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Overview of the DLR RailwayDynamics Library

A. Heckmann, M. Ehret, G. Grether, A. Keck, D. Lüdicke, C. Schwarz
DLR German Aerospace Center
Institute of System Dynamics and Control
Oberpfaffenhofen, Germany

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- Railway Modeling Particularities
- Applications
  - Traction
  - Comfort
  - Roller Rig
- Multidomain Modeling
- Conclusions

Background and Motivation

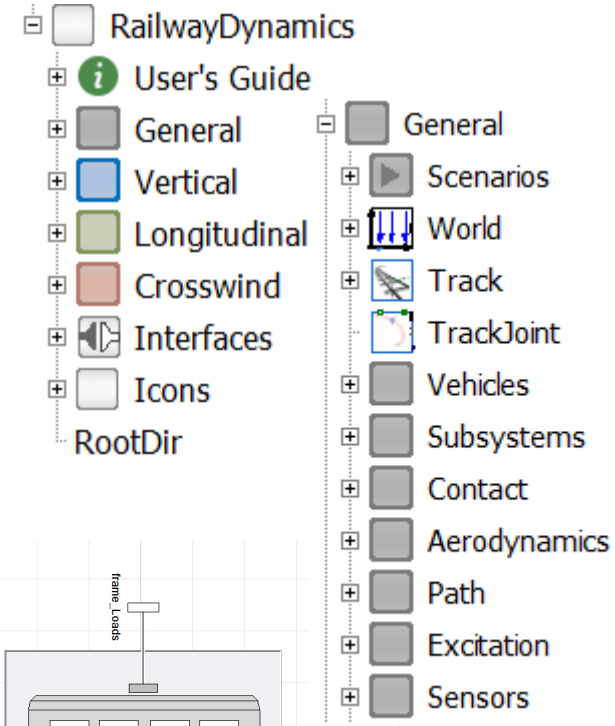
- DLR‘s historical background in multibody and railway dynamics
- DLR‘s Next Generation Train Project
  - Running gear development for an ultra high-speed train in double deck configuration and lightweight design, see video
- Several precursor papers

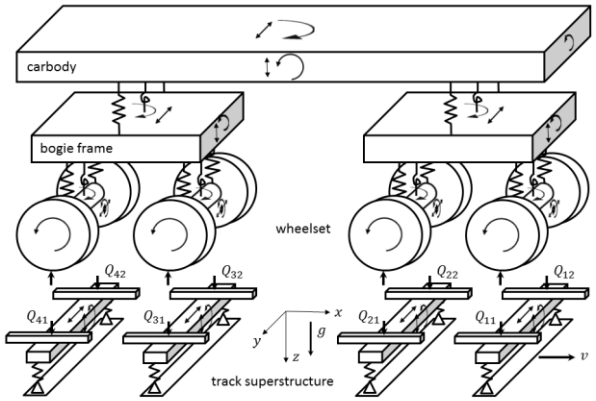
2012	2014	2015	2017	2018	2019
Energy Flows in Networks	*Wheel-Rail-Contact*	Scaled Running Gear	Crosswind Stability	Brake Pneumatics	Railway Dynamics Library

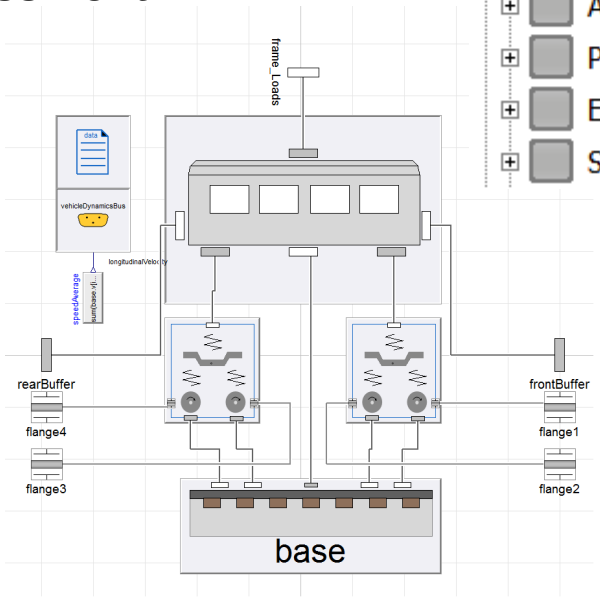
- Objectives
  - Gathering, reorganizing and publishing given models
  - framework for future multidomain engineering tasks

Library, Model and Data Structure (I)

- General subpackage
  - 3D multi-purpose models
    traction, comfort, safety, roller rigs, …
- 3 specialized subpackages
  - Vertical ⇒ comfort
  - Longitudinal ⇒ traction
  - Crosswind ⇒ simplified crosswind assessment
- Vehicle template
  - Railroad base, running gears, carbody

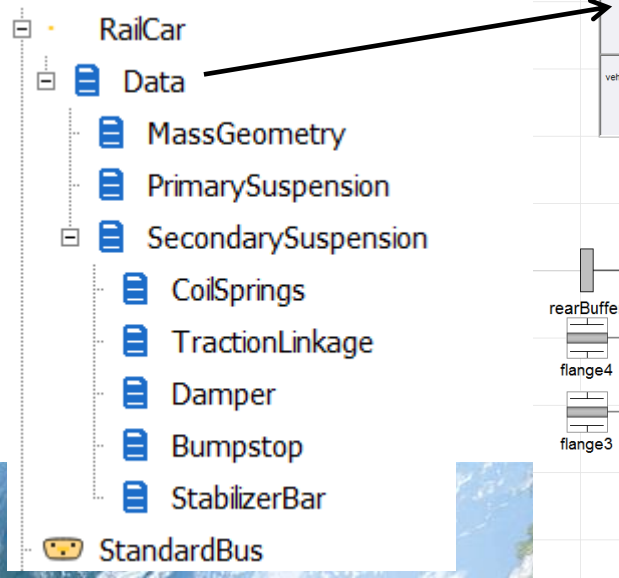


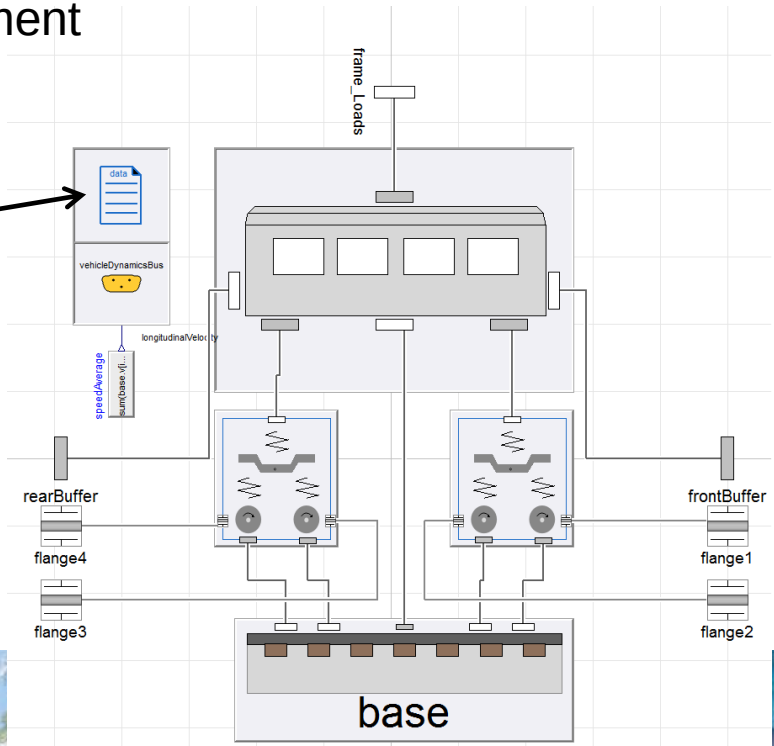




Library, Model and Data Structure (II)

