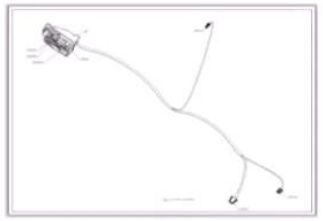


wire harness digital process innovation

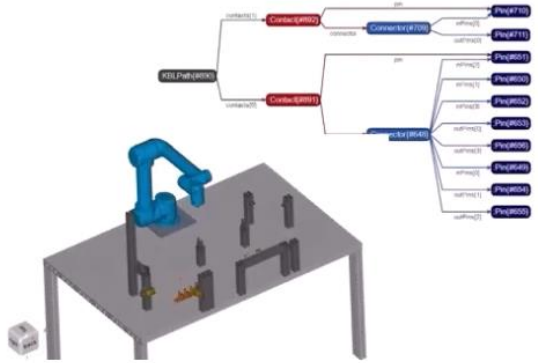
Robotik Challenge 2026

Digitales Modell zur automatisierten Fertigungsplanung von Leitungssätzen

Philipp Kranz · Timo Schuchter · Dr.-Ing. Stephan Rudolph · Dr.-Ing. Roland Weil
ttz-kt.thws · RWU Hochschule Ravensburg-Weingarten University of Applied Sciences · IFB Universität Stuttgart Institut für Flugzeugbau · IILS



