

Design languages for multi-disciplinary architectural synthesis and analysis of complex systems in the context of an aircraft cabin

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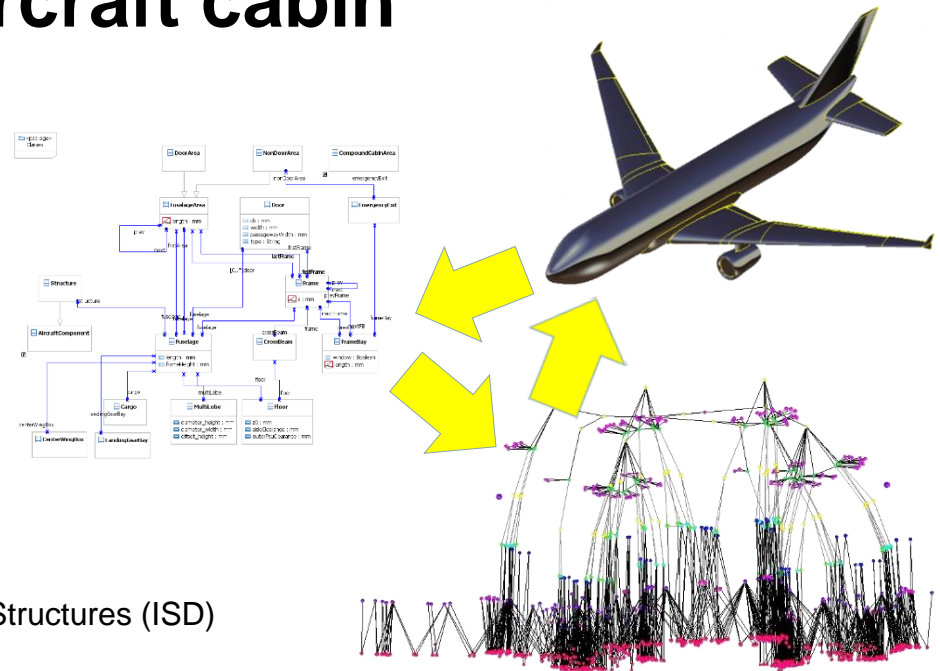
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outline

Why

using graph-based design languages?

How

using graph-based design languages
aircraft cabin (3D geometry and 3D network routing)

More

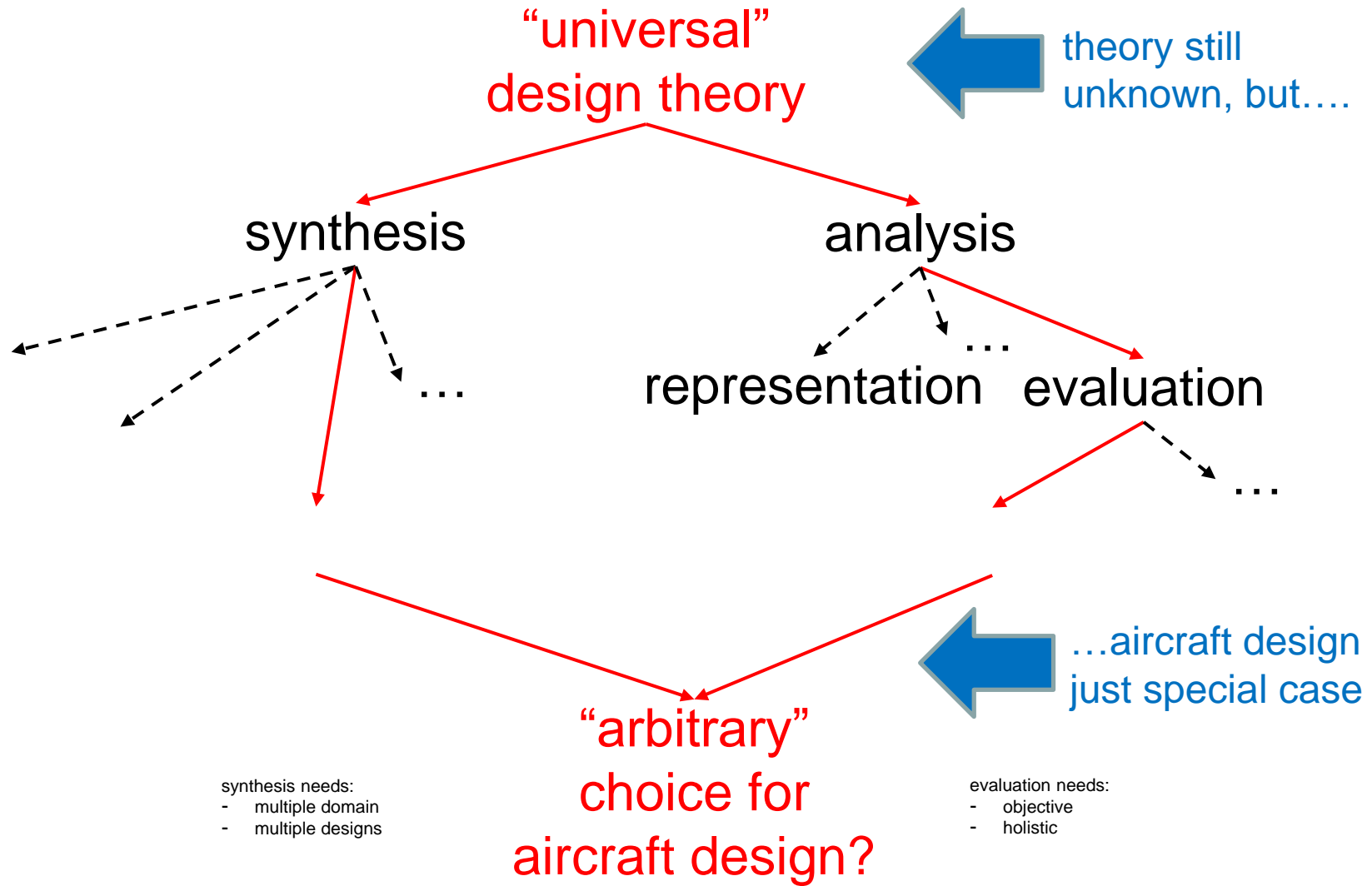
digital factory, fault-tree analysis, ...
fiber-reinforced structures

Future

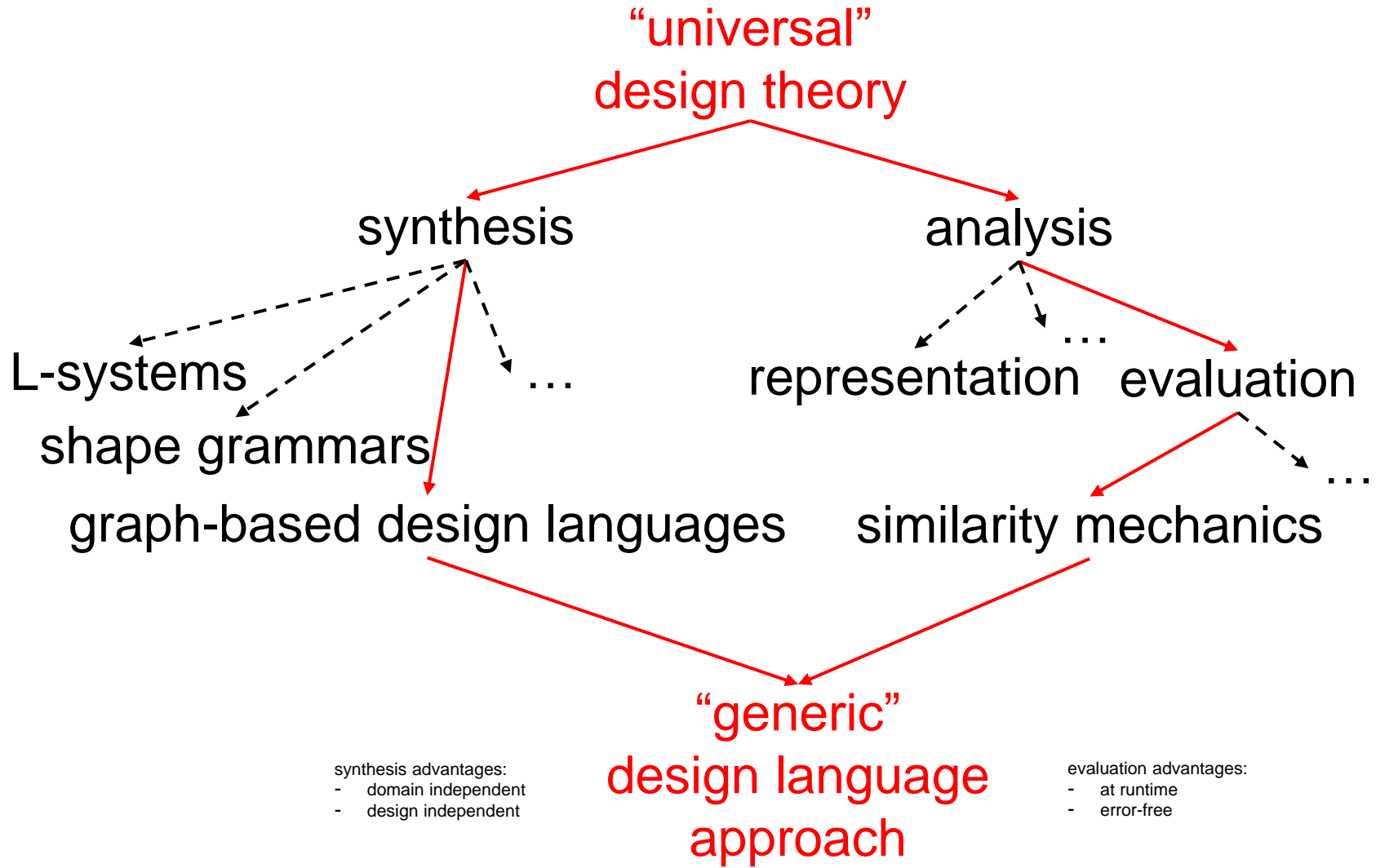
cooperation possibilities (EU-and national projects)
workshop in Stuttgart March 2015



