Model Based Design within Conceptual Aircraft Design

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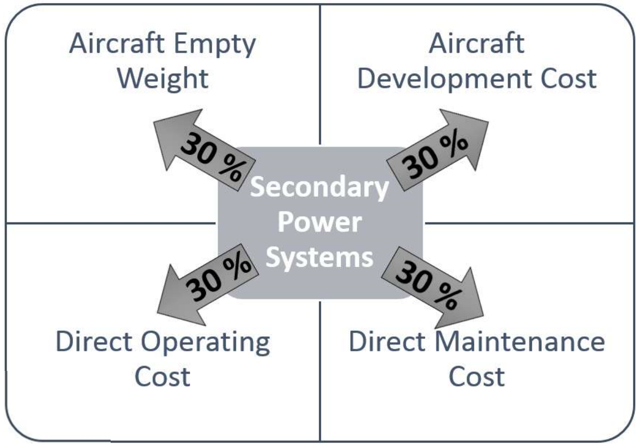
LINKÖPING UNIVERSITY

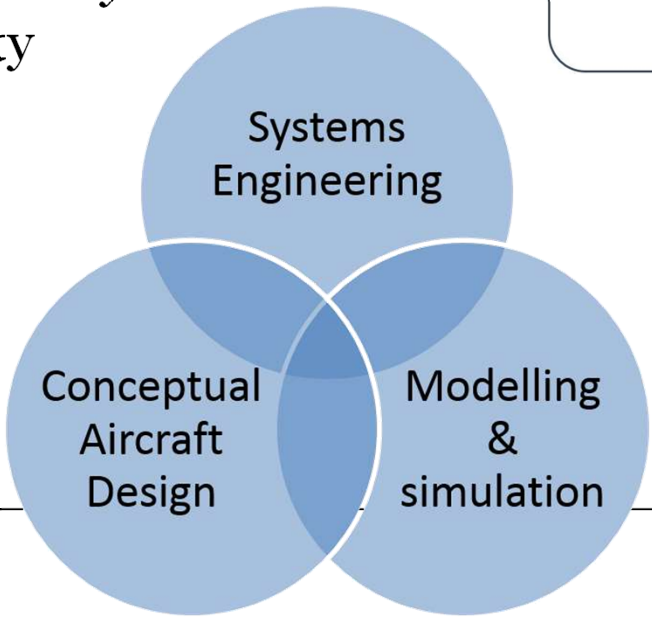
Agenda

- MBSE in Aircraft Systems Conceptual Design (ASCD)
  - new challenges and motivation
- Model Types & the Use of Models
- Modelling Approaches / Integration
  - by means of KBE
  - Graph Modelling

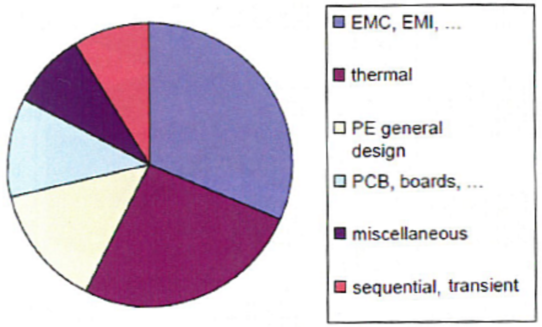
Why Conceptual **Systems** Aircraft Design?

- multi-aspect, multi-domain
- project specific
- low efforts, short period, small team
- enhanced complexity fidelity





More electrical Airplane: Power Electronics



PE technical issues dispatched by discipline

"….the most significant common lessons learned are within the EMI/EMC discipline and could become showstoppers if not identified or applied."

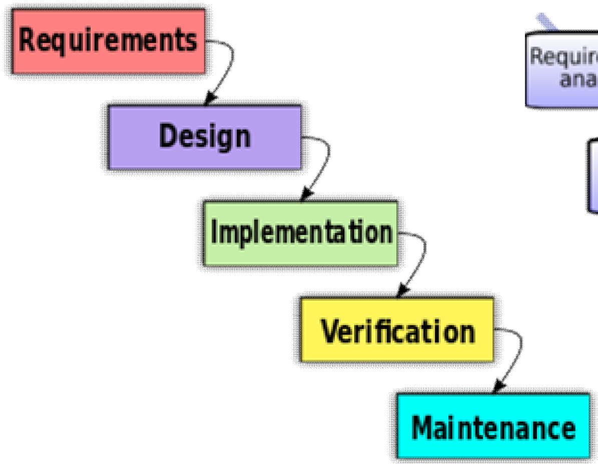
source: Michel Todeschi and Frédéric Salas (Airbus), *"Power Electronics for the Flight Control Actuators"*, in Recent Advances in Aerospace Actuation Systems and Components publisher = {Institute National des Sciences Appliquées (R3ASC), Toulose, France, 2016

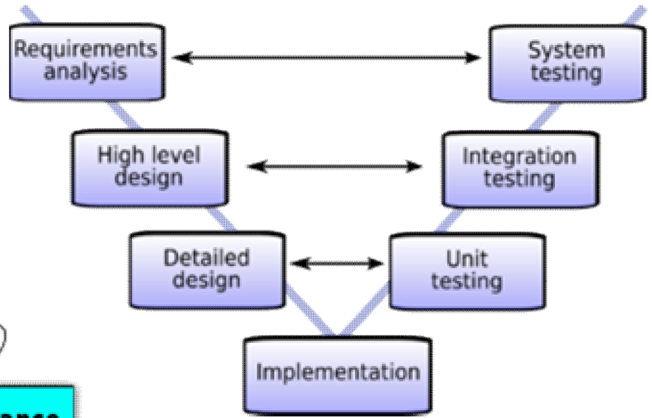
- a possible showstopper?
- workarounds?
- can this be addressed during the conceptual aircraft design process? If yes, how?

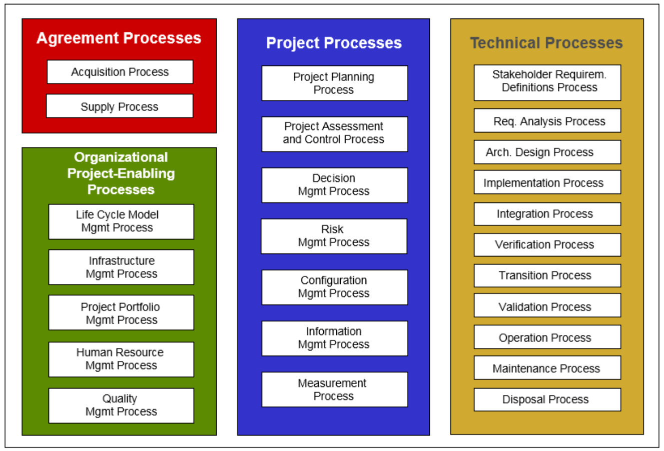
source: http://www.jobyaviation.com/LEAPTech/ (accessed 2016-09-07)