Input
STEP
KBL / VEC

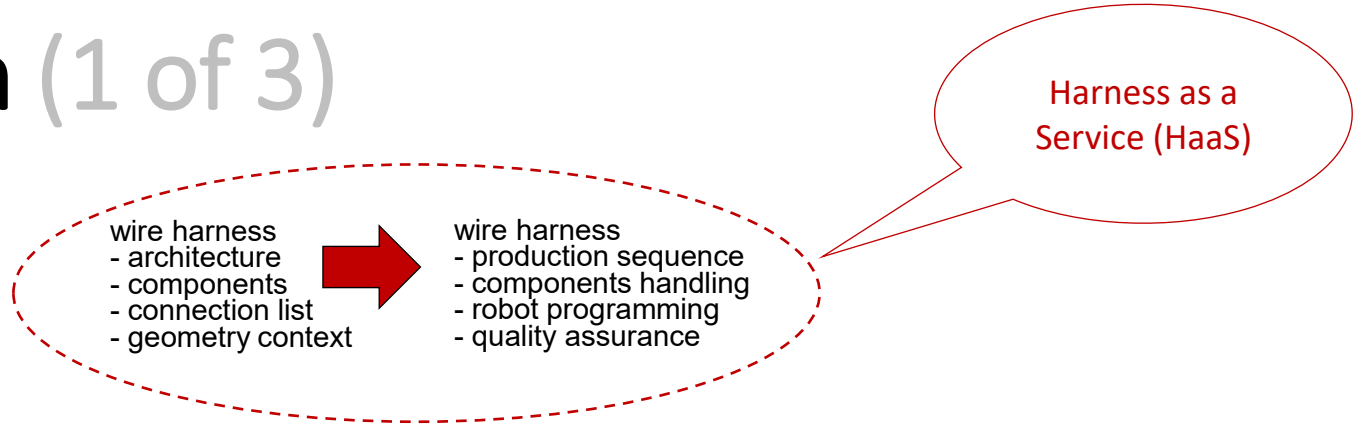


Montageplanung im Design Compiler 43

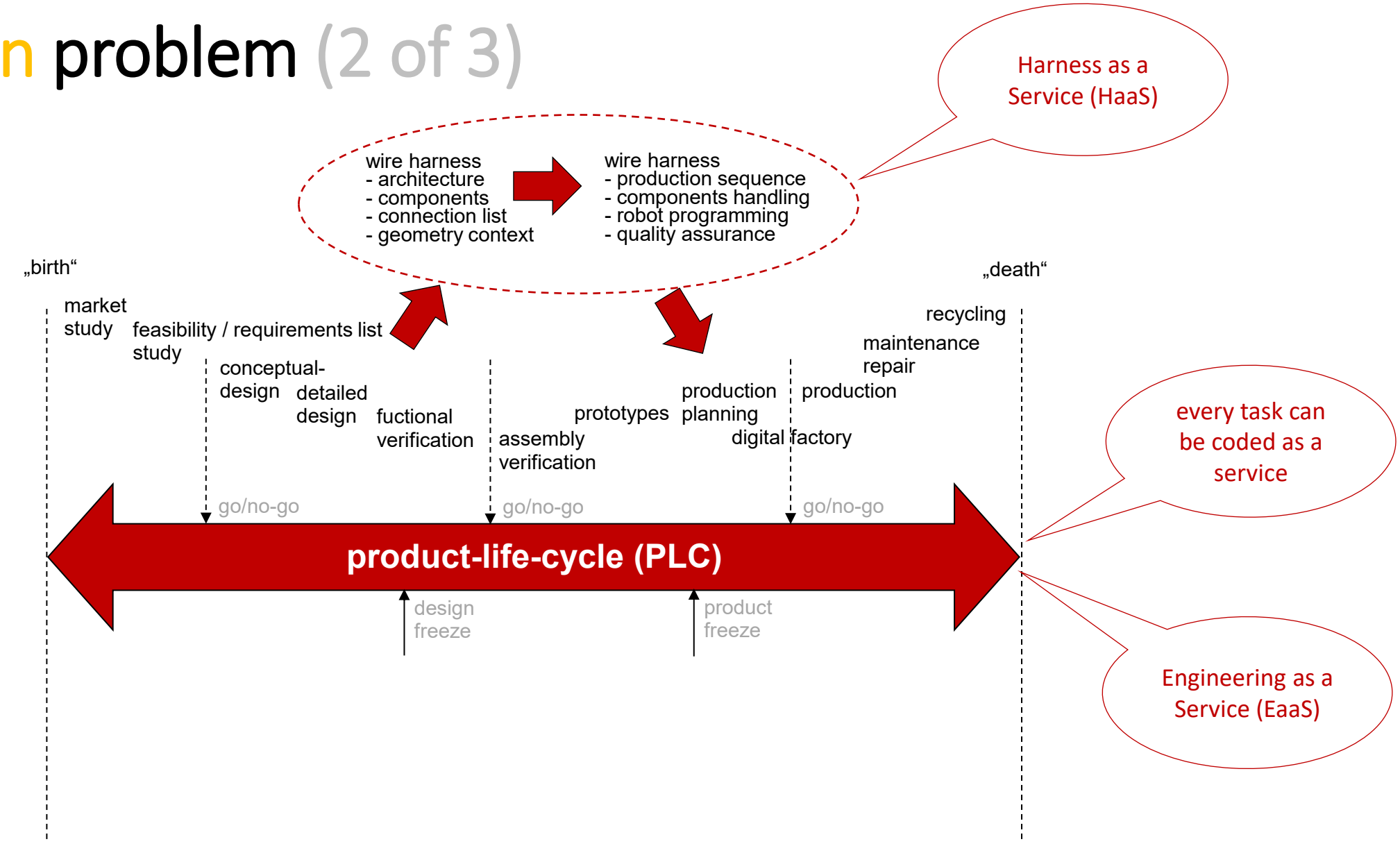
Ausführung am realen Roboter

Output
Montierter Kabelbaum

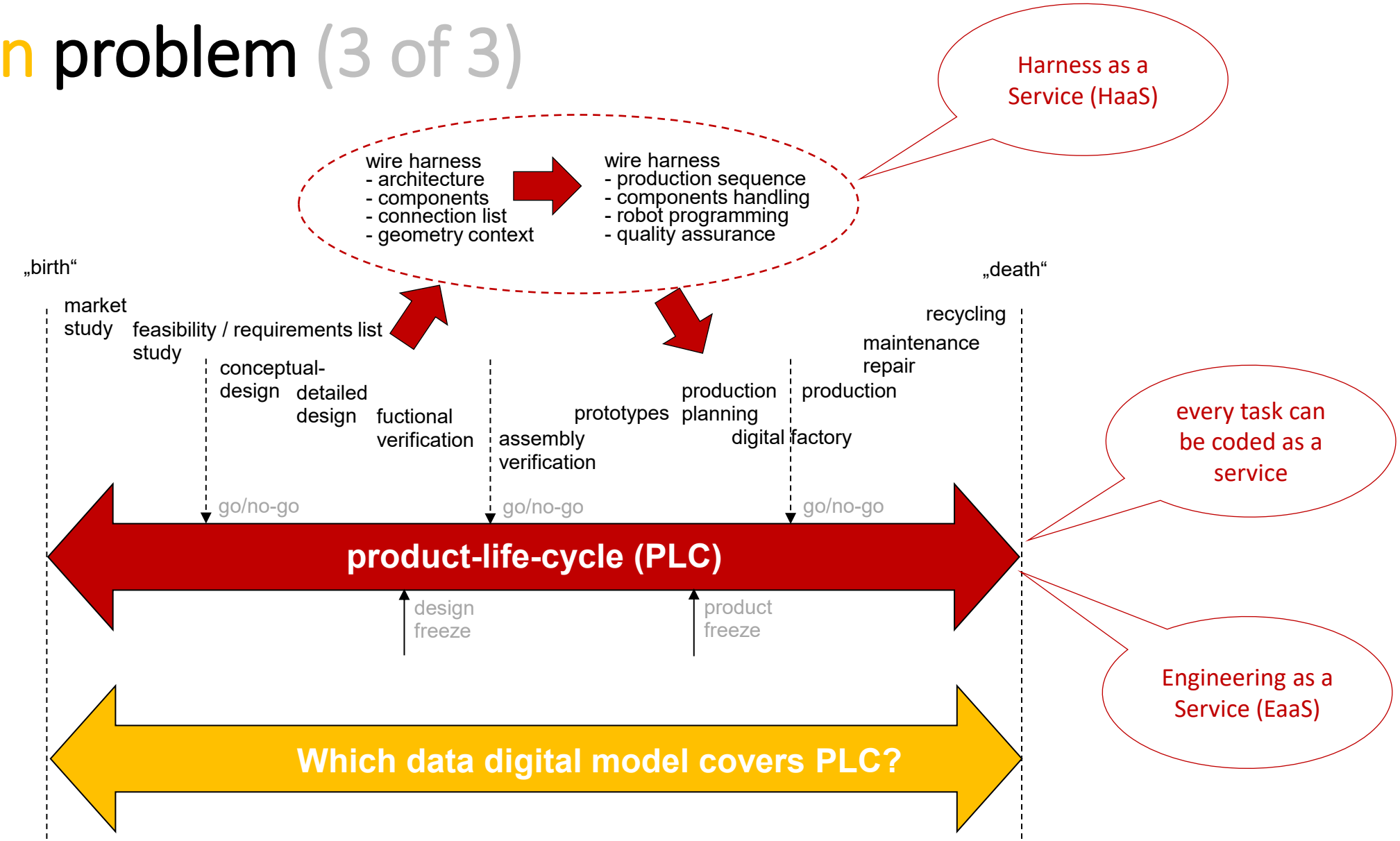
digitalization problem (1 of 3)



digitalization problem (2 of 3)



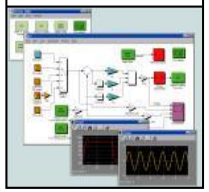
digitalization problem (3 of 3)



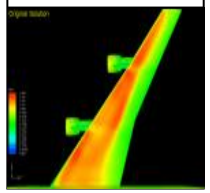
digitalization problem engineering

design

systems



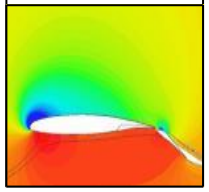
structure



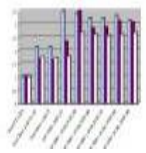
code

- **problems**
  - many disciplines (→ coupling)
  - many models (→ consistency)
  - modifications (→ optimization)
  - product lines (→ know-how-reuse)
- **software solutions**
  - some converters (VDAFS, STEP, …)
  - dream: unified digital master

aero



Euro



production

.....

and
many
more

anything coded
as a service

digitalization problem scope PLC

design

$\mathbb{R}^e$

systems

$\mathbb{R}^d$

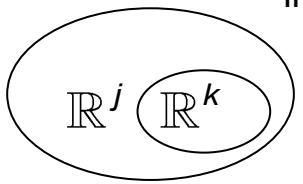
structure

$\mathbb{R}^f$

- **function theory**
  - no bijectivity for $\mathbb{R}^j \neq \mathbb{R}^k$
  - special case: projection (→ dimension reduction is information „one way“ only)

code

$\mathbb{R}^c$



aero

$\mathbb{R}^g$

- **software solutions**
  - some converters (VDAFS, STEP, …)
  - dream: unified digital master

Euro

$\mathbb{R}^b$

production

$\mathbb{R}^a$

.....

and many more

digitalization problem scope PLC

design

$\mathbb{R}^e$

systems

$\mathbb{R}^d$

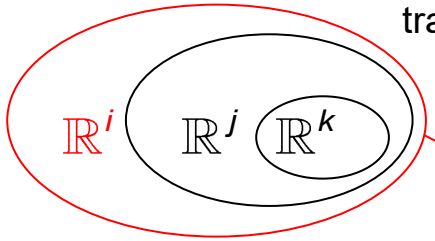
structure

$\mathbb{R}^f$

- **function theory**
  - no bijectivity for $\mathbb{R}^j \neq \mathbb{R}^k$
  - special case: projection (→ dimension reduction by transformation/compilation)

code

$\mathbb{R}^c$



meta-language
„design language“

aero

$\mathbb{R}^g$

- **software solutions**
  - some converters (VDAFS, STEP, …)
  - dream: unified digital master
  - design (language) compiler 43®

