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Science & Innovation



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Recent Advances in Co-Simulation Approaches in Systems Engineering Processes

***Workshop on Simulation and EGSE for Space
Programmes***

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Bildquellen: Daimler AG, Porsche AG, BMW AG, Bosch GmbH, VW AG, Audi AG, Siemens, ESA, Airbus, PTV



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Management Summary

- 30 Years **T**echnisch-**W**issenschaftlicher **T**ransfer
- 300 Experts
- 20 Research Projects
- 3 Perspectives



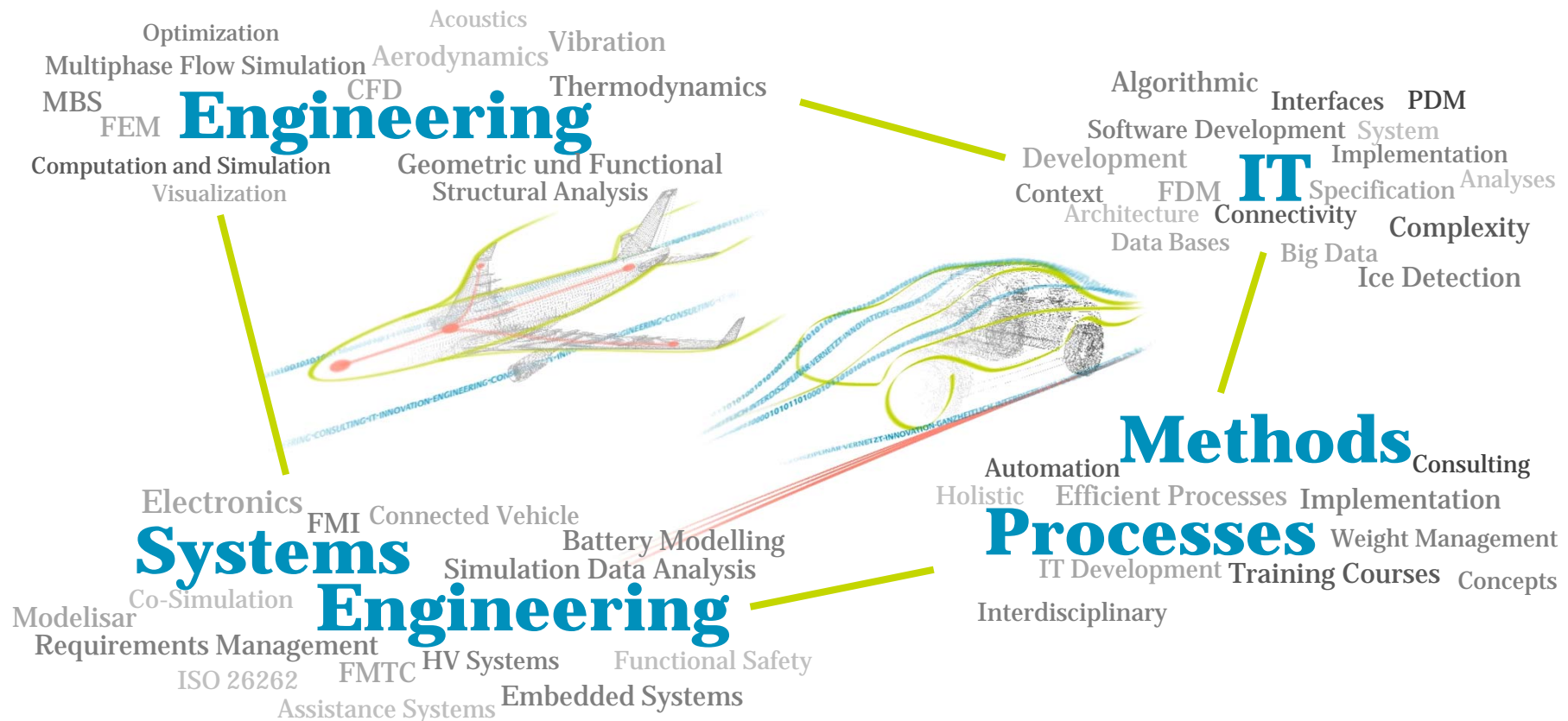
Management Board
Dr. Dimitris Vartziotis
Joachim Laicher
Frank Beutenmüller
Dr. Victor Fäßler