From the Free-/Water-fall towards Concurrent Engineering

- see also: top-down vs. bottom-up approach

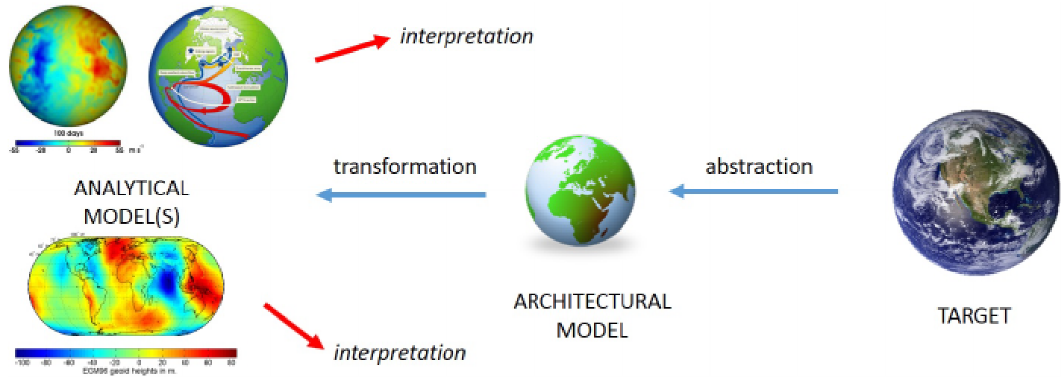


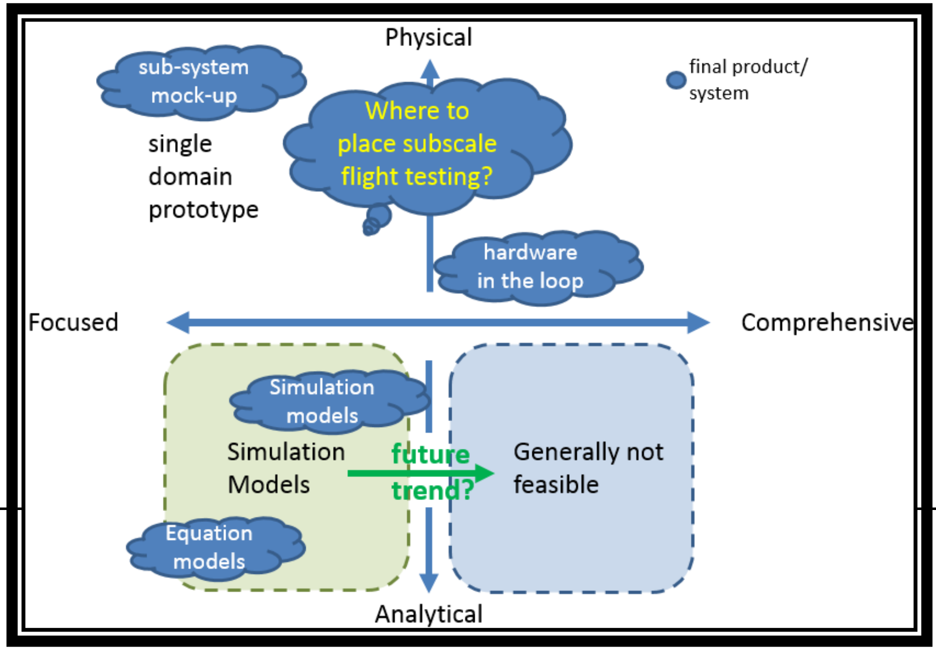




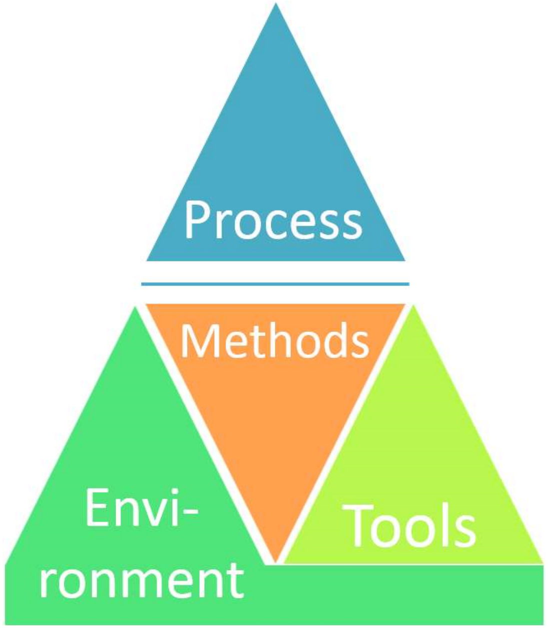
ISO 15288:2008

Model Types, Model Transformations and Model Implementations

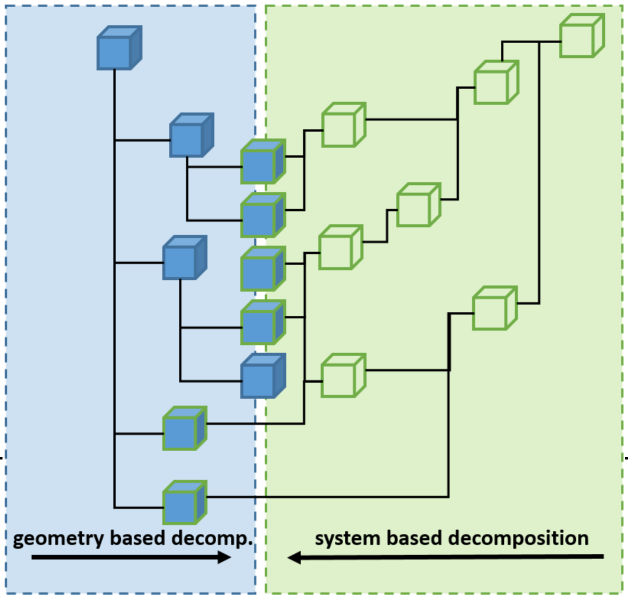




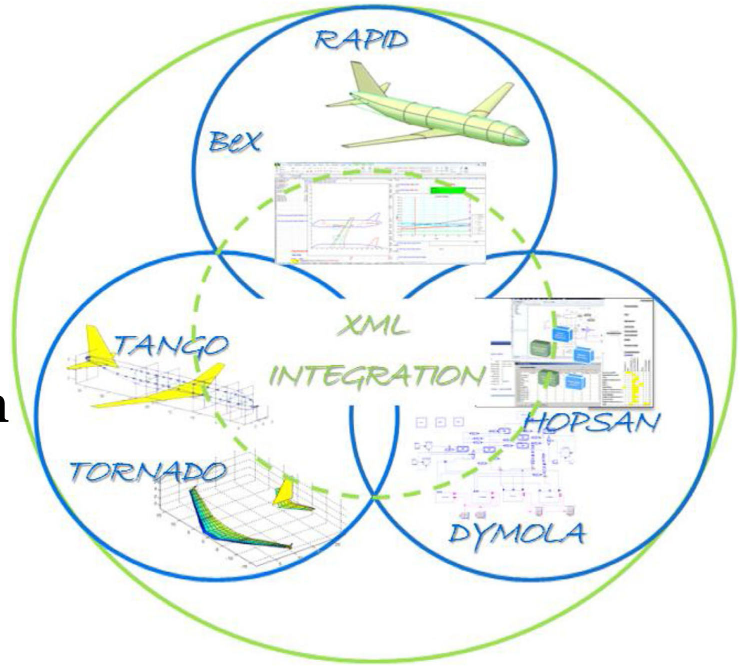
Implementation



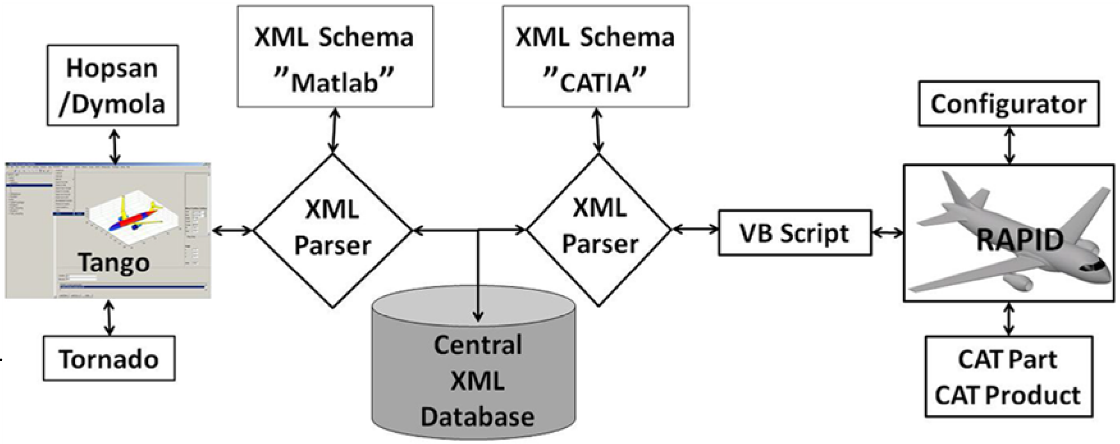
- change from risk management
  to management of complexity & details?
- from pure mechanical engineering towards **software** (data) engineering, **systems engineering** and **project management**
- conventional (eventual OOP), graph based, causal/acausal....
- maintain multi-aspect and multi-domain view



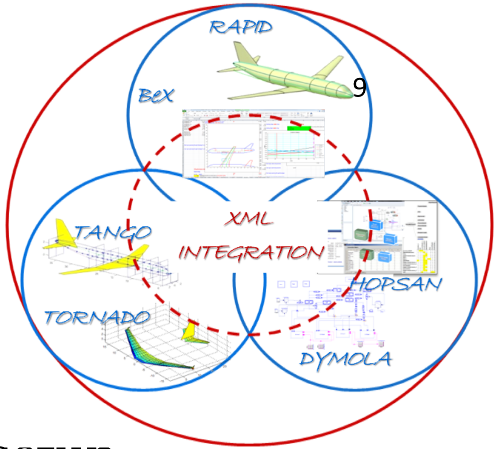
Framework Design: Information Model



- XML based: a good (low-level) solution
  - several standards: CPACS, TEI (literature) , Ecl@ss (acquisition, components), ISO/EC 81346 (construction builiding), etc.
- parametric design
- Object-Oriented Programming (OOP)
- (acausal)