Euro

$\mathbb{R}^b$

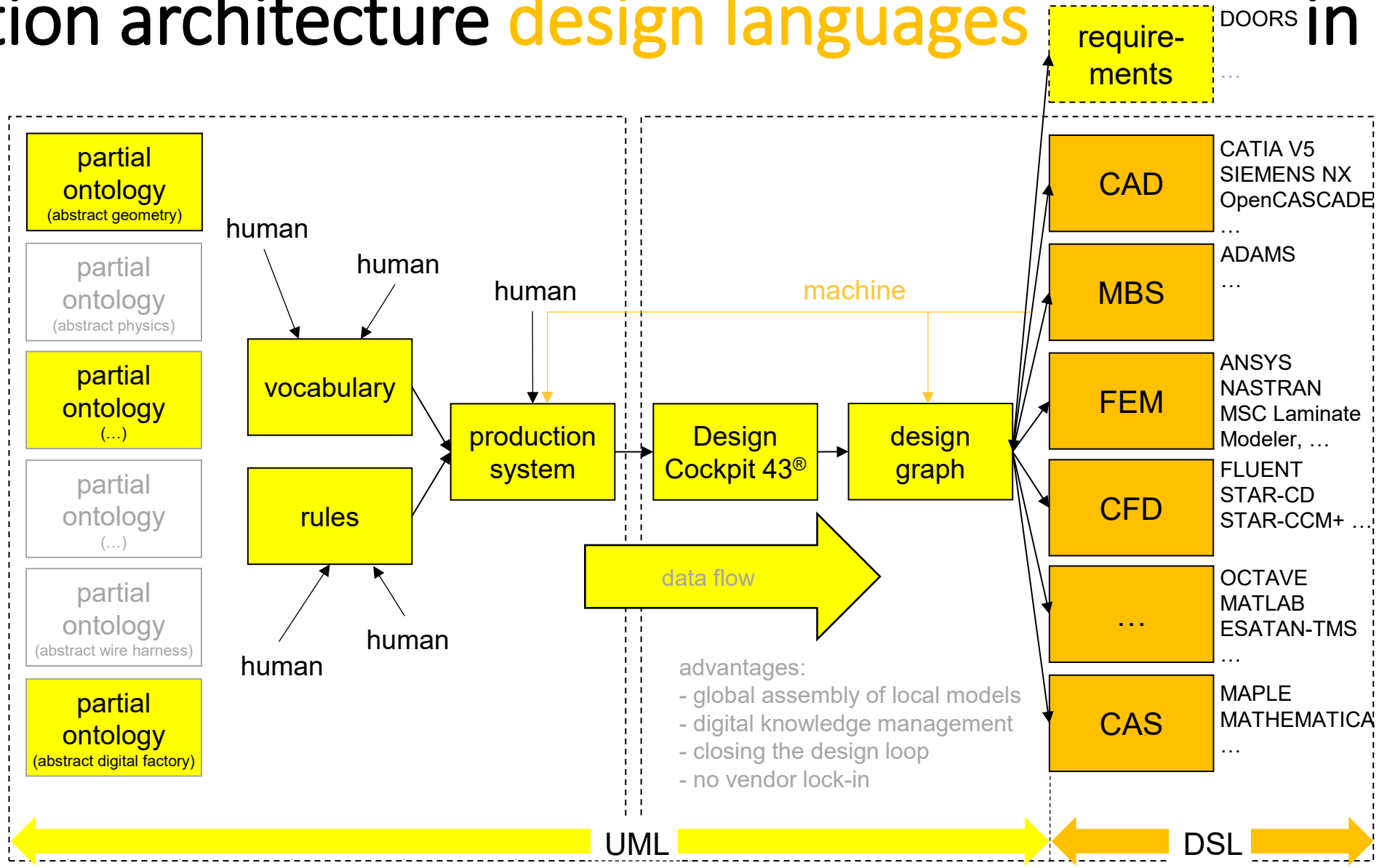
production

$\mathbb{R}^a$

.....

and
many
more

information architecture design languages in DC43®



design languages evolution

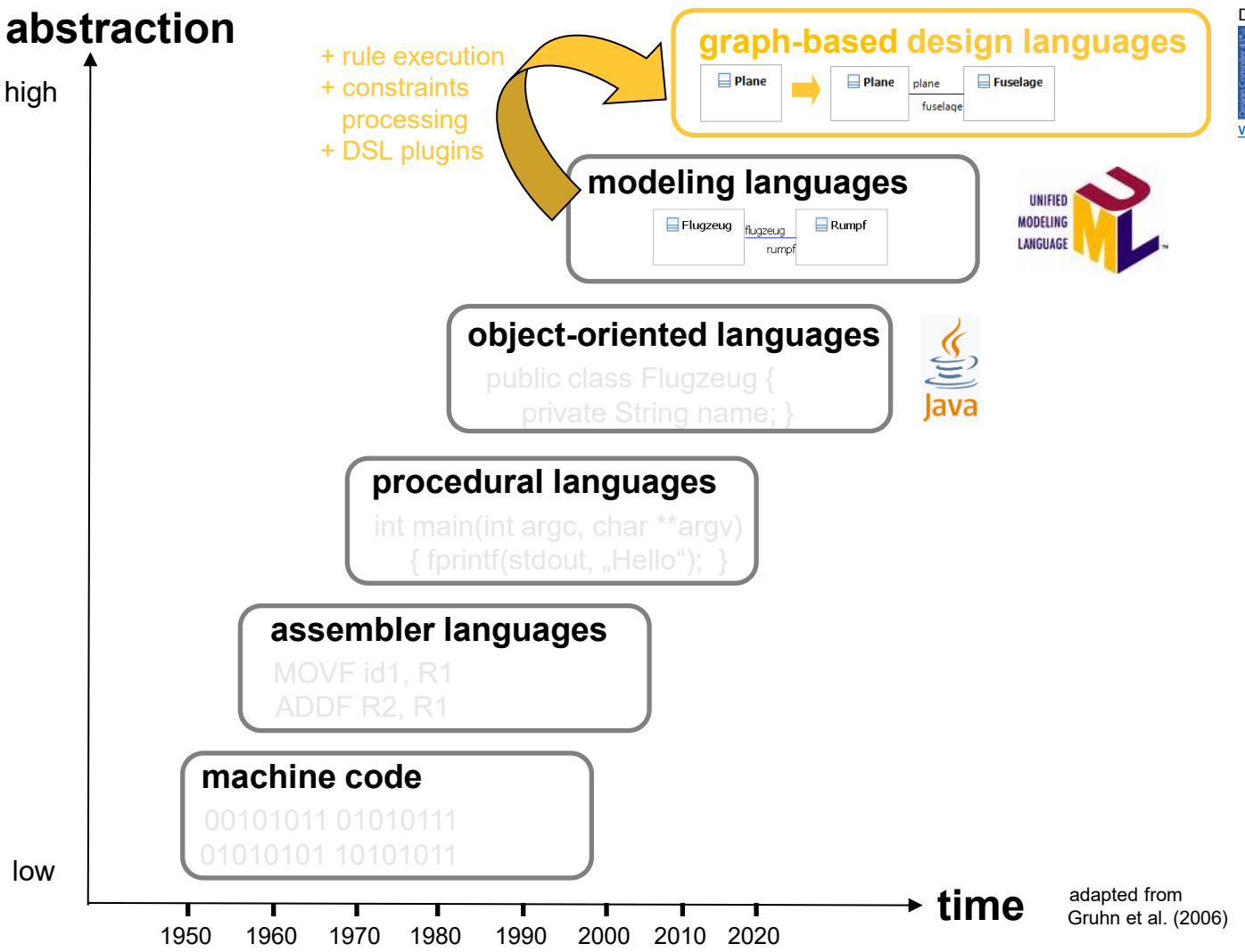
international, vendor-independent format and development tools