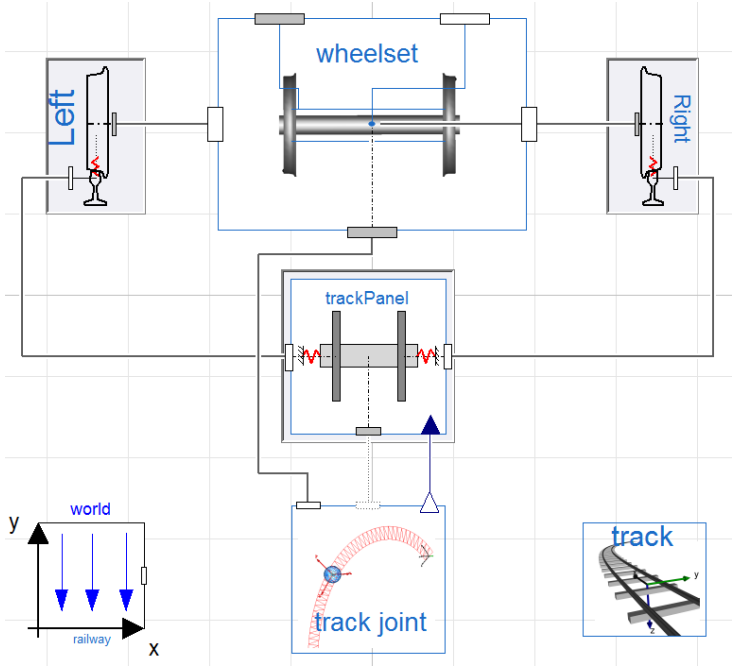
- General subpackage
  - 3D multi-purpose models
    traction, comfort, safety, roller rigs, …
- 3 specialized subpackages
  - Vertical ⇒ comfort
  - Longitudinal ⇒ traction
  - Crosswind ⇒ simplified crosswind assessment
- Vehicle template
  - Railroad base, running gears, carbody
- Data Structure
  - Replaceable encapsulated records

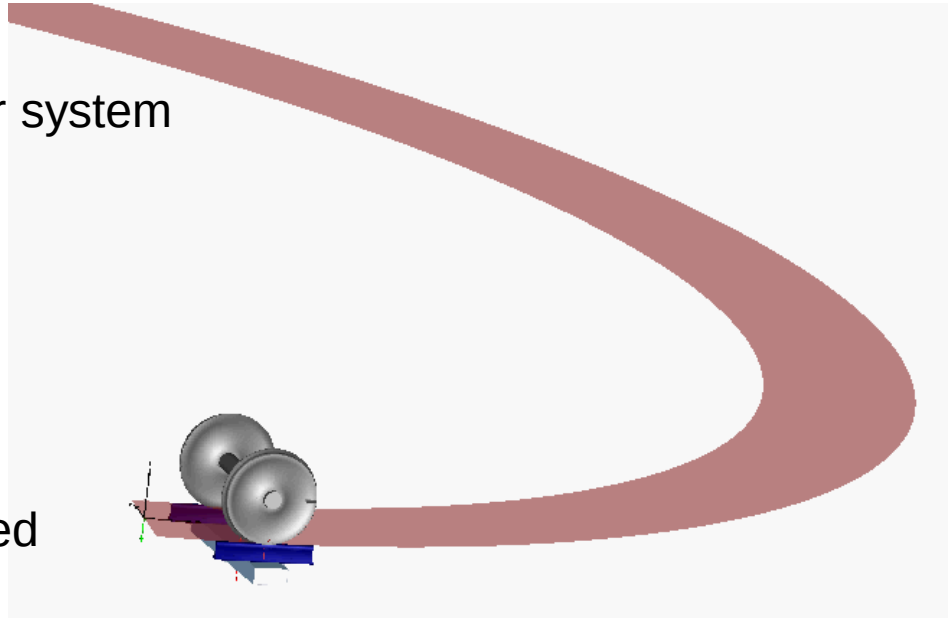




Railway Modeling Particularities
Overview

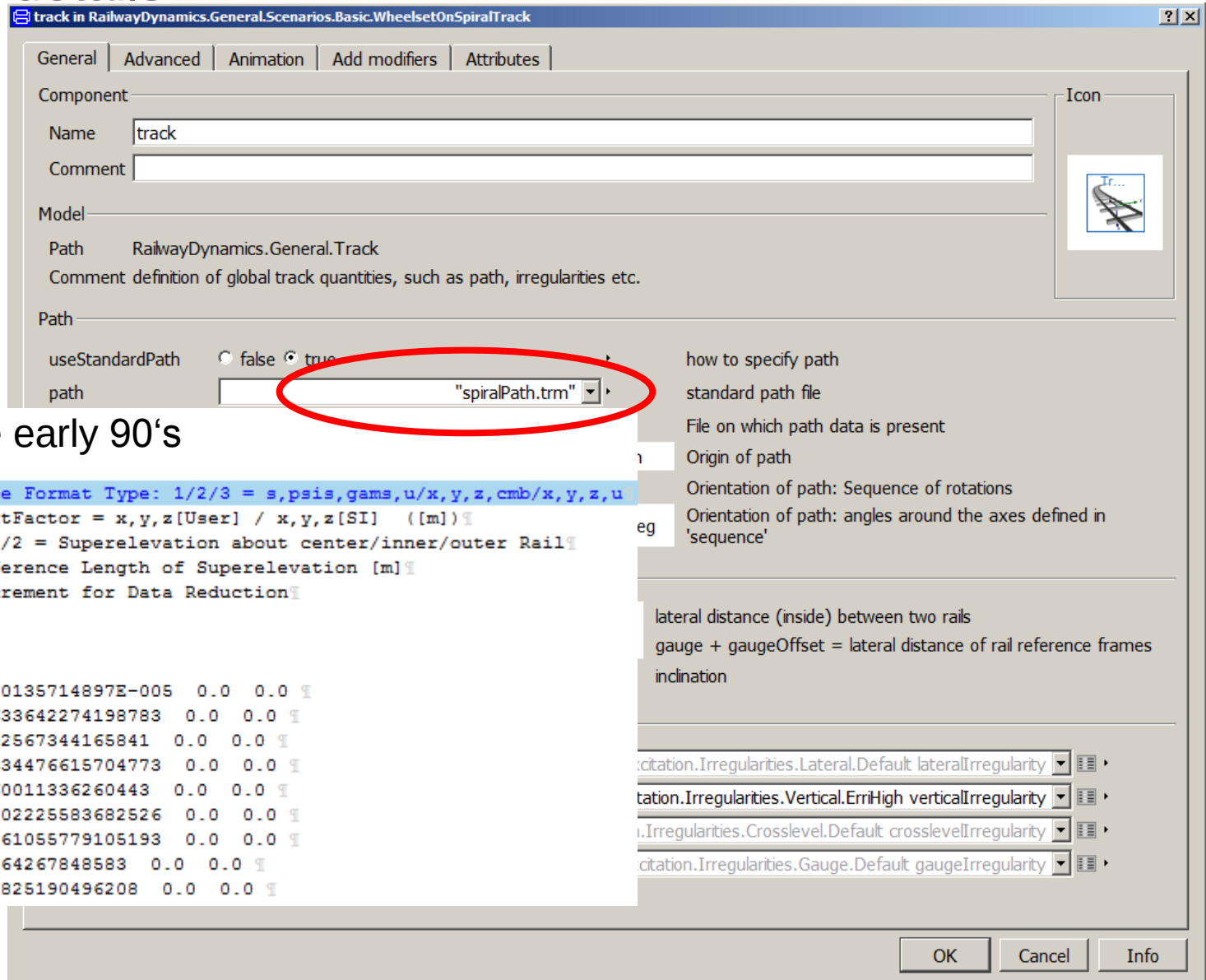
- Track (inner/outer)
  - 3D curve $\vec{r} = \vec{r}(s)$, collateral frame
  - rail position and orientation
  - irregularities
- Track joint
  - Longitudinal degree of freedom
  - 2 states: s, v
- Track panel
  - acompanying mass-spring-damper system
  - 2 rail stubs and sleeper
- Wheelset
  - 5 degrees of freedom
  - Inertia properties
- Wheel-Rail contact
  - UIC60 and S 1002 predefined
  - Linear and Polach model predefined