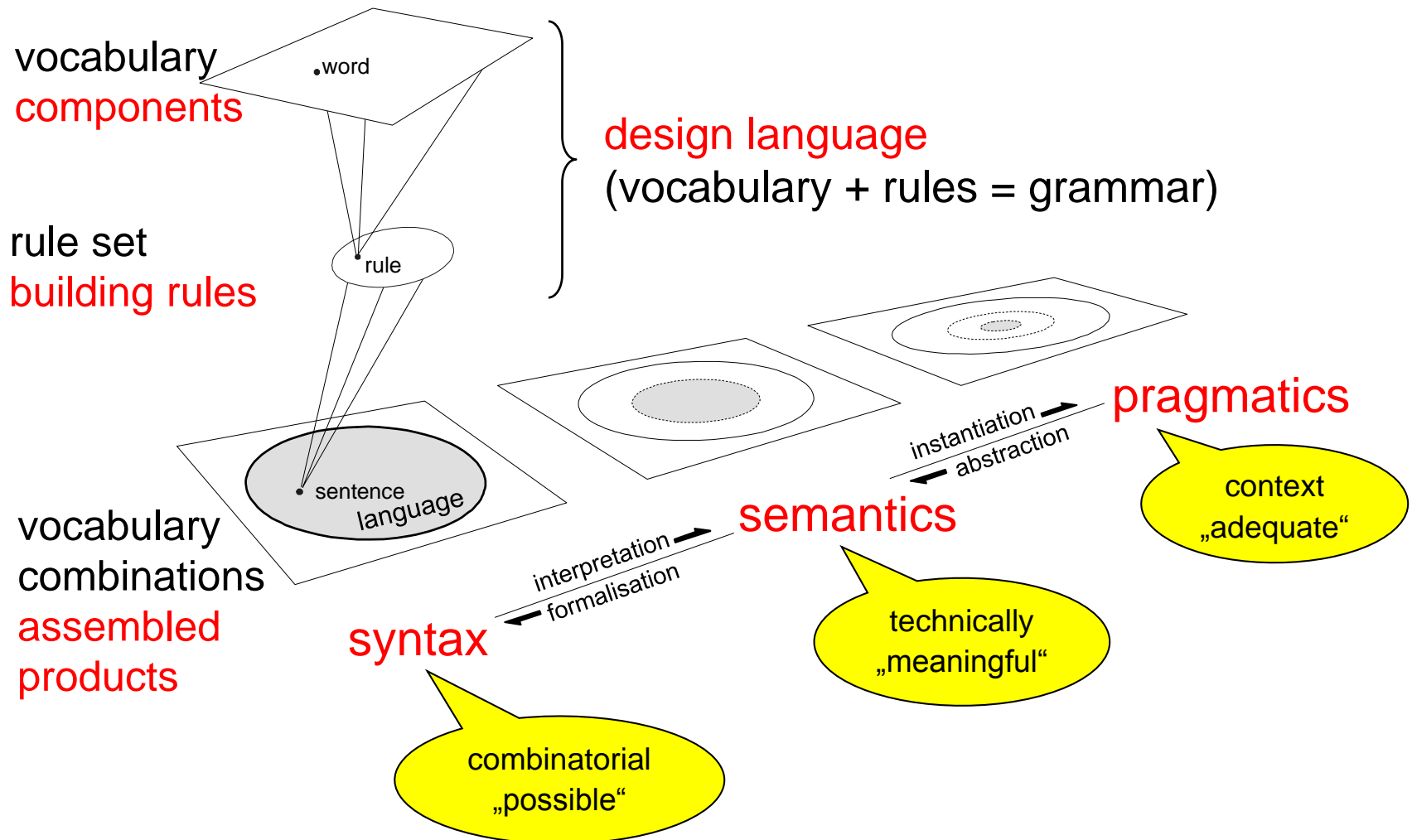
research question



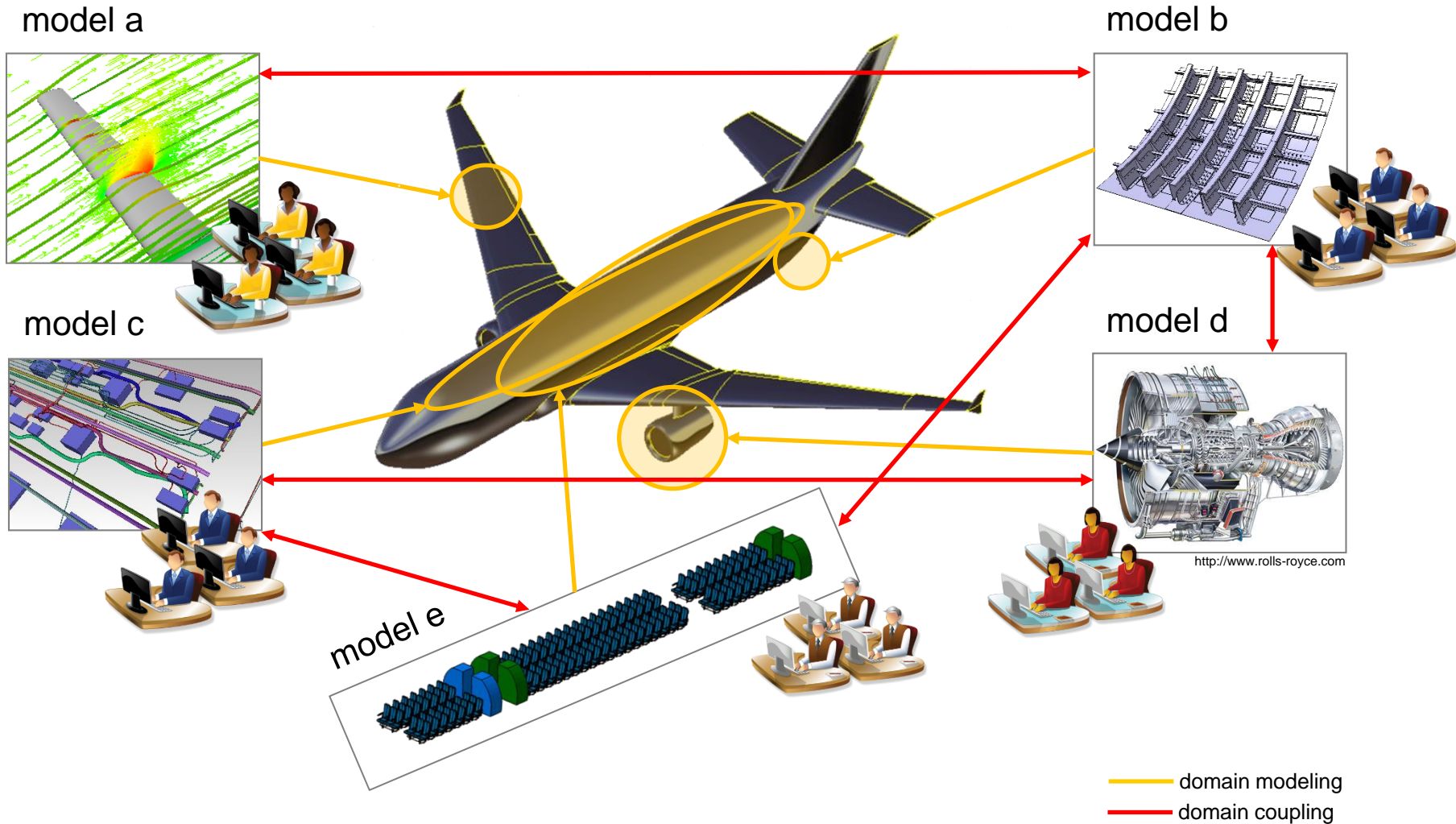
research assumption



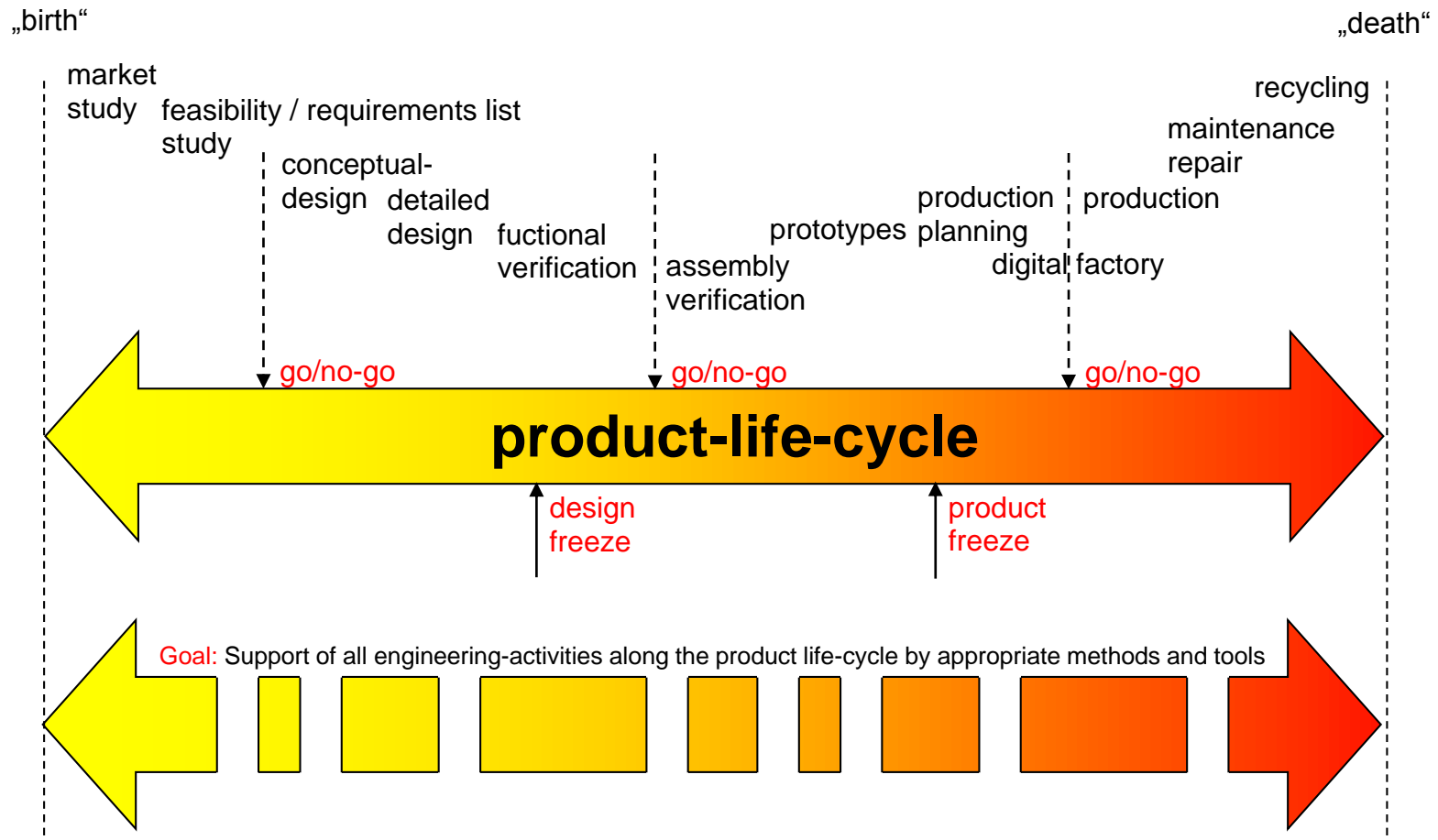
design languages



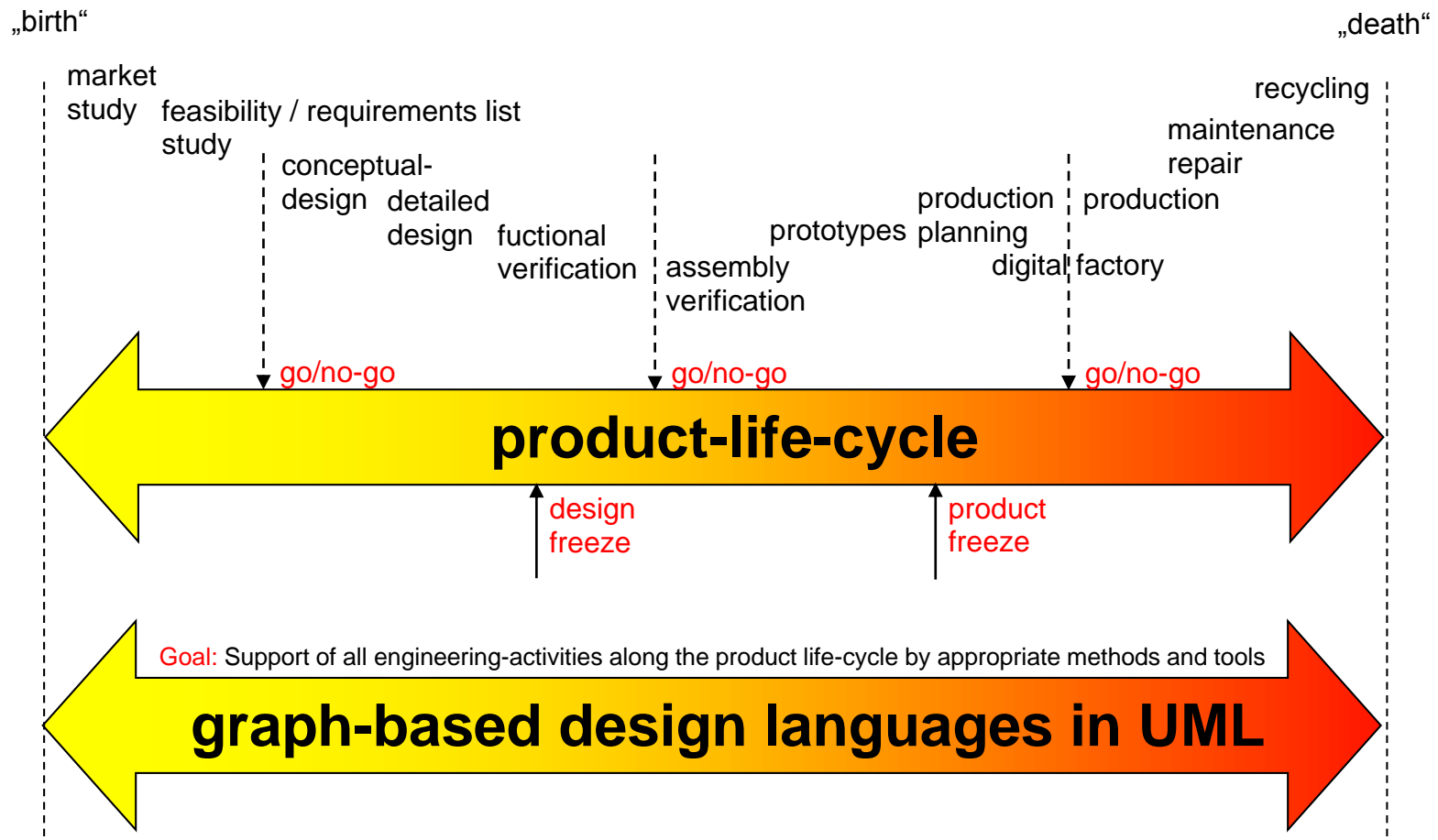
system of systems



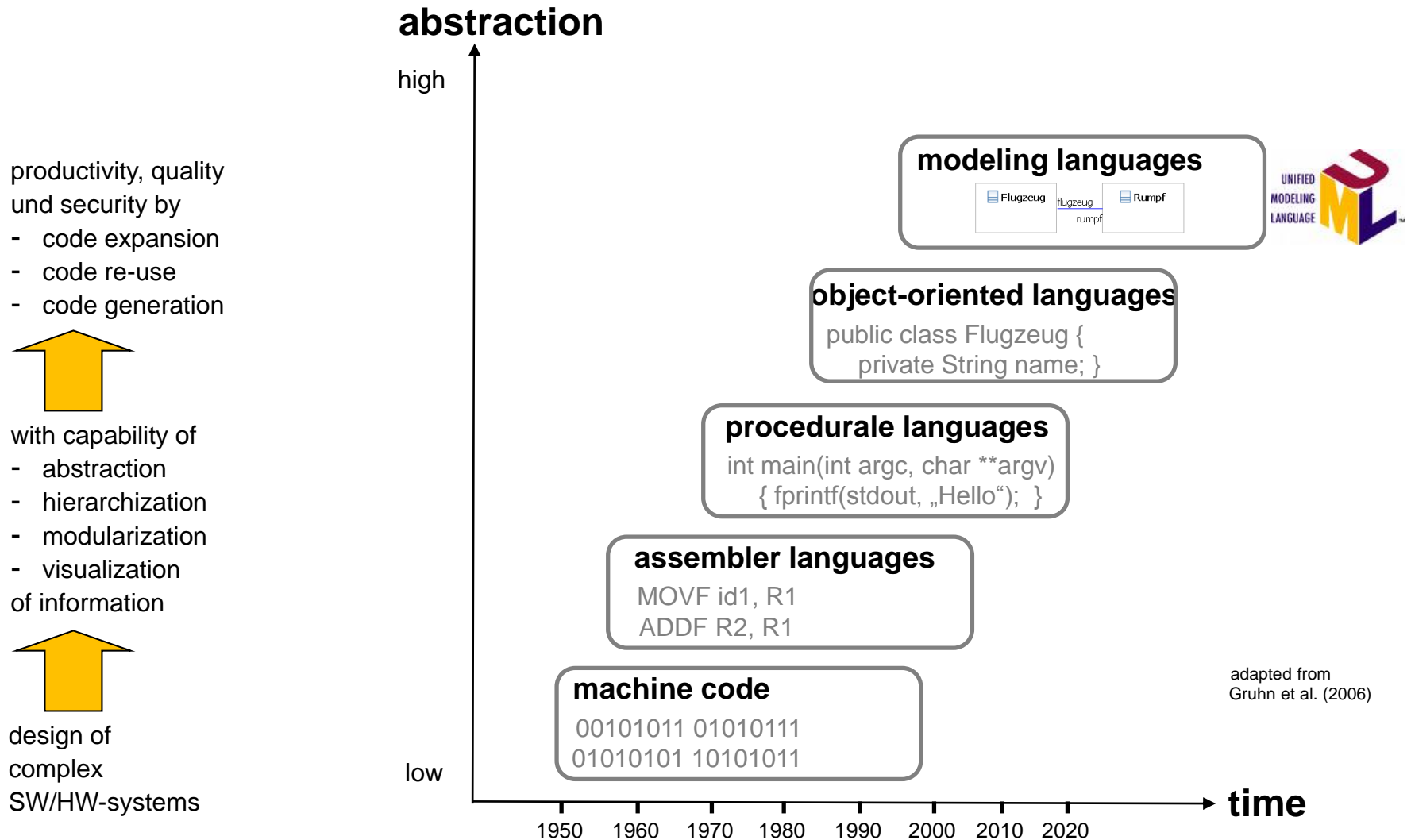
„The“ problem