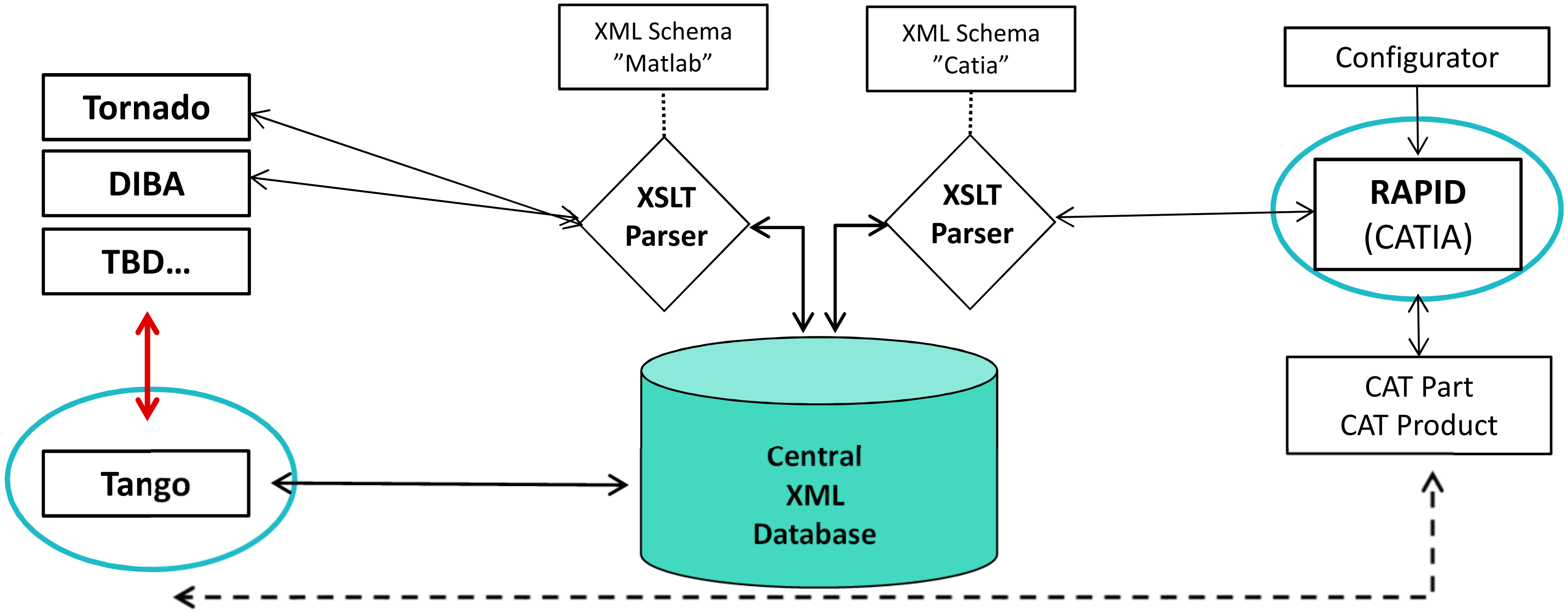


XML Based Tool Integration

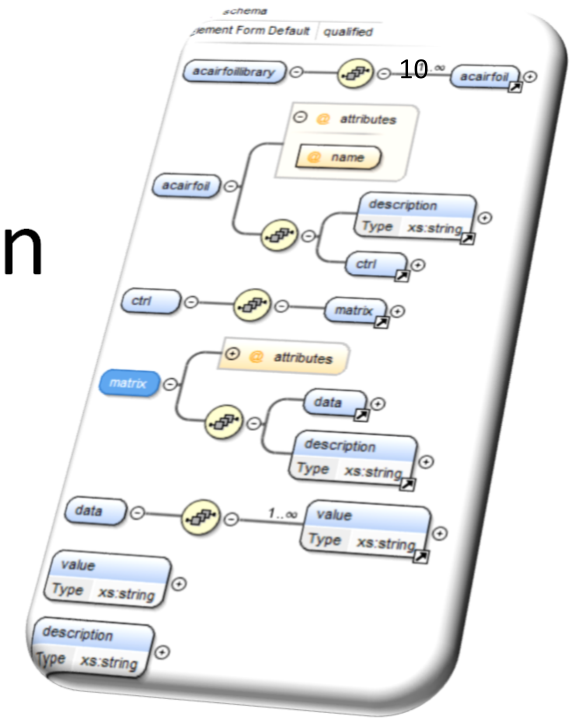


- Strict design space limitation (robustness counts!)
- CATIA model topology different from the XML data setup

  → complex data translations required



Example: Airfoil Representation



Unified parametric airfoil description [Melin T, 2011]:

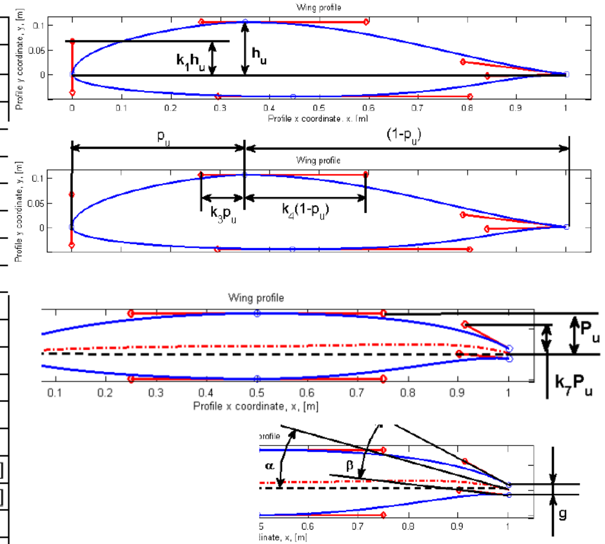
- airfoil representation by four 2nd-order Beziér curves:

$$\bar{x}(t) = (1-t)^3\,\bar{p}_0 + 3(1-t)^2\,t\bar{p}_1 + 3(1-t)t^2\,\bar{p}_2 + t^3\,\bar{p}_3$$

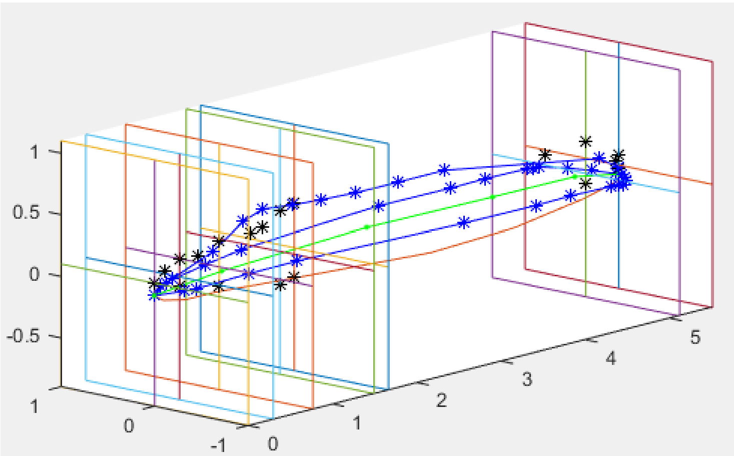
  - very robust format
  - name describing the geometry → perfect condition for (binary) optimization algorithms
  - only drawback: airfoil with a S-shaped trailing edge unrepresentable

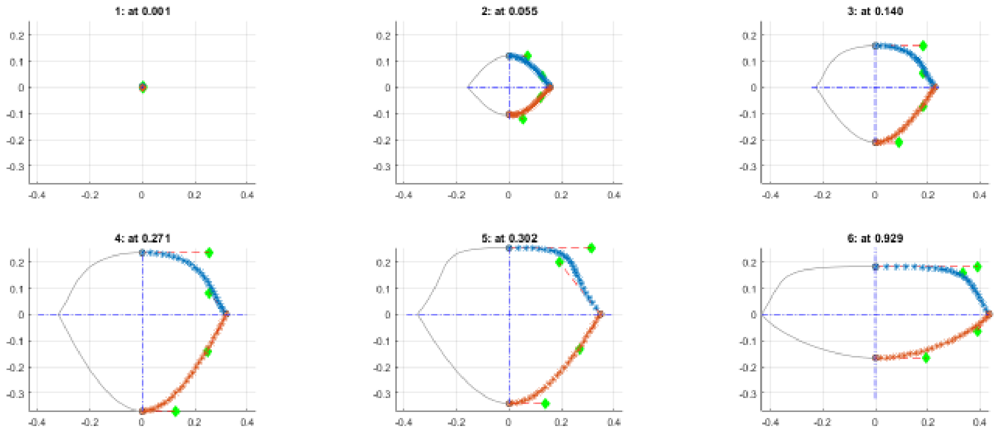
Parameters

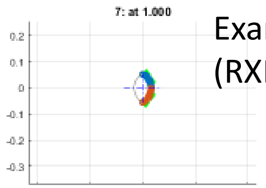
Name	Var	Range
Leading edge		
Upper Nose fraction	k_1	[0..1]
Lower Nose fraction	k_2	[0..1]
Upper side		
Upper thickness	H_U	[0..1]
Upper thickness position	P_U	[0..1]
Upper forward fraction	k_3	[0..1]
Upper rearward fraction	K_4	[0..1]
Lower side		
Lower thickness	H_L	[0..1]
Lower thickness position	P_L	[0..1]
Lower forward fraction	k_5	[0..1]
Upper rearward fraction	K_6	[0..1]
Trailing edge		
Trailing edge gap	g	[0..1]
Boat tail angle	β	[−π..π]
Release angle	α	[−π..π]
Upper trailing edge fraction	k_7	[0..1]
Lower trailing edge fraction	k_8	[0..1]