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Digital Product Development

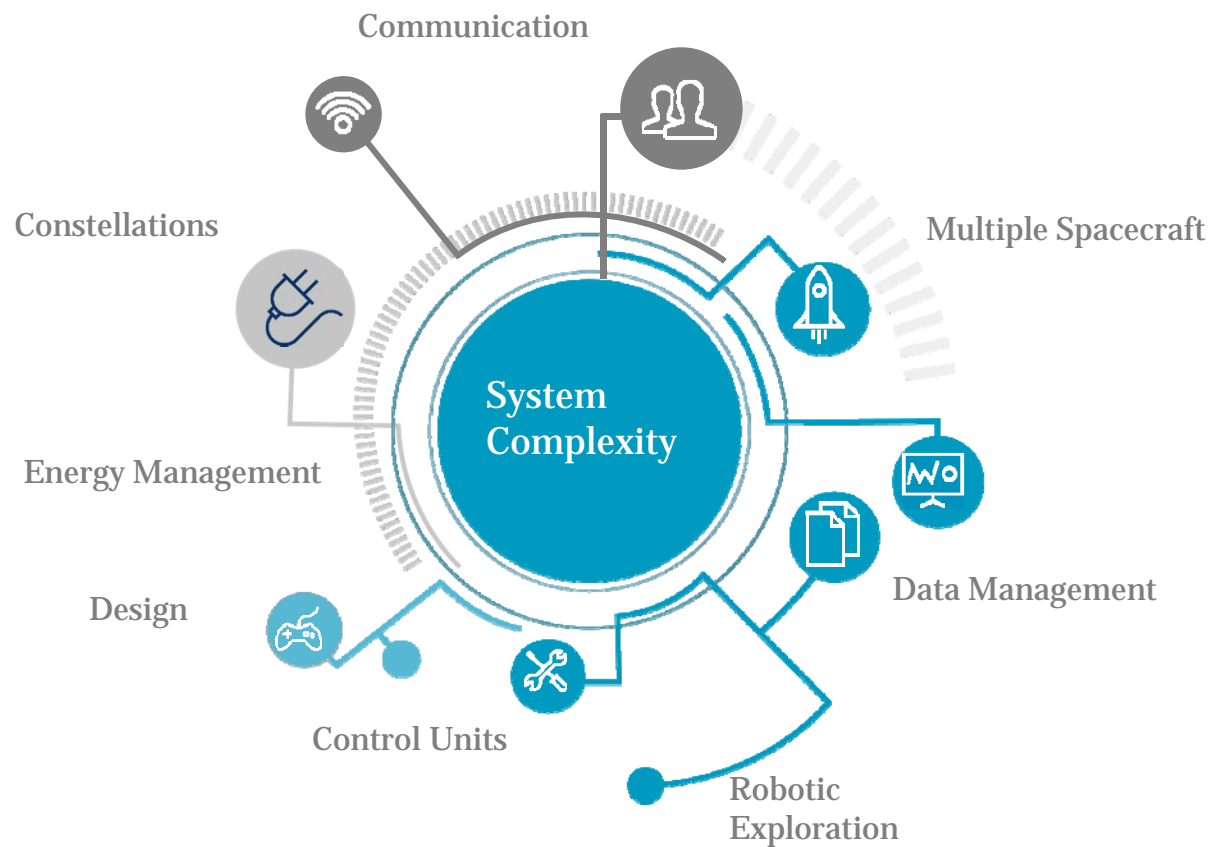




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Managing Complexity

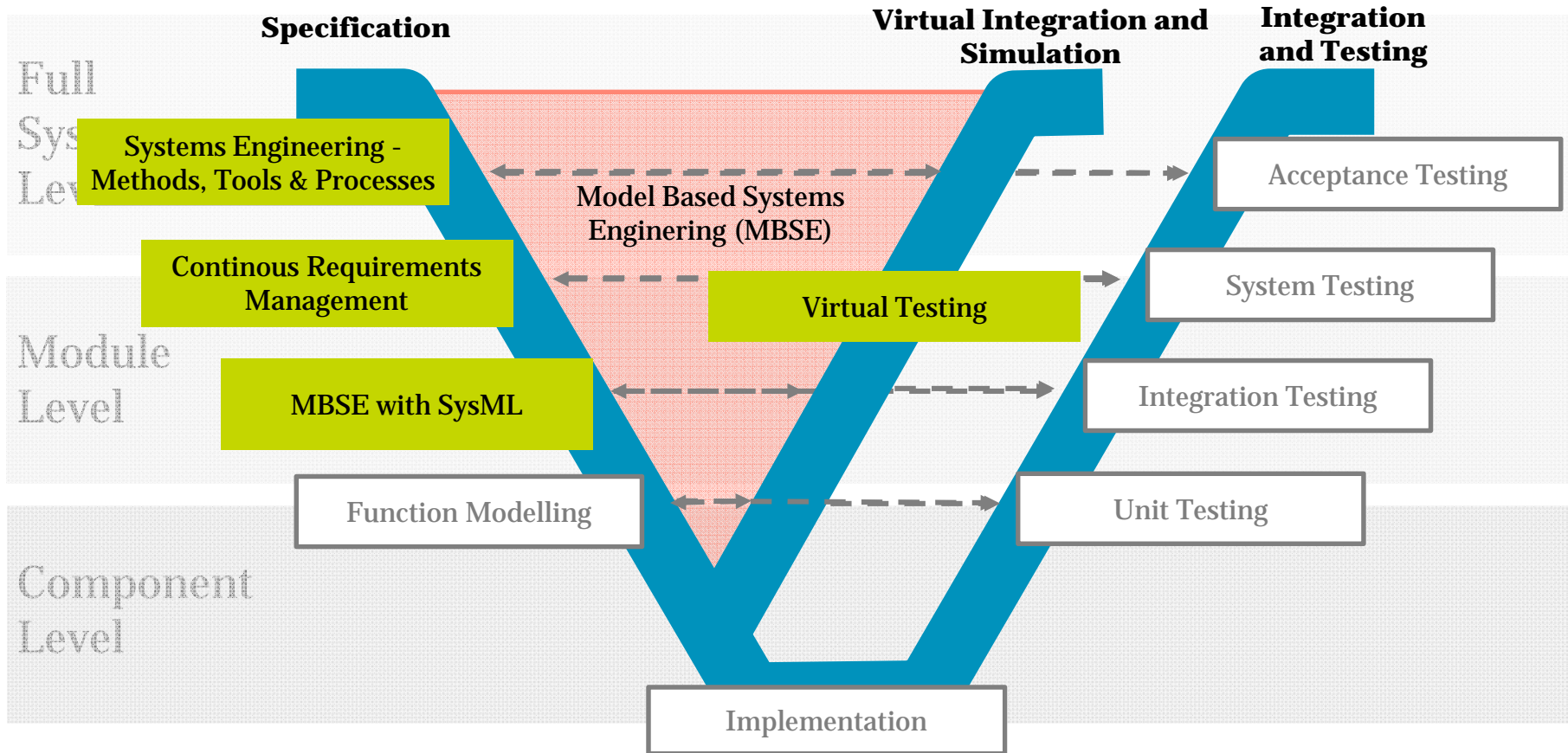
Model Based Systems Engineering





Continous Product Development Process

V-Model





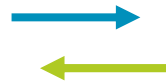
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Standardization Functional Mock-Up Interface (FMI)

FMI – Standard

FMI – Advantages

Model Exchange



Open Standard
(www.fmi-standard.org)

