



dSPACE



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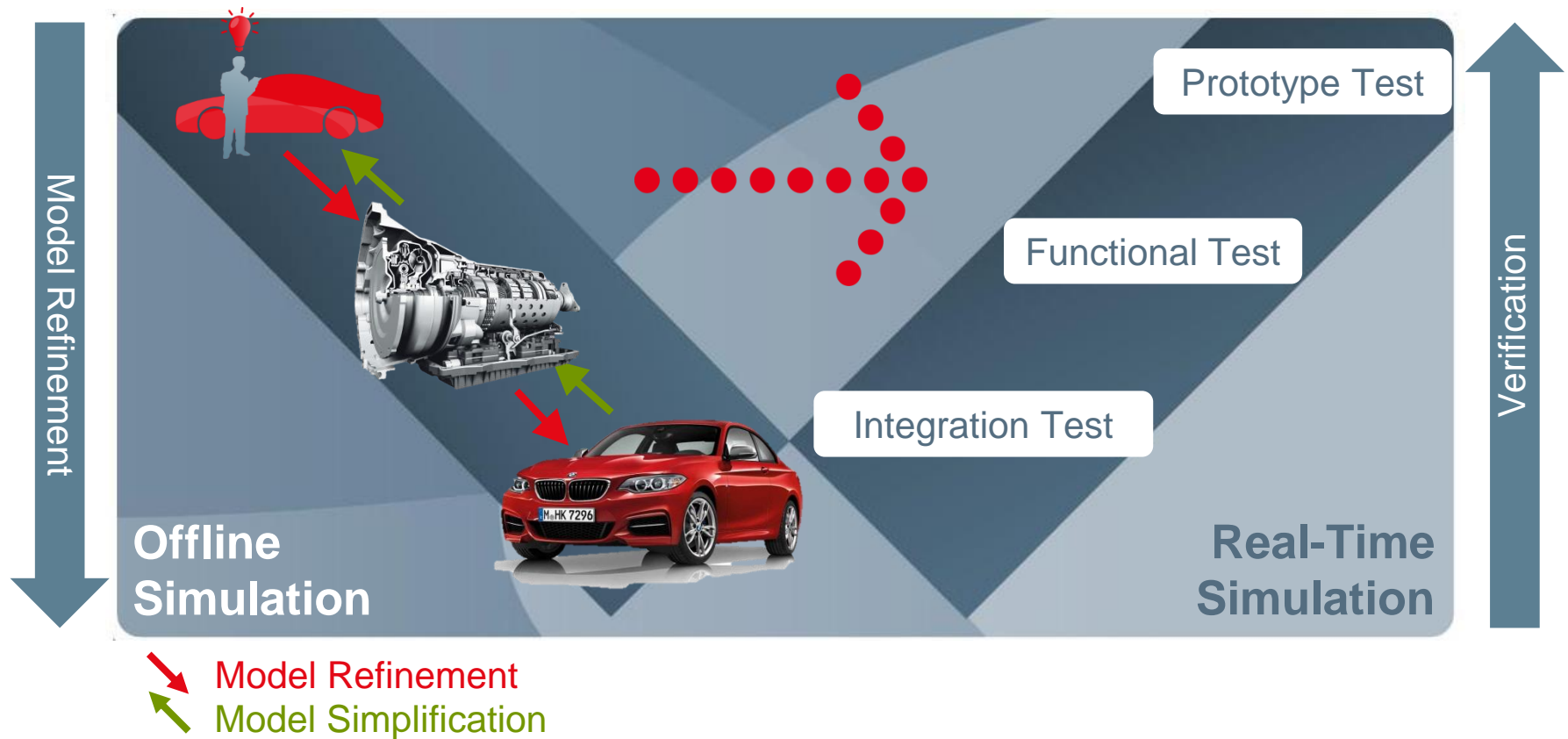
HiL Real-time Testing of a Gearbox Controller Unit Including a Physical Gearbox FMU

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Christian Kehrer, ITI GmbH

Modeling Throughout all Development Steps



All-in-all: various models, various tools and various suppliers require standardized tool-vendor independent interfaces

