



MBD Digital Twin

Application in Chassis Rig Test

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World-class engineering in the heart of Sweden's automotive cluster

- Innovation center for ZEEKR and Geely group since 2013
- Extensive international engagement with innovation hubs and start-ups
- A significant and business-oriented IP portfolio
- Delivers to Volvo Cars, Lotus, Polestar and Lynk & Co

1700 researchers,
designers and engineers

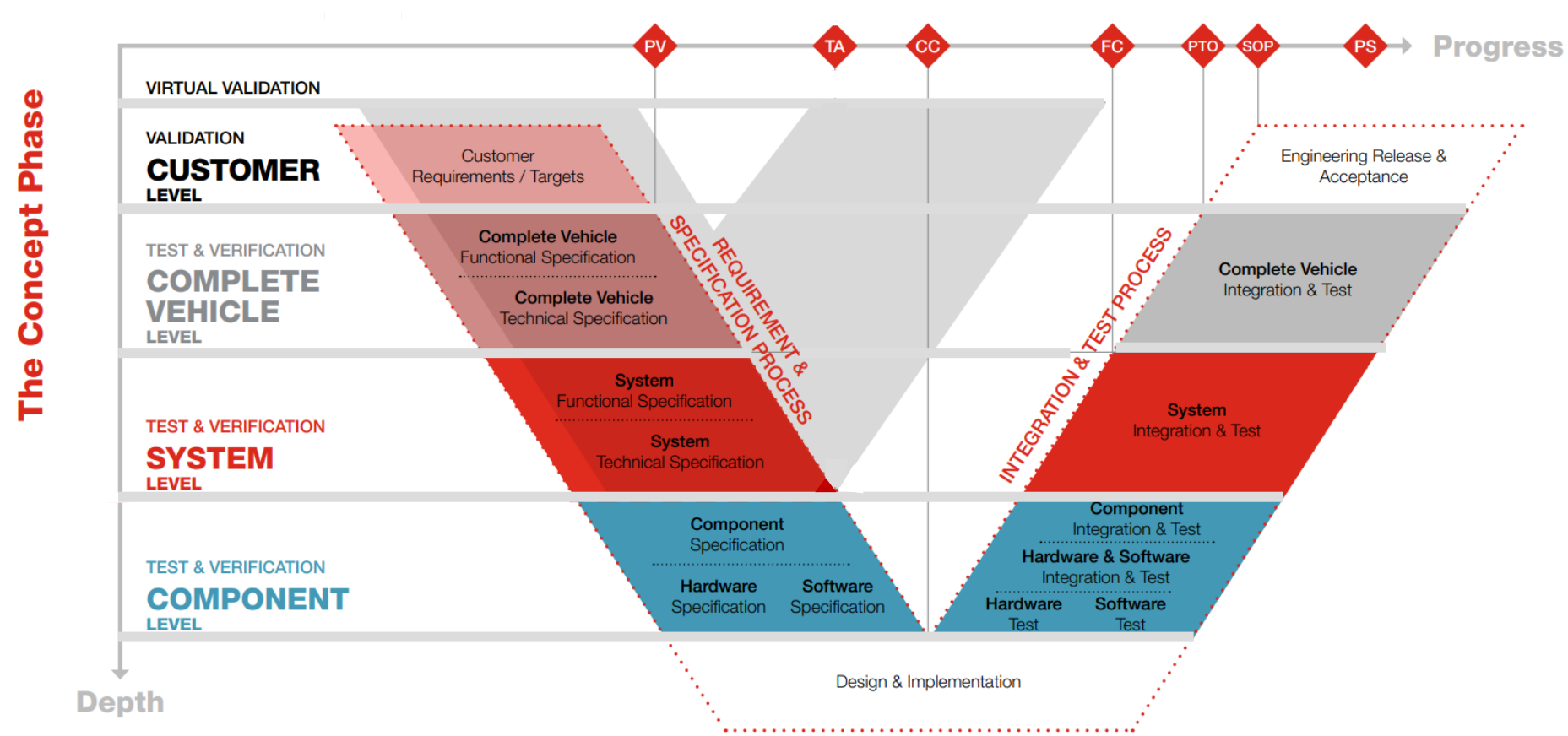


200 inventions annually



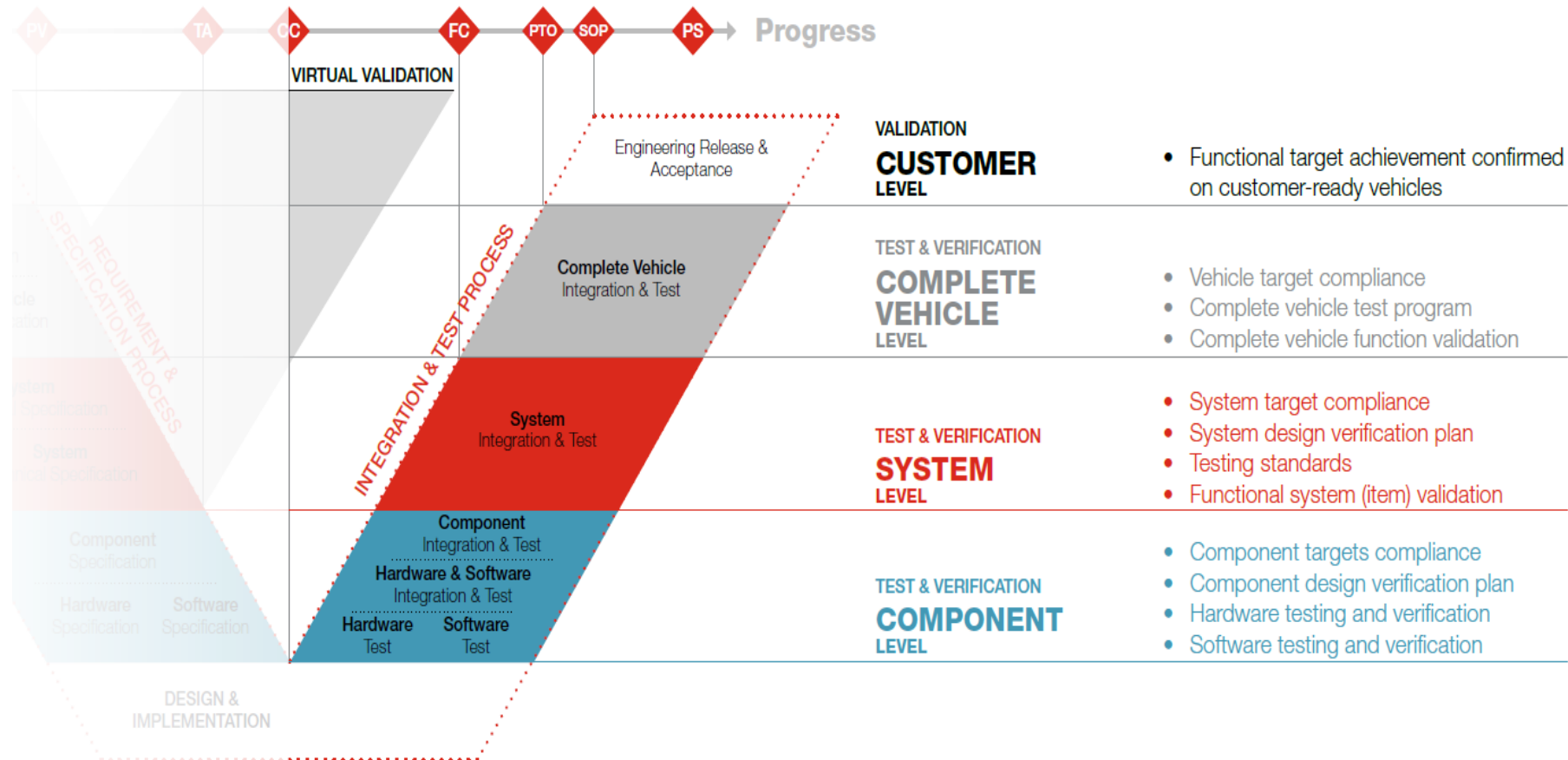


V Model





Testing and Verification





Chassis rig test

- Derived from full vehicle verification test

- More than 30 events