Co-Simulation



Tool independent

Product Lifecycle Management



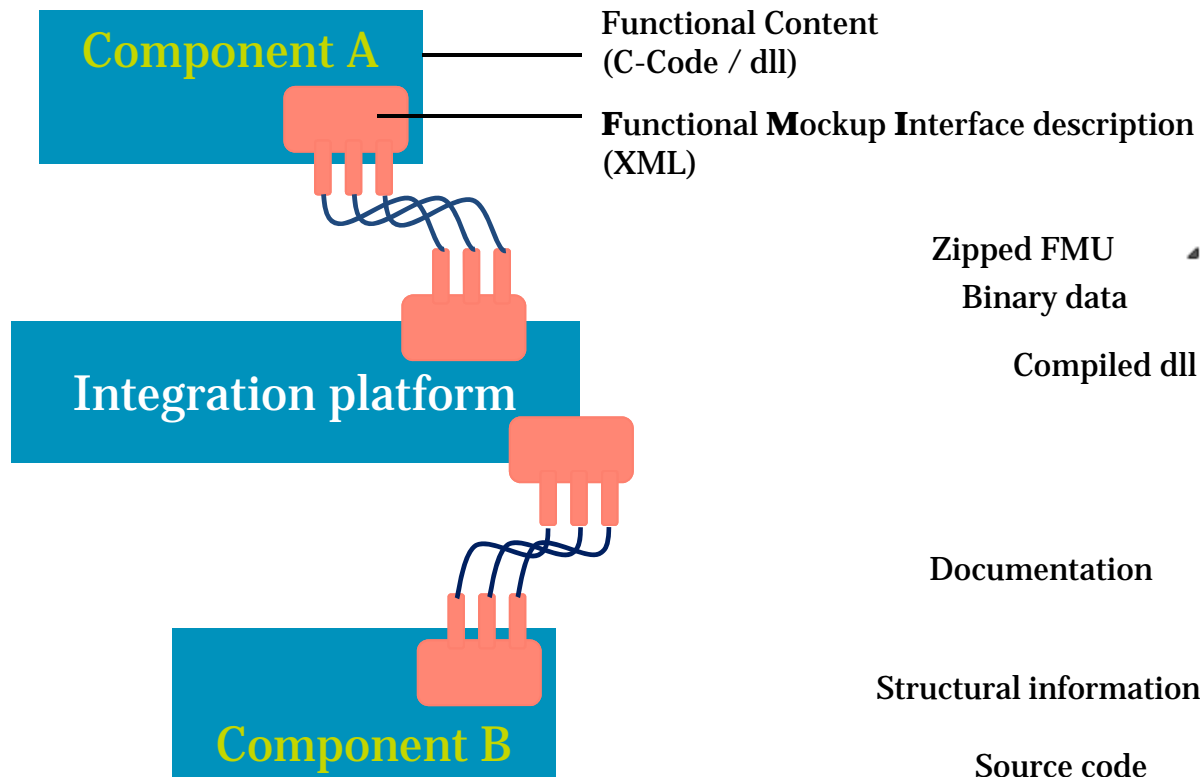
Traceability





Standardization

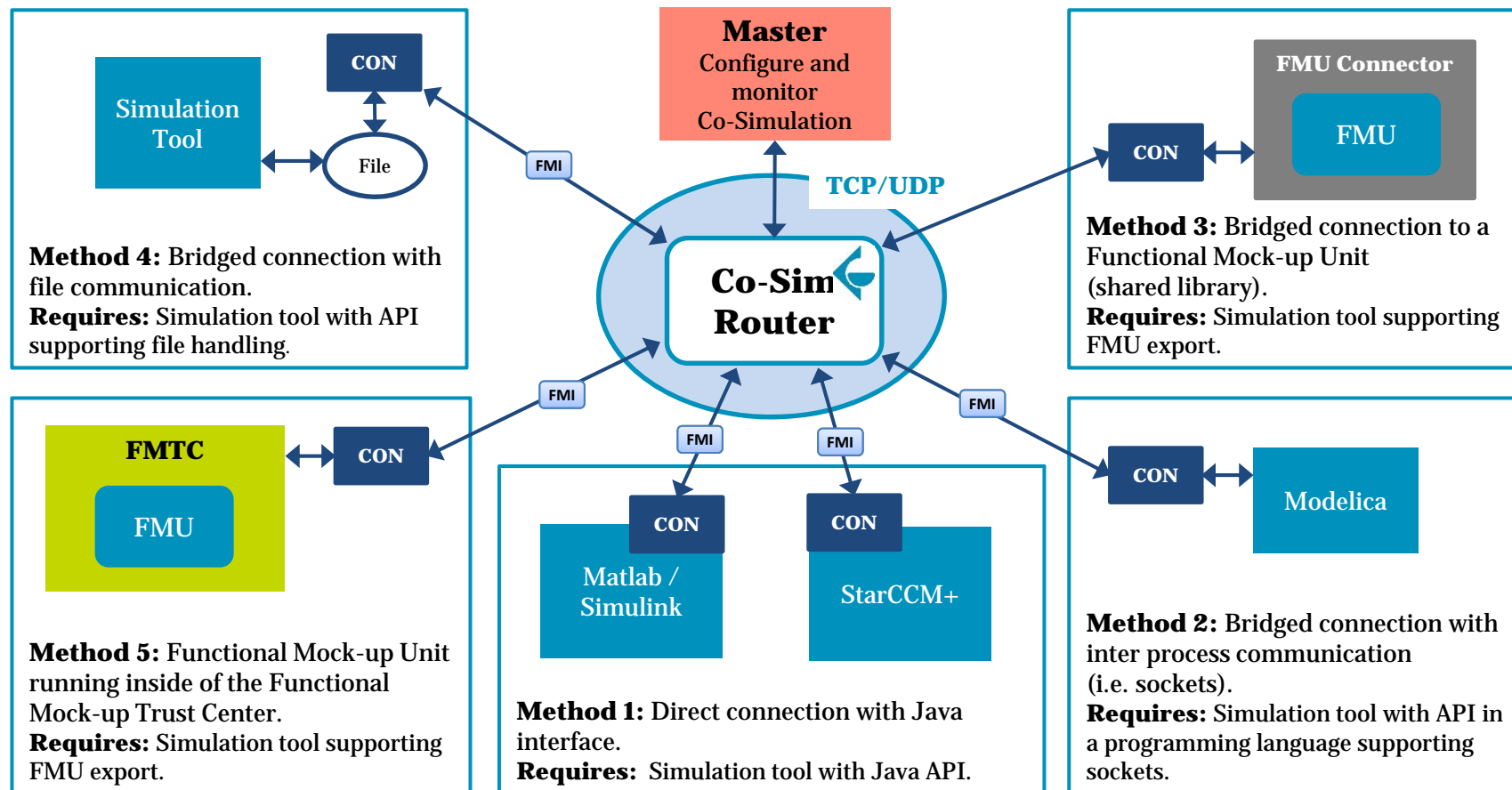
FMI Modular Approach



| | | |
|------------------------|----------|----------------------|
| Zipped FMU | 220,0 KB | example.fmu |
| Binary data | 188,0 KB | binaries |
| Compiled dll | 88,0 KB | win32 |
| | 88,0 KB | example.dll |
| | 28,0 KB | linux64 |
| | 24,0 KB | darwin32 |
| | 24,0 KB | darwin64 |
| | 24,0 KB | linux32 |
| Documentation | 20,0 KB | documentation |
| | 8,0 KB | [2 Dateien] |
| | 4,0 KB | model.png |
| Structural information | 4,0 KB | modelDescription.xml |
| Source code | 4,0 KB | sources |
| | 4,0 KB | example.c |



Application of FMI Co-Simulation





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Application of FMI

Functional Mock-Up Trust Centre - FMTC

Encrypted model on dedicated server

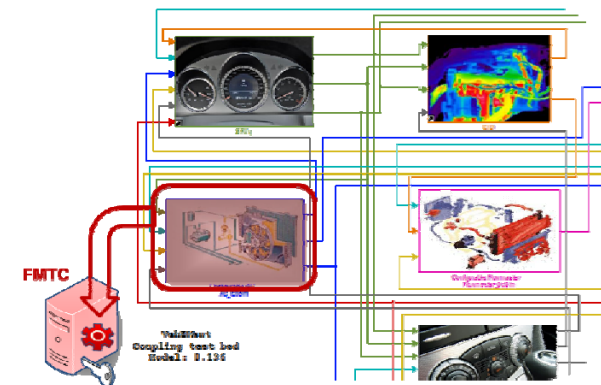
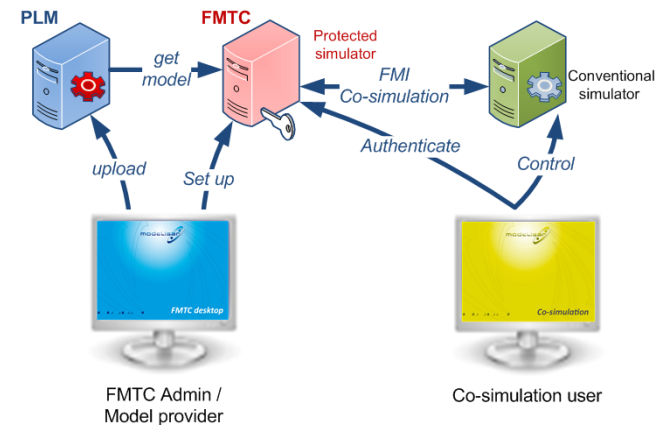
Collaborative simulation settings

Execution strictly limited

Shared use of models provided by OEM and supplier

Protection of intellectual property is key issue

Further challenge: Product life cycle management (PLM)

