November 13–14, 2024 | Online

Powertrain Modeling in Heavy-Duty Vehicles

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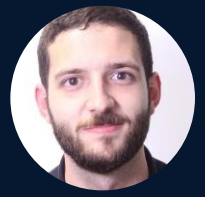
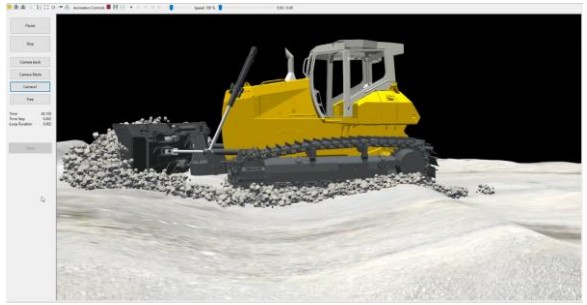


MATLAB EXPO

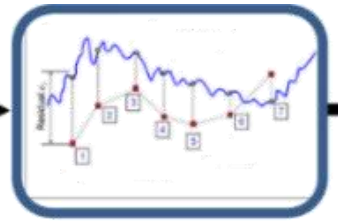
Agenda

- Introduction to the Digital Twin Lab Project (DTL).
  Modeling of Powertrains with MATLAB® and Simscape™
- Development Structure
- Means, Tools and Composition
- Co-Simulation Environment and Simulation Examples
- Current and Future Development
- Overview and Conclusion

The DTL main objective is to provide all the necessary means to represent multi-physical models of heavy-duty vehicles

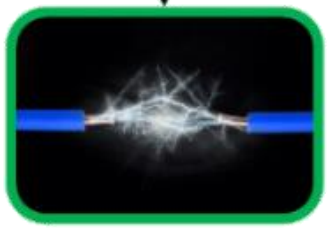


Drivetrain



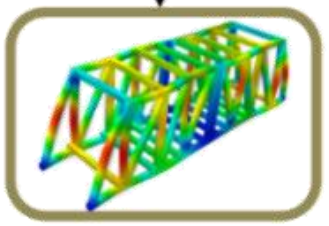
Parameter fitting

MBS co-simulation

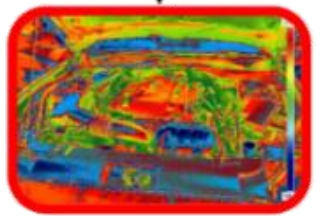


Electrification

Data driven methods/AI



Vibrations



Thermal simulation

Virtual trainer

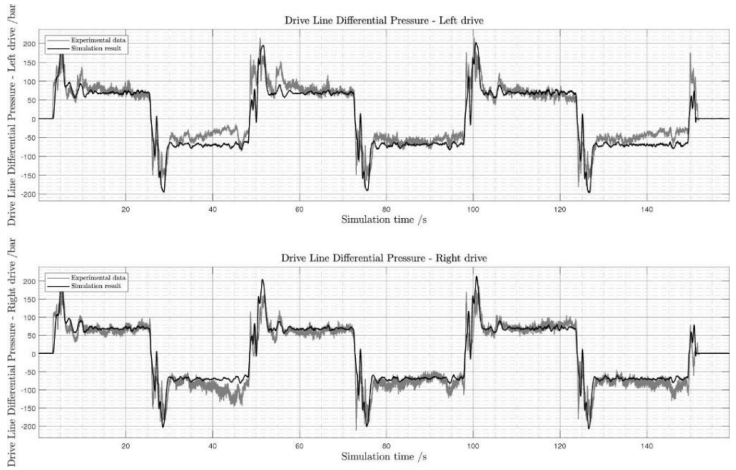
Autonomous op

Condition monitoring

Predictive Maintenance

Multi physics

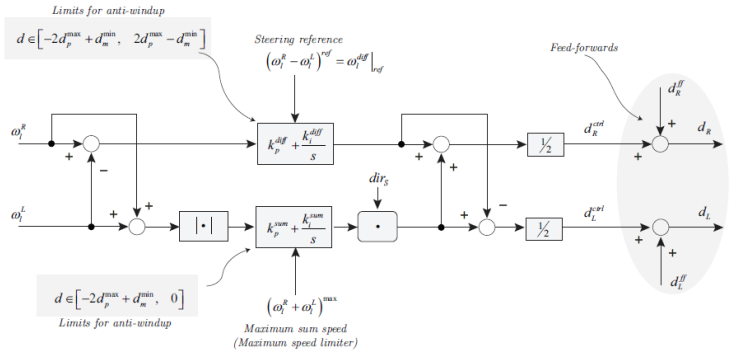
Which are the specific use cases this project aims to address?



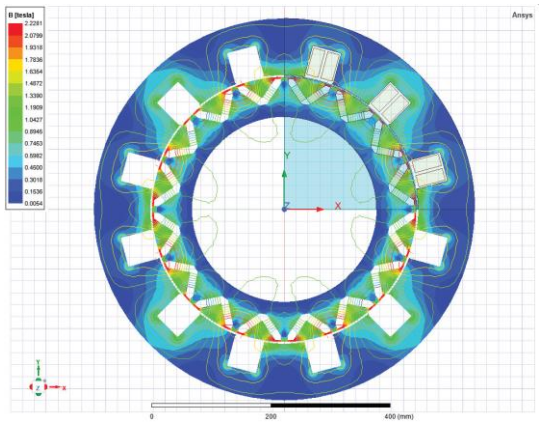
Reliable and **detailed digital models** of the vehicles

Vehicle-environment interaction

Test behaviour under **different field conditions**



Implement different **control strategies**



Design new machines and components, especially new zero-emission variants

Assistive & Autonomous driving strategies

The project partners

- **University of Applied Sciences, MCI**
  - **Digital Twin Lab Team**:
    - Andreas Mehrle
    - Manuel Ferdik
    - Jasper Volmer
    - Davide Bagnara
    - Alejandro Secades

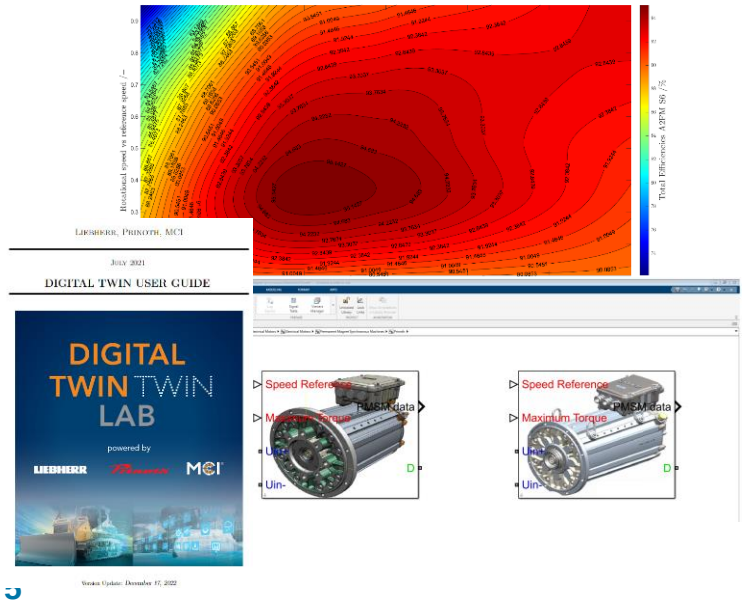
- **Liebherr-Werk Telfs**
- **Prinoth AG**
- Project funded by **Land Tirol** in cooperation with the **FFG**