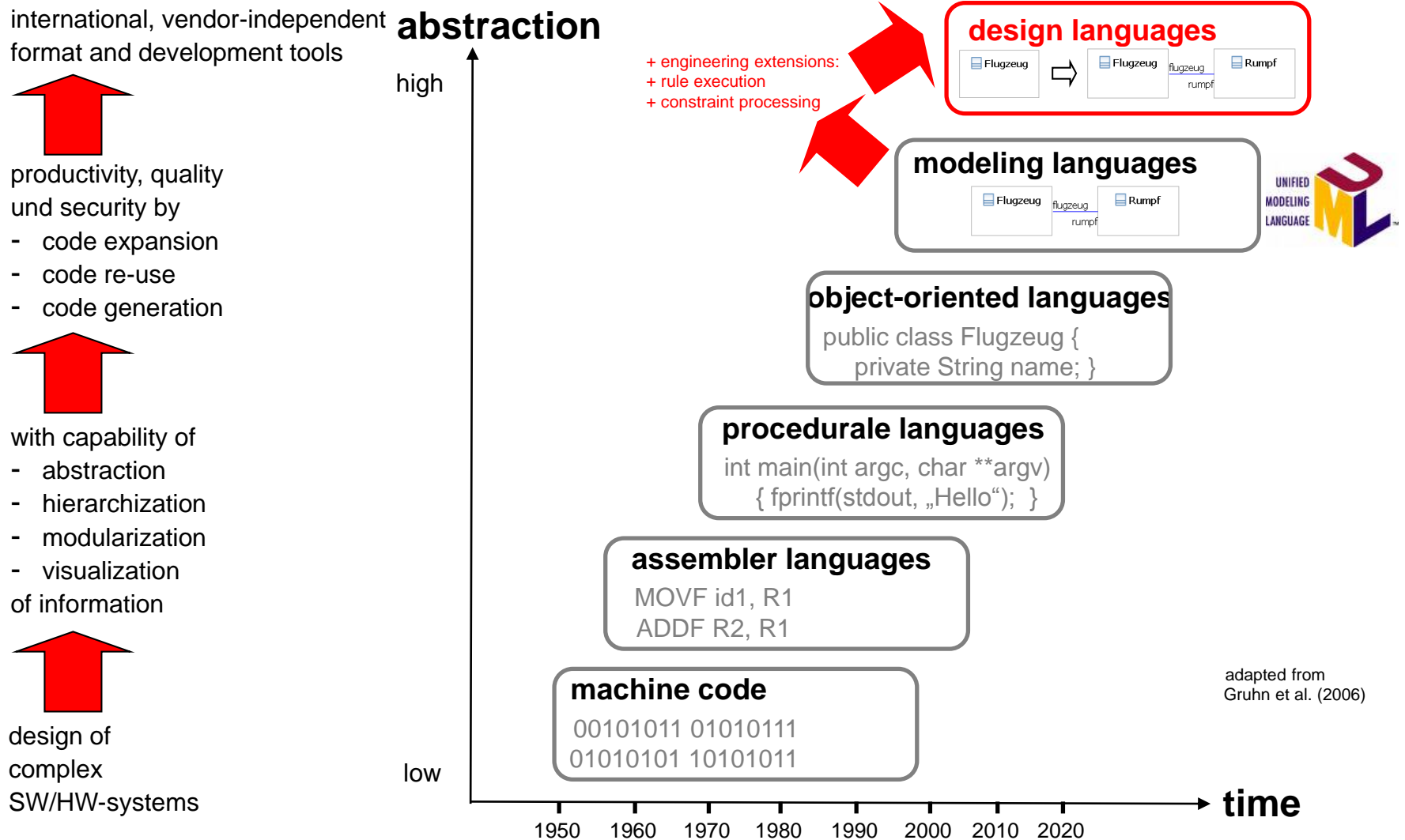
„The“ solution



evolution of programming languages



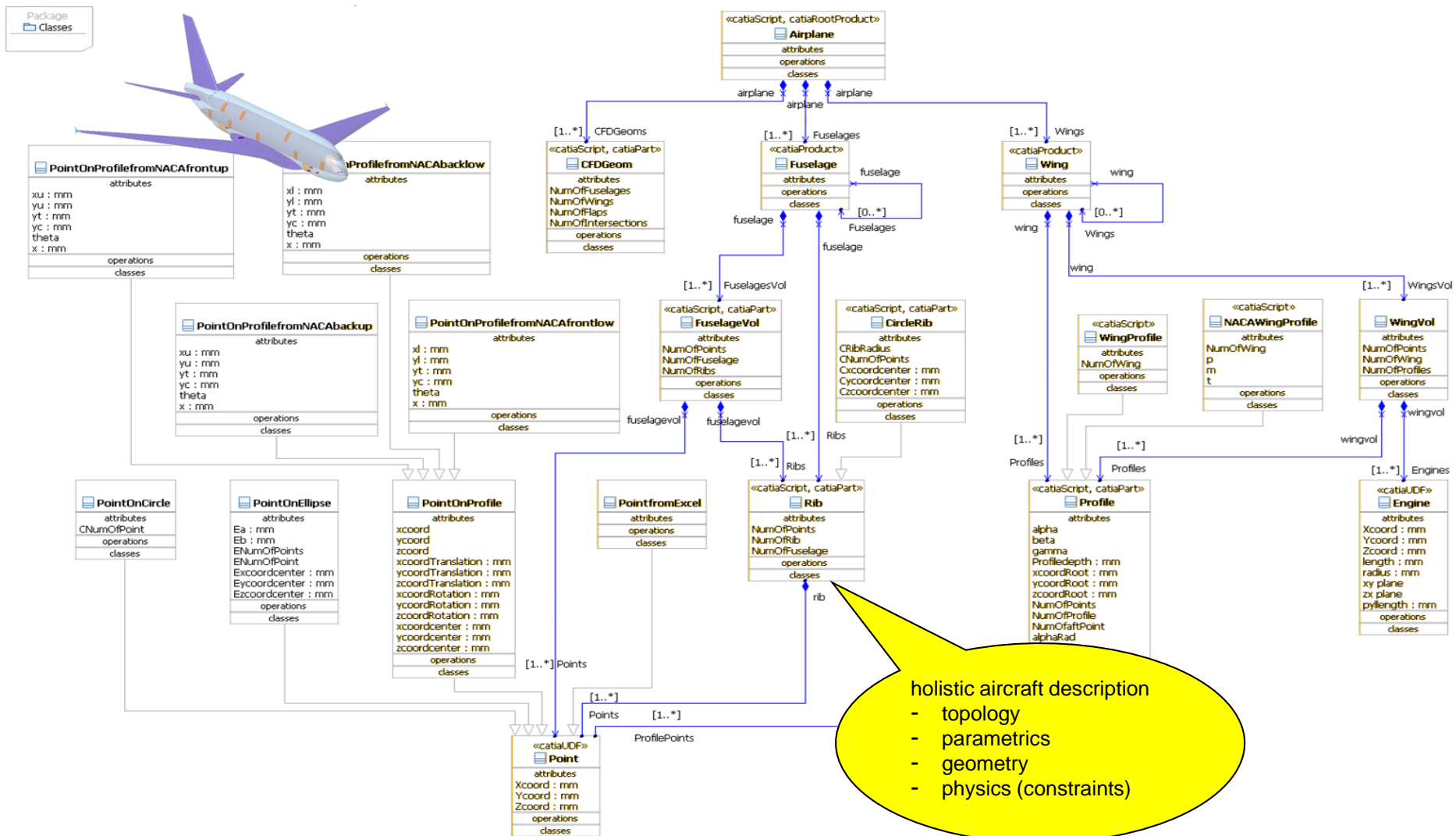
evolution of **design** languages



class decomposition

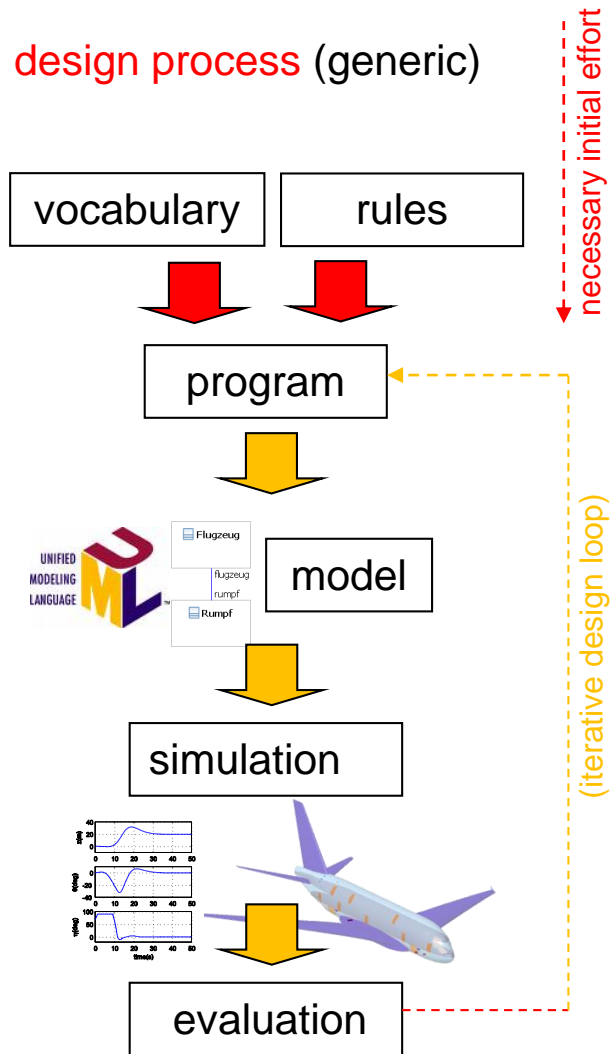


UML class diagramm



graph-based design language (in UML)