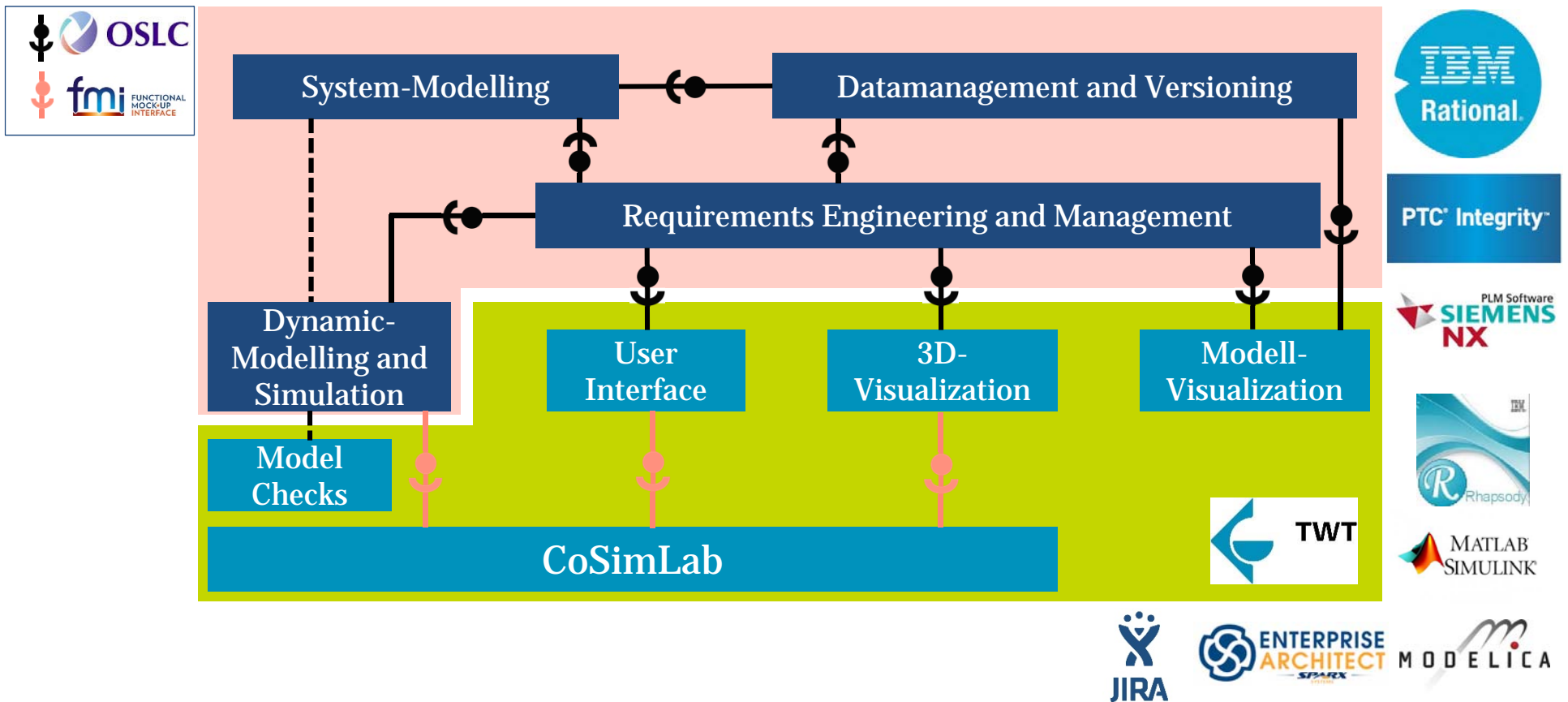




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Continous Product Development Process

Standardized Interfaces





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Continuous Product Development Process

The screenshot displays the TWT Co-Simulation Framework interface. At the top, there are tabs for 'Control' and 'Config'. Below this is a 'Co-Simulation Control' section with a 'Simulations' table. The table lists various simulation components, their states, addresses, engines, and timing parameters. Below the table is an 'Event Log' section showing a series of messages and events related to the simulation process, such as simulator name changes and initialization status.

| Simulation name | Router | State | Address | Simulation Engine | Sim Time | Comm step size | Sim step size | Rel. | Started |
|------------------------------|--------|---------|------------------|---------------------------------|--------------|----------------|---------------|------|--------------------|
| ArtSim | | STOPPED | /127.0.0.1:58652 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:15 - 16.1... |
| ArtSim | | STOPPED | /127.0.0.1:58660 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:15 - 16.1... |
| ArtSim | | STOPPED | /127.0.0.1:58639 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:15 - 16.1... |
| ArtSim | | STOPPED | /127.0.0.1:58653 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:15 - 16.1... |
| DistPlot | | STOPPED | /127.0.0.1:58663 | com.twt.cosim.core.network.i... | 235 s | 200 ms | 1 s | 5.0 | 09:07:15 - 16.1... |
| Dist_Ctrl_Driver | | STOPPED | /127.0.0.1:58925 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:23 - 16.1... |
| Dist_Ctrl_GUI | | STOPPED | /127.0.0.1:58972 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:22 - 16.1... |
| Dist_Ctrl_GUI | | STOPPED | /127.0.0.1:58920 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:21 - 16.1... |
| Dist_Ctrl_GUI | | STOPPED | /127.0.0.1:58917 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:21 - 16.1... |
| FMDriverU | | STOPPED | /127.0.0.1:58274 | com.twt.cosim.core.network.i... | 234 s 800 ms | 200 ms | 200 ms | 1.0 | 09:07:09 - 16.1... |
| FMEnvU | | STOPPED | /127.0.0.1:58273 | com.twt.cosim.core.network.i... | 234 s 800 ms | 200 ms | 200 ms | 1.0 | 09:07:09 - 16.1... |
| FMInterU | | STOPPED | /127.0.0.1:58327 | com.twt.cosim.core.network.i... | 234 s 800 ms | 200 ms | 200 ms | 1.0 | 09:07:09 - 16.1... |
| MBS_Model2 | | STOPPED | /127.0.0.1:58723 | com.twt.cosim.core.network.i... | 234 s 800 ms | 200 ms | 200 ms | 1.0 | 09:07:09 - 16.1... |
| Master_ALMERIA-1481875217630 | | PASSIVE | /127.0.0.1:56907 | com.twt.cosim.core.network.i... | 200 ms | 200 ms | 200 ms | 1.0 | 09:00:17 - 16.1... |
| SimpleMotor | | STOPPED | /127.0.0.1:58782 | com.twt.cosim.core.network.i... | 234 s 600 ms | 200 ms | 200 ms | 1.0 | 09:07:18 - 16.1... |
| TL_Controller | | STOPPED | /127.0.0.1:58376 | com.twt.cosim.core.network.i... | 234 s 800 ms | 200 ms | 200 ms | 1.0 | 09:07:10 - 16.1... |