productivity, quality und security by
- code expansion
- code re-use
- code generation

with capability of
- abstraction
- hierarchization
- modularization
- visualization

of information

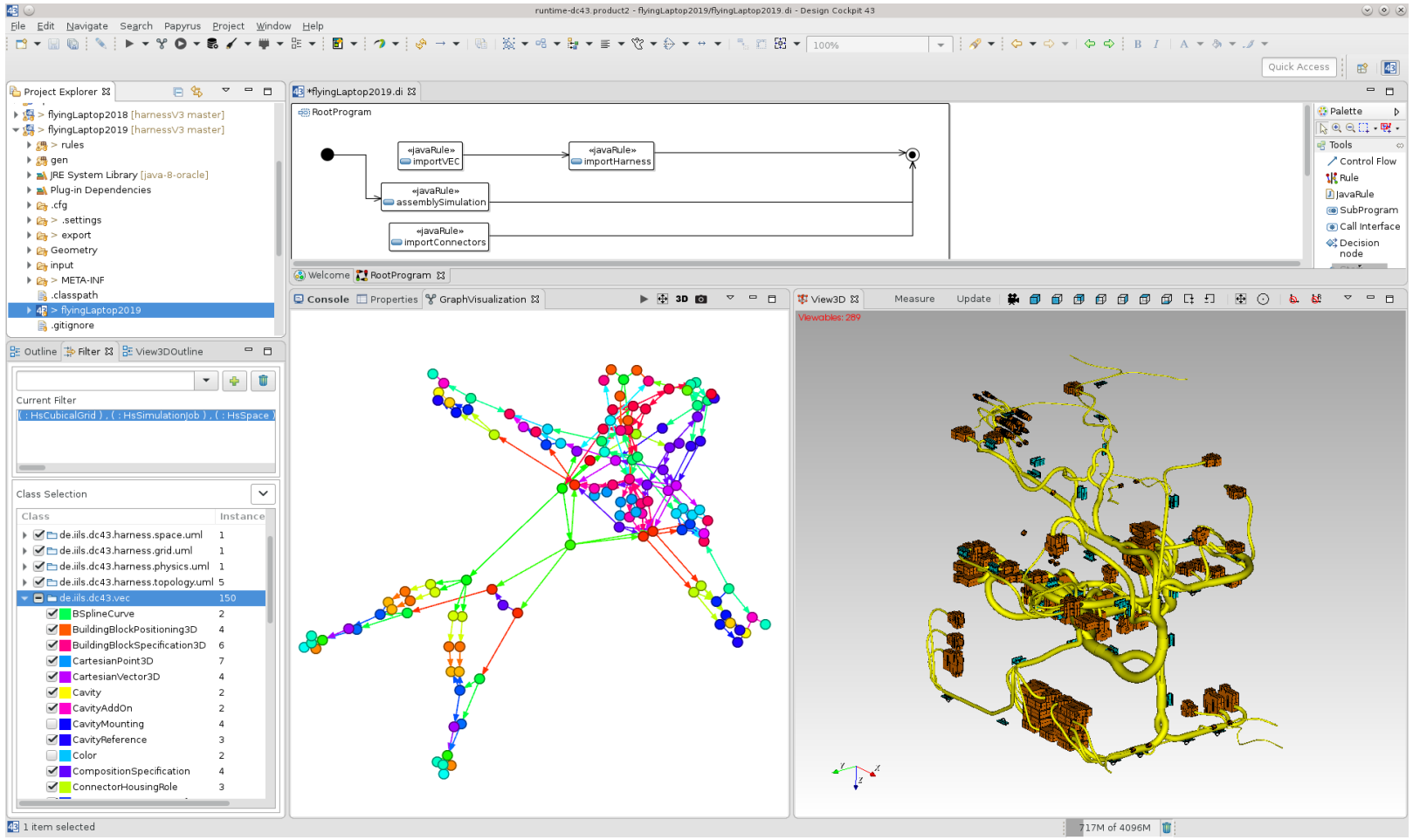
design of complex SW/HW-systems



Design Cockpit 43®
www.iils.de

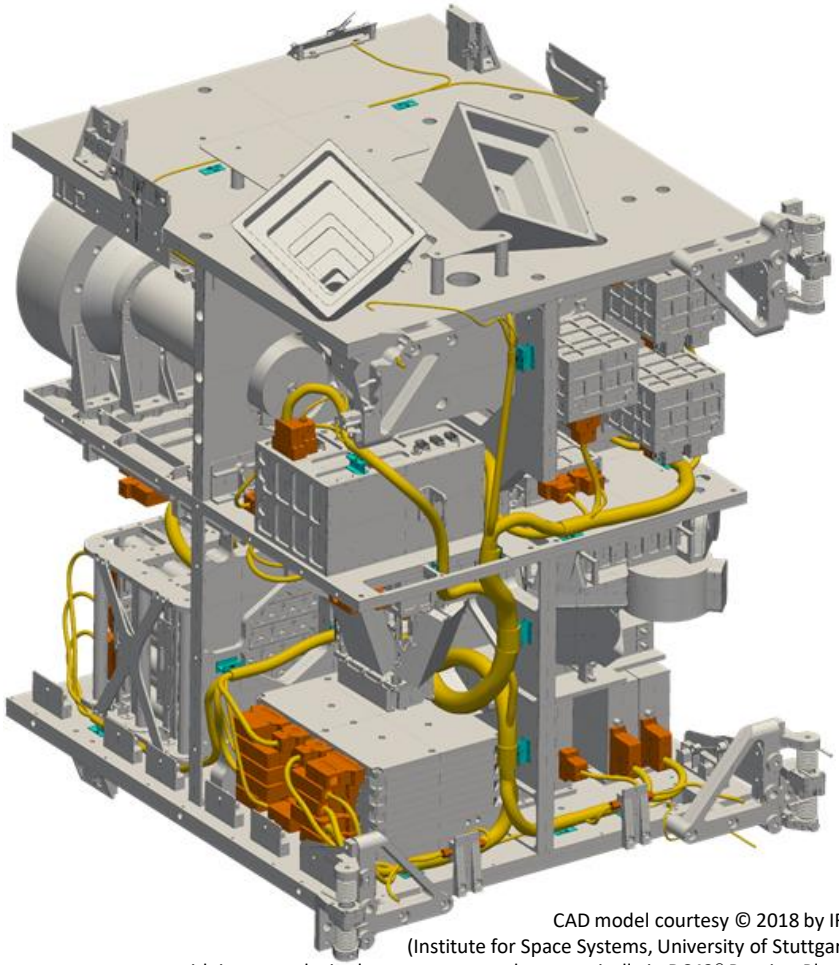
adapted from Gruhn et al. (2006)