Railway Modeling Particularities (I)

Track: some details



File format from the early 90‘s

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header.begin
  data.type    = 3       ! File Format Type: 1/2/3 = s,psis,gams,u/x,y,z,cmb/x,y,z,u
  data.par(1) = 1.0      ! UnitFactor = x,y,z[User] / x,y,z[SI]   ([m])
  data.par(4) = 1        ! 0/1/2 = Superelevation about center/inner/outer Rail
  data.par(5) = 1.506    ! Reference Length of Superelevation [m]
  data.par(7) = 1        ! Increment for Data Reduction
header.end

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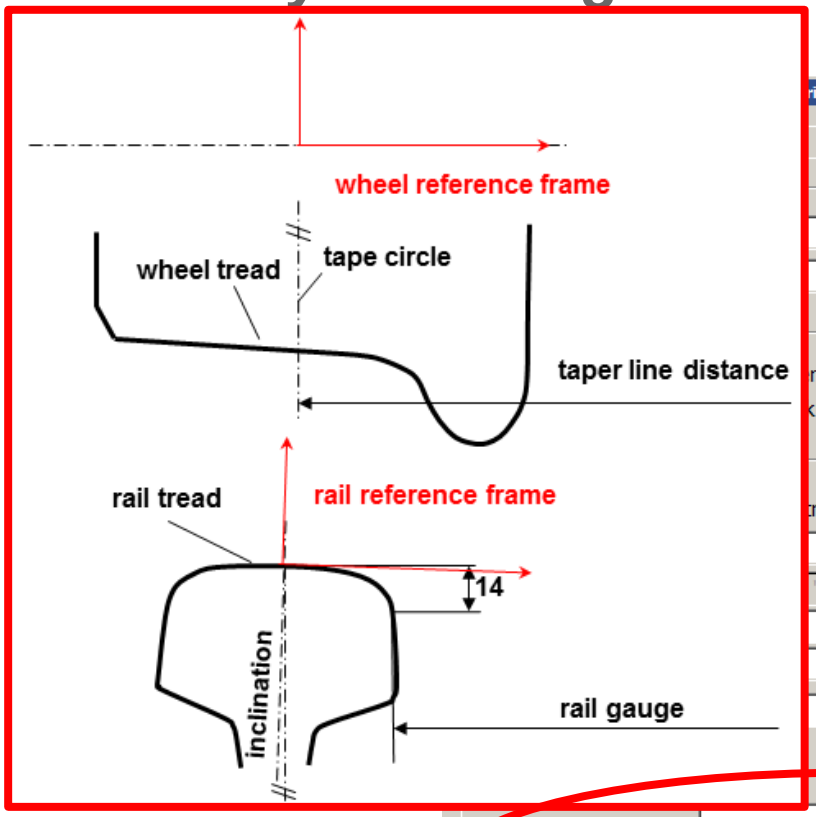
Railway Modeling Particularities (II)



rios.Basic.WheelsetOnSpiralTrack

Add modifiers | Attributes

Icon

ral.Track

k quantities, such as path, irregularities etc.

true			how to specify path
"spiralPath.trm"			standard path file
"Resources/Data/Track/" + path			File on which path data is present
{0,0,0}		m	Origin of path
{1,2,3}			Orientation of path: Sequence of rotations
{0,0,0}		deg	Orientation of path: angles around the axes defined in 'sequence'
gauge	1.435	m	lateral distance (inside) between two rails
gaugeOffset	0.072	m	gauge + gaugeOffset = lateral distance of rail reference frames
incl	1/40		inclination

Irregularities

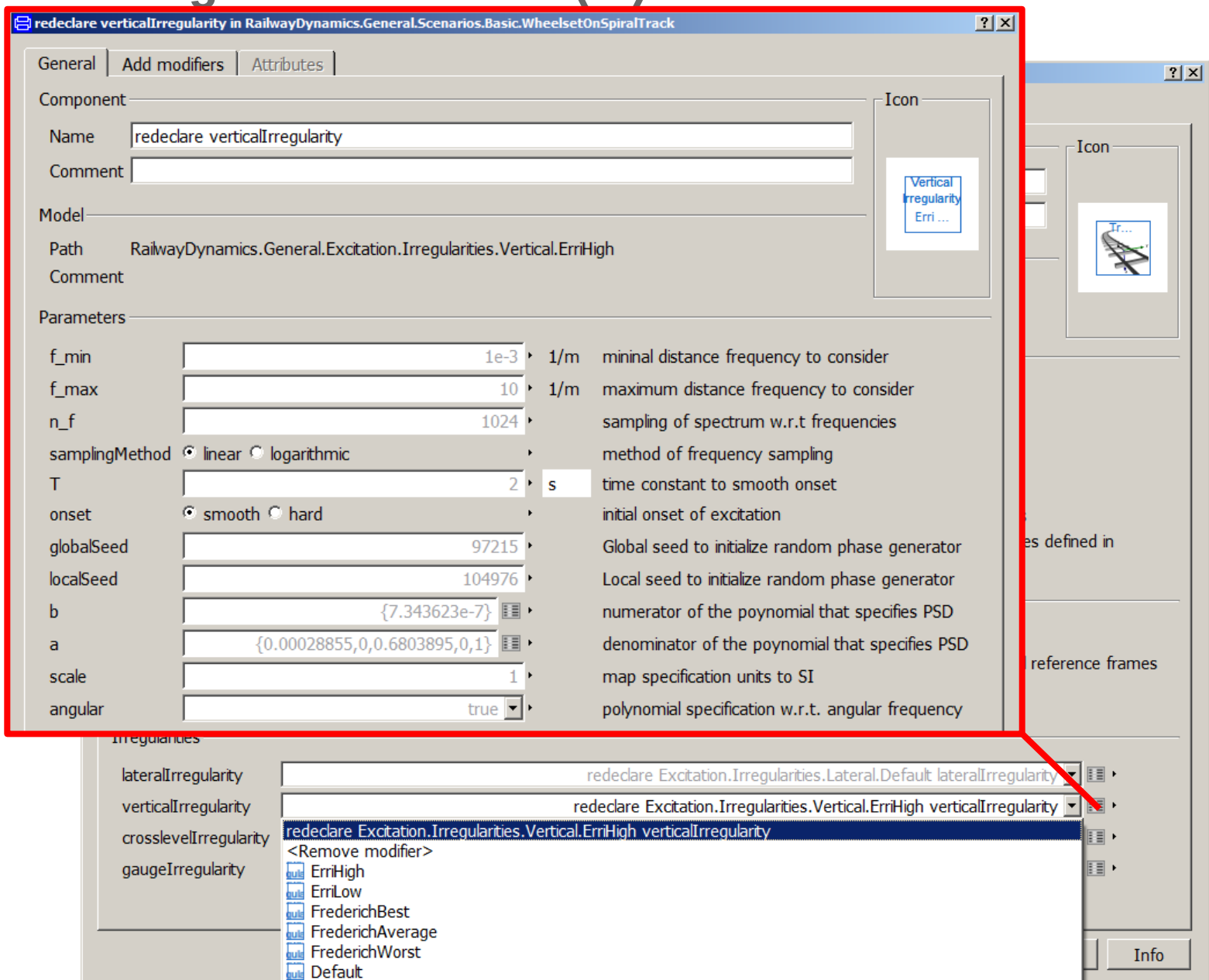
lateralIrregularity	redeclare Excitation.Irregularities.Lateral.Default lateralIrregularity
verticalIrregularity	redeclare Excitation.Irregularities.Vertical.ErriHigh verticalIrregularity
crosslevelIrregularity	redeclare Excitation.Irregularities.Crosslevel.Default crosslevelIrregularity
gaugeIrregularity	redeclare Excitation.Irregularities.Gauge.Default gaugeIrregularity