| Timestamp | Event Type | Event |
|---------------------------|--------------|---|
| 16-12-2016 - 09:07:22,502 | RECEIVED_MSG | Simulator changed name from TL_Controller to TL_Controller, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.FmuSimulator from address /127.0.0.1:58376 |
| 16-12-2016 - 09:07:24,897 | RECEIVED_MSG | Simulator changed name from DistPlot to DistPlot, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:58663 |
| 16-12-2016 - 09:07:23,143 | RECEIVED_MSG | Simulator changed name from Dist_Ctrl_GUI to Dist_Ctrl_GUI, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:58920 |
| 16-12-2016 - 09:00:57,368 | RECEIVED_MSG | Simulator changed name from ArtSim to ArtSim, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:57340 |
| 16-12-2016 - 09:02:38,757 | RECEIVED_MSG | Simulator changed name from FMInterU to FMInterU, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.FmuSimulator from address /127.0.0.1:57115 |
| 16-12-2016 - 09:02:38,750 | RECEIVED_MSG | Simulator changed name from MBS_Model2 to MBS_Model2, description Forwards the Co-simulation network traffic over a socket connection and vice versa, engine com.twt.cosim.cor... |
| 16-12-2016 - 09:07:52,647 | INFO | Received new step sync confirmation from 'FMEnvU' which is: [FMEnvU, NO_DESCRIPTION, com.twt.cosim.core.network.impl.FmuSimulator, 1822711636, 1481875629600, 1.0, 200000000, ... |
| 16-12-2016 - 09:02:38,674 | RECEIVED_MSG | Simulator changed name from Dist_Ctrl_Driver to Dist_Ctrl_Driver, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:57601 |
| 16-12-2016 - 09:07:17,62 | RECEIVED_MSG | Simulator changed name from ArtSim to ArtSim, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:57345 |
| 16-12-2016 - 09:02:39,53 | RECEIVED_MSG | Simulator changed name from ArtSim to ArtSim, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:57345 |
| 16-12-2016 - 09:07:52,717 | INFO | Received new step sync confirmation from 'FMInterU' which is: [FMInterU, NO_DESCRIPTION, com.twt.cosim.core.network.impl.FmuSimulator, 2105886027, 1481875629376, 1.0, 200000000, ... |
| 16-12-2016 - 09:07:17,100 | INFO | All simulators have reported to be initialized, simulation is ready for step handshake! |
| 16-12-2016 - 09:00:57,367 | RECEIVED_MSG | Simulator changed name from ArtSim to ArtSim, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:57316 |
| 16-12-2016 - 09:07:17,117 | RECEIVED_MSG | Simulator changed name from DistPlot to DistPlot, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:58663 |
| 16-12-2016 - 09:07:20,176 | RECEIVED_MSG | Simulator changed name from MBS_Model2 to MBS_Model2, description Forwards the Co-simulation network traffic over a socket connection and vice versa, engine com.twt.cosim.cor... |
| 16-12-2016 - 09:07:11,721 | INFO | All simulators have reported to be initialized, simulation is ready for step handshake! |
| 16-12-2016 - 09:02:14,555 | INFO | All simulators have reported to be synced, initiating signal name broadcast! |
| 16-12-2016 - 09:07:19,83 | RECEIVED_MSG | Simulator changed name from ArtSim to ArtSim, description NO_DESCRIPTION, engine com.twt.cosim.core.network.impl.MatlabSimulator from address /127.0.0.1:58653 |
| 16-12-2016 - 09:07:23,343 | INFO | All simulators have reported to be initialized, simulation is ready for step handshake! |



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Industrial Application of Co-Simulation Facts & Figures

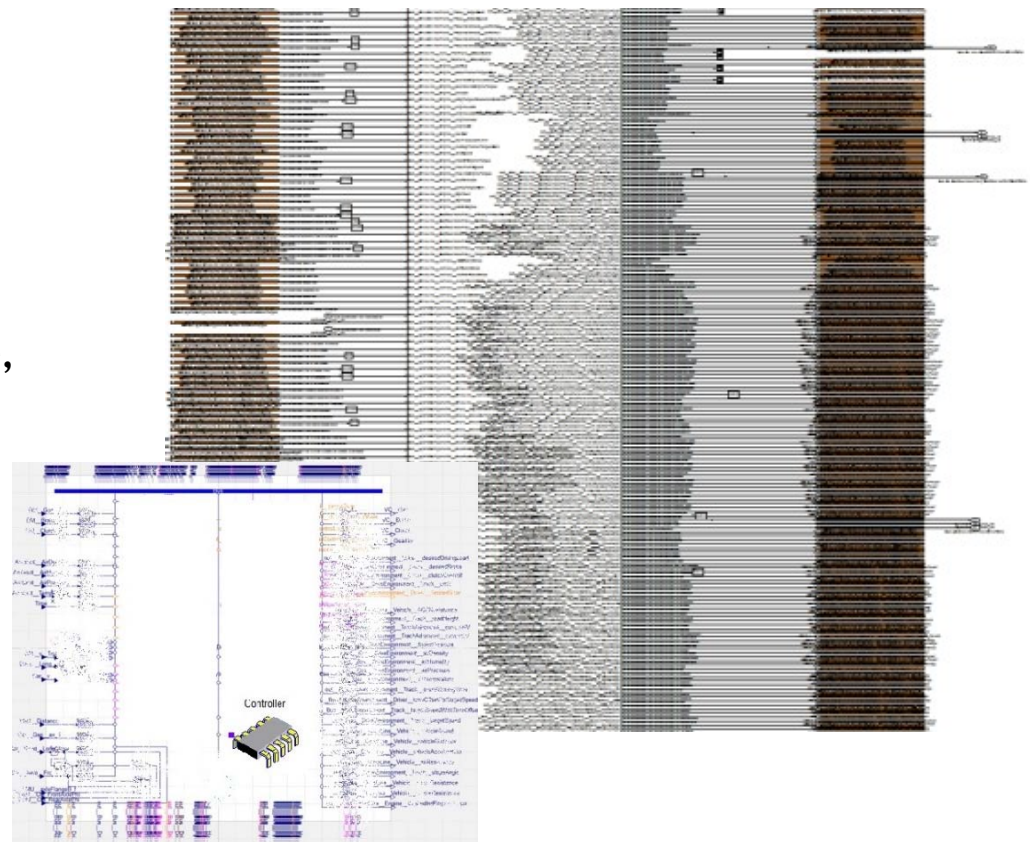
Interface size > 700 signals

FMU XML size > 12 MB

FMU XML > 300'000 lines

Various solver used, e.g. sundials code,
vendor modified dassl solver, ...