FMI and HiL Simulations

New features in FMI 2.0 are beneficial for HiL use cases

- **Change parameter values during run-time of simulation**
(FMI 2.0: tunable parameters)
 - e.g., interactive experiments with dSPACE ControlDesk® and real hardware-in-the-loop
- **Transport sample times of model with FMU**
(FMI 2.0: *stepSize* in default experiment)
 - Improves support for specialized real-time solvers

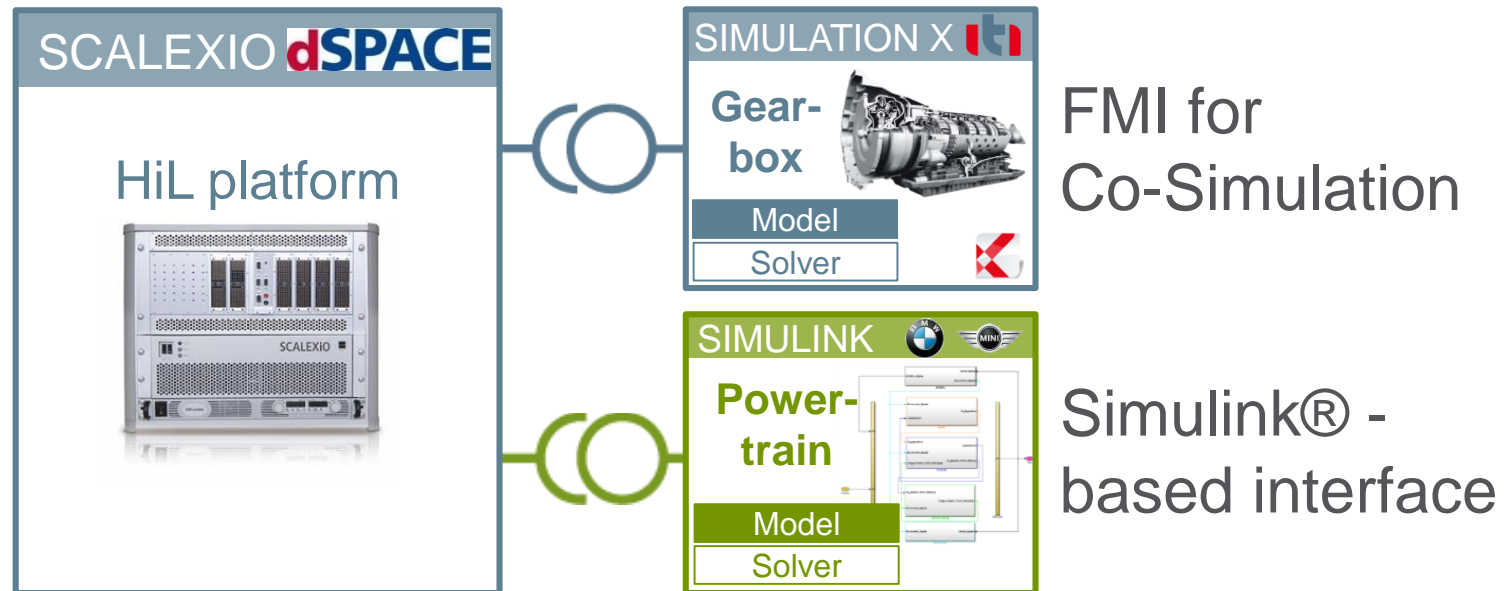
FMI and HiL Simulations

General restrictions are also valid for FMI

- **Real-time capability**
 - Limits model complexity, solver type and co-simulation approach
- **Platform independence**
 - Requires source code
- **Intellectual property (IP) protection**
 - Often based on compiled libraries, requires a pre-selection of target platforms