Development structure => Part I.
System foundation comprising the data & components

Simulation-Based Development of Working Machines

DTL Toolbox

- Library of Components
- Documentation
- Data, UI



Development structure => Part II.
Physical modeling of the actual powertrains

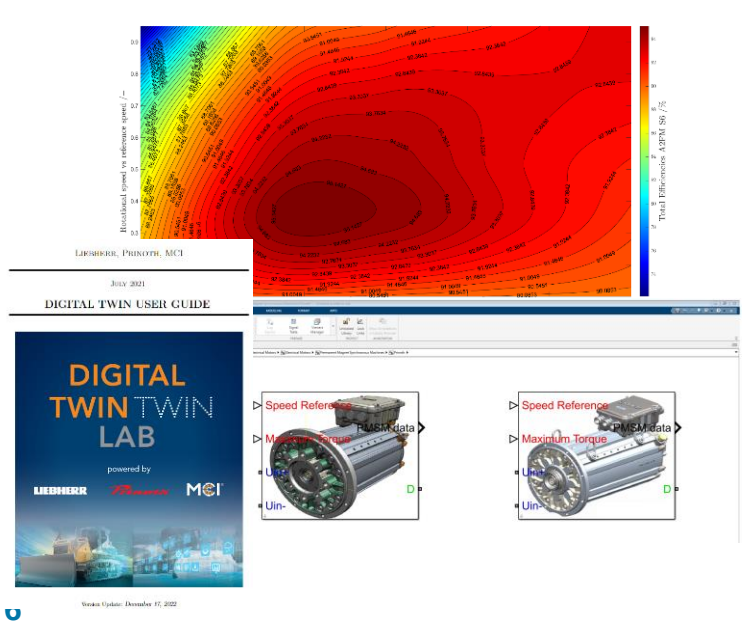
Simulation-Based Development of Working Machines

DTL Toolbox

- Library of Components
- Documentation
- Data, UI

Powertrain Modeling

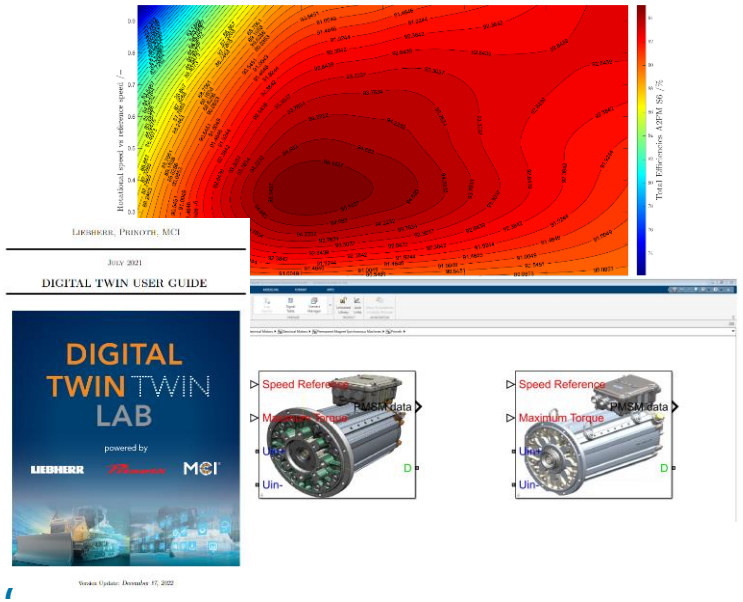
- 1D Physical Vehicle Models
- Vehicle Control Schemes
- Electrified Drivetrains

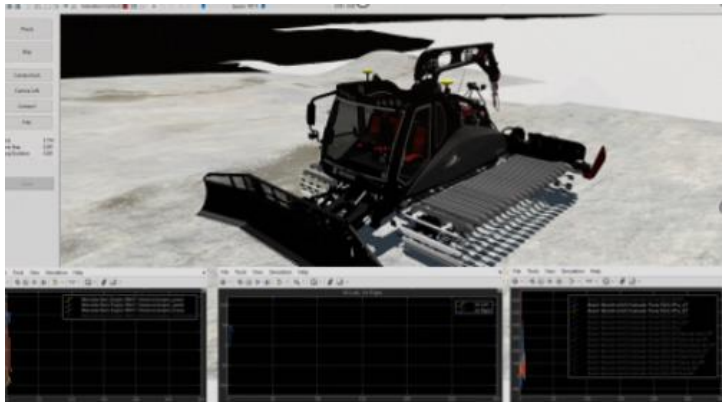


Development structure => Part III.
3D environment interaction with the powertrain

Simulation-Based Development of Working Machines

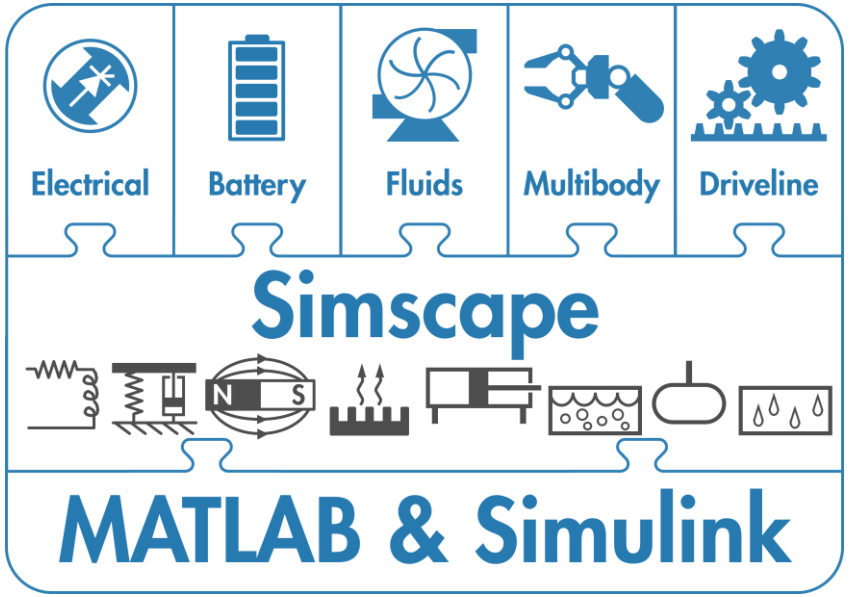
DTL Toolbox	Powertrain Modeling	Multibody Simulation
• Library of Components • Documentation • Data, UI	• 1D Physical Vehicle Models • Vehicle Control Schemes • Electrified Drivetrains	• 3D Mechanical Models • Environment (Terrain)