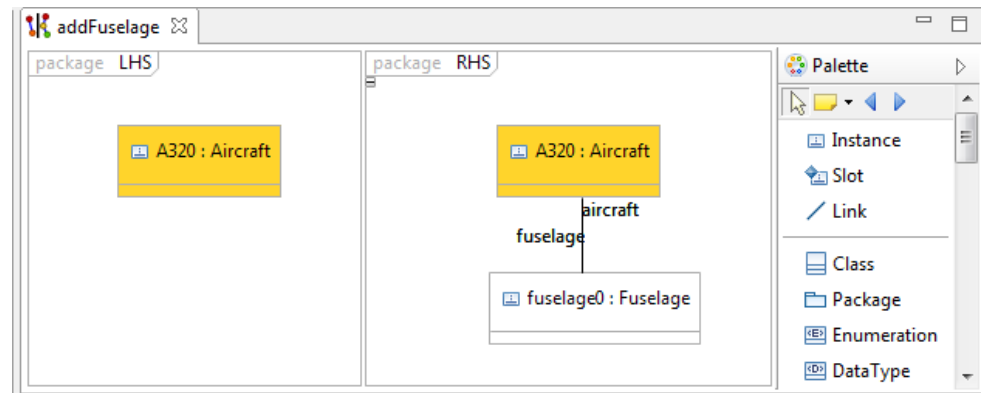
- **design process** (generic)



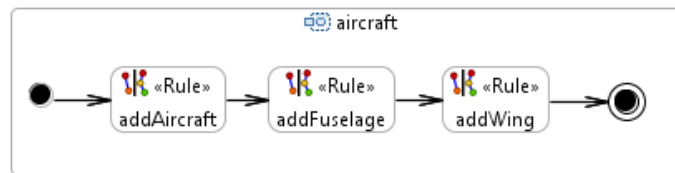
- **vocabulary** (as UML classes)



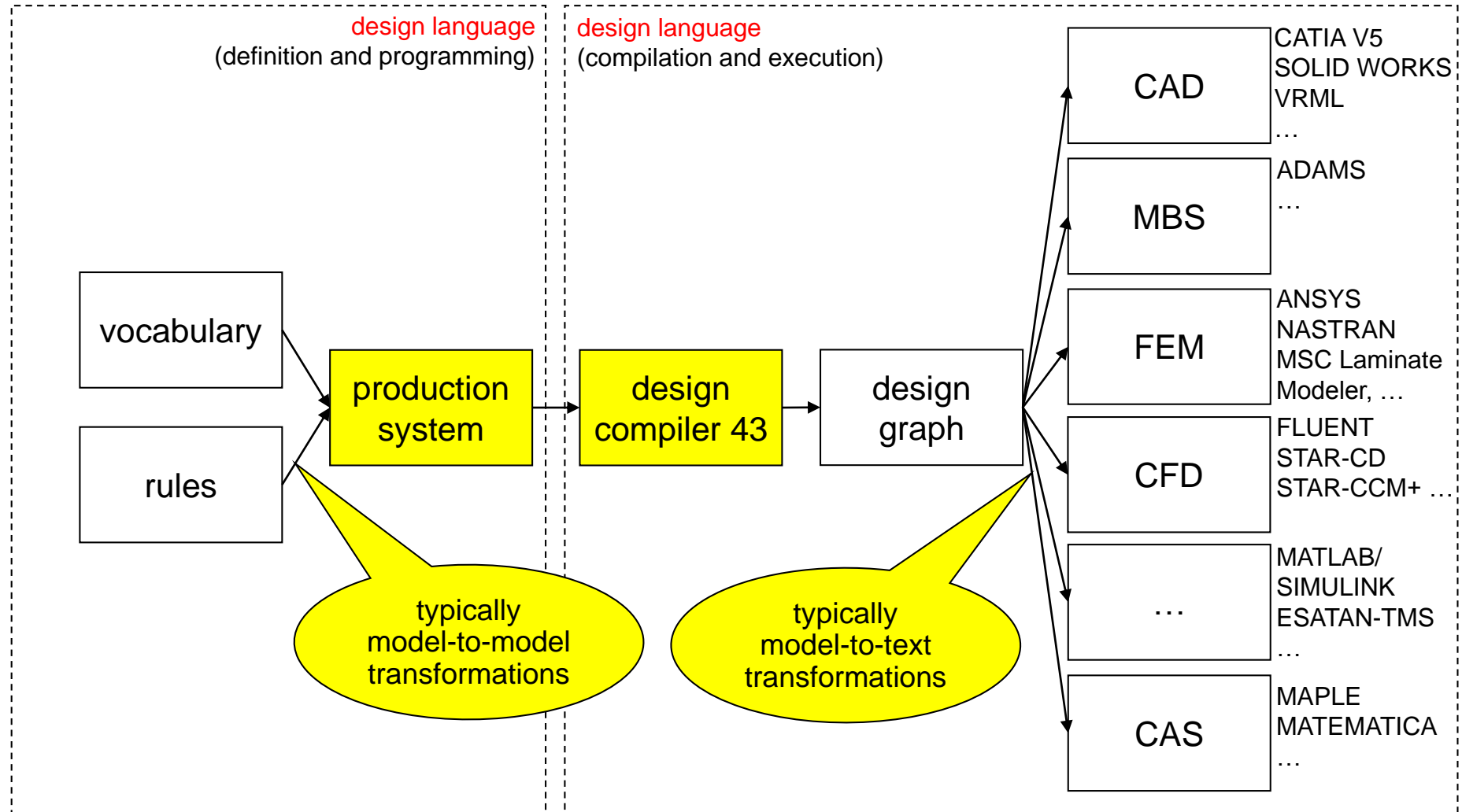
- **rules** (as UML model-transformations)



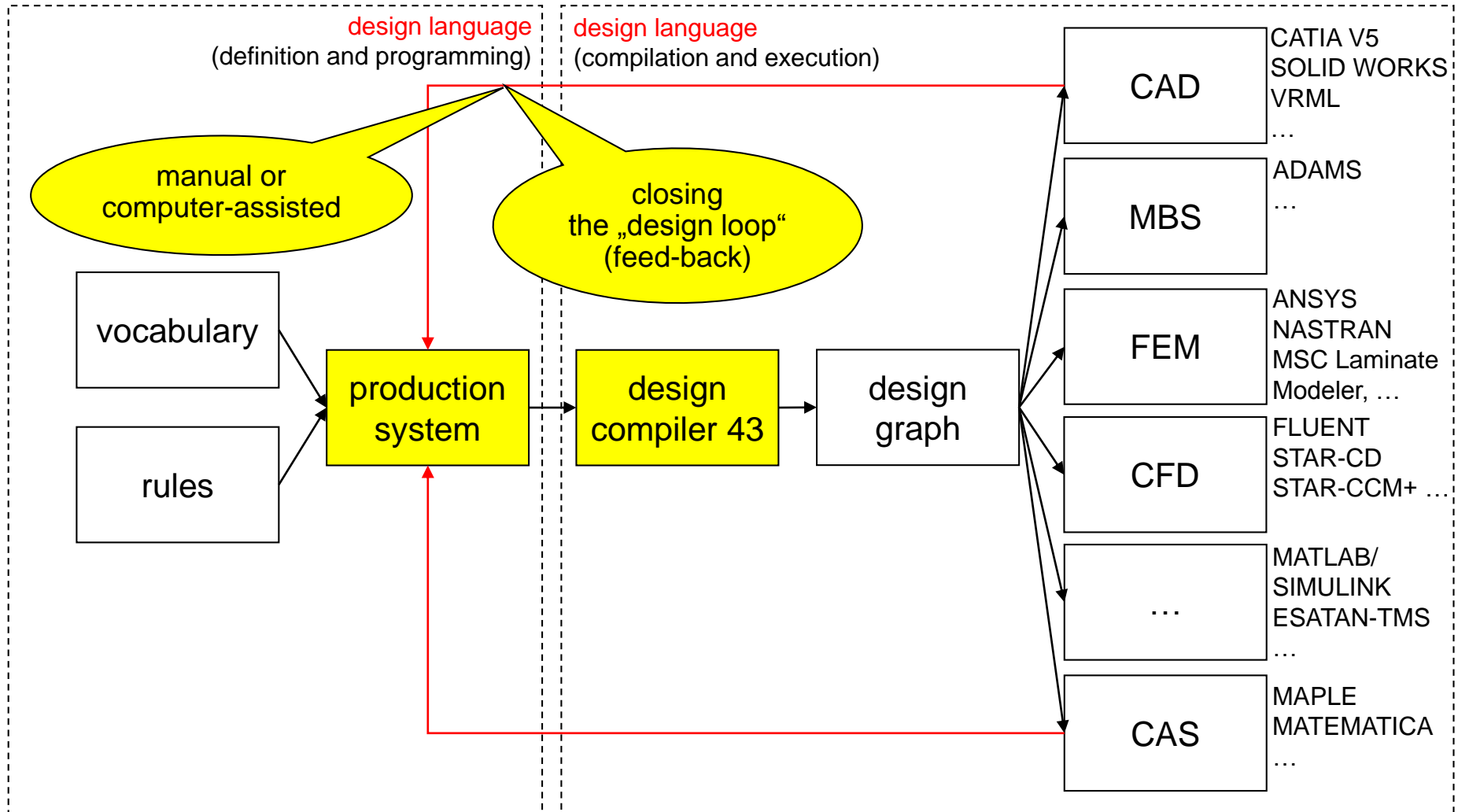
- **production system** (as UML activity diagram)
consists of a sequence of design rules



design language



design loops



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Future

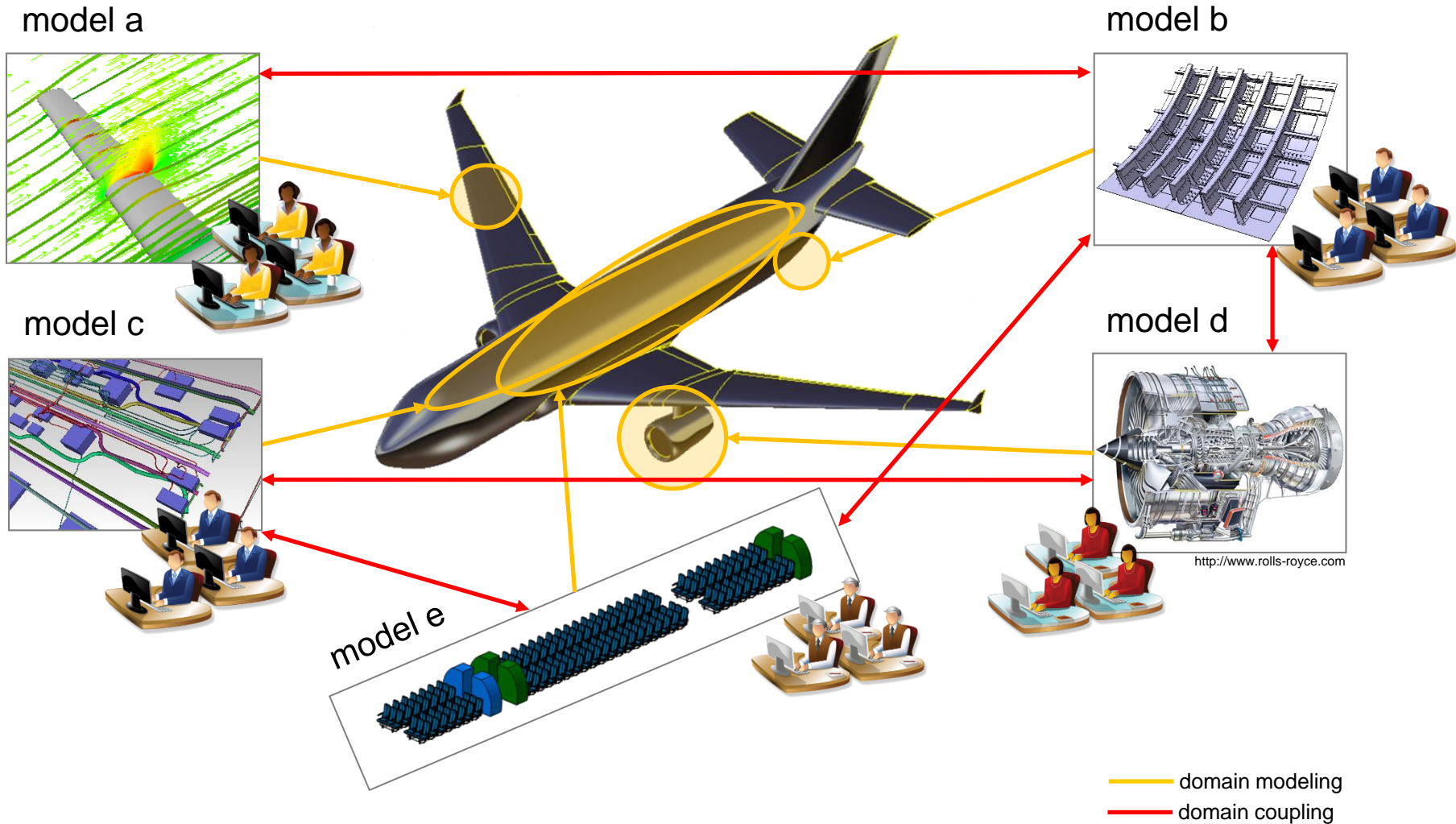
cooperation possibilities (EU-and national projects)
workshop in Stuttgart March 2015



aircraft cabin (**geometry** + **systems** + ...)