Design Cockpit 43® Routing-Plug-In



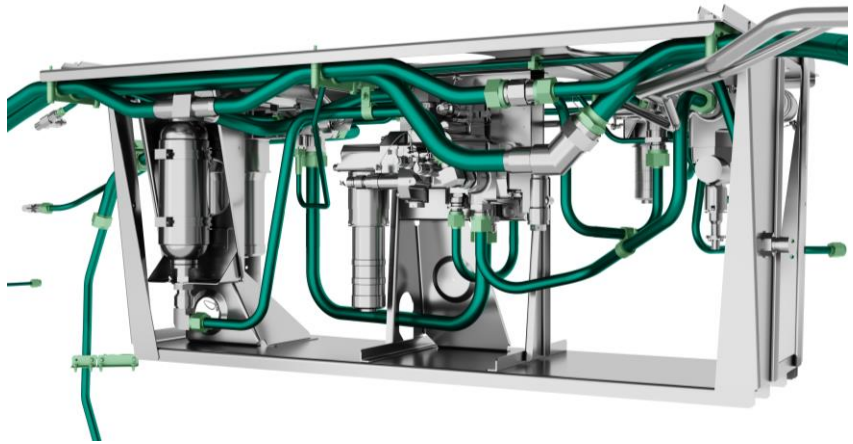
© 2018 by IILS mbH. Design Compiler 43® with Routing-Plugin

(Harness shown was automatically generated in approx. 15 mins on PC with i5@3,2GHz, 32GB RAM)

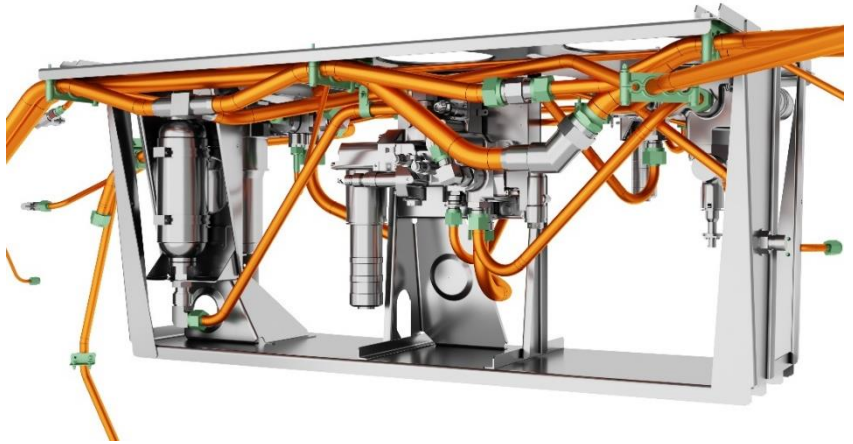


CAD model courtesy © 2018 by IRS
(Institute for Space Systems, University of Stuttgart)
with integrated wire harness generated automatically in DC43® Routing-Plugin

Design Cockpit 43® Piping-Plug-In



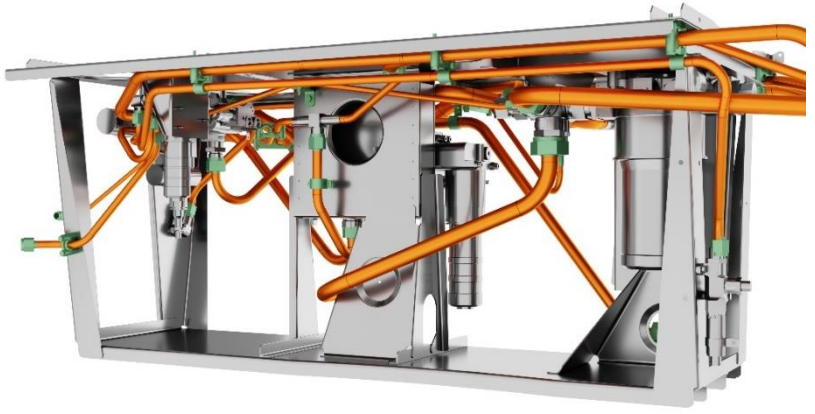
manually designed series solution AIRBUS A320
(pipe lengths 22.6 [m], 107 bends)



© 2022 Aerospace
Neumaier, M.; Kranemann, S.; Kazmeier, B.; Rudolph, S.:
Automated Piping in an Airbus A320 Landing Gear Bay Using Graph-Based Design Languages.
Aerospace 2022, 9, 140.
https://doi.org/10.3390/aerospace9030140

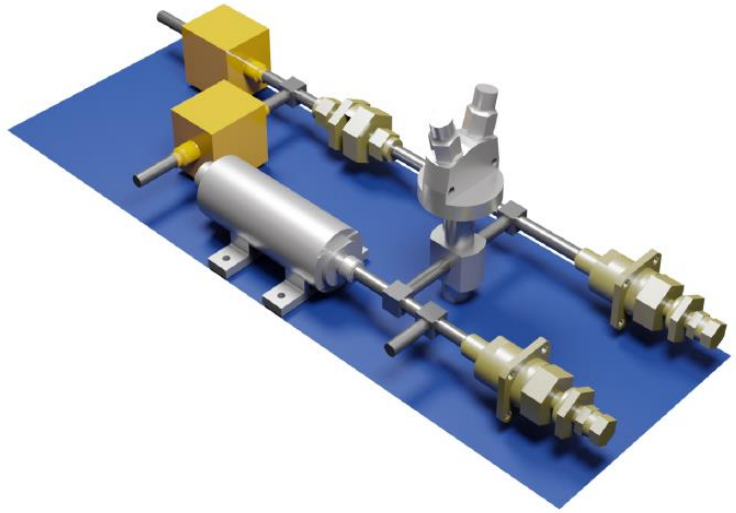
© H2020 CleanSky2 Project PHAROS
Physical Wing Architecture Optimization System
https://cordis.europa.eu/project/id/865044

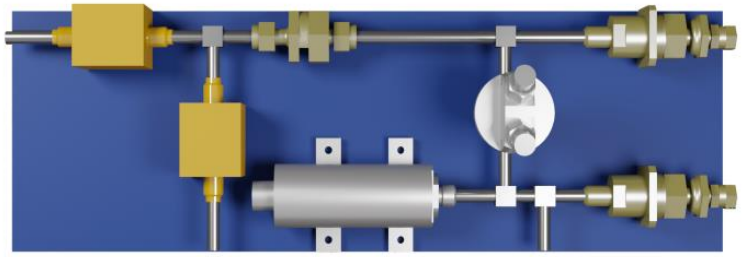
DC43® extensions (planned for 2023/2024)
- real-time pressure drop prognosis using pre-trained neural networks
- off-line automated full 3D fluid flow simulation for pressure drop validation
- inclusion of artificial intelligence techniques to learn from experience (e.g. simulation)