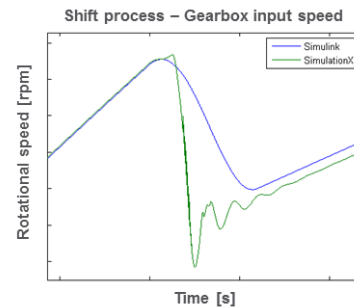
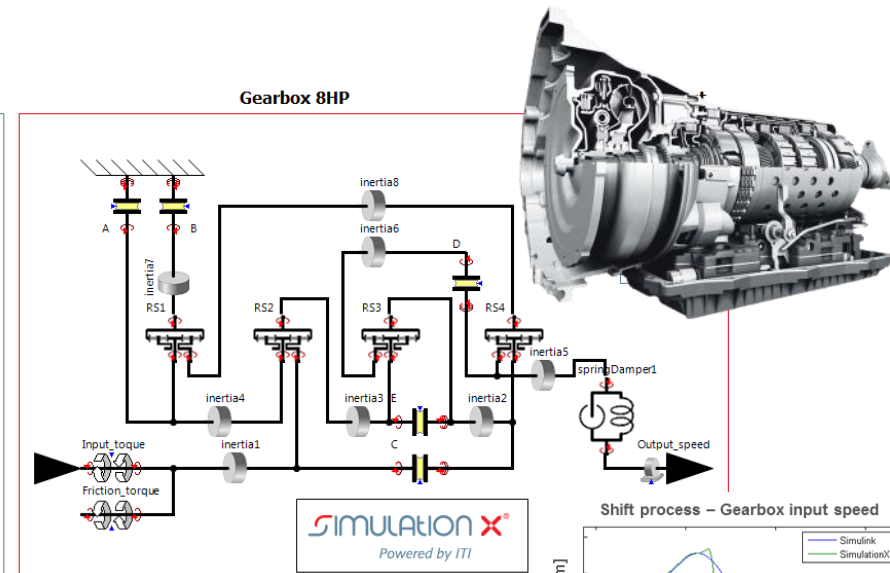
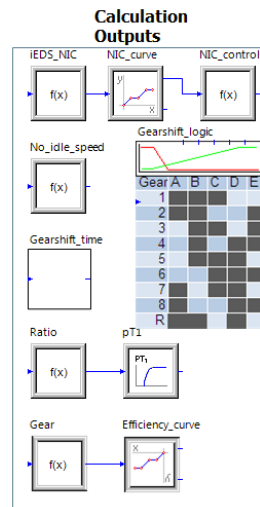
BMW Use Case – HiL test of 8HP gearbox ECU

- Functional Mock-up Interface in mechatronic gearshift simulation for cars
- Workflow test of real-time use case for FMI 2.0 for Co-Simulation
- Project partners: BMW, dSPACE, and ITI GmbH



Gearbox Model in SimulationX®

- Real-time-capable physical, non-linear model to calculate transient shifting processes, incl.
 - Planetary gear sets with variable ratios
 - Clutches with physical friction behavior
 - Shifting logic, incl. torque-dependent shifting diagram
- Couplable to actuation models



HiL Project for 8HP ECU – FMI-related workflow steps

Exchange interface
information between
project partners

Create the model
interface in the
modeling environments

Import models and
connect the model
interface

- **Required model functionality**
- **Model interface description**
 - input/outputs, start values, ranges, units, ...
- **Technological framework**
 - version information, compiler, real-time requirements, ...