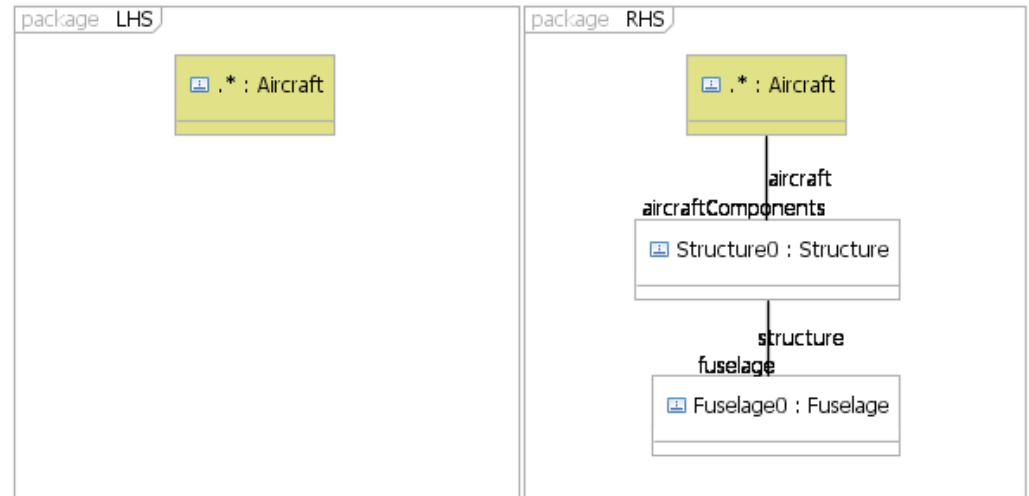
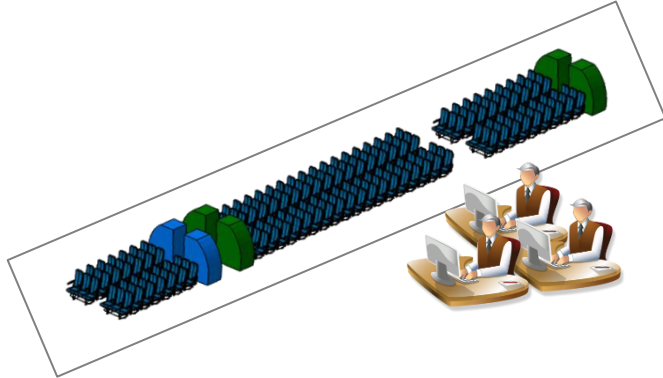


system of systems

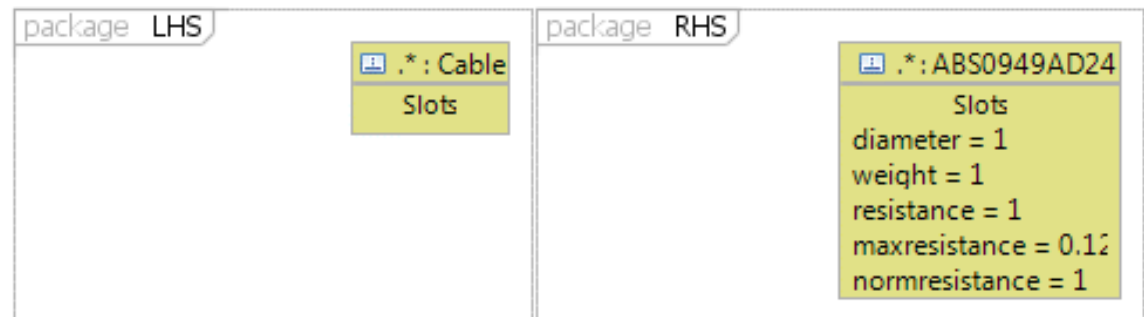
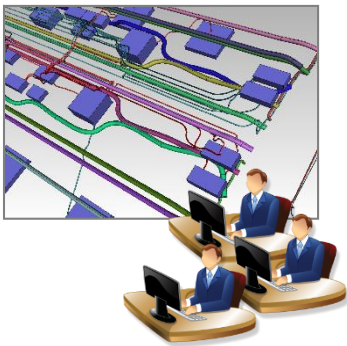


rule definition (M2M-transformation)

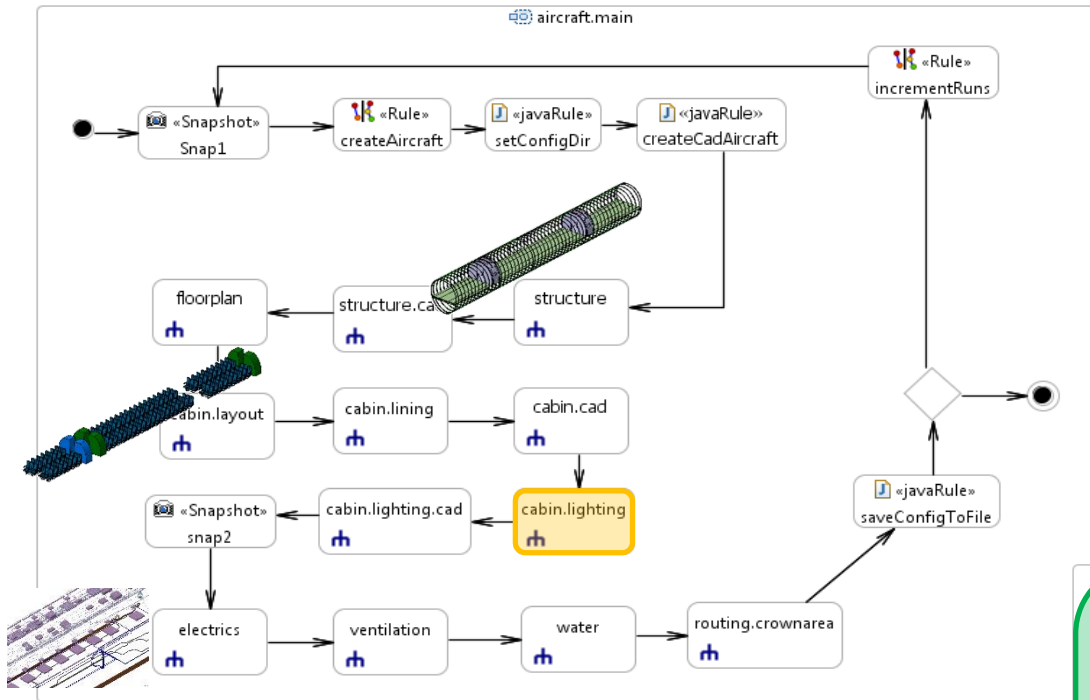
domain expert(s) → **rule:** add instances to an existing instance aircraft



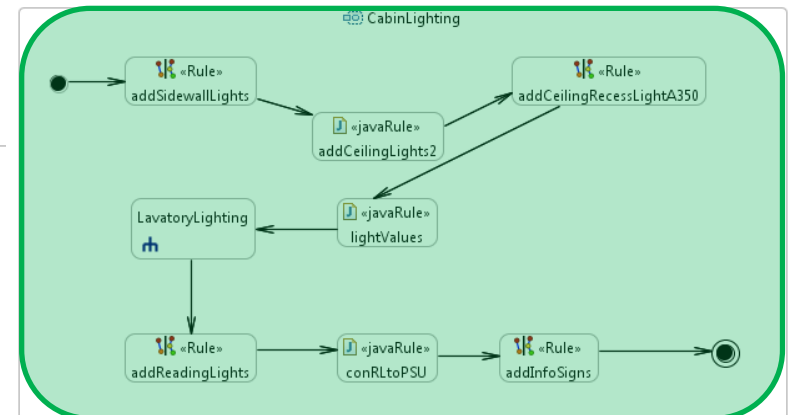
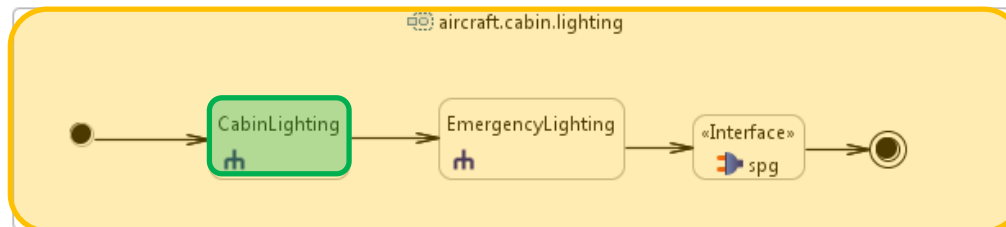
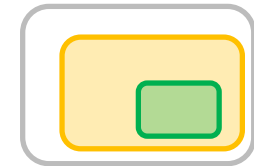
domain experts → **rule:** specialization of a generic cable to a specific type (cast, slots added)



production system (activity diagram)

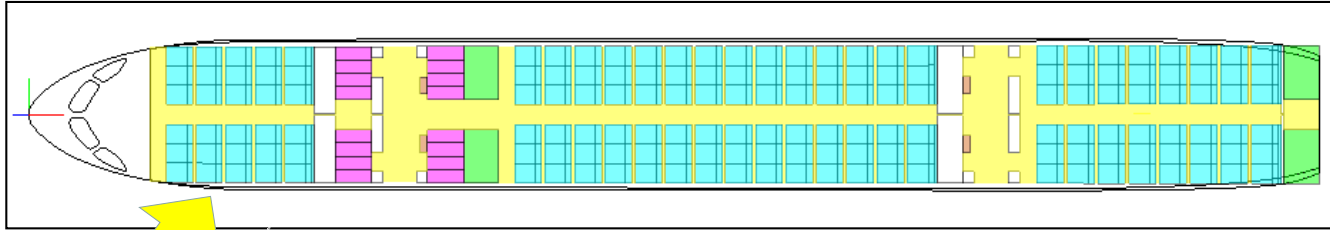


Hierarchical nesting of production systems in aircraft cabin design language

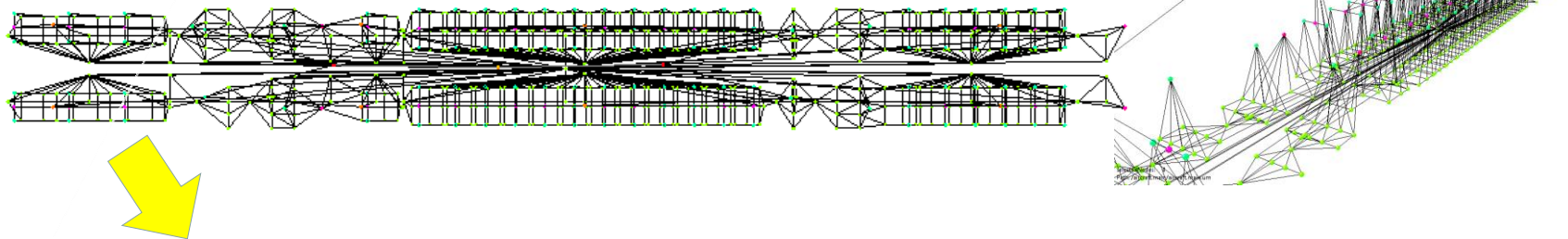


cabin layout

layout design language: calculation of layout according to requirements



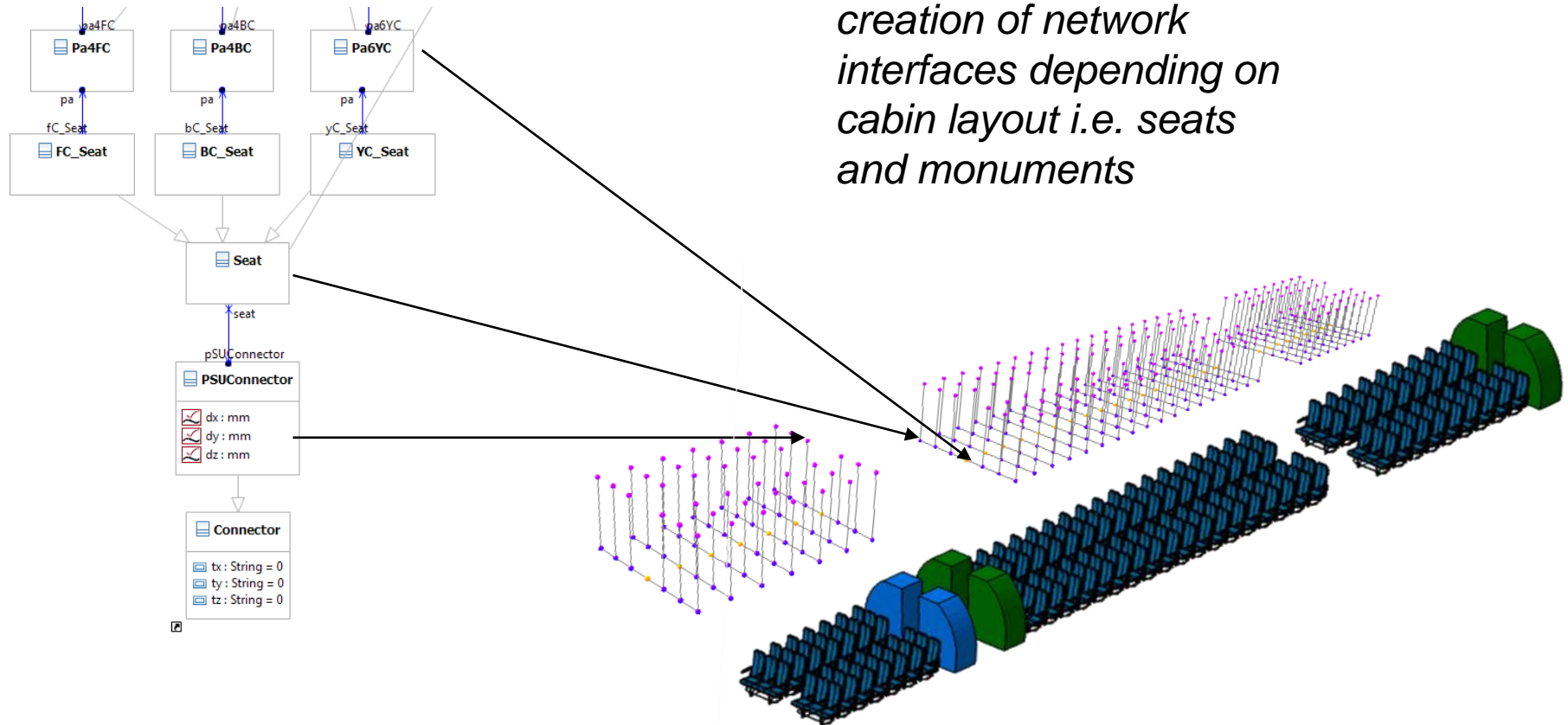
design graph: data structure of the cabin layout