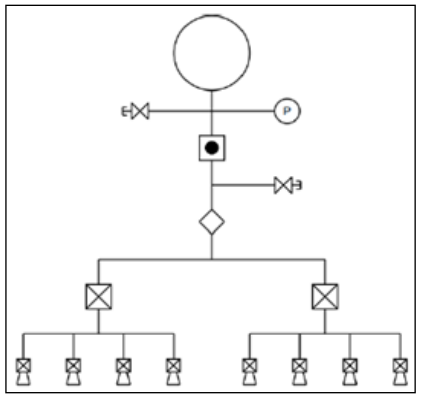
DC43® automatically generated solution
(pipes lengths 20.414 [m], 95 bends)
10% length and weight savings with 12 bends less

Design Cockpit 43® Packaging Plug-In



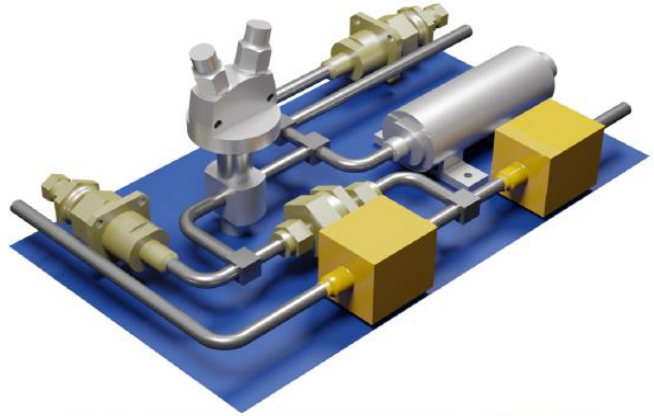


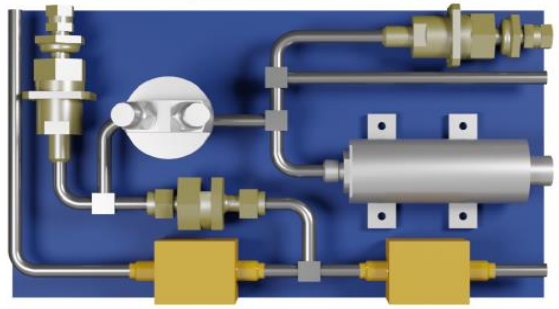
automatically generated packaging in DC43®
(bendings forbidden, area 457 cm²)



packaging algorithm
maps logical architecture

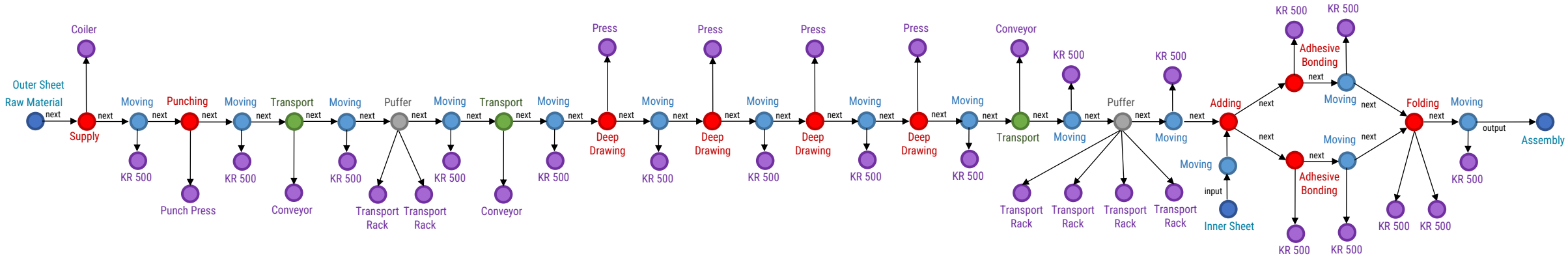
to physical architecture
w/o side-constraints





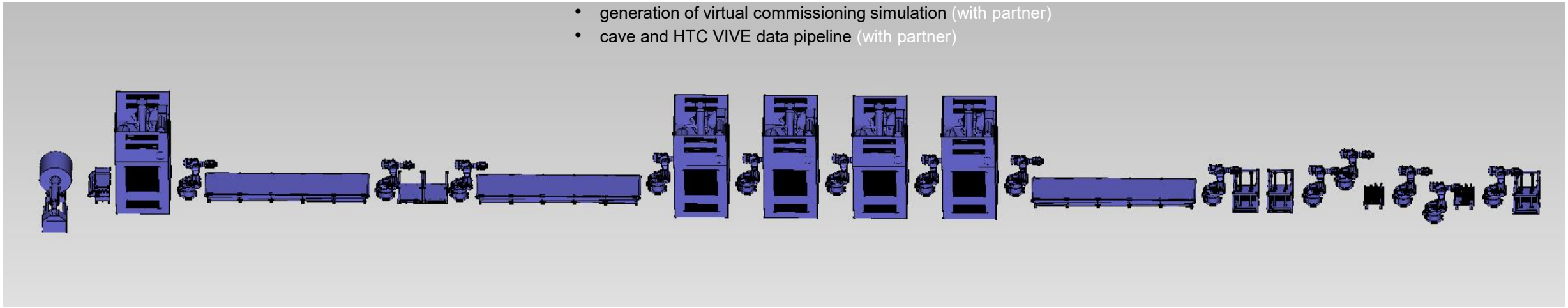
automatically generated packaging in DC43®
(bendings allowed, area 361 cm²)
22% space savings by 6 bends