OK | Cancel | Info

DLR

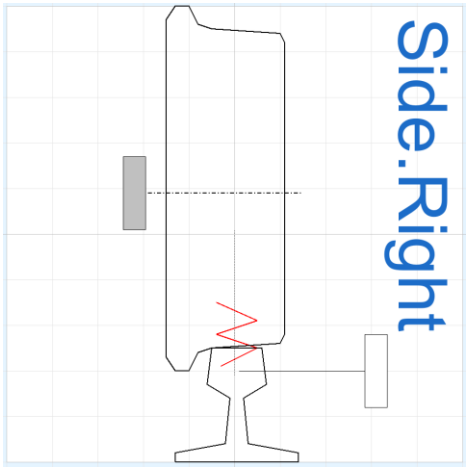
Railway Modeling Particularities (III)

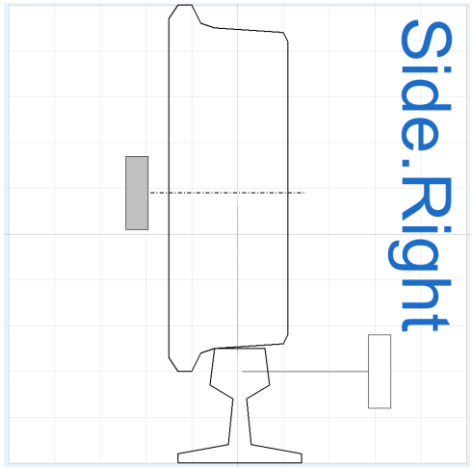
Track:

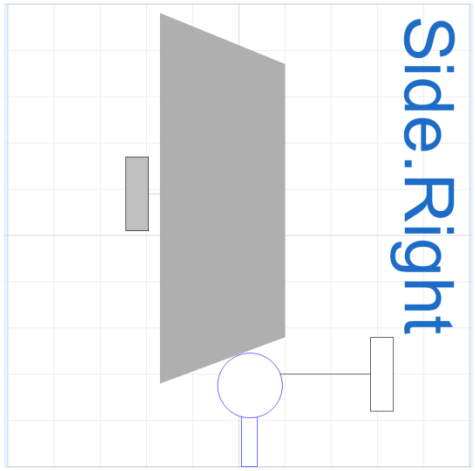


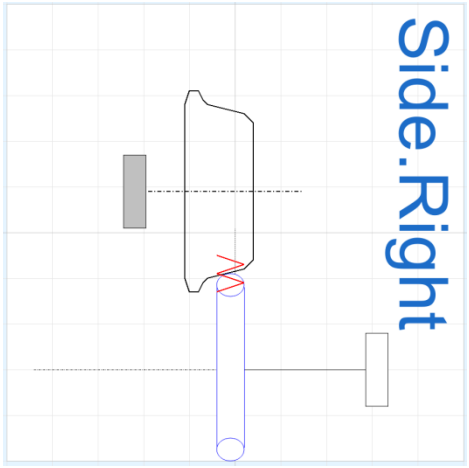
Railway Modeling Particularities (I)