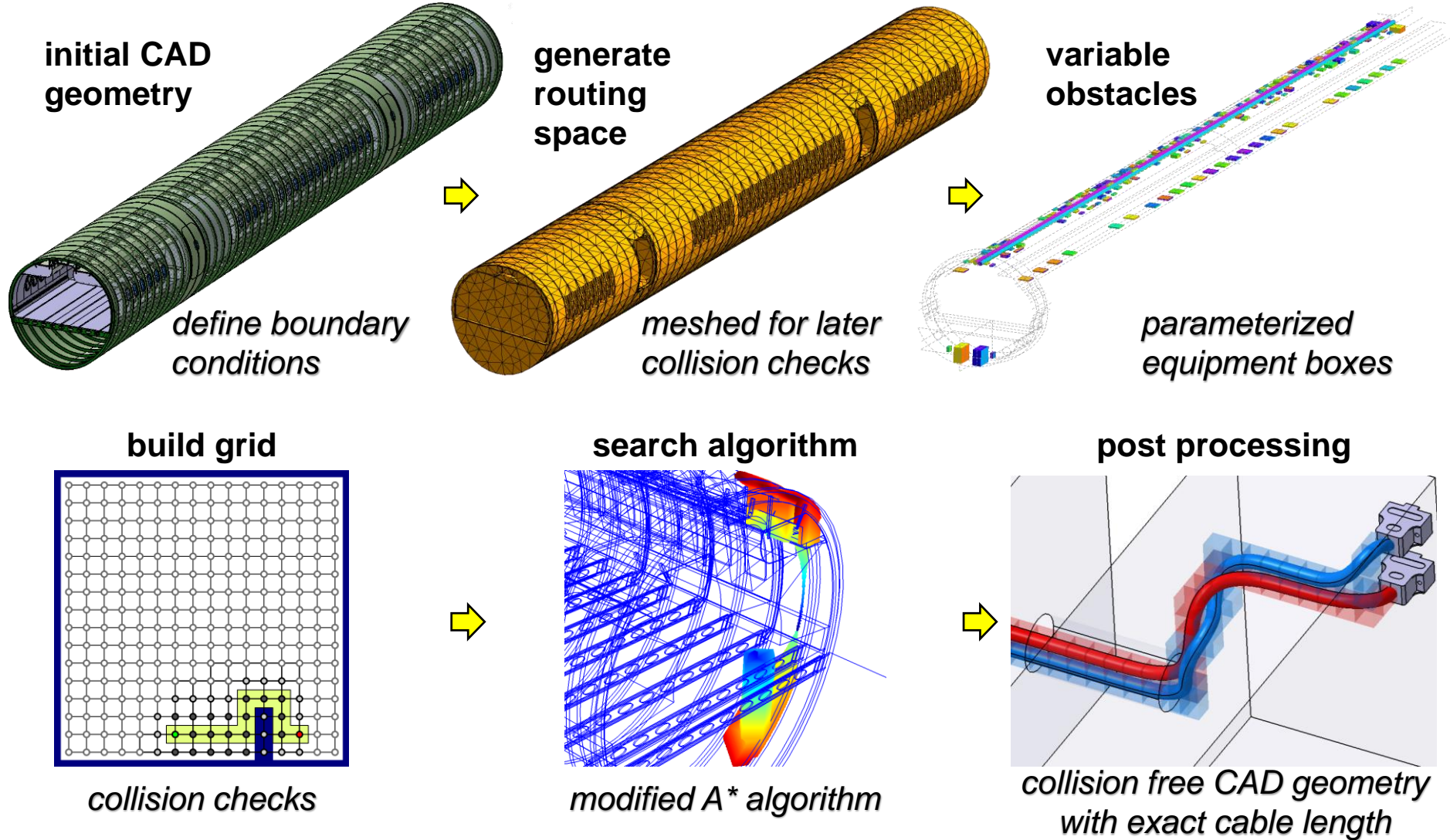
geometry design language: generation of aircraft cabin geometry



from cabin layout to network

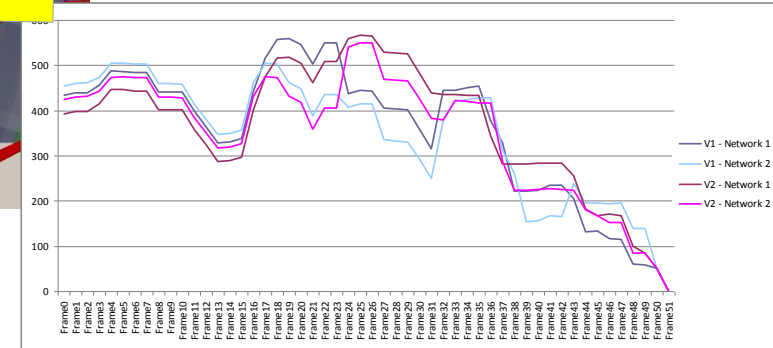
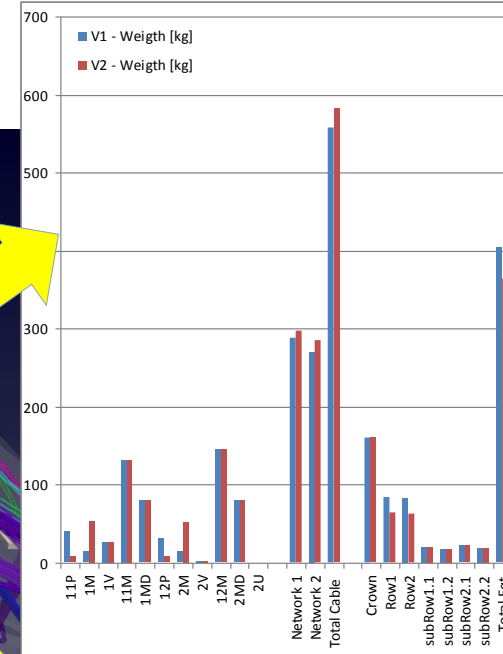
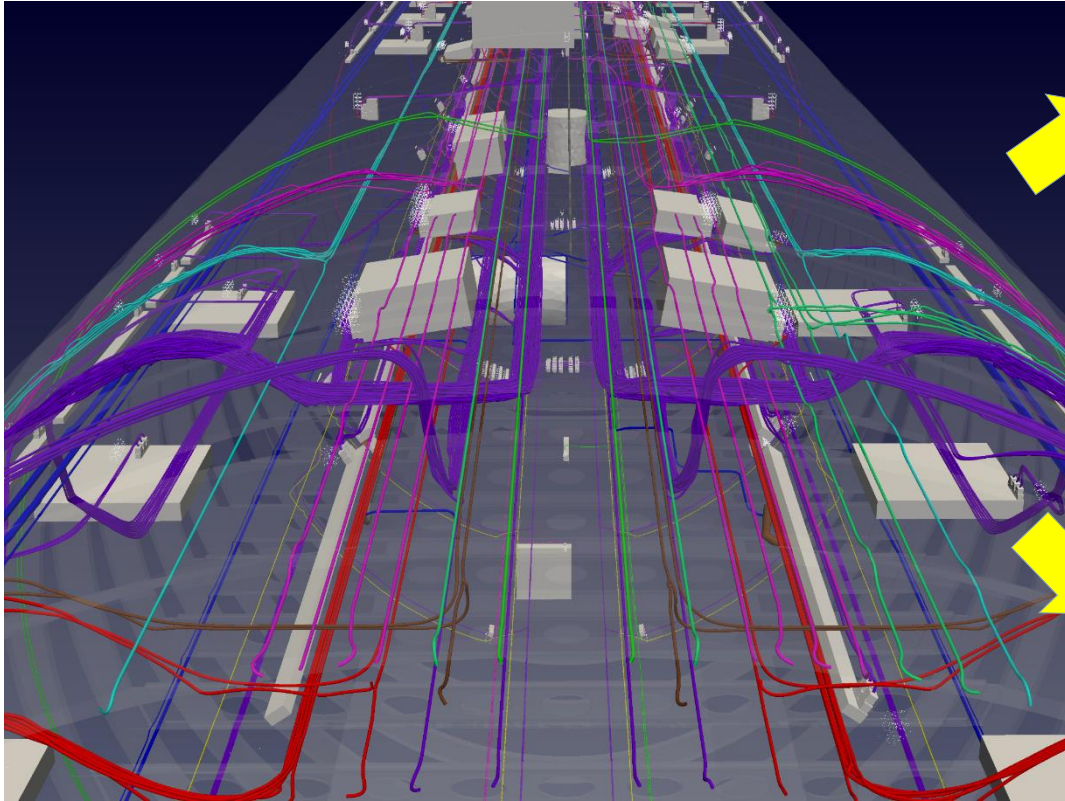


network generation and full 3-D routing



design trades (2 network variants)

design trade: 8 versus 4 SPDBs



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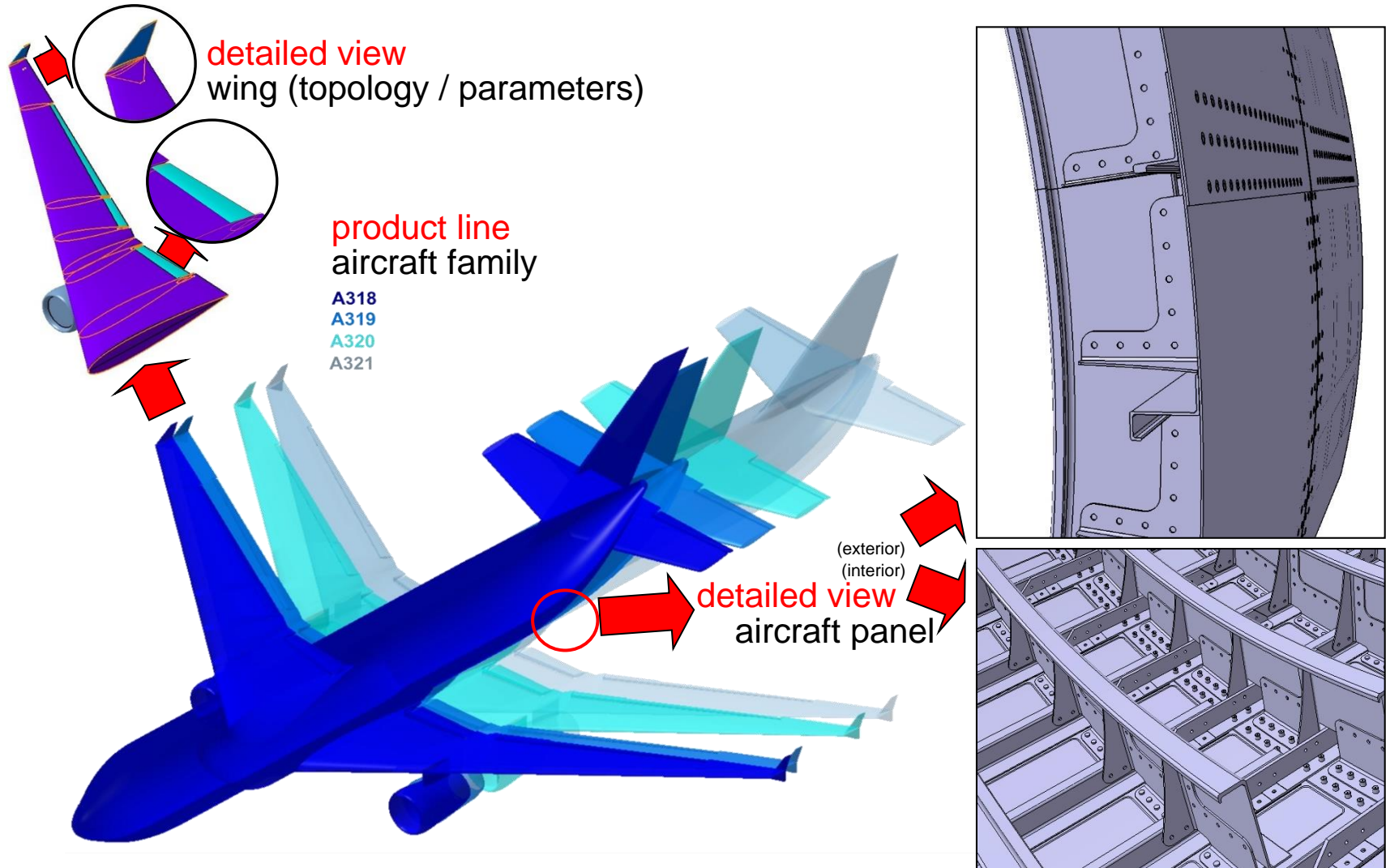
digital factory, fault-tree analysis, ...
fiber-reinforced structures