Simulation integrates designs from many teams for testing on deformable terrain

- **Simulation environment** from MATLAB, Simulink, and Simscape

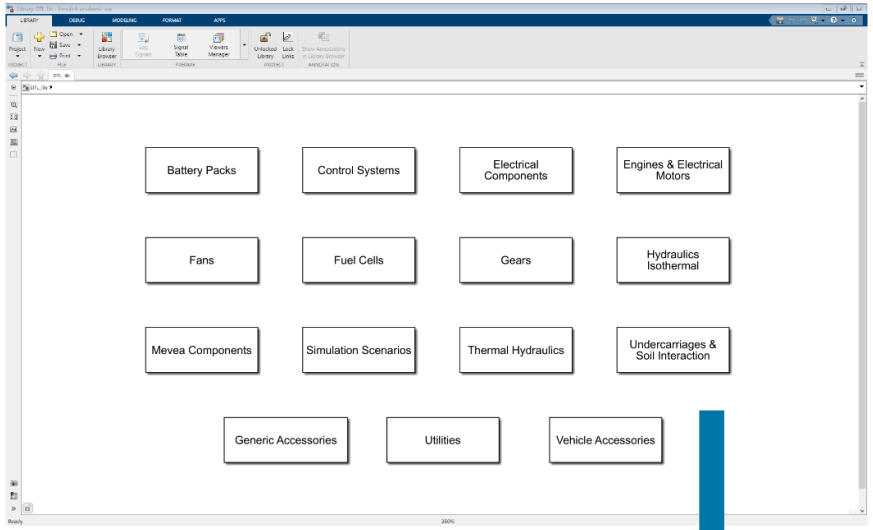


- **Interaction with terrain** modeled in Mevea
  - Multibody simulation software (MBS)