xxfuselage.m





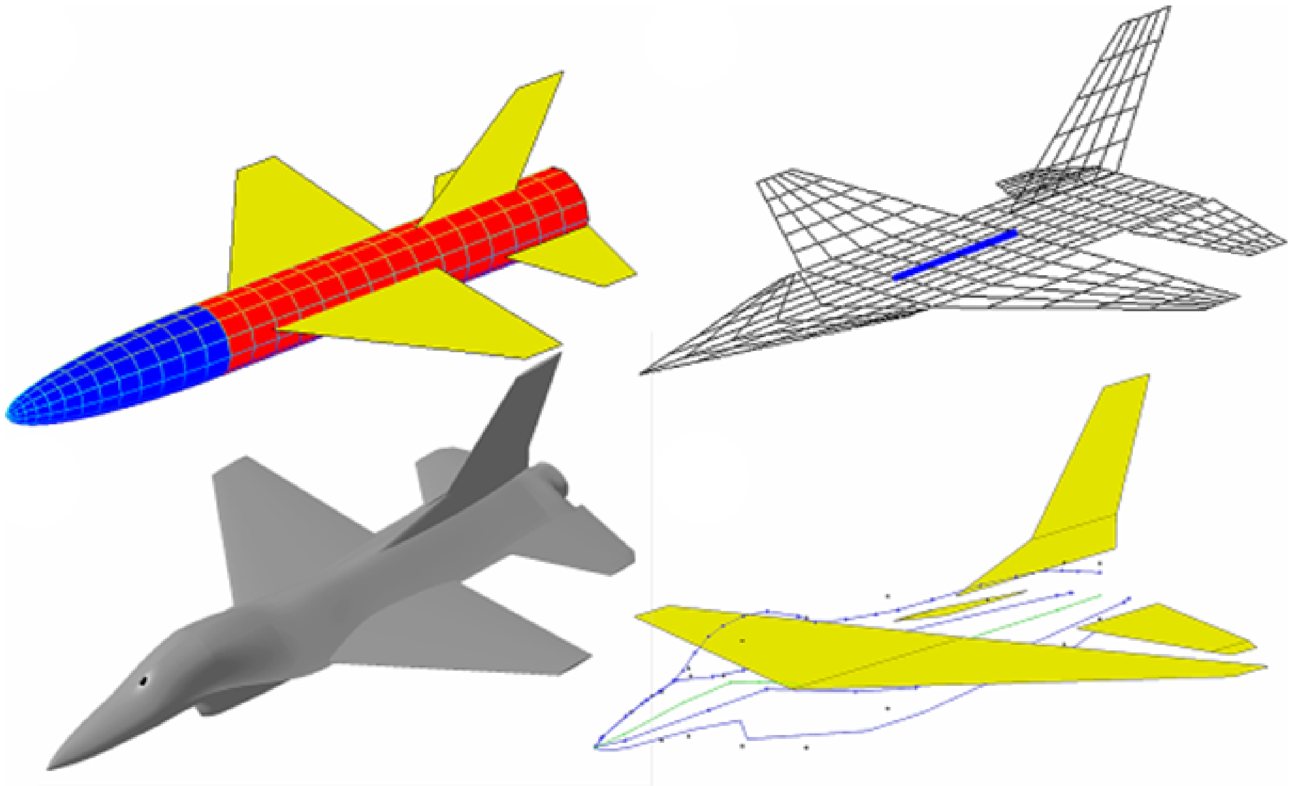


Example: X36 fuselage imported from RAPID (RXML)

```
xxfuselage with properties:

         name: 'fuselageSplines'
       origin: [1x1 xxpos]
     topCurve: [1x1 catspline]
  bottomCurve: [1x1 catspline]
    sideCurve: [1x1 catspline]
  centerCurve: [1x1 catspline]
       csXPos: [9.090909090909091e-04 0.054545454545455 0.140000000000000 0.270909090909091 0.301818181818182 0.929090909090909 1]
      csShape: {1x7 cell}
        CCPtZ: [0.100414782182459 0.124144046347076 0.158758315259559 0.200231871634599 0.206773087711345 0.185228819621525 0.126341119766233]
        UCPtZ: [0.003849348808590 0.118844251043589 0.157195673371483 0.233855439922611 0.252837956337231 0.181019220466613 0.051243119766233]
        BCPtZ: [0.002689499448654 0.102338781443703 0.211452197300955 0.368413438422219 0.339551103348670 0.166093028059933 0.057239880233767]
        SCPtY: [0.003931507667016 0.157264255436601 0.226082600281460 0.319071406826992 0.347772387751561 0.433007135881411 0.032668000000000]
```

One Dataset – Different Low fidelity Geometry Representation



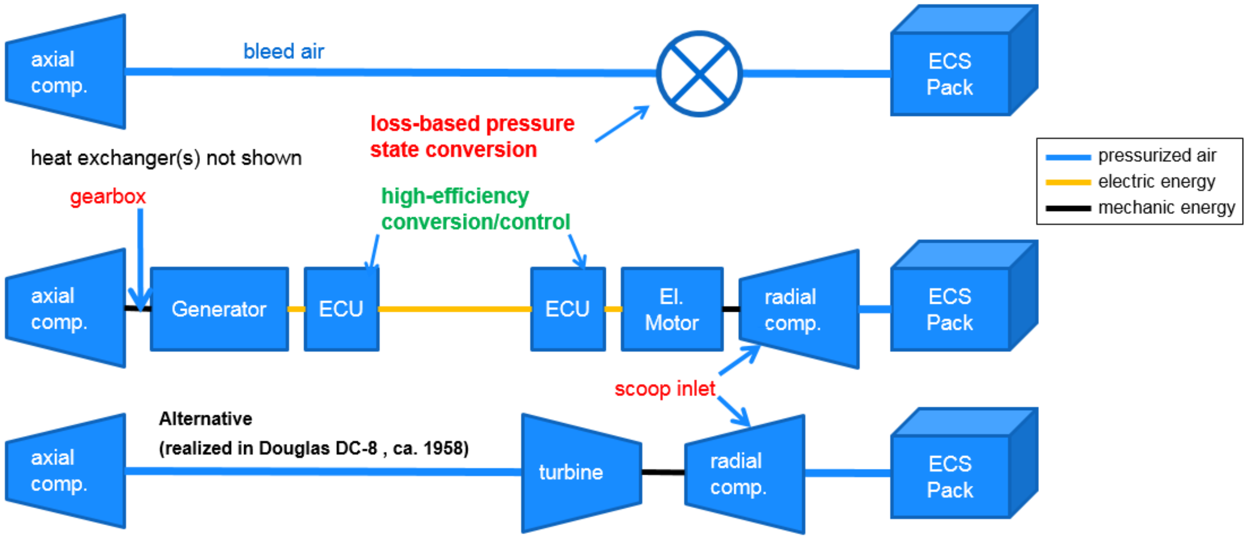
Modelling Approach: Power Components vs. Signal (Control) Components

Power Components:

- energy/power conversion
- power/energy control

Signal Components:

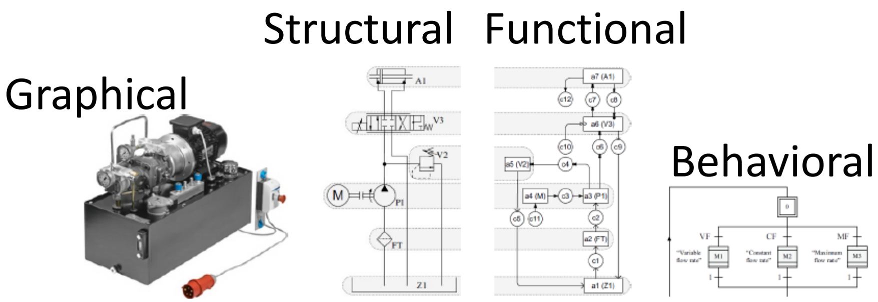
- control
- behavior



ECS technology comparison

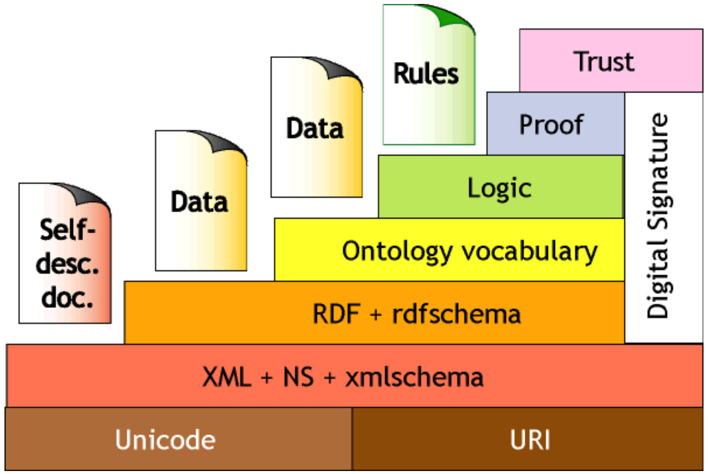
Modelling Trends: Unified Modelling or Semantic Handling Capabilities?

- Cyber-Physical Systems
- unified modelling or enabled model interpretation?
- *"the right tool/method for the right topic"*
  (efficiency, transparency, effort)



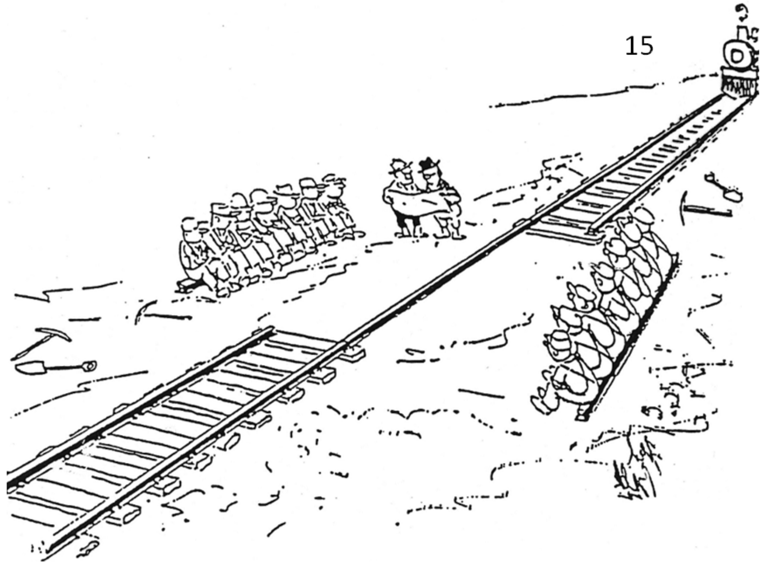
(a) *Hydr. power pack* (b) *Hydr. circuit* (c) *C-A net* (d) *Grafcet*

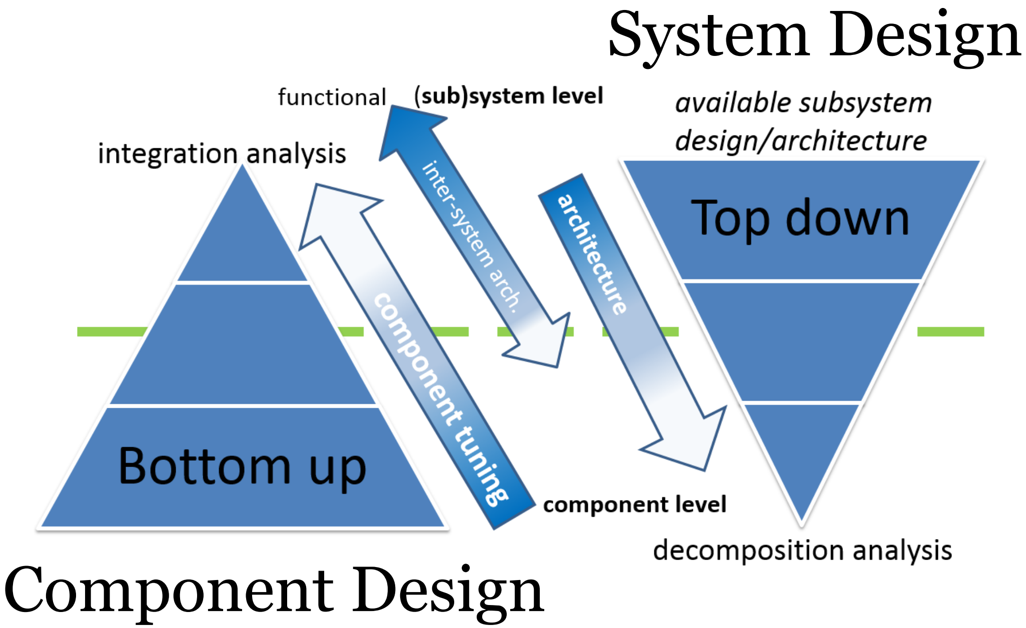
Different (analytical) models of a hydraulic power supply