- **SimulationX**
 - gearbox model
- **Simulink**
 - overall powertrain model

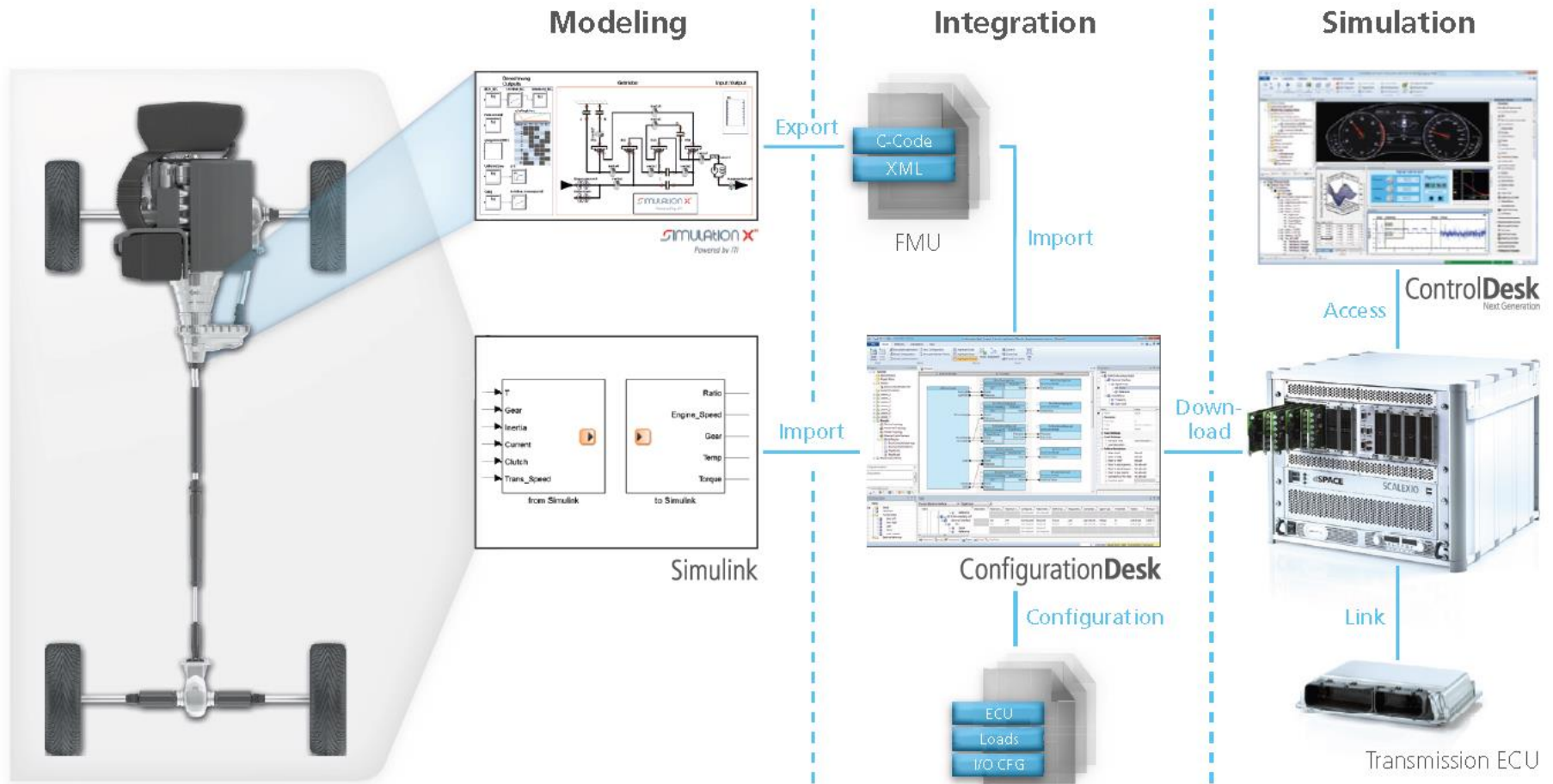
- **ConfigurationDesk®**
 - Connect models
 - Connect models to HiL I/O

HiL System Setup

- Information exchange with BMW
 - Electrical interface of 8HP gearbox ECU
 - Planned HiL test cases
- SCALEXIO® – Off-the-Shelf
 - Channels for signal generation and measurement
 - Channels for CAN bus simulation
- Load rack
 - ECU connectors
 - Valve carrier
 - OBD connector
 - ...



HiL Project Using dSPACE SCALEXIO



Project Results

- Successful integration of FMU into existing powertrain model
 - Integrated dynamic model considering vibration phenomena up to 40 Hz runs in real-time (sample time 1 ms)
 - Co-simulation is numerically stable
 - 8HP ECU runs without fault memory entries
- Performance of gearbox model FMU vs. S-function
 - Max. task turnaround time:
 - S-function: 175 μ s
 - FMU: 173 μ s



Conclusion

- Straightforward integration into original BMW Simulink-based powertrain model
- Performance (task turnaround time) of FMU suitable for real-time applications
- ECU runs in HiL tests without fault memory entries
- Test case for ProSTEP SSE project workflow
 - Exchange of interface and additional data
 - Standardized workflow is beneficial
 - Closes gaps by reusing existing models

Outlook

- Workflow test for FMUs with IP protection
- Use case investigations
- Tool improvements
- Development of FMI 2.1 in FMI project



Thank you for your attention!

dSPACE



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