Typically developed within specialized
departments and modelling tool





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Model Re-Use Modularization

Re-use of (sub)-components

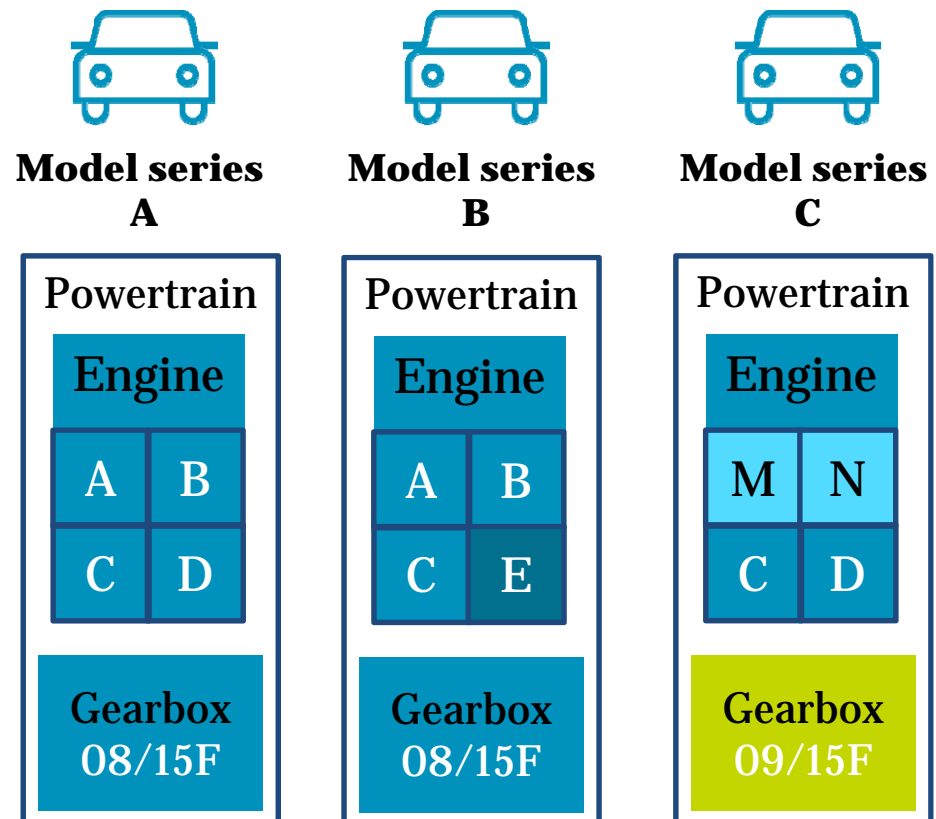
Faster development cycle

Lower development costs

Long term stability

Traceability

PLM possible





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Model Re-Use II Responsibility

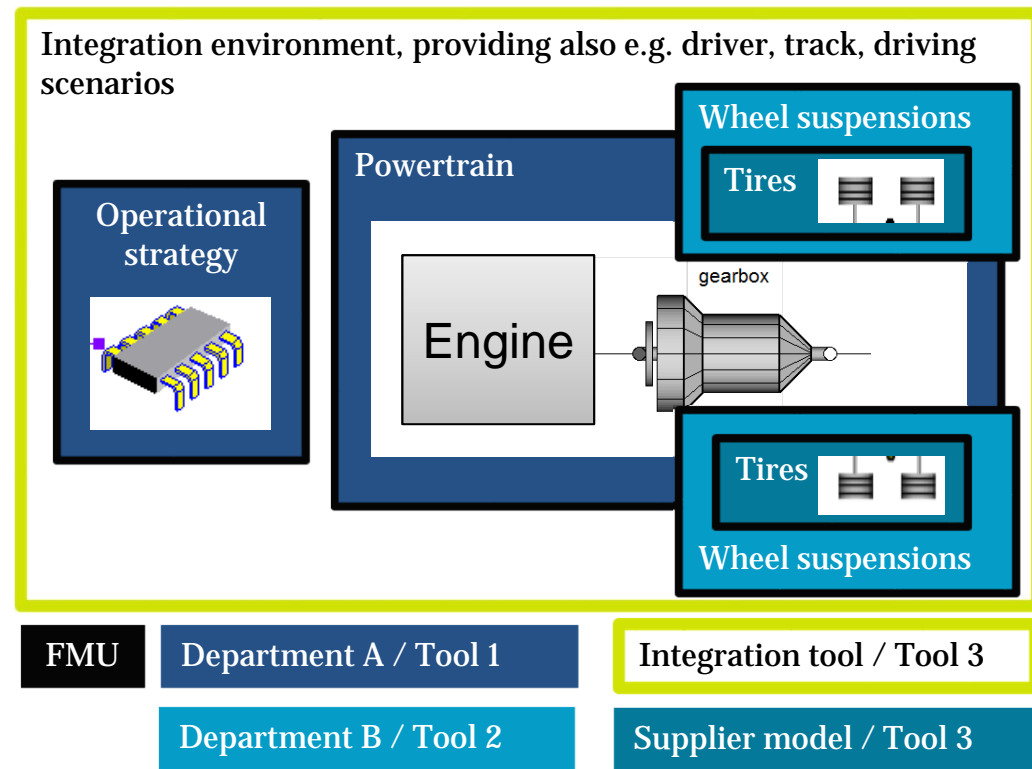
Single point of truth

CoC responsible for all aspects of component development

No re-modelling of 'Department-A-components' in Department B

Integration of (final) supplier components

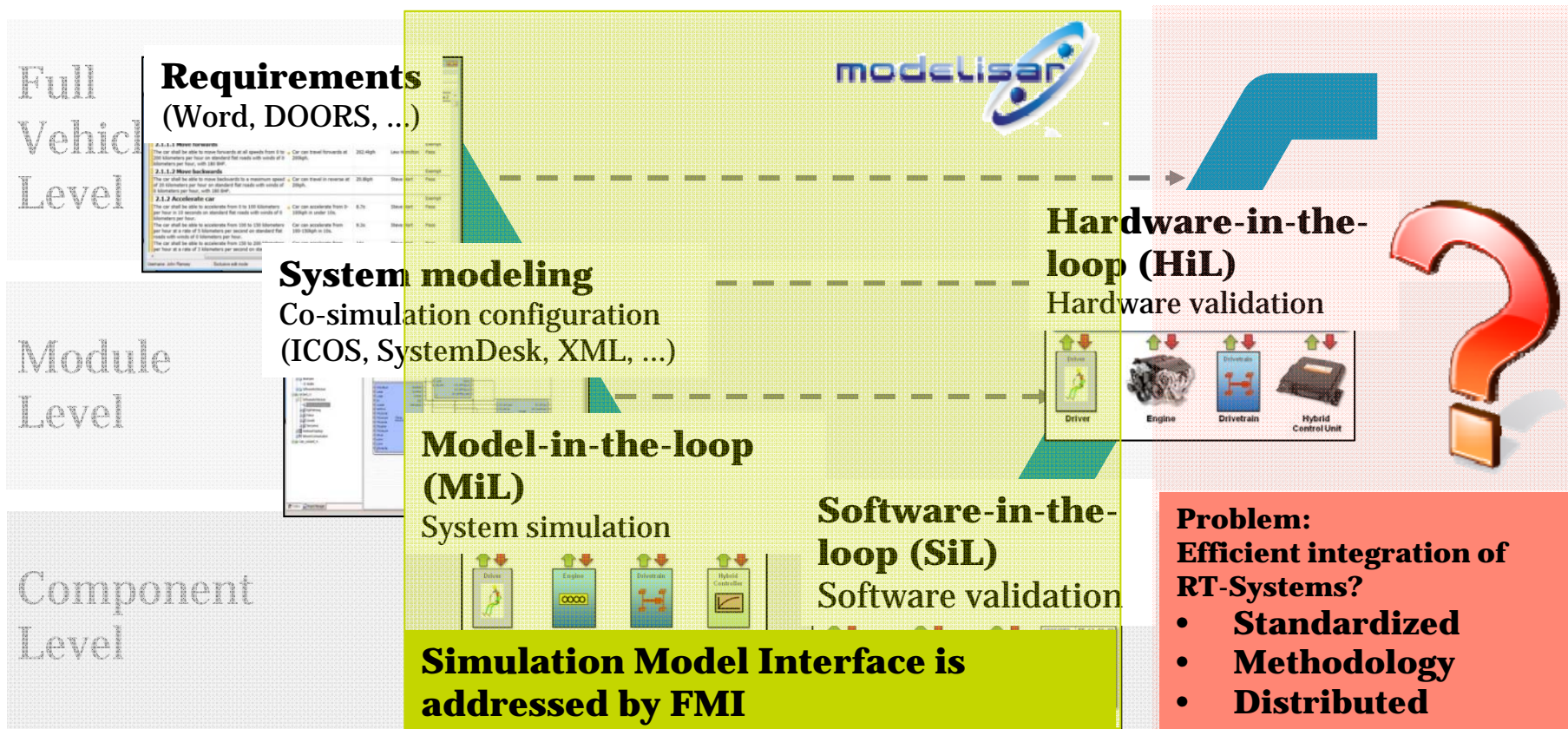
Tool-independence -> re-use of outer world designs