Future

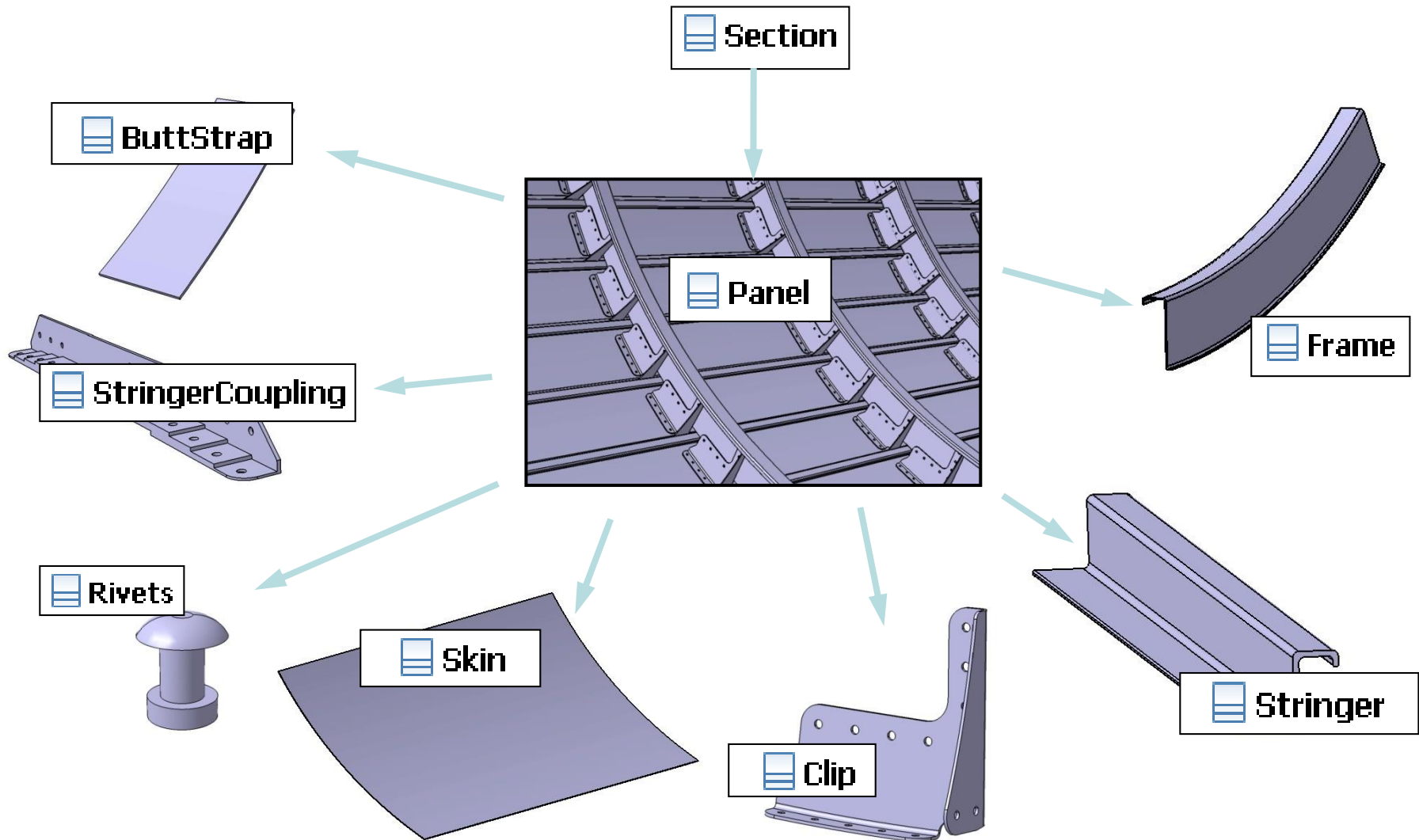
cooperation possibilities (EU-and national projects)
workshop in Stuttgart March 2015



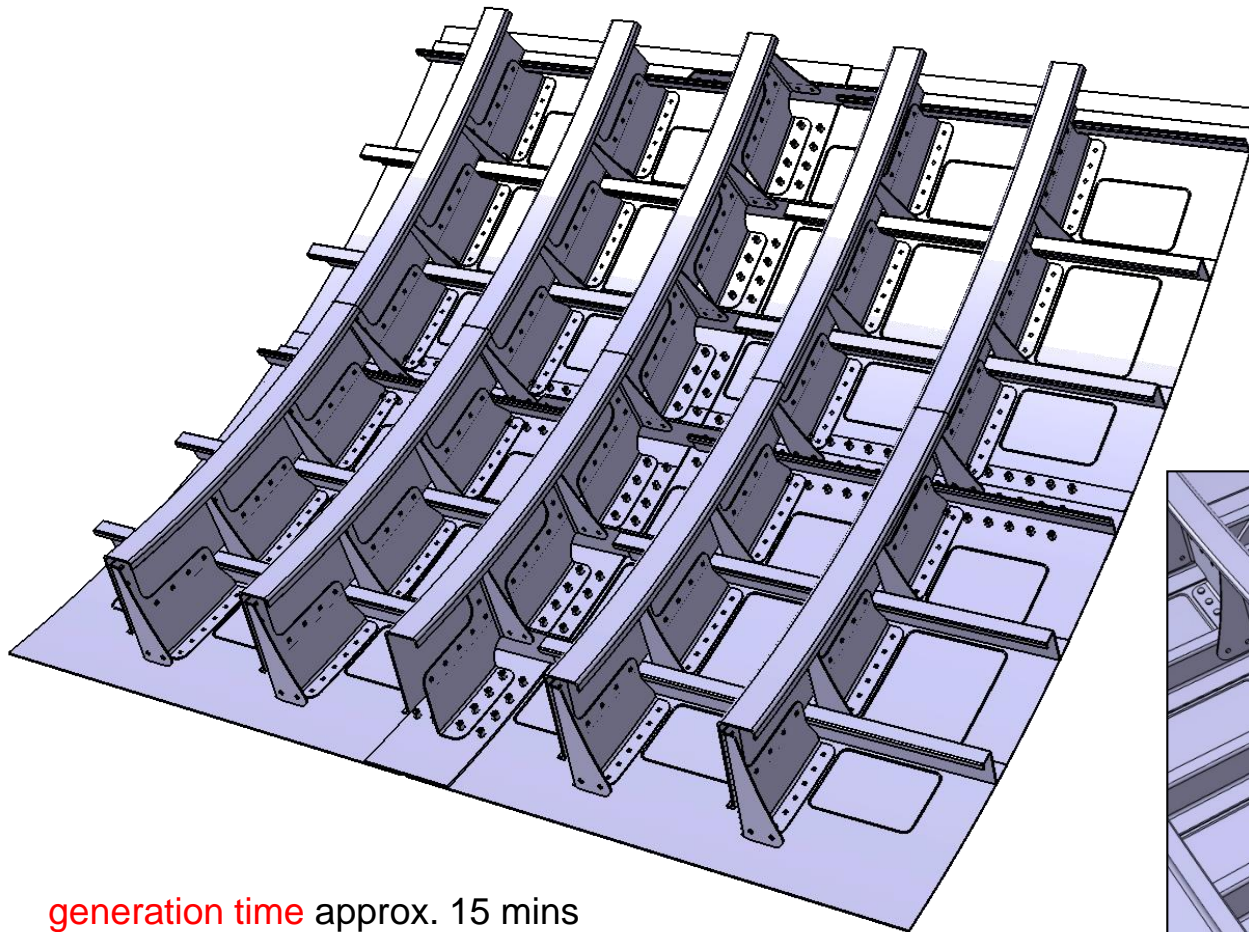
aircraft design language



aircraft panel



aircraft panel (CATIA V5)

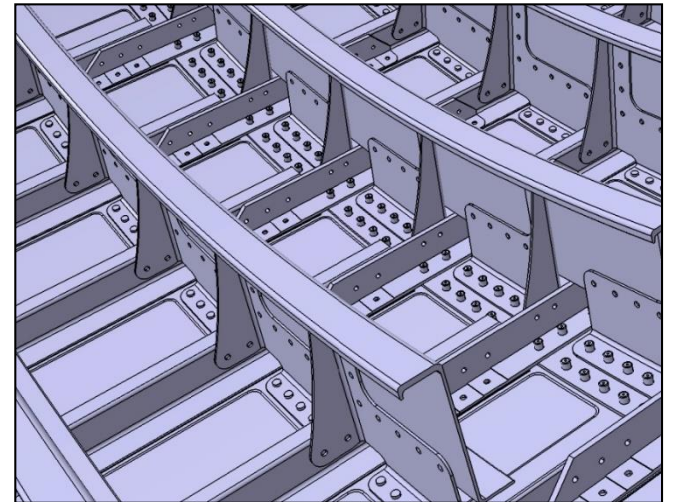


fuselage section

- 4 panels
- lateral and longitudinal structural connections
- riveting
- parameters:

nFrame=5

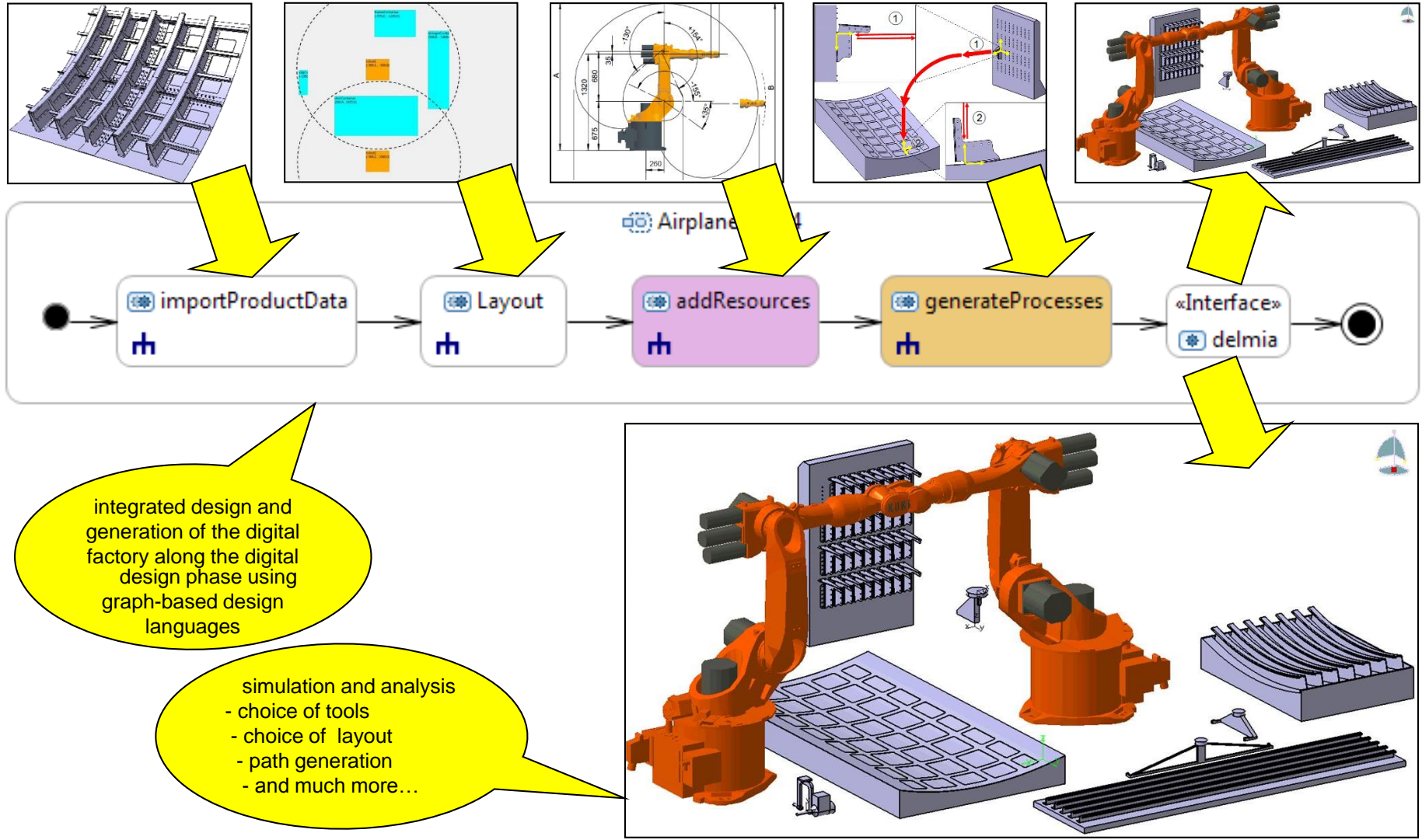
nStringer=6



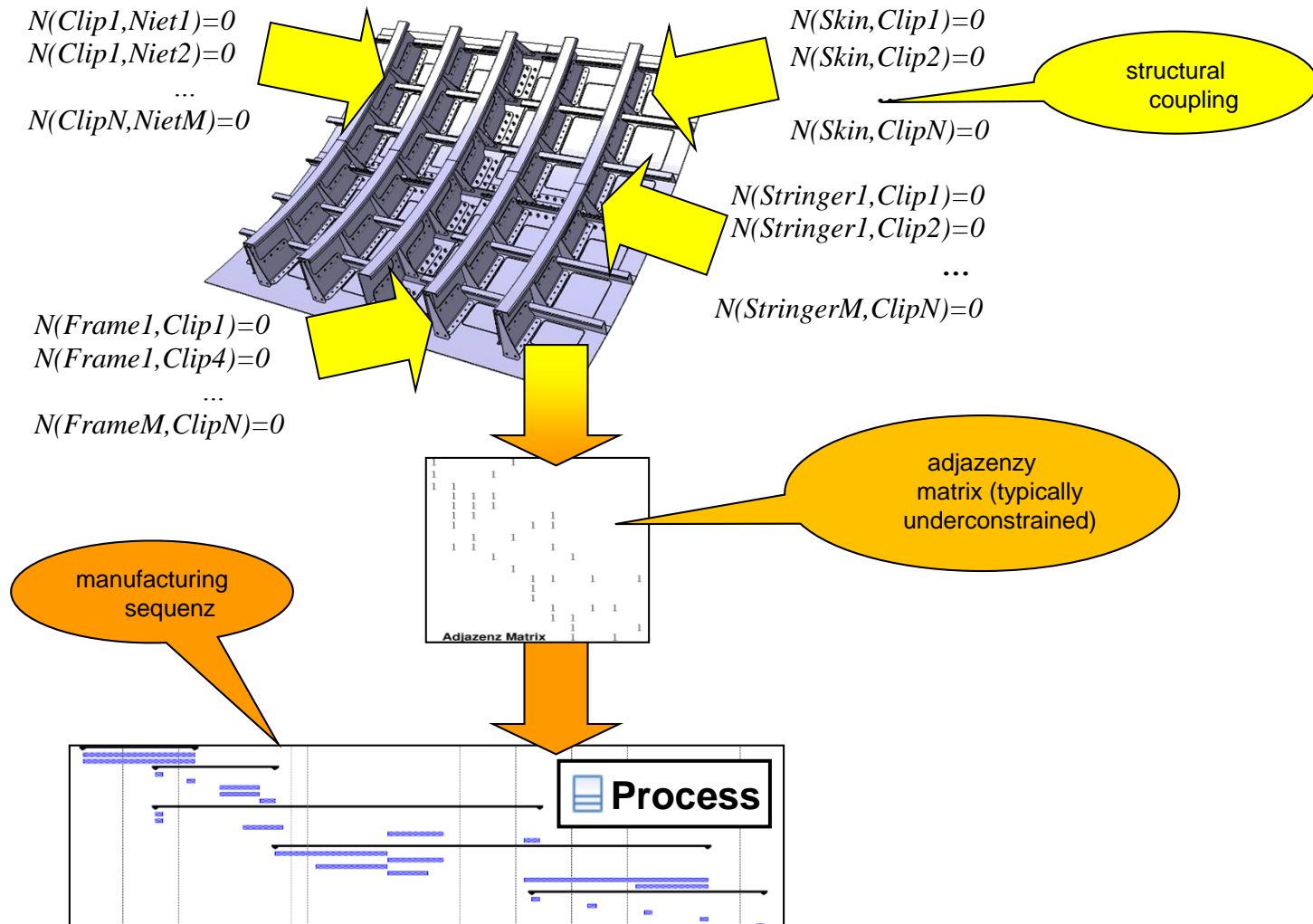
generation time approx. 15 mins
(about 2/3 spent for CATIA V5 model)



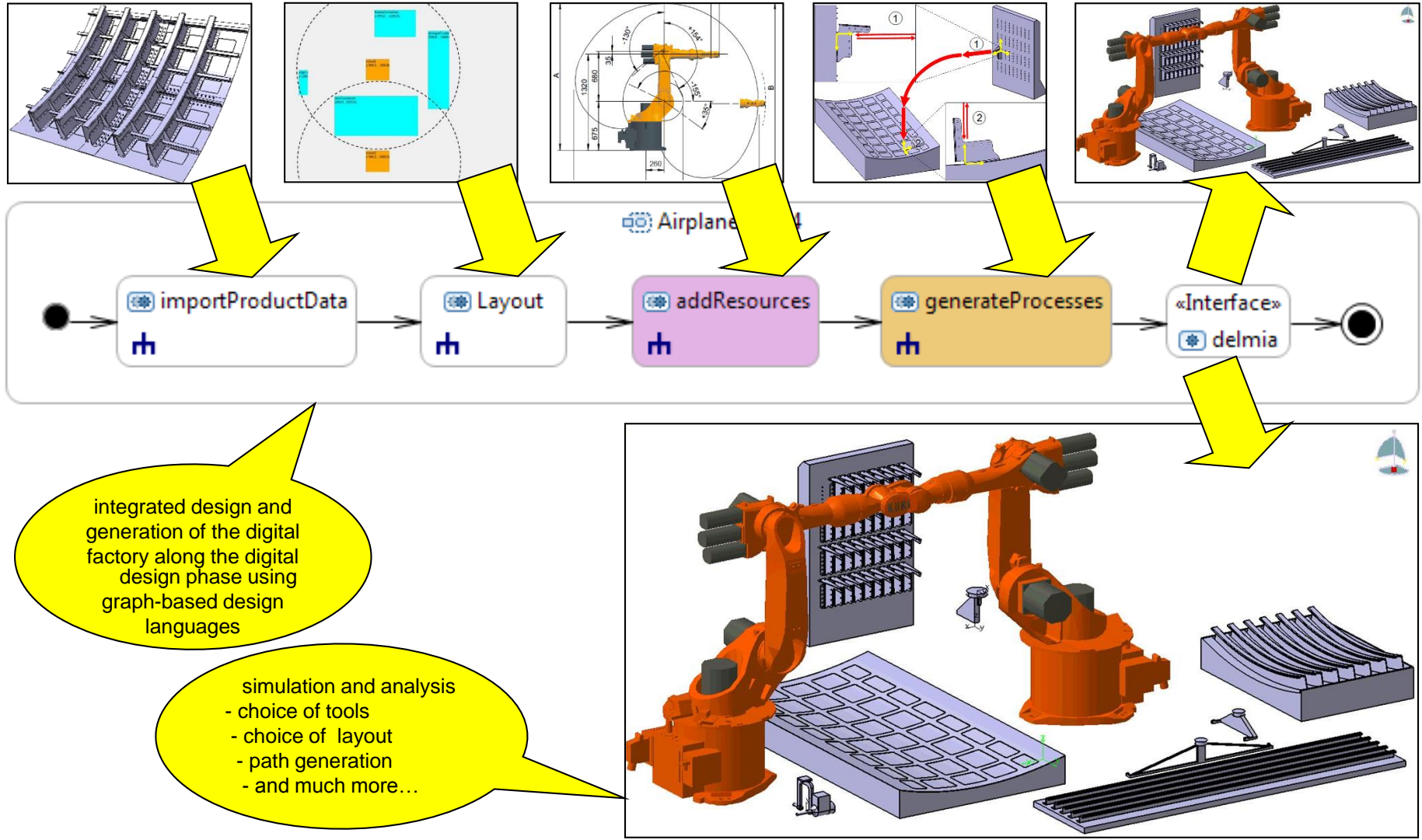
digital factory



manufacturing sequence



digital factory



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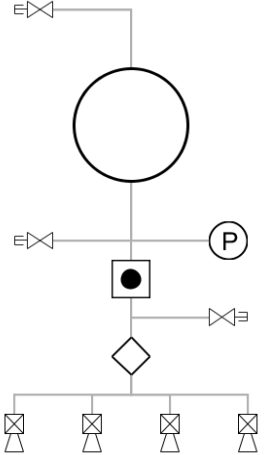
digital factory, **fault-tree analysis**, ...
fiber-reinforced structures

Future

cooperation possibilities (EU-and national projects)
workshop in Stuttgart March 2015

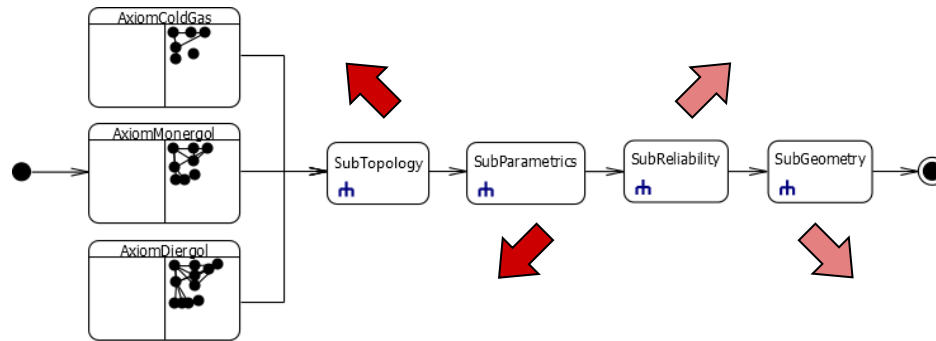


propulsion system (design and FTA)

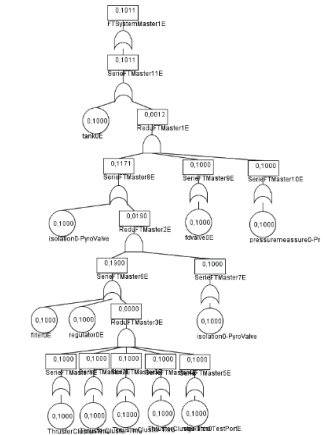


Architecture

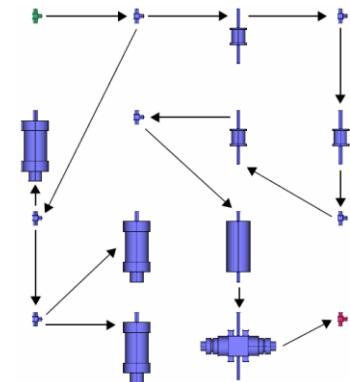
- design language shown encodes
„systematic german
design methodology“
(Pahl and Beitz, 1972)



Design Language



Reliability



Geometry

| Parameter | Masse [kg] | Parameter | Masse [kg] |
|------------------------|------------|------------------------|------------|
| m_{act} | 1156,63 | m_{act} | 817,50 |
| m_{dy} | 840,68 | m_{dy} | 810,40 |
| $m_{propellant}$ | 315,96 | $m_{propellant}$ | 7,10 |
| $m_{pressurant}$ | 1,16 | $m_{propulsionSystem}$ | 10,40 |
| $m_{propulsionSystem}$ | 40,68 | m_{dead} | 0,18 |
| m_{fuel} | 319,11 | m_{fuel} | 7,28 |
| m_{t1} | 47,15 | m_{t1} | 7,10 |
| m_{t2} | 268,80 | | |

| Parameter | Masse [kg] | Parameter | Masse [kg] |
|------------------------|------------|----------------|------------|
| m_{act} | 1758,79 | m_{fuel} | 311,68 |
| m_{dy} | 932,97 | $m_{oxidizer}$ | 514,19 |
| $m_{propellant}$ | 825,81 | m_{t1} | 54,48 |
| $m_{pressurant}$ | 4,31 | m_{t2} | 426,37 |
| $m_{propulsionSystem}$ | 132,97 | m_{t3} | 344,97 |
| m_{dead} | 8,26 | | |

Mass Balance

- Pahl and Beitz (1972)
design means consistent mapping:
requirements → abstract product
functions → solution principles →
embodiments

cooperation

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digital factory, fault-tree analysis, ...
fiber-reinforced structures

Future

cooperation possibilities (EU-and national projects)
knowledge-based methods workshop
at Stuttgart University in March 2015



thanks / questions

.... ask / approach me for cooperation ideas....
Horizon 2020 Factory of the Future (FoF program)...

... you provide the application know-how
... we do the processing

...and the PhD candidates of the „Similarity Mechanics Group“
Dipl.-Ing. Peter Arnold
Dipl.-Ing. Marc Eheim
Dipl.-Ing. Jürgen Freund
Dipl.-Ing. Stefan Hess
Dipl.-Ing. Martin Motzer
Dipl.-Ing. Marius Riestenpatt genannt Richter
Dipl.-Ing. Jens Schmidt
Dipl.-Ing. Roland Weil