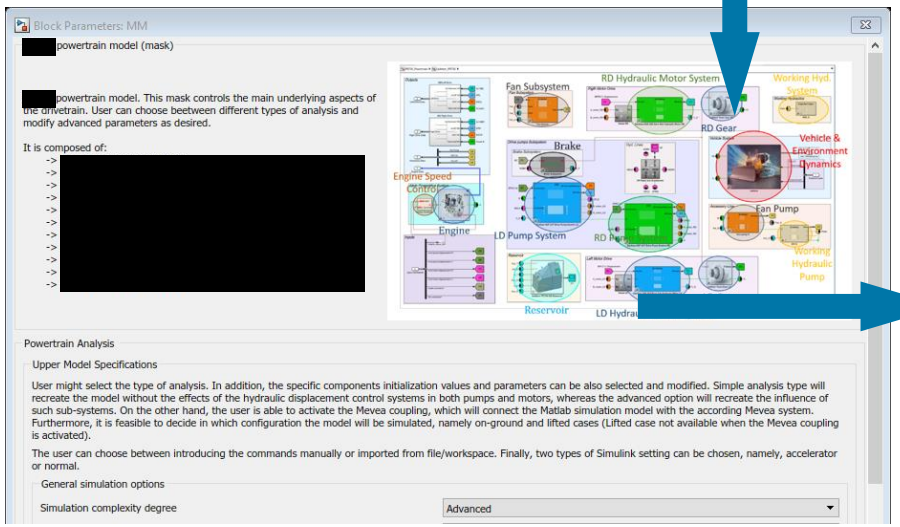
Mevea
Simulation solutions

Foundation elements & Powertrains modeled using MATLAB and Simscape

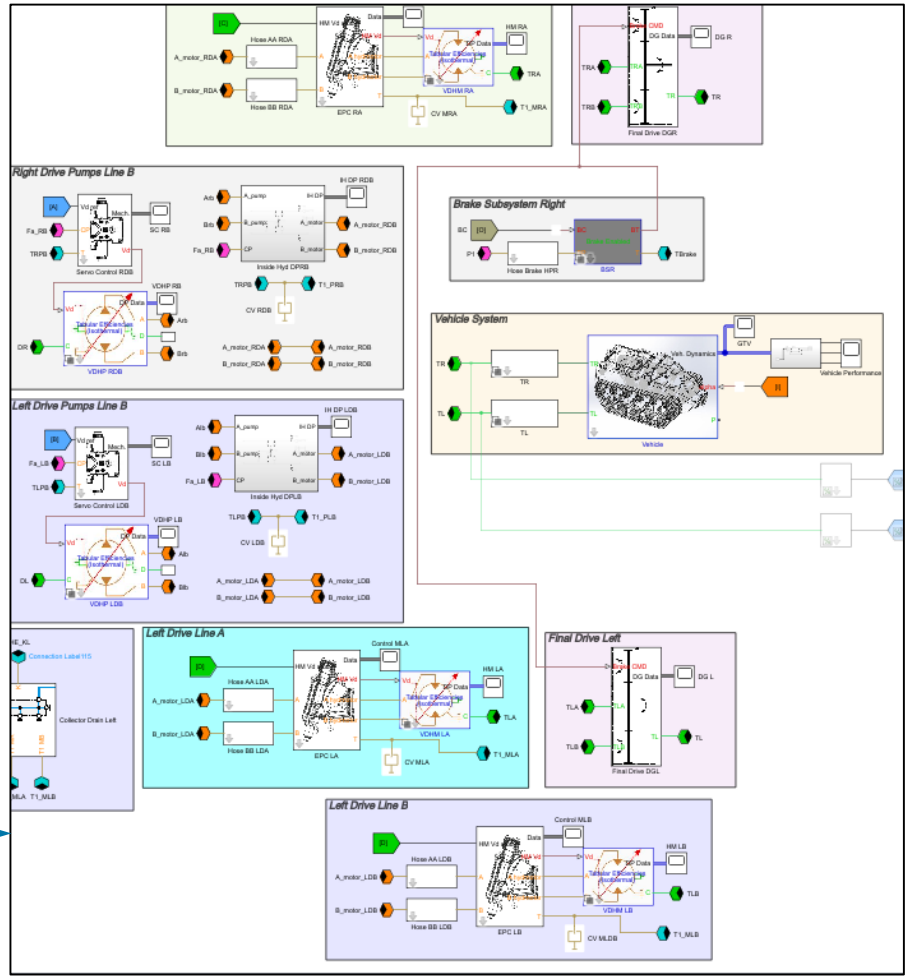
DT Toolbox



UI



Powertrain Model



User Guidance

LIEBHERR, PRINOTH, MCI

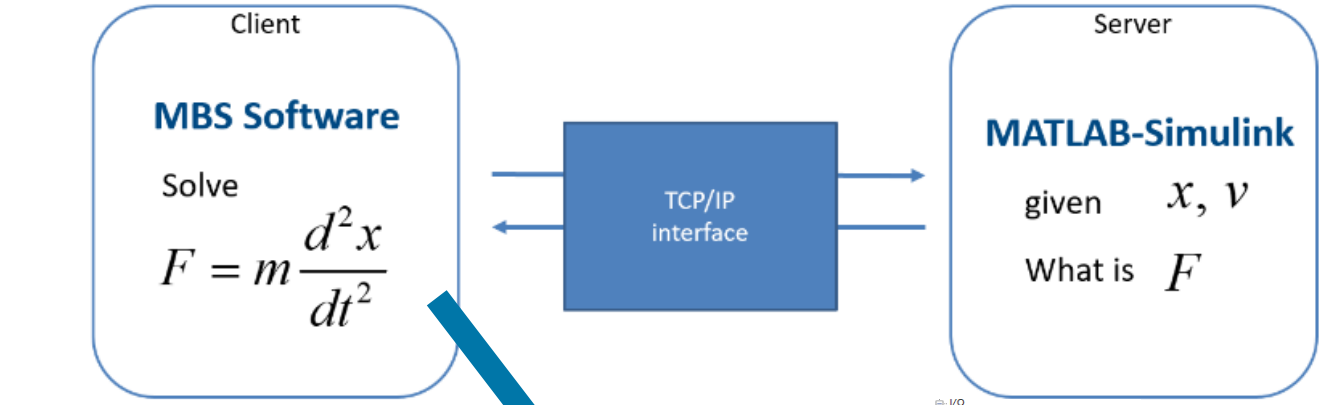
JULY 2021

DIGITAL TWIN USER GUIDE

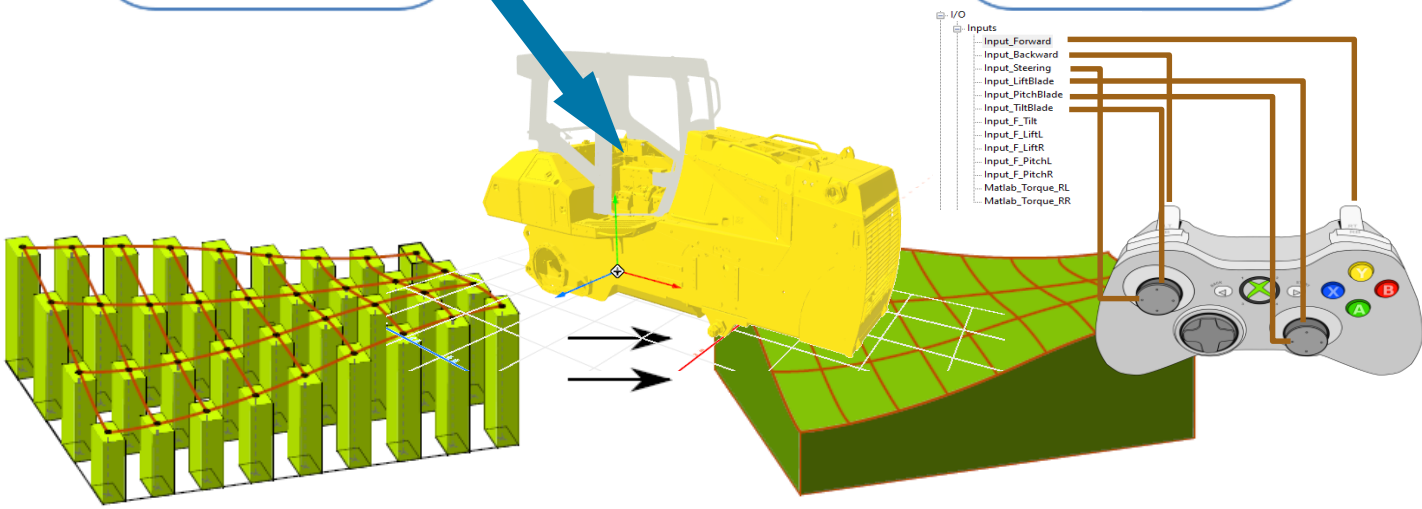
Version Update: December 17, 2022

Deformable terrain system modeled in Multibody Simulation Software (MBS) Mevea

- **Co-Simulation** between Mevea and Simulink
  - Mevea MBS Software takes user commands for controlling the vehicle
  - Relevant boundary conditions are communicated back and forth between the two packages



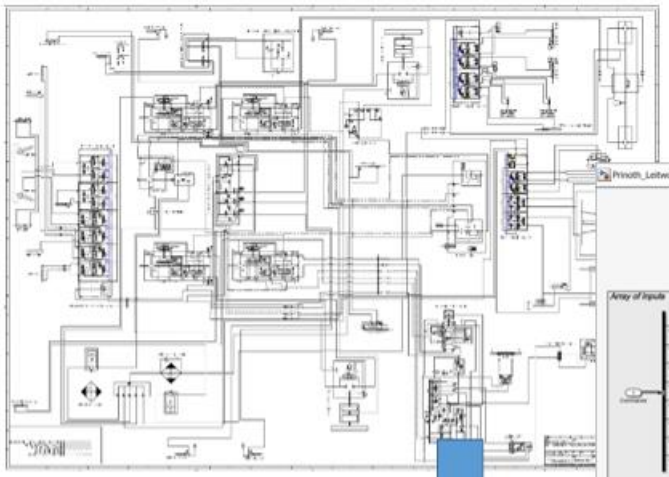
- Mevea provides:
  - Rigid bodies + Constraints
  - Interaction with the terrain
  - Communication with the user