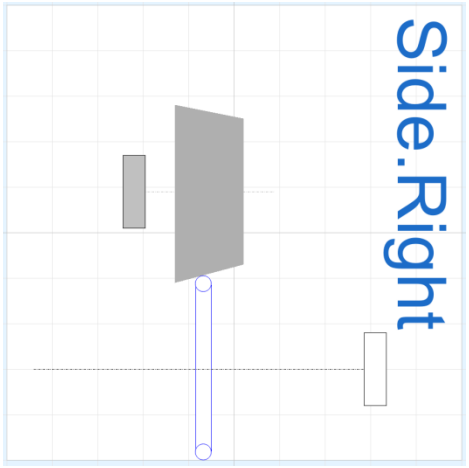
Contact: some details





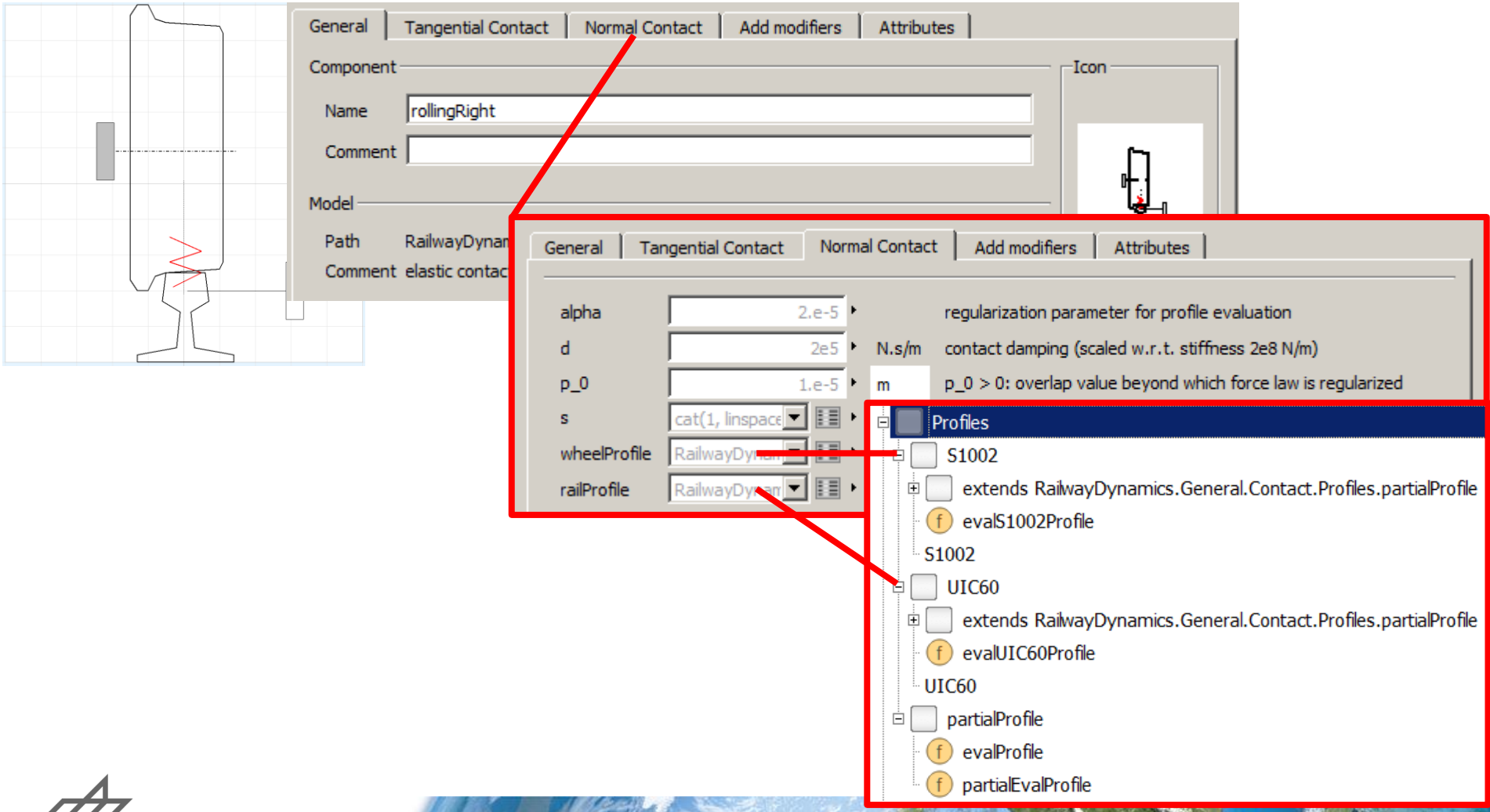






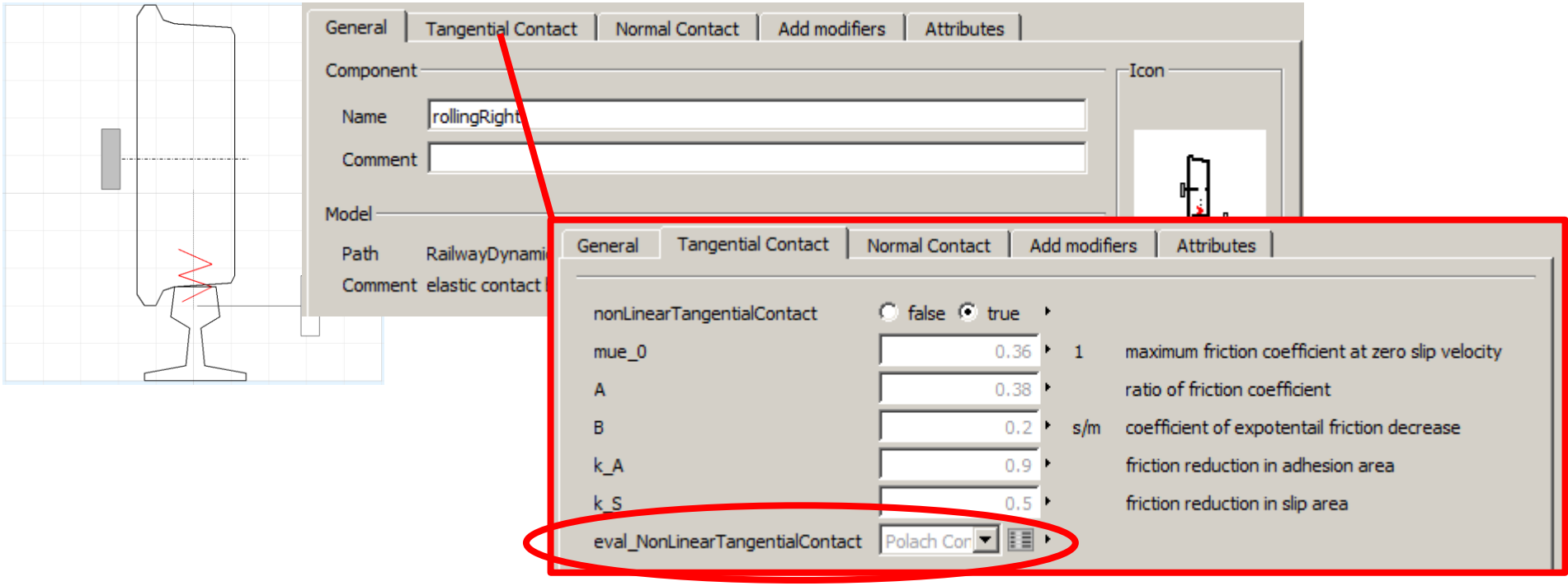
Railway Modeling Particularities (II)

Contact: some details



Railway Modeling Particularities (III)

Contact: some details

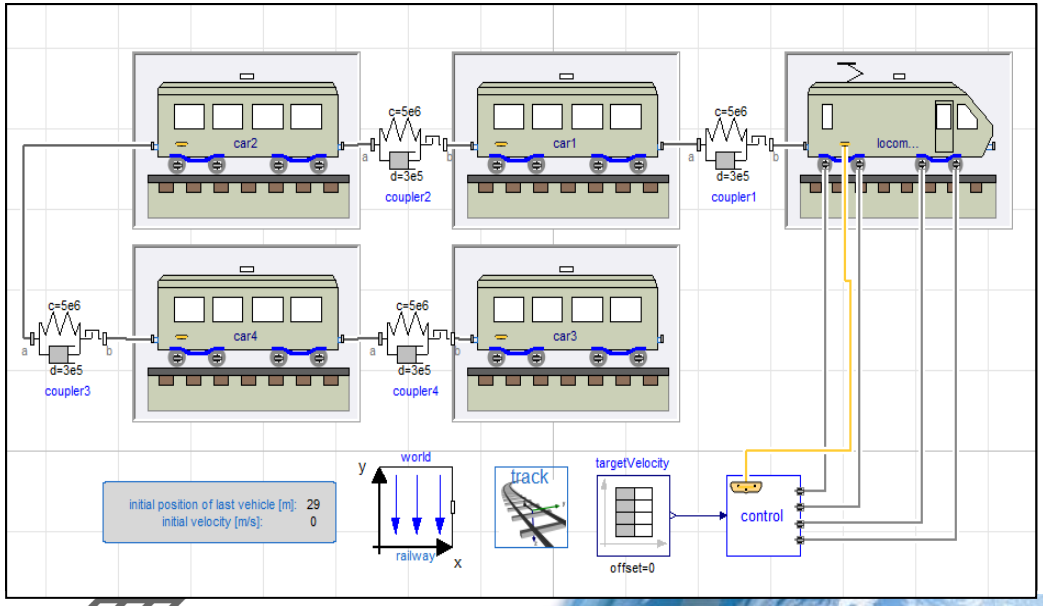


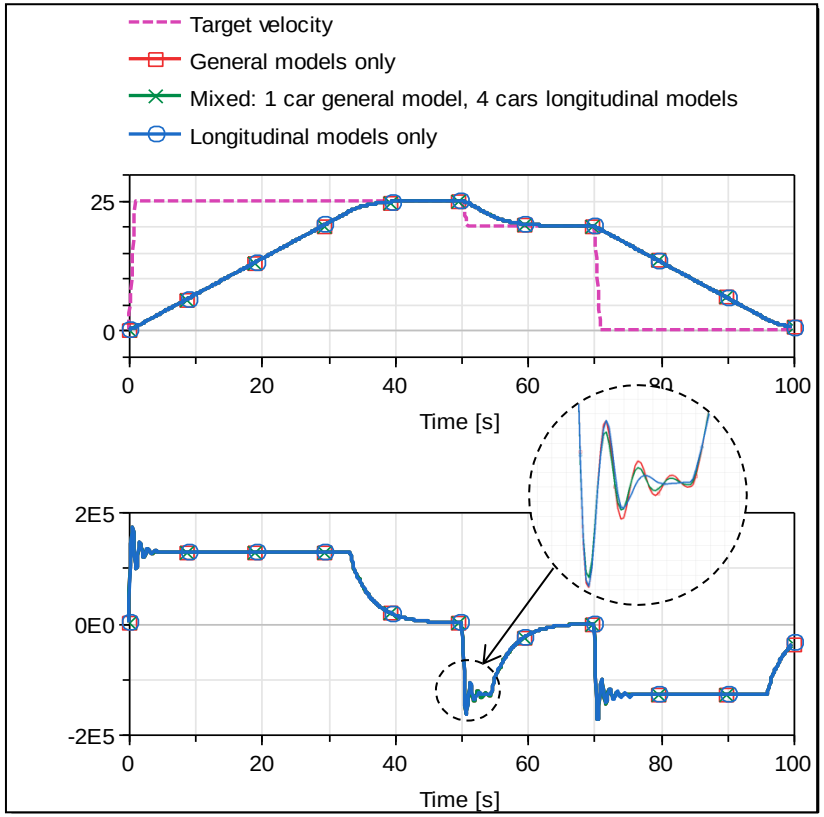
Applications: Traction

- Estimate longitudinal forces & oscillations during braking and accelerating

➢Use reduced models: simulate large systems (e.g. freight train with 50 cars)

Example: Train with 5 cars	CPU-s/s	Number of states
General models only	69.5	605
Mixed: 1 car 3D + 4 cars 1D	6.65	157
Longitudinal models only	0.08	51