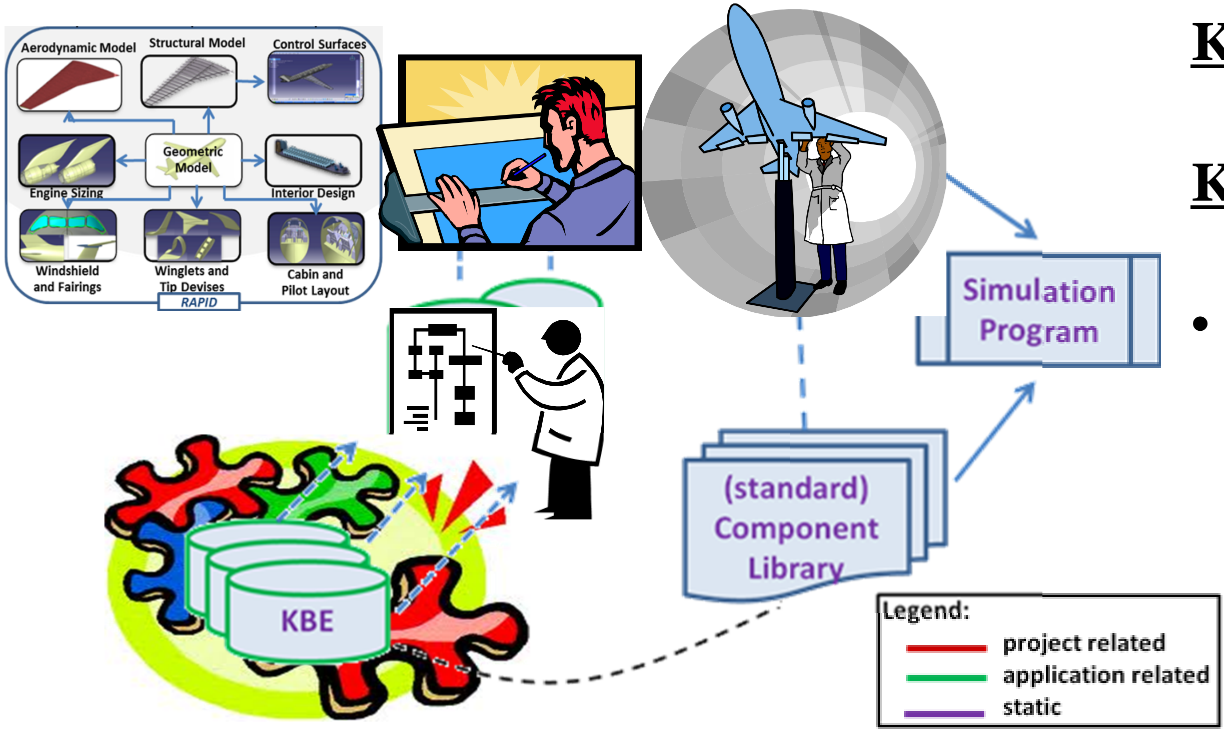
The semantic web approach (source: Bernes Lee)

Closing the Gap





KBE: System Architecture and Integration of Simulation Models

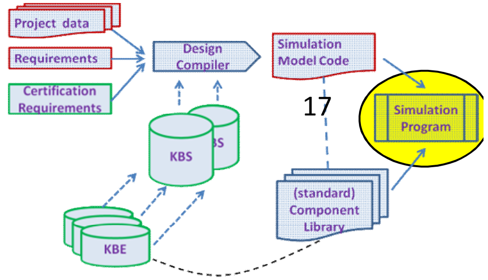


KBS: System Knowledge Base

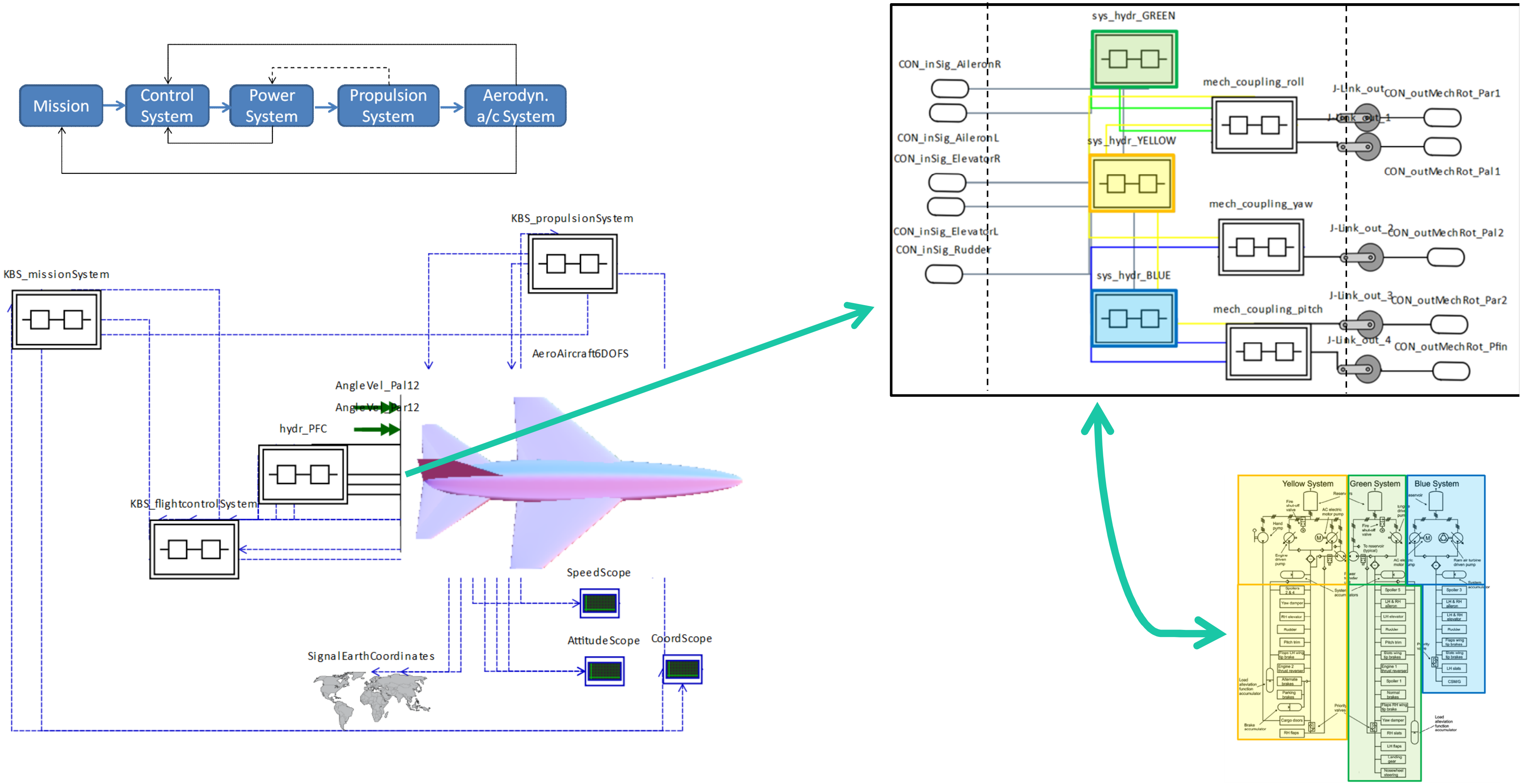
KBE: Element Knowledge Base

- serve for the translation from meta-components towards the simulation components in the library