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Real-time Interaction FMI and Co-Simulation





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Bundesministerium
für Bildung
und Forschung



ITEA 3

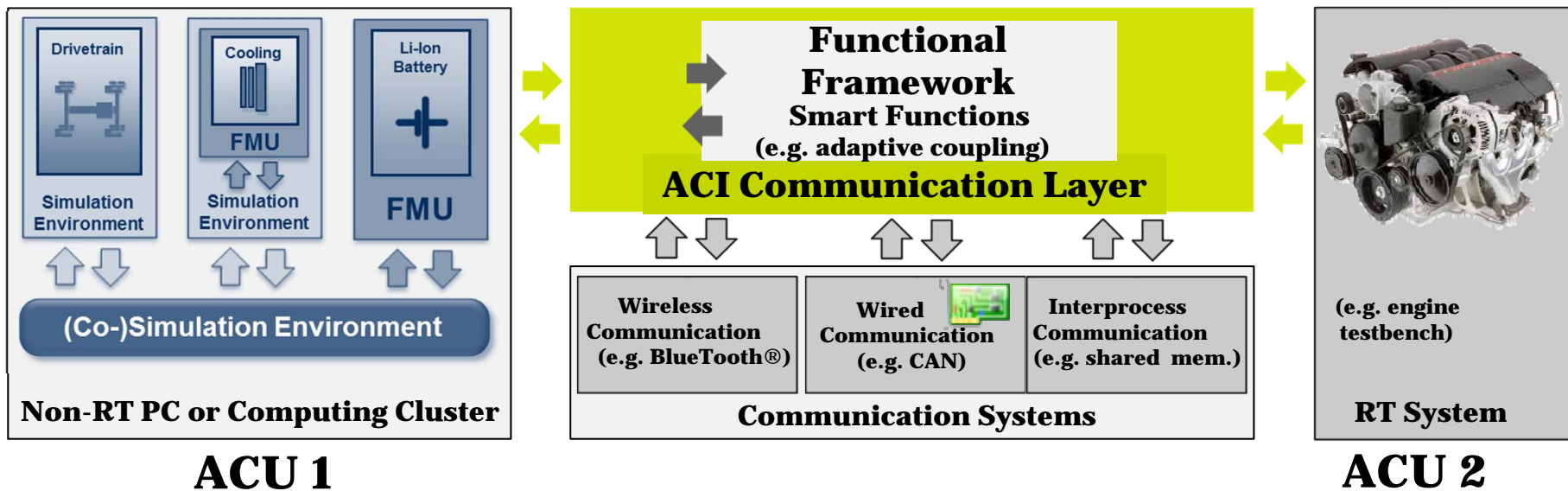
ACOSAR
ADVANCED CO-SIMULATION OPEN SYSTEM ARCHITECTURE

Real-time Interaction Advanced Co-Simulation Interface

ACI integrates real-time systems and simulation environments

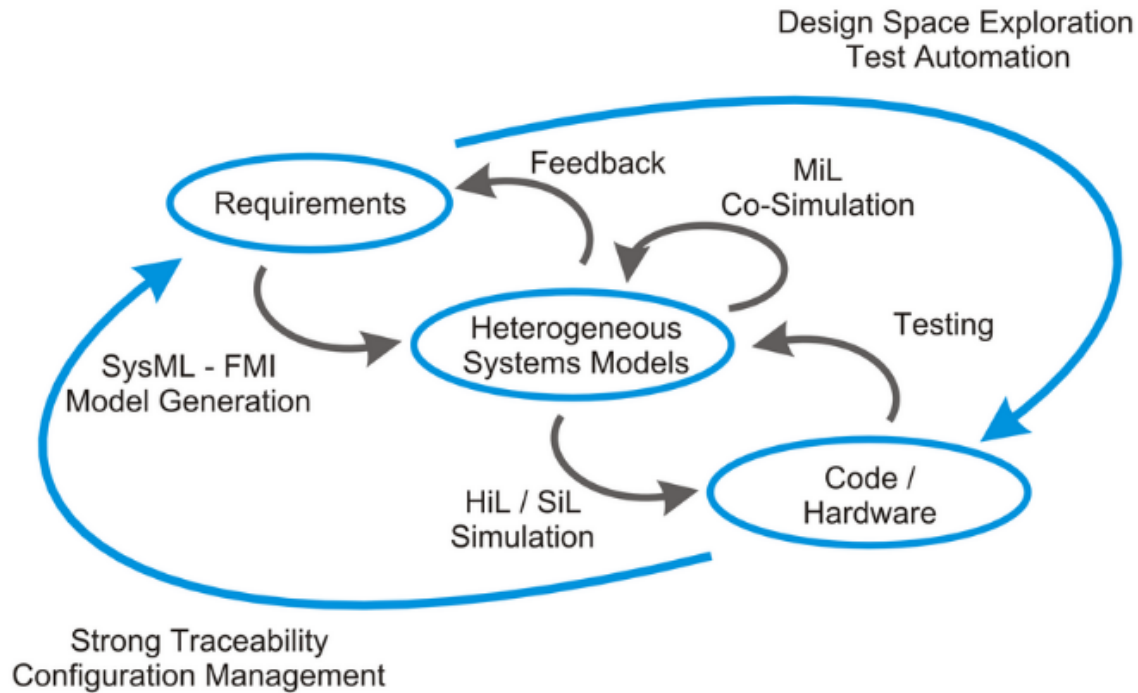
ACI ... Advanced Co-Simulation Interface