Design Cockpit 43® Digital Factory-Plug-In



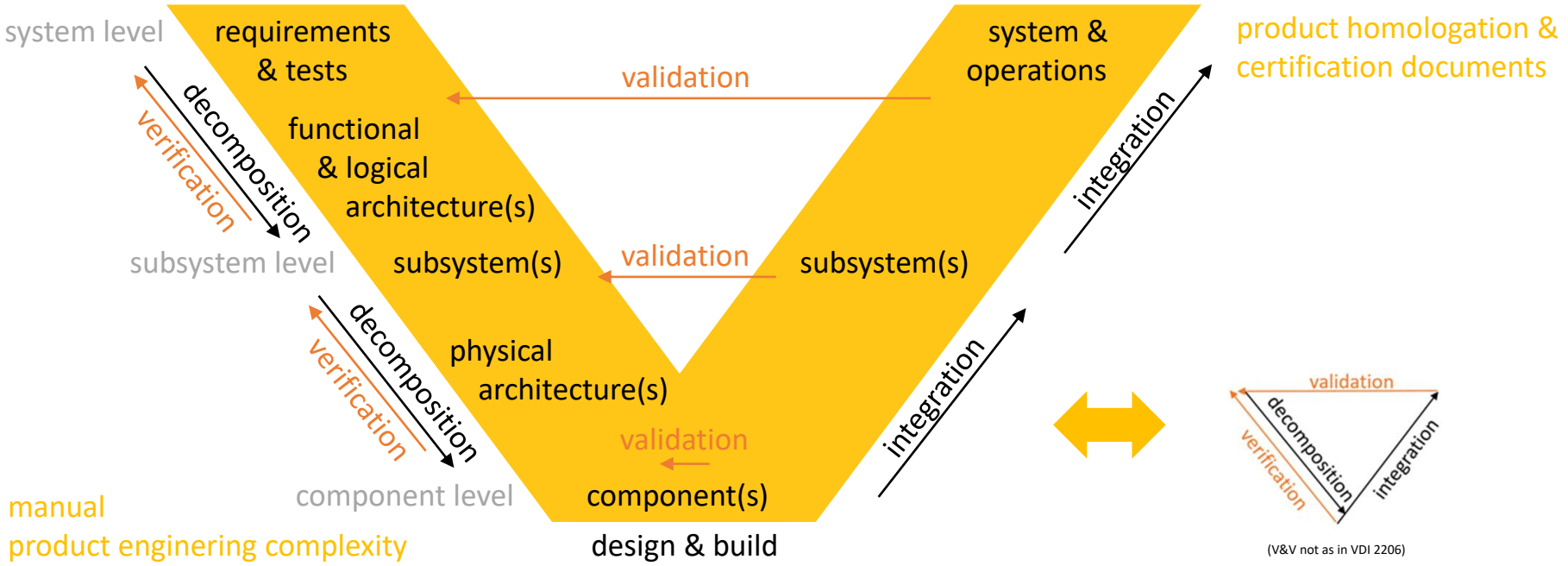
digital factory in Design Cockpit 43®

- algorithmic layout and throughput optimization of transfer line (with partner)
- generation of virtual commissioning simulation (with partner)
- cave and HTC VIVE data pipeline (with partner)

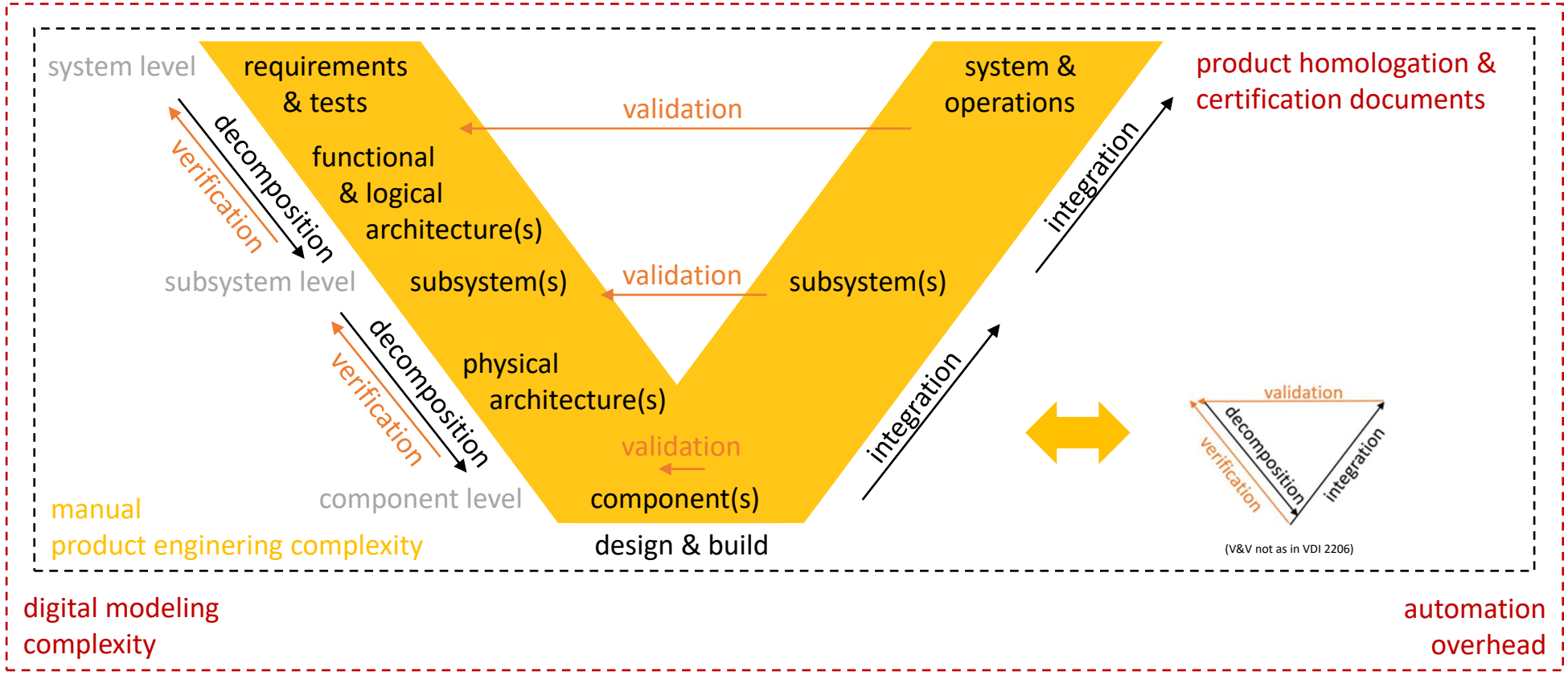


© 2020 by IILS. Modeled, programmed and generated with Design Compiler 43® with Digital Factory-Plugin