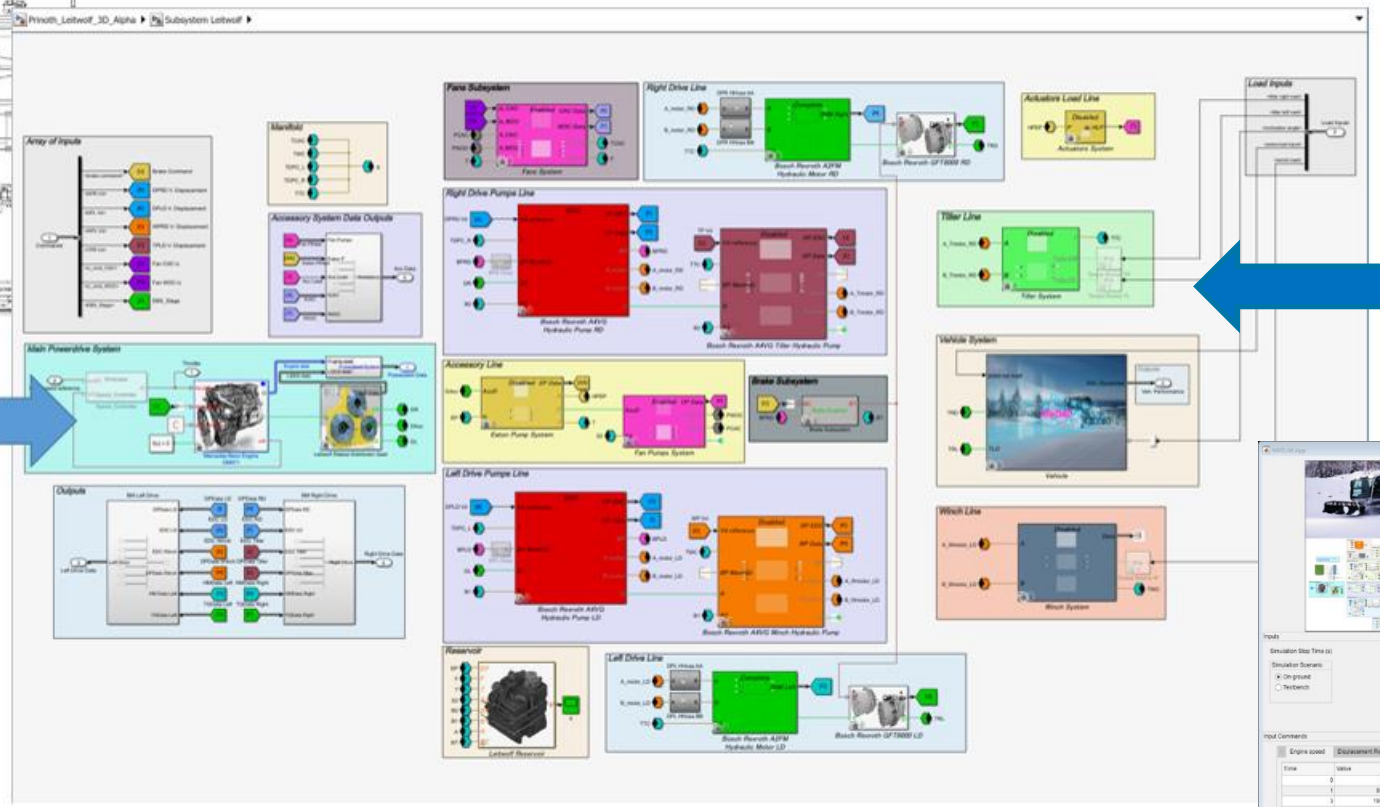
Terrain model

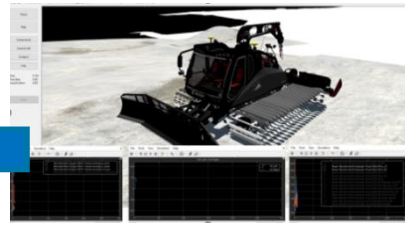
Rendered component

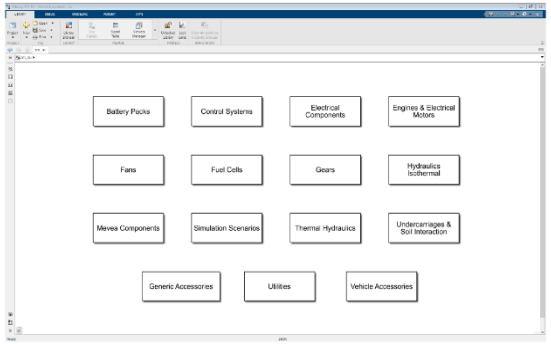
Simulink enables integration of powertrain and machine dynamics => Co-Simulation Environment