Req. & project related data → (total) system simulation

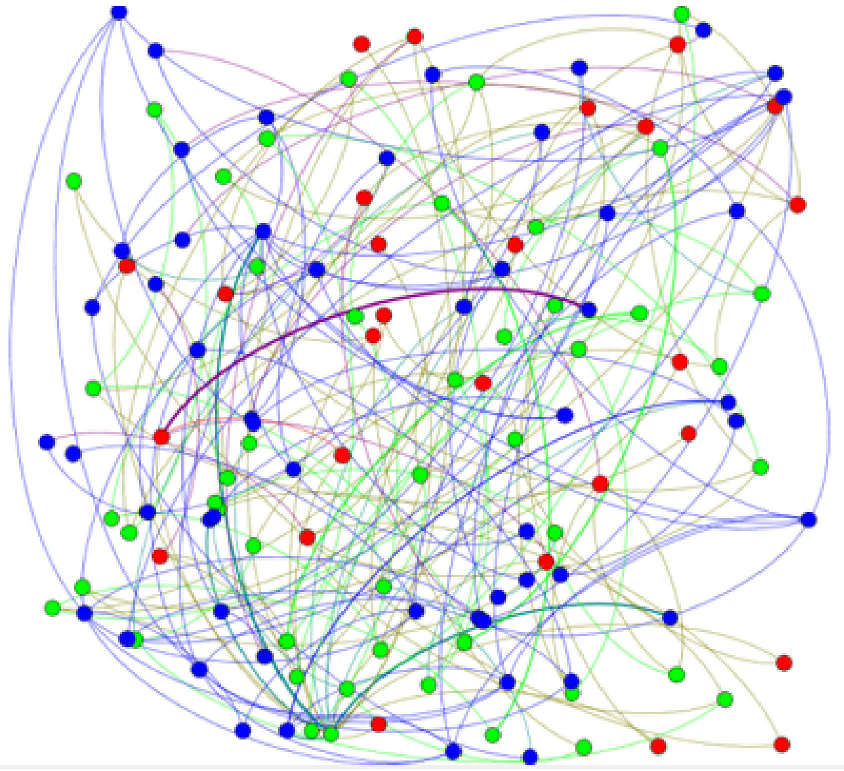


Example Result: Simulation Model



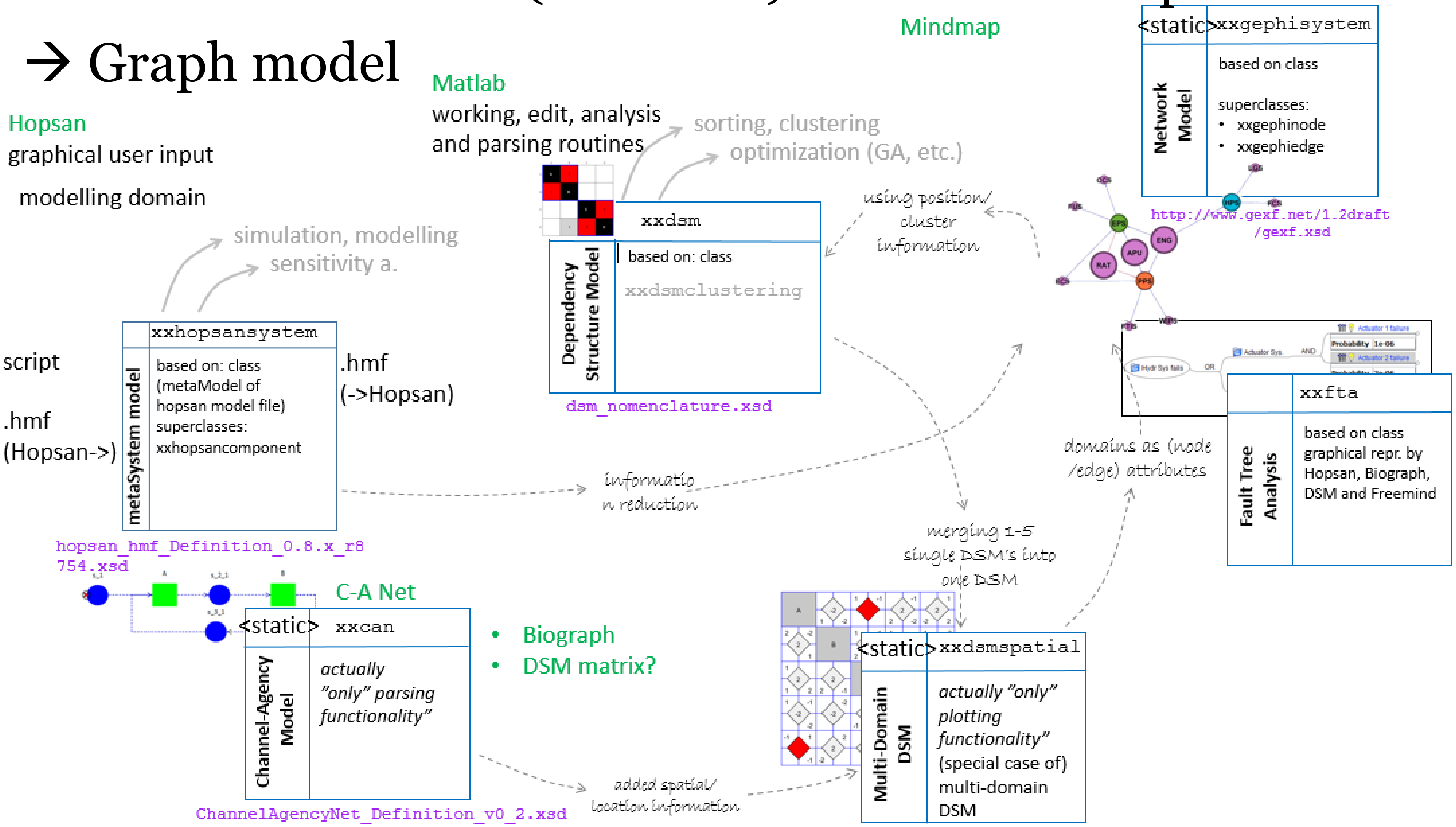
Complexity – How to maintain a **TRANSPARENT** process?

- how to hold overview?
- how to **present/visualize** huge data and **complex dependencies** (network/graph) structure
- tool efficiency (e.g. build-up and maintenance of KBE tools)
- flexibility

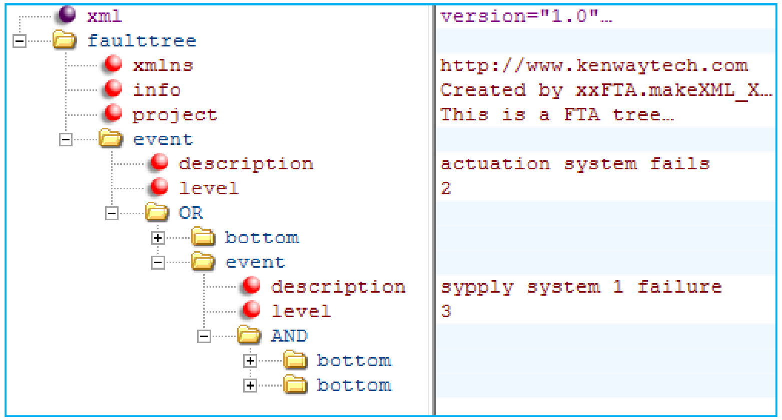


Graph Modelling – the Solution?

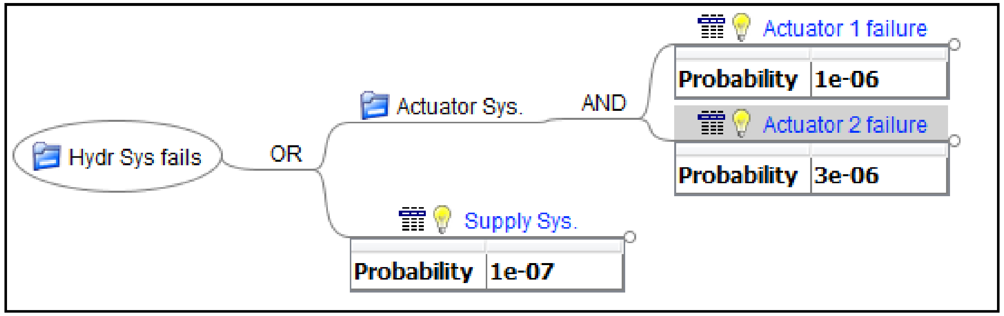
- conventional: product tree with cross-references
- --> Nework of nodes (instances) and relationships
- → Graph model



XML - FTA



- System related FTA analysis
- OOP MATLAB implementation
- automated system reliability analysis possible?
- <u>Weak point: FMEA!</u>



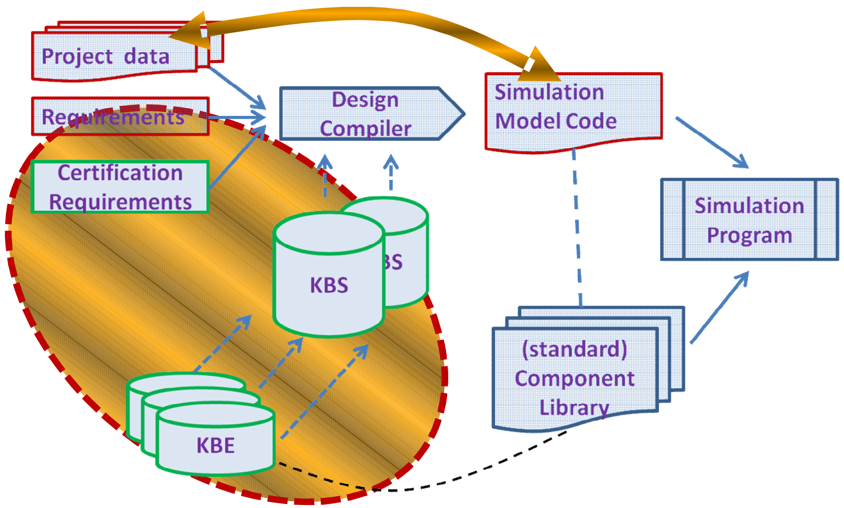
Probability (Quantitative)		1.0	10^{-3}	10^{-5}	10^{-7}	10^{-9}
Probability (Descriptive)	FAR	Probable		Improbable		Extremely Improbable
	JAR	Frequent	Reasonably Probable	Remote	Extremely Remote	Extremely Improbable
Failure condition severity classification	FAR	Minor		Major		Catastrophic
	JAR	Minor		Major	Hazardous	Catastrophic

- Using:
- XML format "Extensible Fault Tree Object Model" (XFTOM)
- graphic representation using mind map "Freemind" format (.mm)