machine-executable MBSE V-model



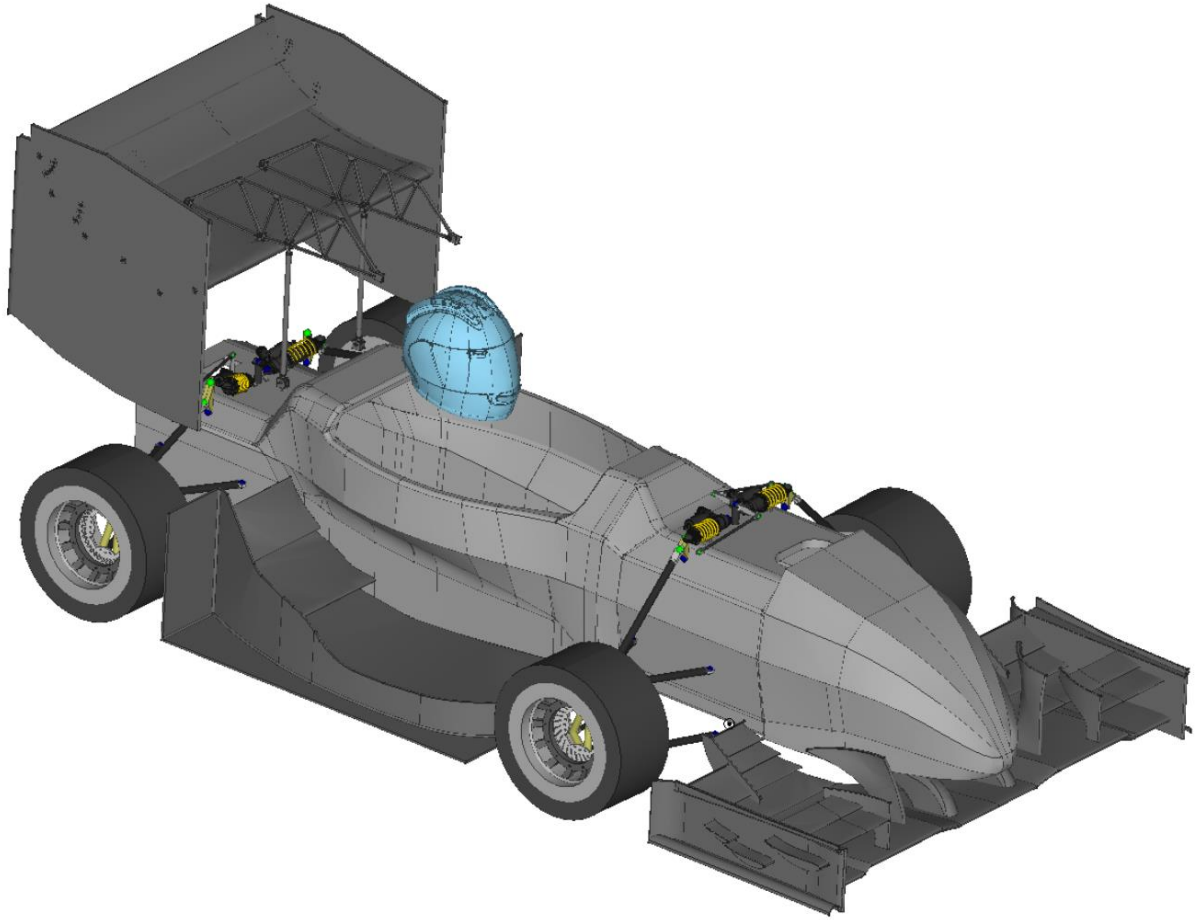
design languages complexity overhead

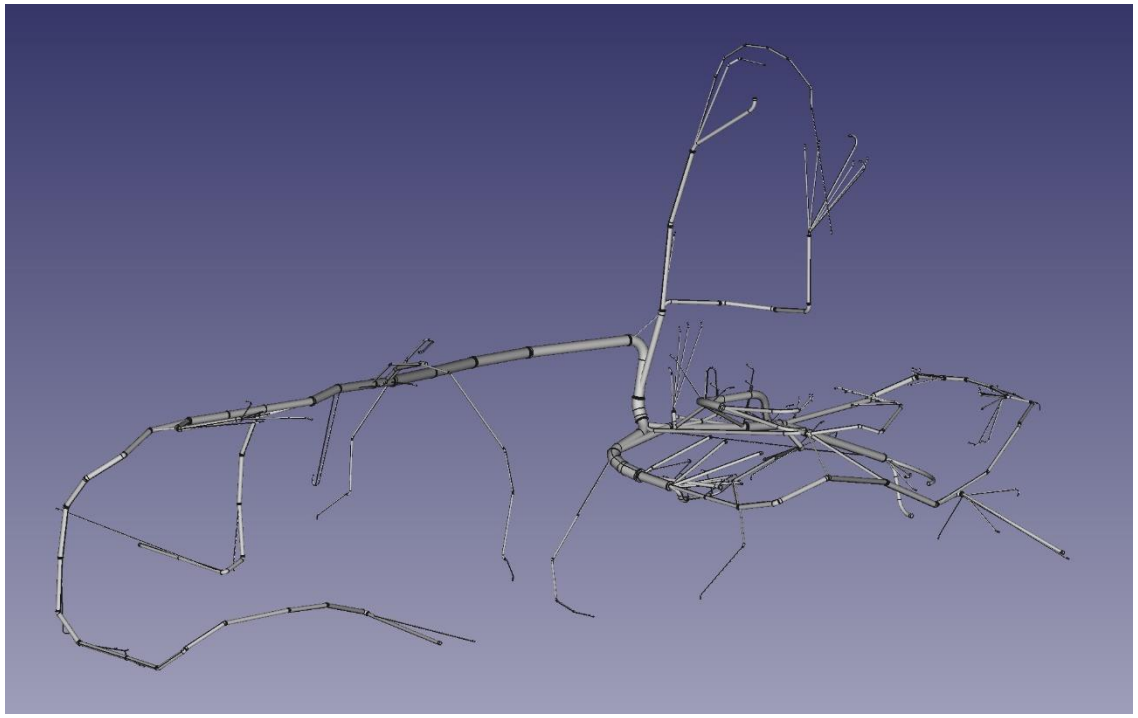


Formula Student racecar generation in Design Cockpit 43®

8 Rennteams: Weingarten, Kiel, Pforzheim, Darmstadt, Schweinfurt, Stuttgart, Hamburg und Manchester use Design Cockpit 43®

FS Pforzheim harness generation in Design Cockpit 43®





digitalization paradigms

Engineering as Code (EaC)

coding of an engineering task in design languages

Engineering as a Service (EaaS)

combining services in DesignCockpit43® process chains

references and contact

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Pfaffenwaldring 31, D-70569 Stuttgart
rudolph@ifb.uni-stuttgart.de

wire harness design

- Weil, R.: Entwicklung und Implementierung einer Softwarearchitektur zur automatisierten Leitungssatzgenerierung, Dissertation Universität Stuttgart, 2024. 10.18419/opus-15288
- Weil, R.: 3D-Kabelbaumentwurf automatisieren, 2025. https://www.leitungssatz-hub.de/wp-content/uploads/IILS_3D-Kabelbaumentwurf__2025-11-04_update.pdf
- Eheim, M. et al.: On Automation Along the Automotive Wire Harness Value Chain, SCAP2020. https://doi.org/10.1007/978-3-662-62962-8_21
- ARENA2036 Transformationshub Leitungssatz https://www.leitungssatz-hub.de/technologien/3d-kabelbaumentwurf-automatisieren/
- ARENA2036 Video 3D-Kabelbaumentwurf automatisieren, 2025 (ganz unten auf der Seite)
  https://www.leitungssatz-hub.de/en/technological/Automating-3D-wiring-harness-design/

digital factory twin wire harness

- EU-project FORTIFIER https://www.era-learn.eu/network-information/networks/manunet-iii/manunet-call-2020/aritifical-intelligence-enhanced-digital-factory-twins-for-wire-harness-manufacturing
- H2020 CS2 Project PHAROS Physical Architecture Optimization System https://cordis.europa.eu/project/id/865044)
- Schuchter, T.: Digital Integrated Design and Assembly Planning Processes for Sports Vehicles Using the Example of a Skateboard https://www.mdpi.com/2624-8921/7/1/22

software wire harness

- IILS mbH, Software Design Cockpit 43® (DC43®) https://www.iils.de
  IILS mbH, DC43® Harness https://www.iils.de/en/product/dc43_harness/#dc43_harness
- Video Entwurfsmethodik https://www.youtube.com/watch?v=lic7iGzwWqs (Entwurfsautomatisierung, Teaser, 1 min)
- Video Kabelbaumentwurf https://www.youtube.com/watch?v=D9eHhdaIVqI&t=2s (3D-Kabelbaumentwurf, 30 min)

vision-based cable insertion

- Mahmoud, A.: You Only Orient Once (YOOO): Vision-Driven Robotic Cable Insertion https://am-robo-projects.github.io/cableOrienter/

Formula Student

- Entwurfsautomation Rennauto https://doi.org/10.3390/vehicles8010024
- Variantenmanagement Rennteams https://doi.org/10.3390/vehicles8020043