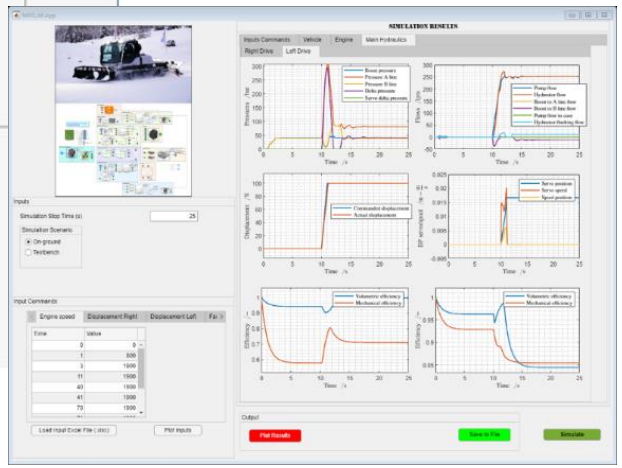
Machine Drivetrain Model





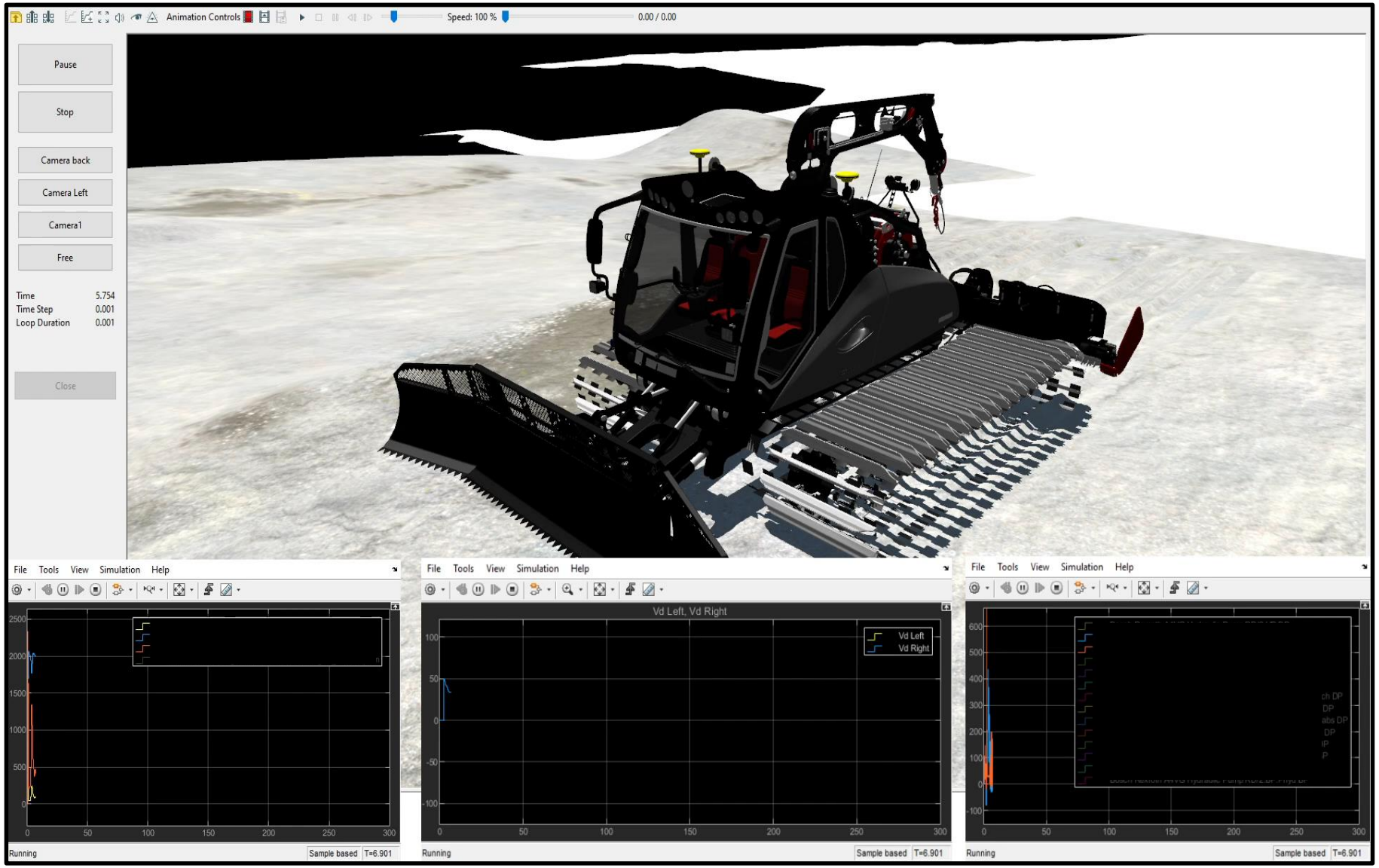


DT Toolbox

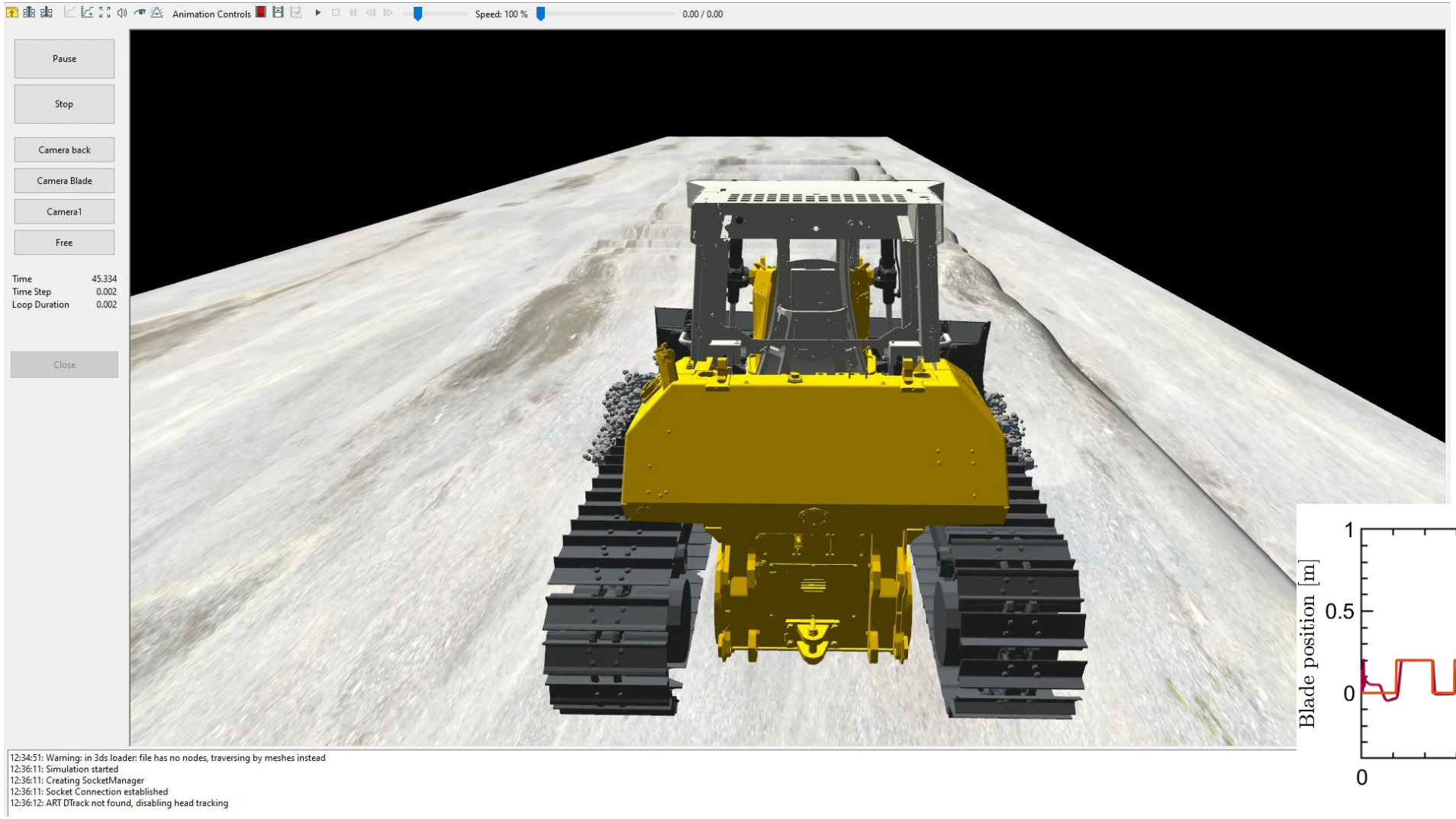


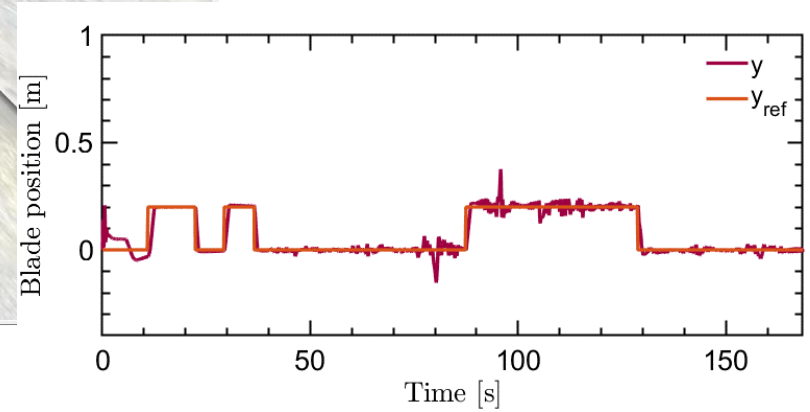
User Standalone Apps

Integrated model captures effect of deformable terrain



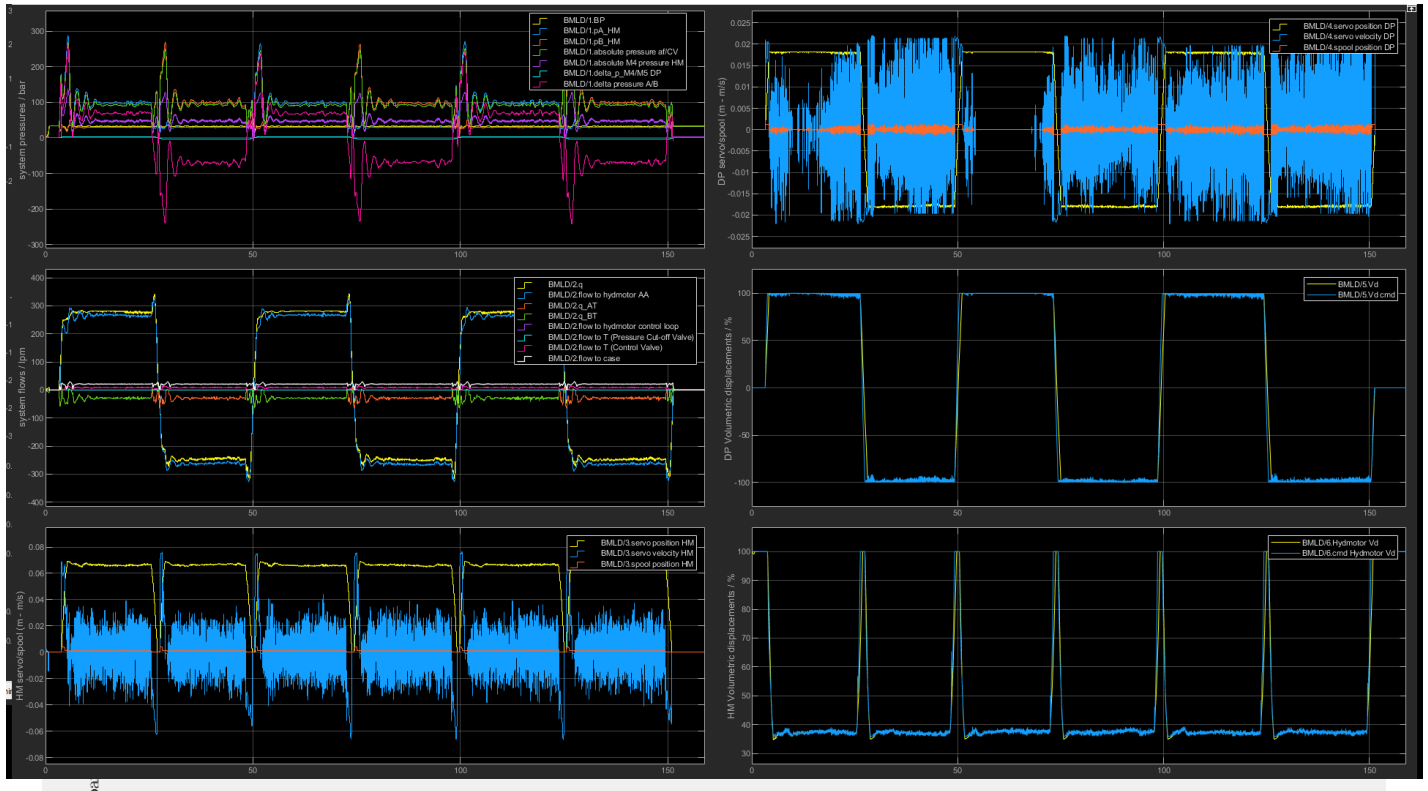
Full model enables testing of blade position control





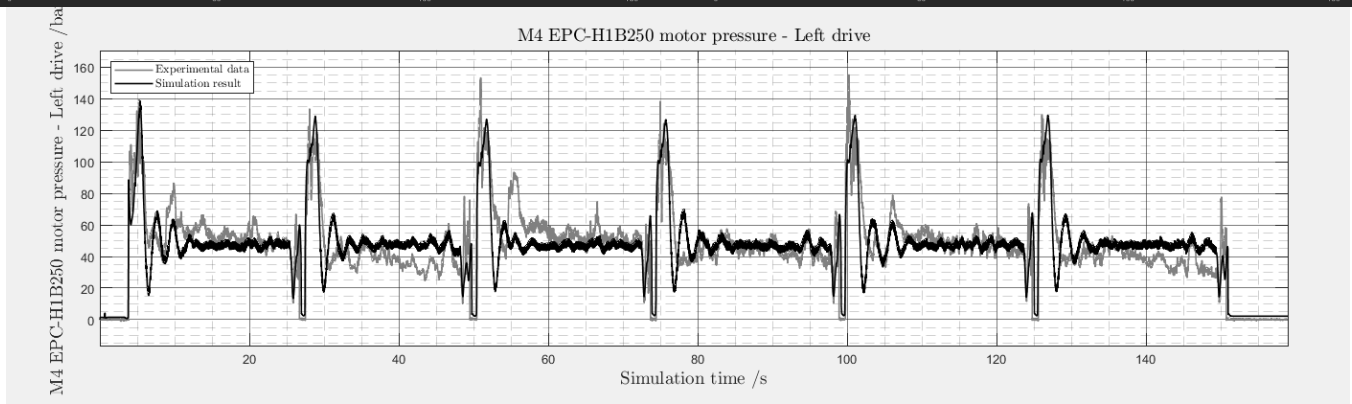
Simulation results can capture the powertrain performance under a variety of scenarios