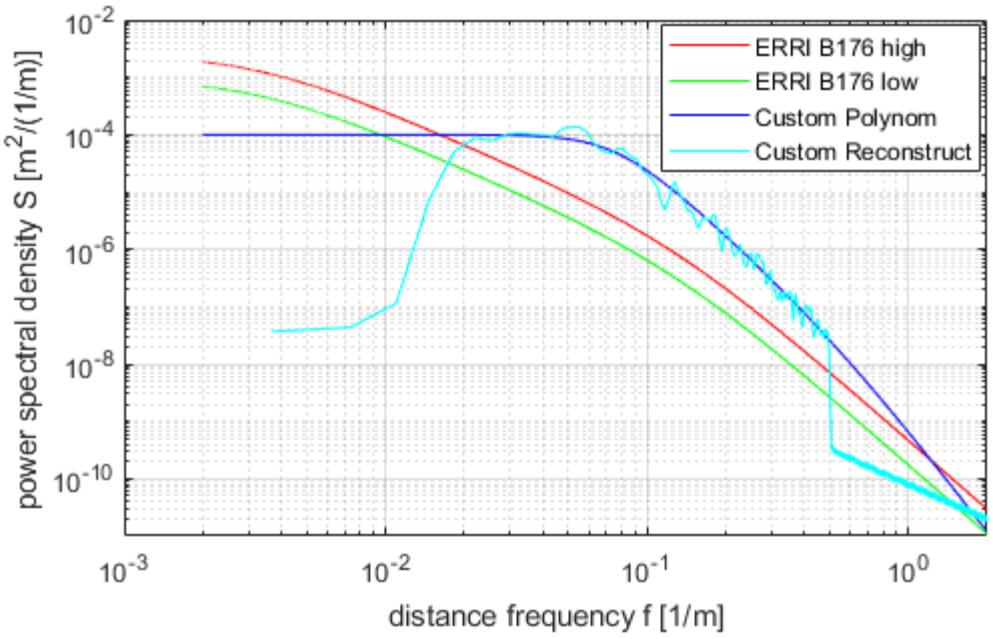


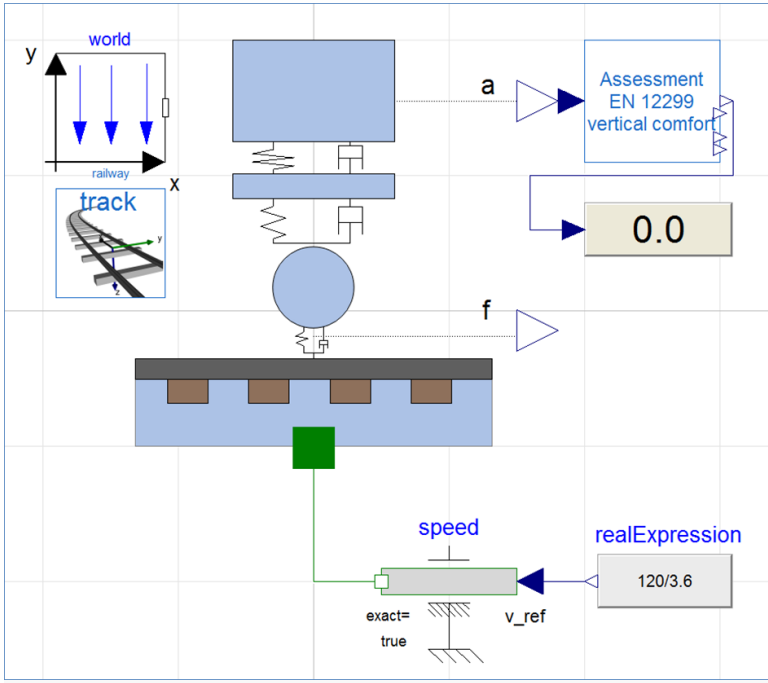
➢ Peaks of coupler forces occur at beginning of brake and acceleration phases

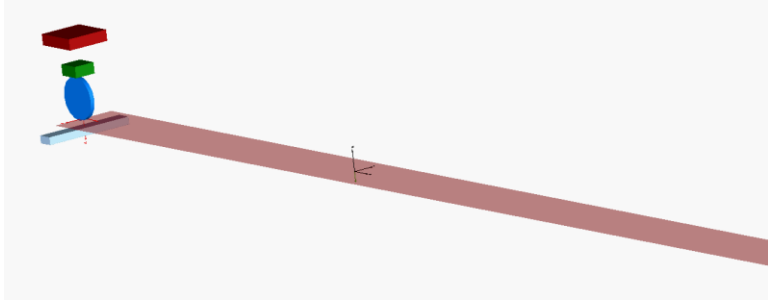
➢ Simulation results of different models coincide

Applications: Comfort

$$S(\Omega) = \frac{b_0 + b_1\Omega^2}{a_0 + a_2\Omega^2 + a_4\Omega^4 + a_6\Omega^6} \qquad f = \frac{\Omega}{2\pi}\left[\frac{1}{\mathrm{m}}\right]$$