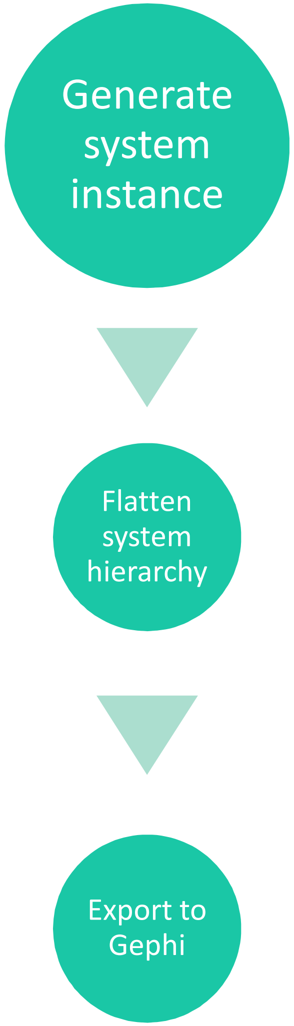
Conclusion

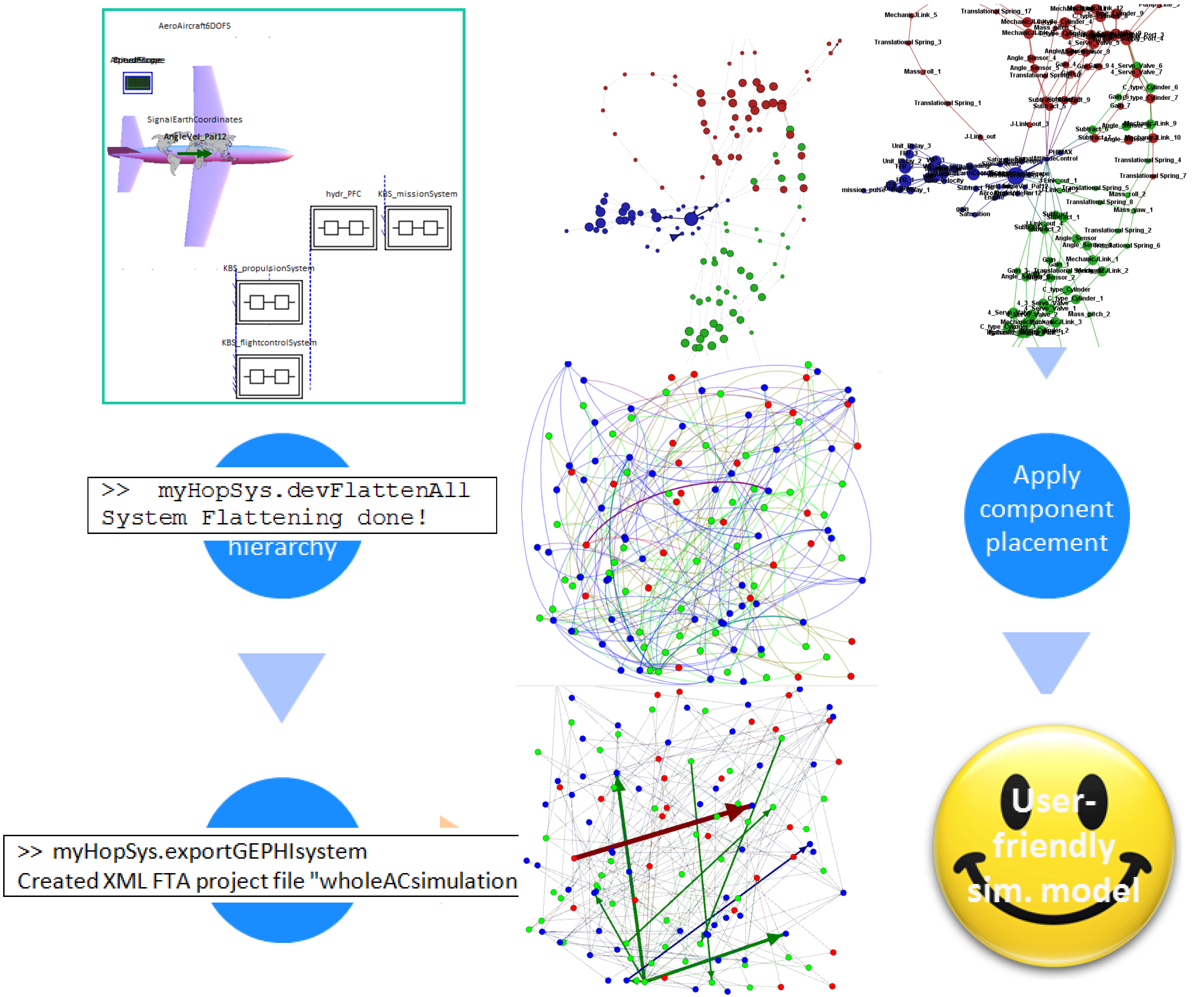
- ✓ automated simulation integration process
- ✓ knowledge base approach
- ✓ backed by the XML language family
- ✓ Good adaptability
- ✓ Simulation model graphics

- design compiler/ configurator integration
- requirement – KBS translation
- Graph based implementation



Networking…

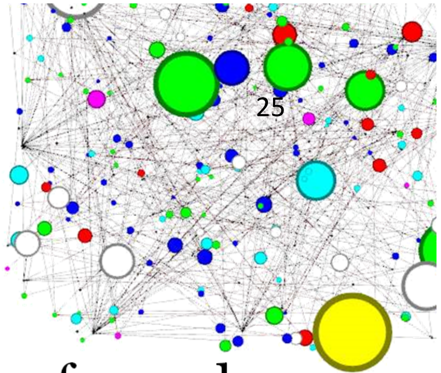

Generate system instance
Flatten system hierarchy
Export to Gephi



AeroAircraft6DOFS
SignalEarthCoordinates
AngleVel_Par12
hydr_PFC
KBS_missionSystem
KBS_propulsionSystem
KBS_flightcontrolSystem
>> myHopSys.devFlattenAll
System Flattening done!
hierarchy
>> myHopSys.exportGEPHIsystem
Created XML FTA project file "wholeACsimulation
Apply component placement
User-friendly sim. model

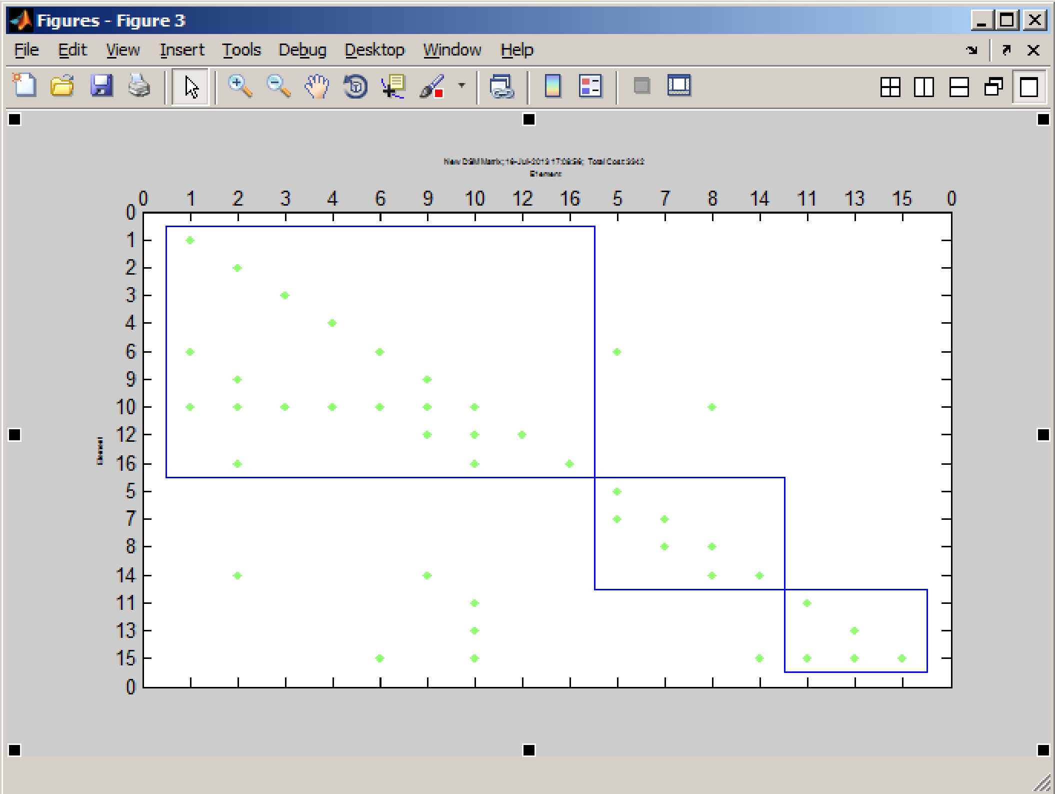
ingo.staack@liu.se

https://www.iei.liu.se/flumes

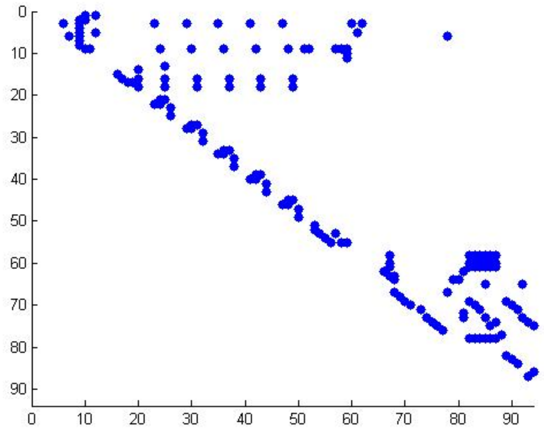


Additional (XML) Benefits

- ca. 100 Components; ca. 200 connections.

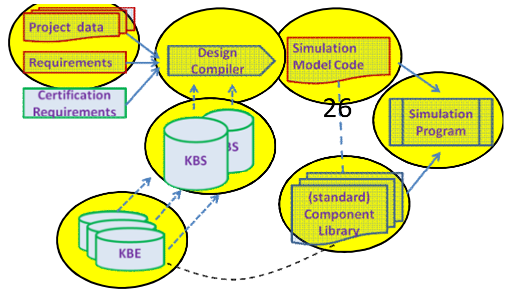


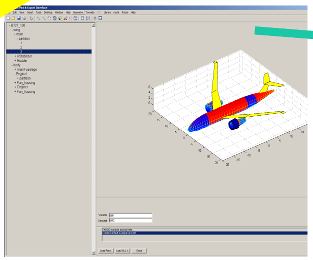
- re-grouping of complex-multidisciplinary systems
  - ”optimized” subsystem grouping
  - separation of different systems; e.g. control system extraction