- Full forwards-backwards field test with real input data & comparison with measured variables



Monitoring of Hydraulic Drive Line

- Example of pressure comparison between simulated and measured values

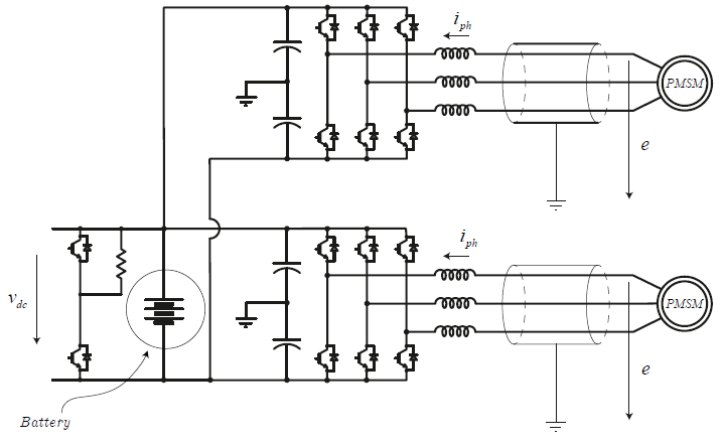


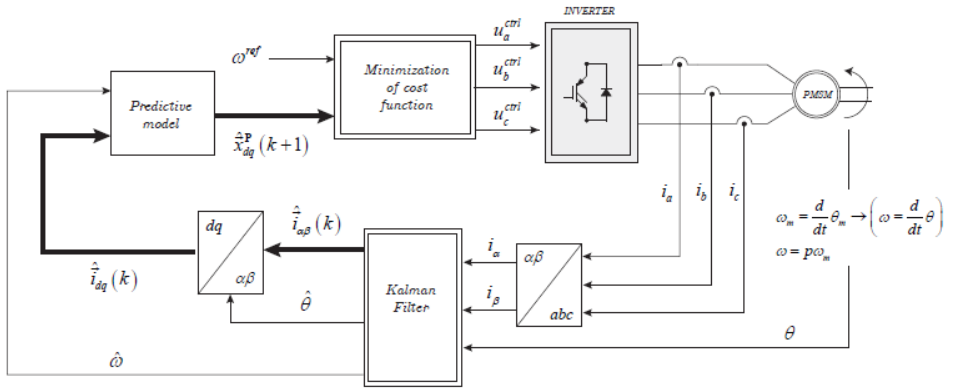
MATLAB EXPO

DTL present & future development areas

- State of the art of vehicle-soil interaction characterization and modelling
  - Dissertation Project with the University of Innsbruck.
- Design of alternative powertrains.
- Conception of new advanced vehicle control strategies.