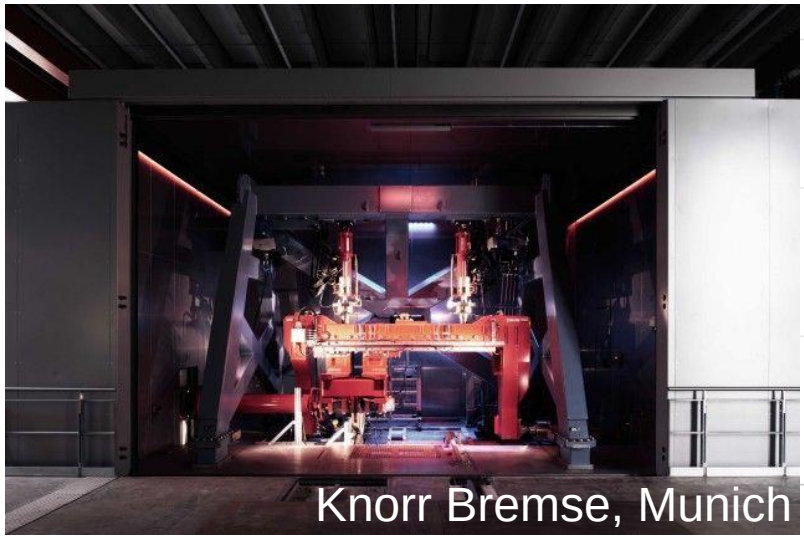


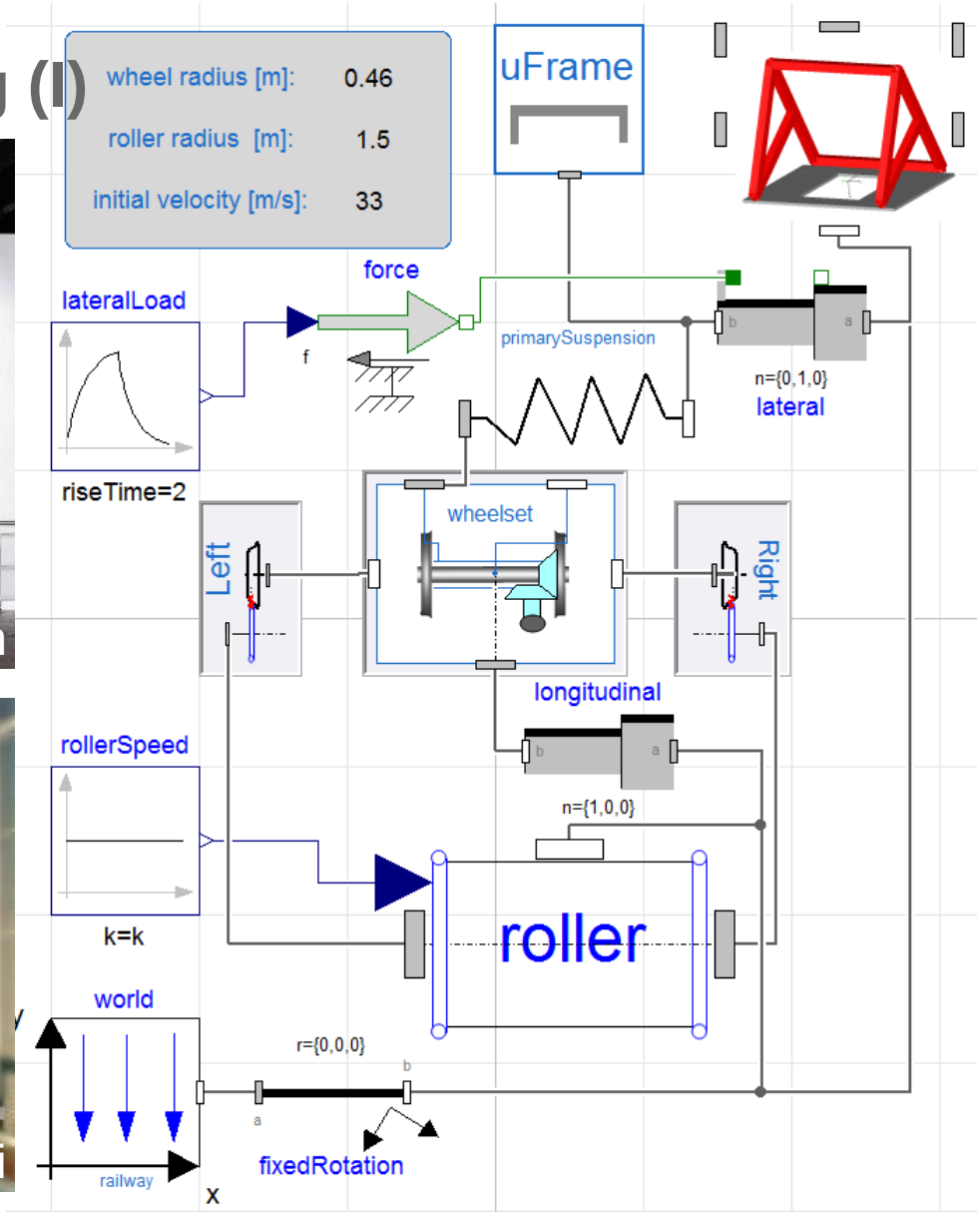




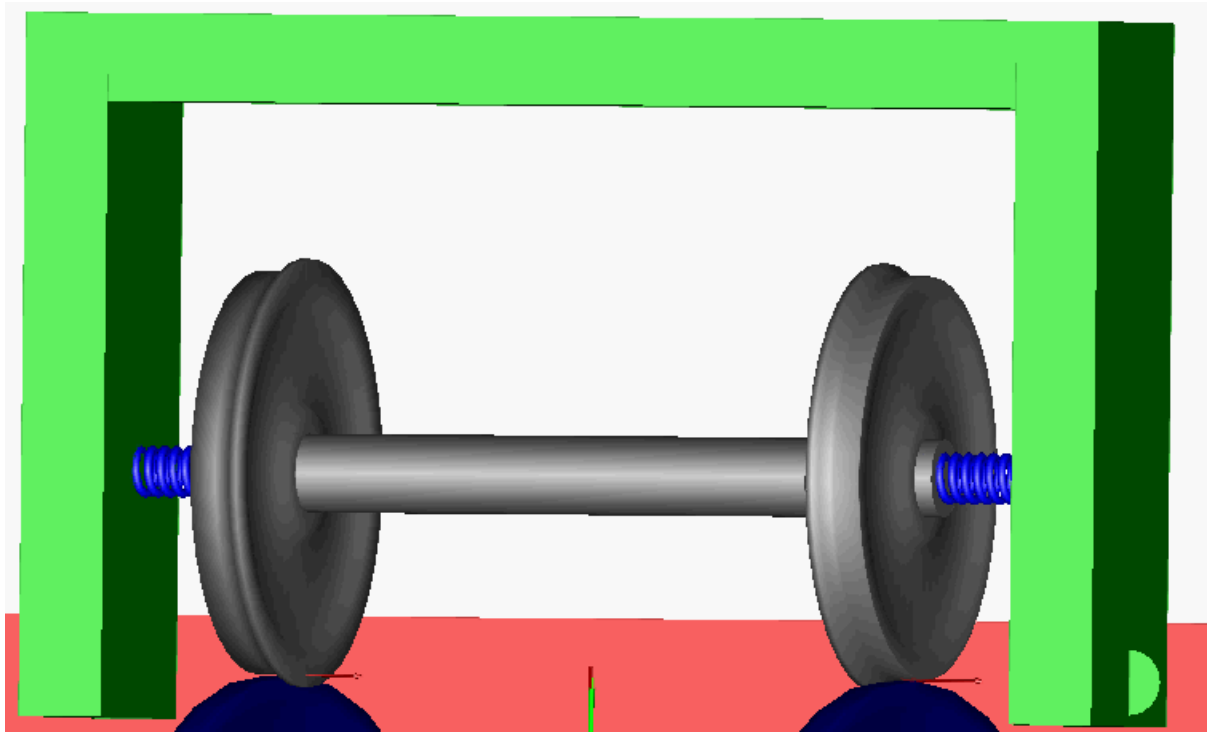
	CPU-s/s	N_{MVZ}
Quarter vehicle	1.58	0.63
Full vehicle	9.08	0.43 … 0.83

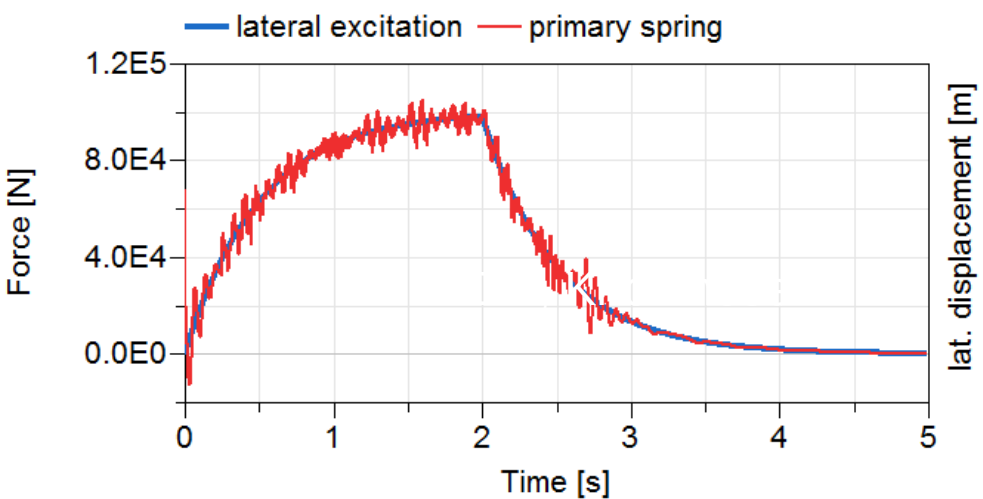
Applications: Roller Rig (I)