ACU ... Advanced Co-Simulation Unit



Holistic Tool Integration

Co-Simulation



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Linköping University



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THE UNIVERSITY of York

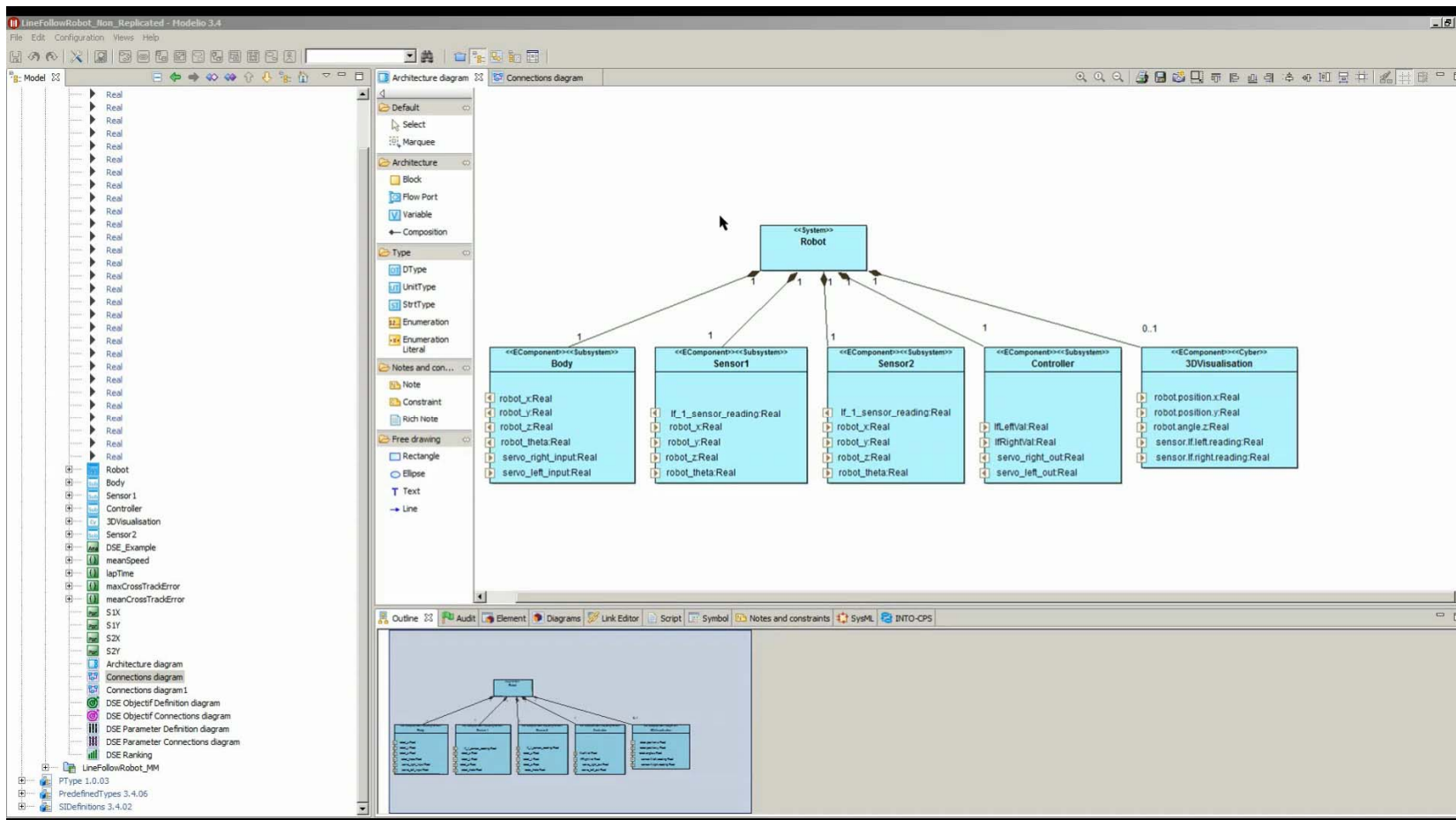


Holistic Tool Integration

Co-Simulation



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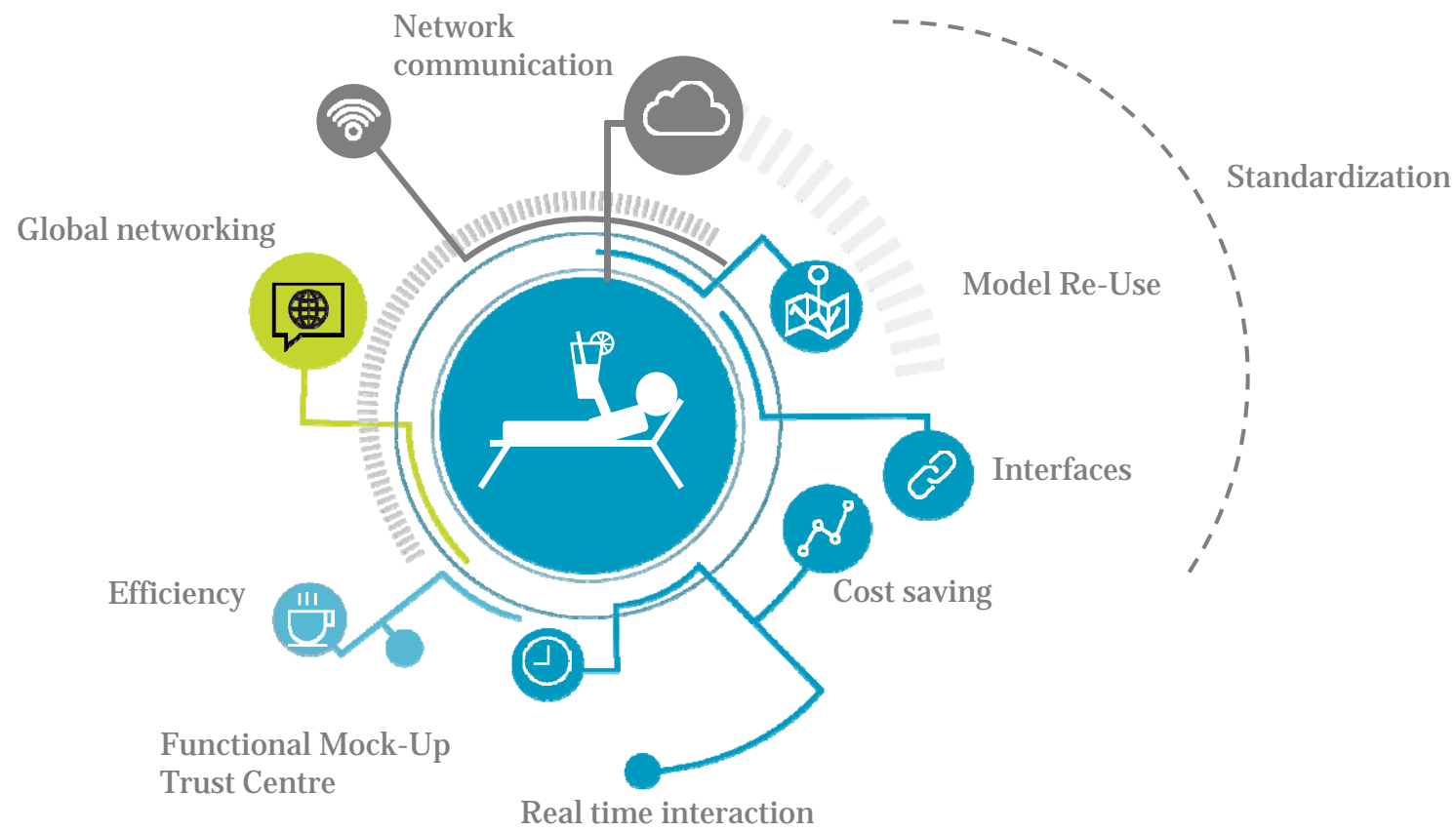


Confidential



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Summary





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Thank you for your attention

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ACI Architecture (draft)