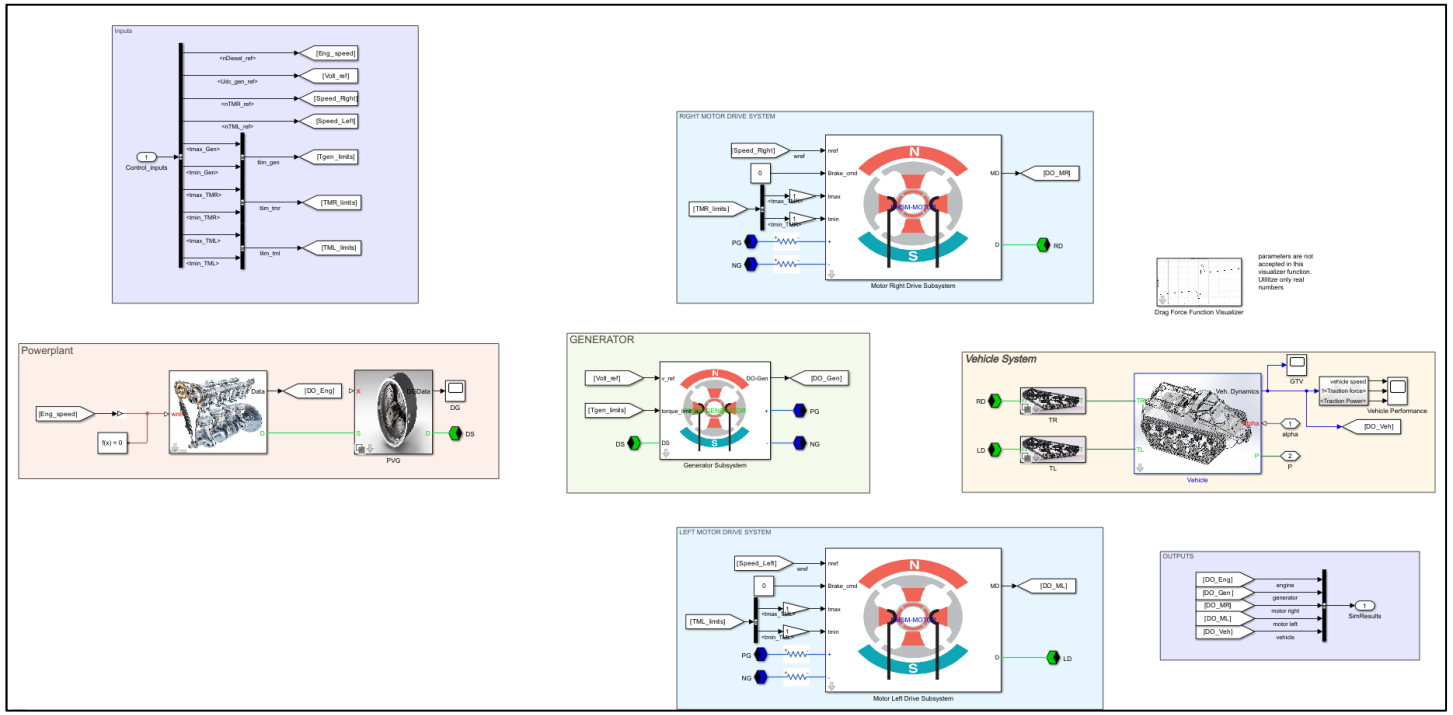
universität innsbruck





Virtual testing with digital twins improves product development

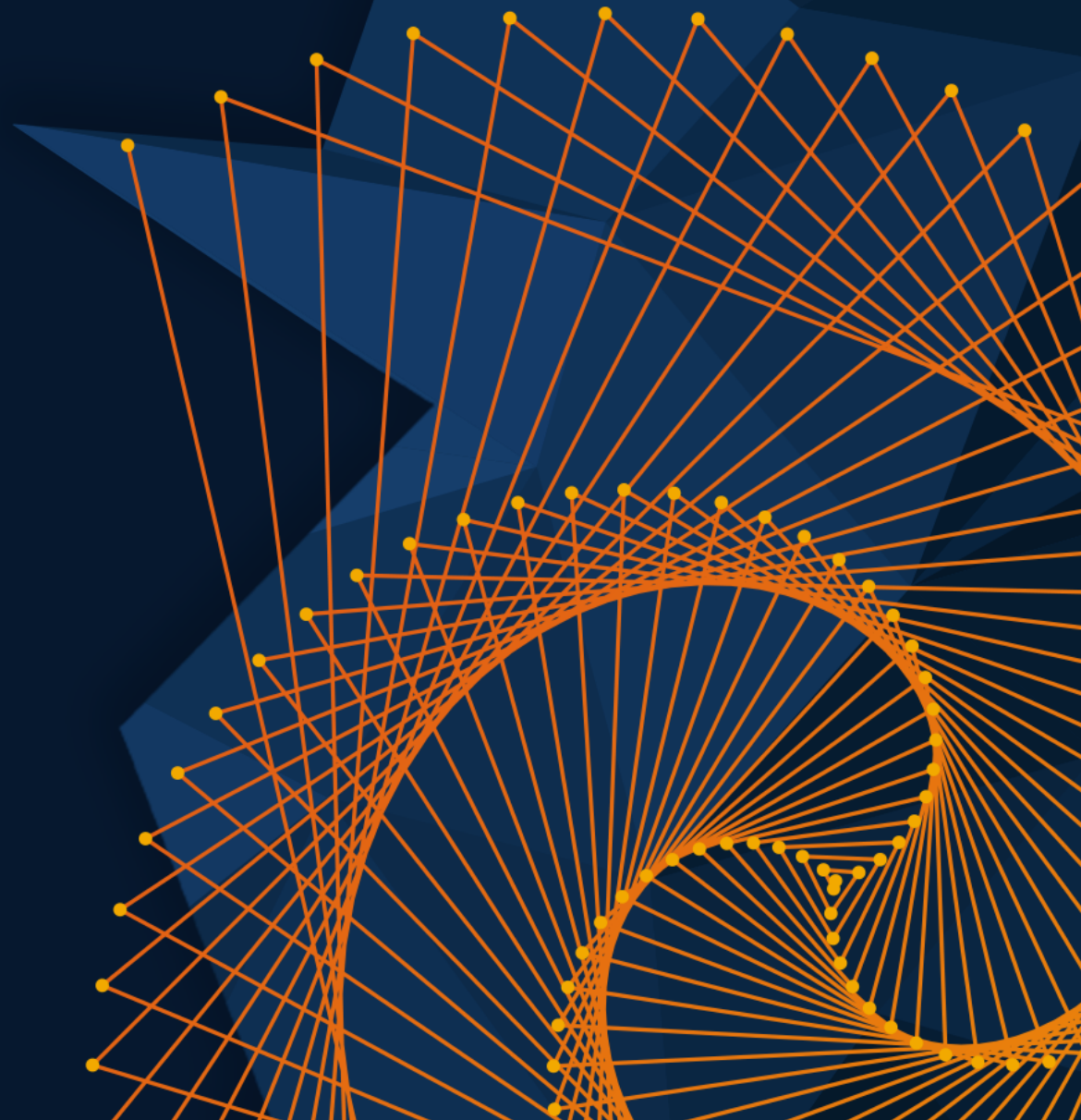
- Reliably simulate vehicle performance for **all conditions and machine configurations**:
  - Critical working points
  - Minimizing fuel consumption
- Develop new machines and components, especially **zero-emission variants**
  - Hybrid & fully Electric drivetrains
  - Fuel-cell driven systems
- Test and improve **control strategies** and implement **advanced** strategies:
  - Model Predictive Control
  - Neural Network Training.
- **Assistive** and **autonomous** driving solutions.



Hybrid Powertrain

MATLAB EXPO

Thank you!



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