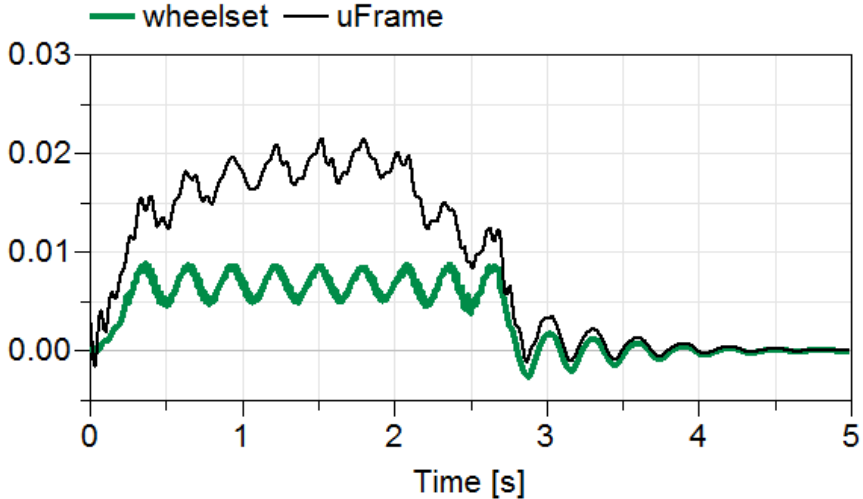




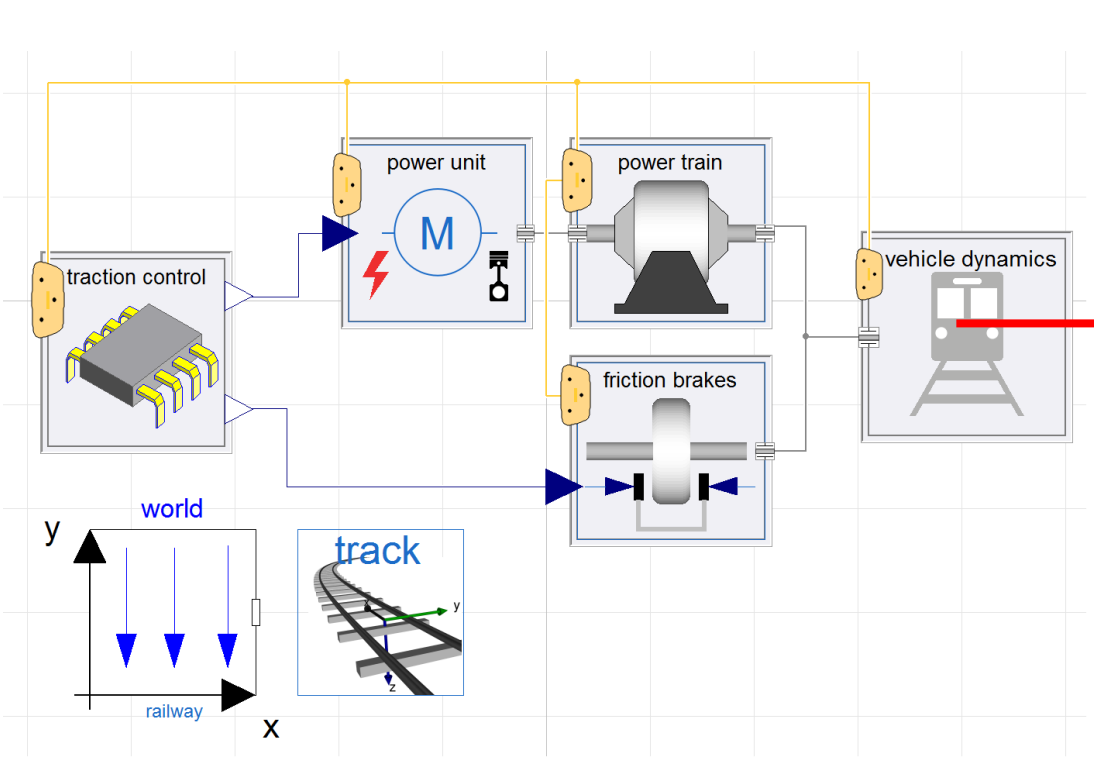
Applications: Roller Rig (II)

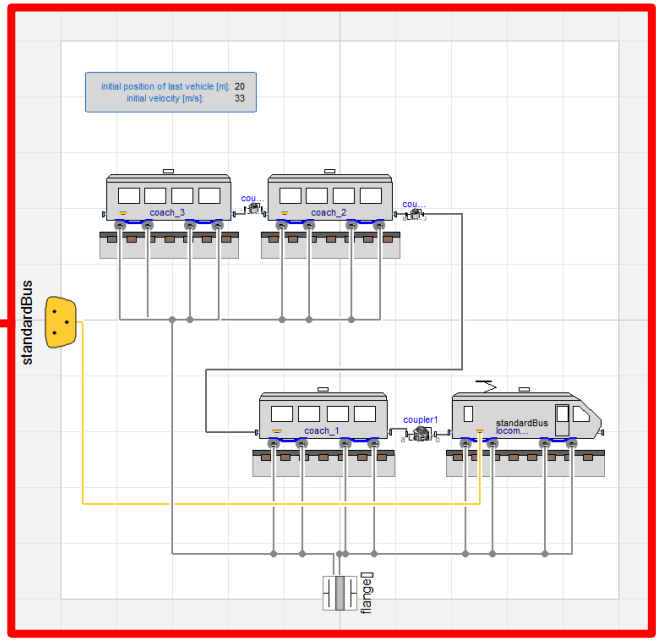




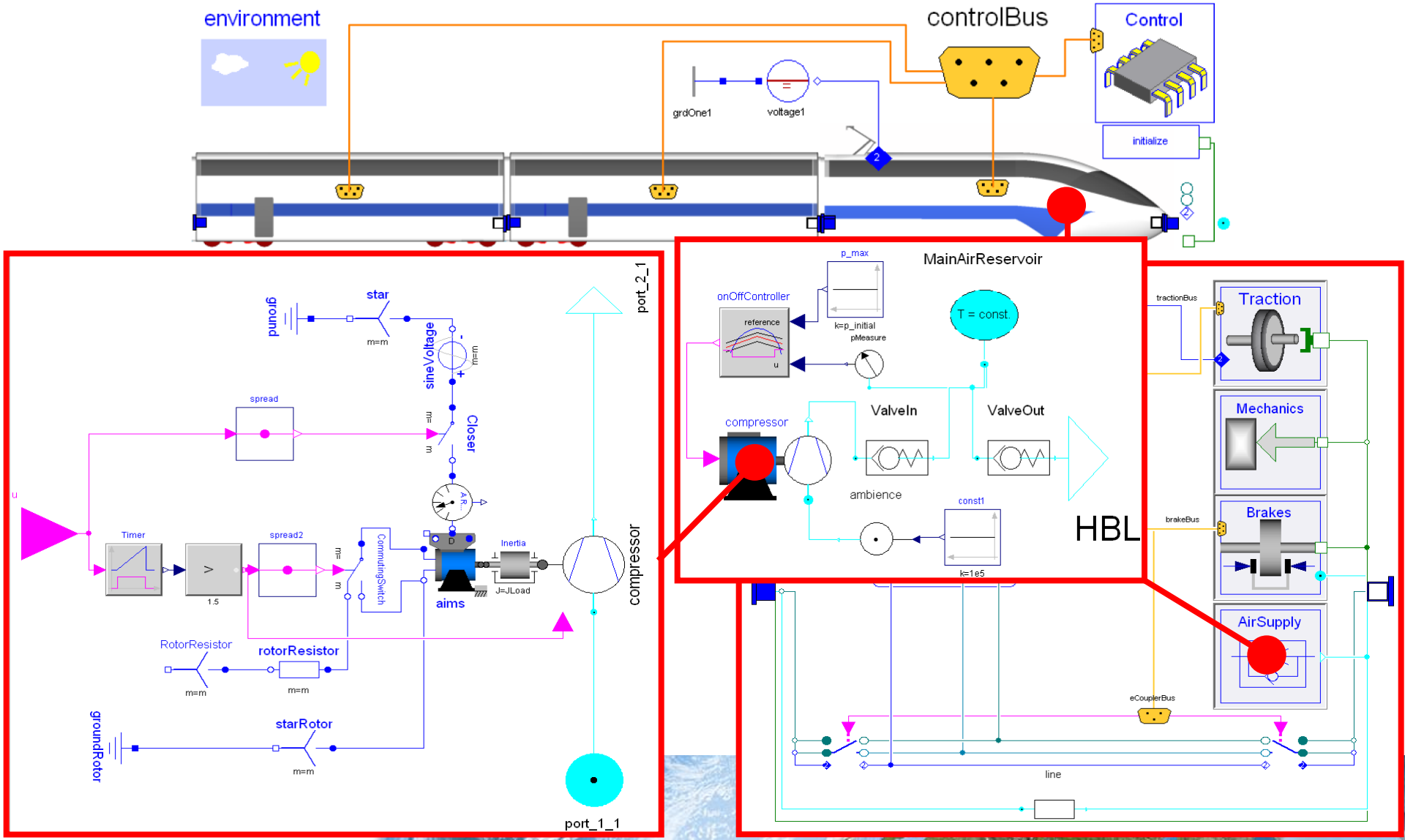


Multidomain Modeling
VehicleInterfaces Library reloaded





Multidomain Modeling
Alternative Proposal



Conclusions

- The DLR RailwayDynamics Library covers railway dynamics.
- Different levels of details up to realtime capability: SiL, HiL
- Synthesis of advanced observer and controller lay-outs
- Multidomain modeling in one consistent environment
  - Pneumatics: brakes, air suspensions
  - Power trains: electric, Diesel-hydraulic, Diesel-electric
  - Regeneration of electric energy
  - Adhesion and interaction of traction and power-train
  - Auxiliary systems
  - ….