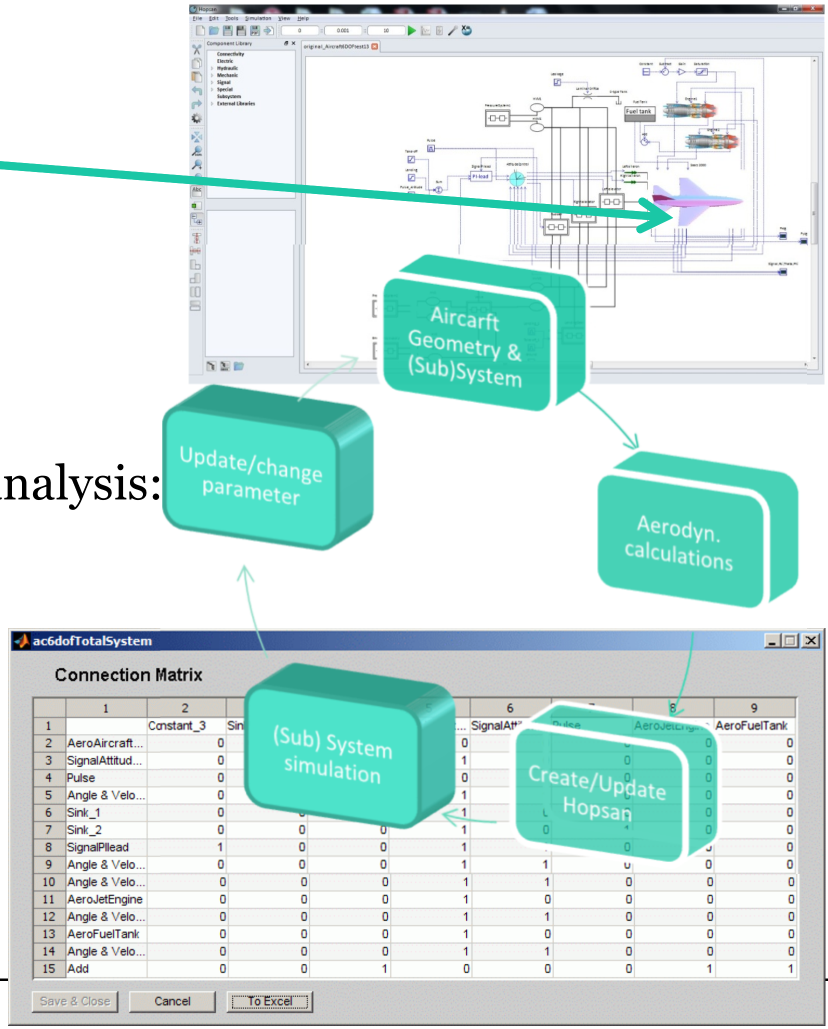


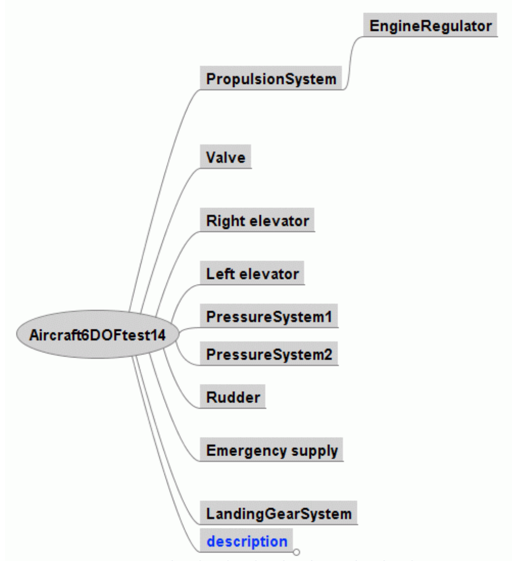
Application Example

Testcase: Hopsan(XML) in Matlab









- System analysis:

	Constant_3	Sink	AeroJetEngine_1	AeroAircraft6DOF	SignalAttitudeControl	Pulse	AeroJetEngine	AeroFuelTank
AeroAircraft6DOF	0	1	1	0	0	0	0	0
SignalAttitudeControl	0	0	0	1	0	0	0	0
Pulse	0	0	0	0	1	0	0	0
Angle & Velocity Source	0	0	0	1	1	0	0	0
Sink_1	0	0	0	1	0	0	0	0
Sink_2	0	0	0	1	0	1	0	0
SignalPIlead	1	0	0	1	1	0	0	0
Angle & Velocity Source_1	0	0	0	1	1	0	0	0
Angle & Velocity Source_2	0	0	0	1	1	0	0	0
AeroJetEngine	0	0	0	1	0	0	0	0
Angle & Velocity Source_3	0	0	0	1	1	0	0	0
AeroFuelTank	0	0	0	1	0	0	0	0
Angle & Velocity Source_4	0	0	0	1	1	0	0	0
Add	0	0	1	0	0	0	1	1

Conclusion

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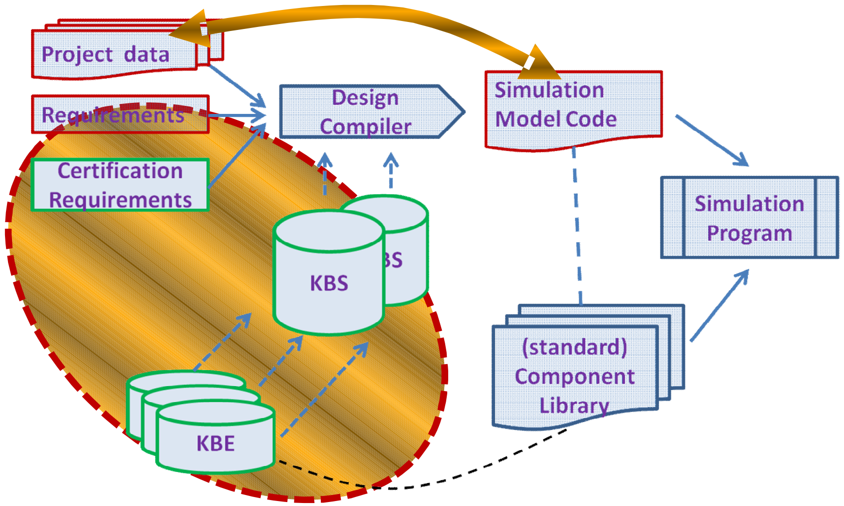

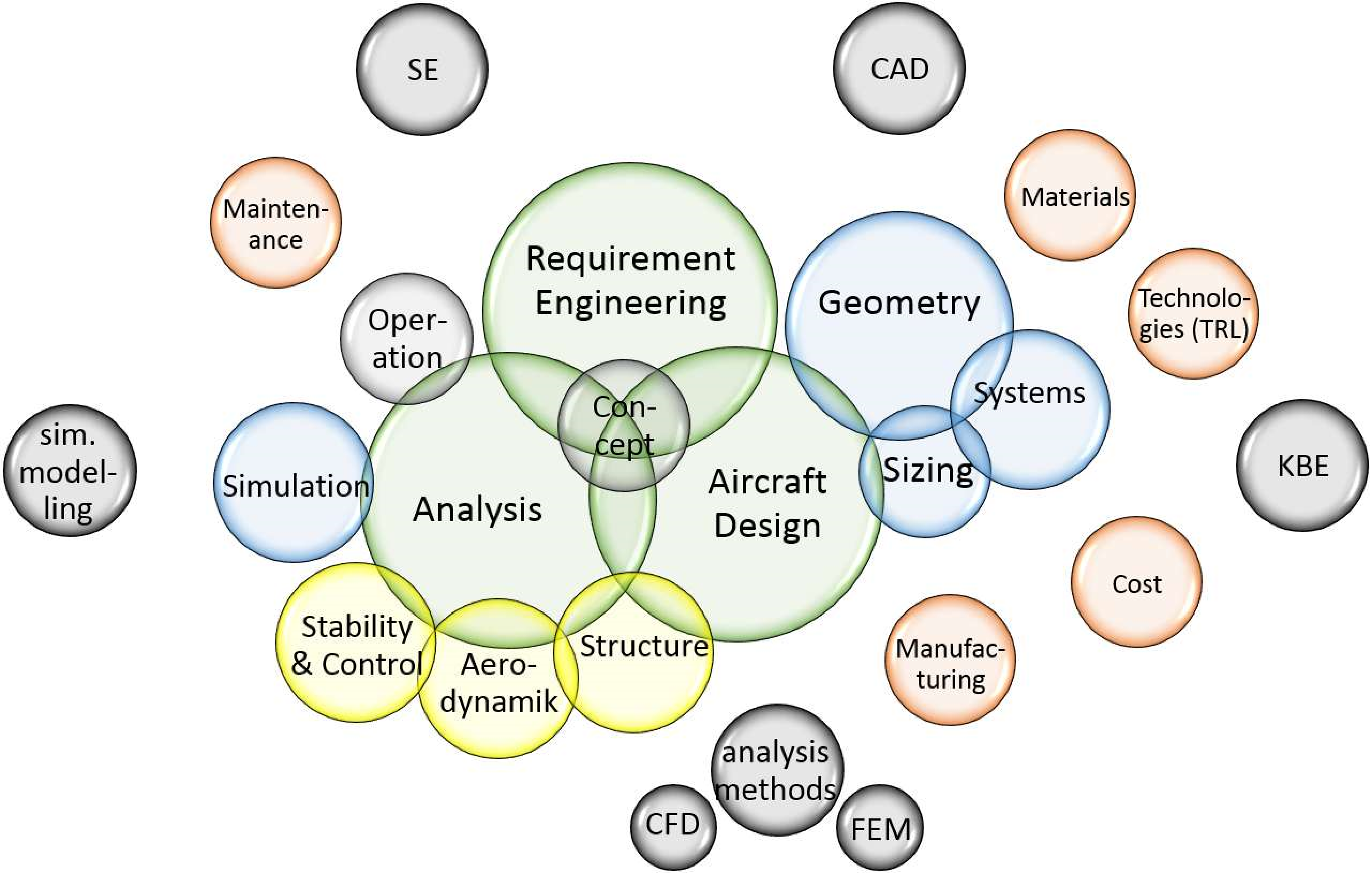
SE
CAD
Mainten-ance
Materials
Requirement Engineering
Geometry
Technolo-gies (TRL)
Oper-ation
Systems
Con-cept
sim. model-ling
Simulation
Analysis
Aircraft Design
Sizing
KBE
Cost
Stability & Control
Aero-dynamik
Structure
Manufac-turing
analysis methods
CFD
FEM

What is the “optimal” amount of details?

- Quantitative assessment of uncertainty possible (knowledge, overhead)
- application / topic dependent (system design vs. component design)