- Transient road obstacles

- Random rough road vibrations

- Sinus-sweep obstacles

- Curve driving

- Static steering

- Extreme ABS-braking

- Low-intensity acceleration and regen braking

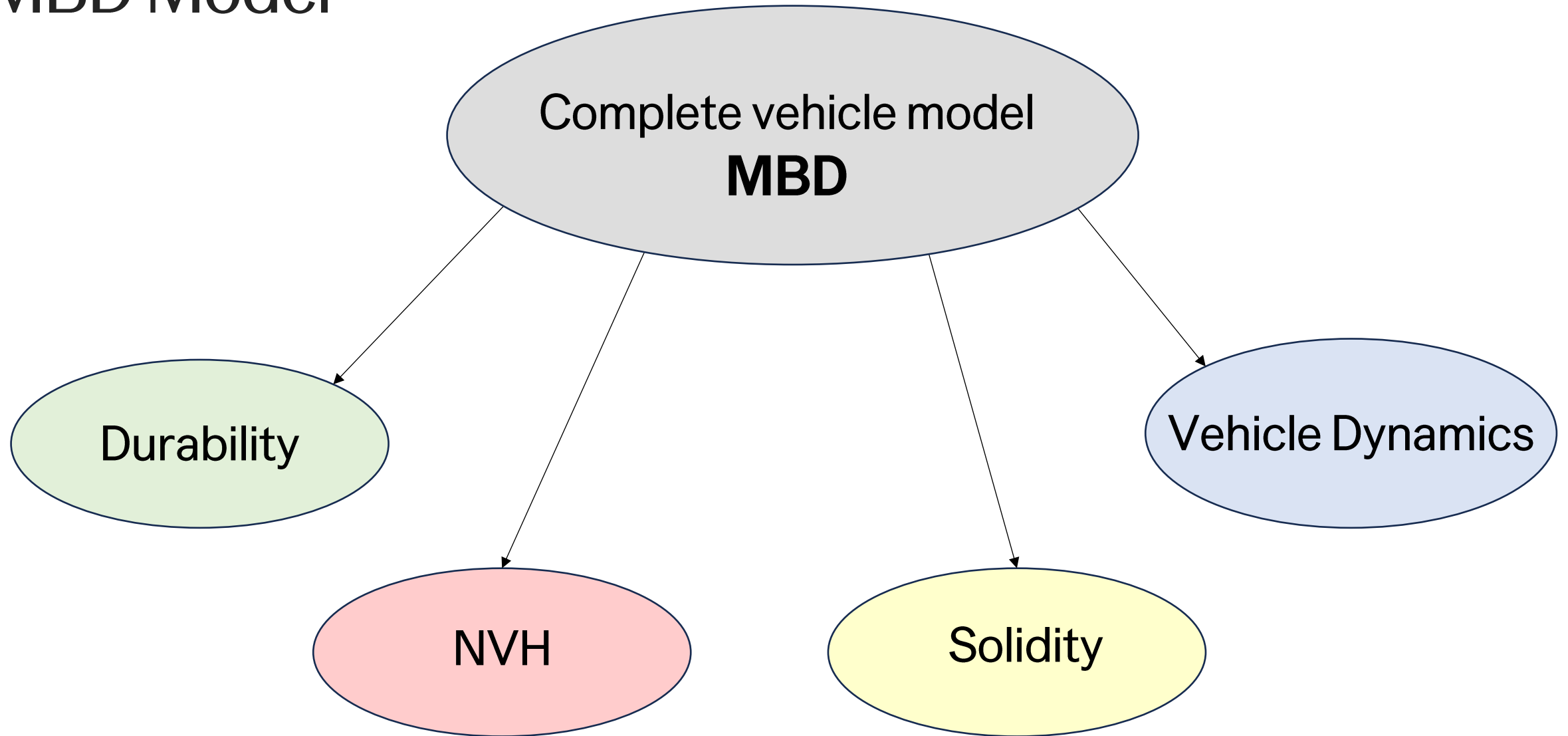
- Drive signals

- Past: Full vehicle Measurement signals

- Present: Full vehicle Simulation signals



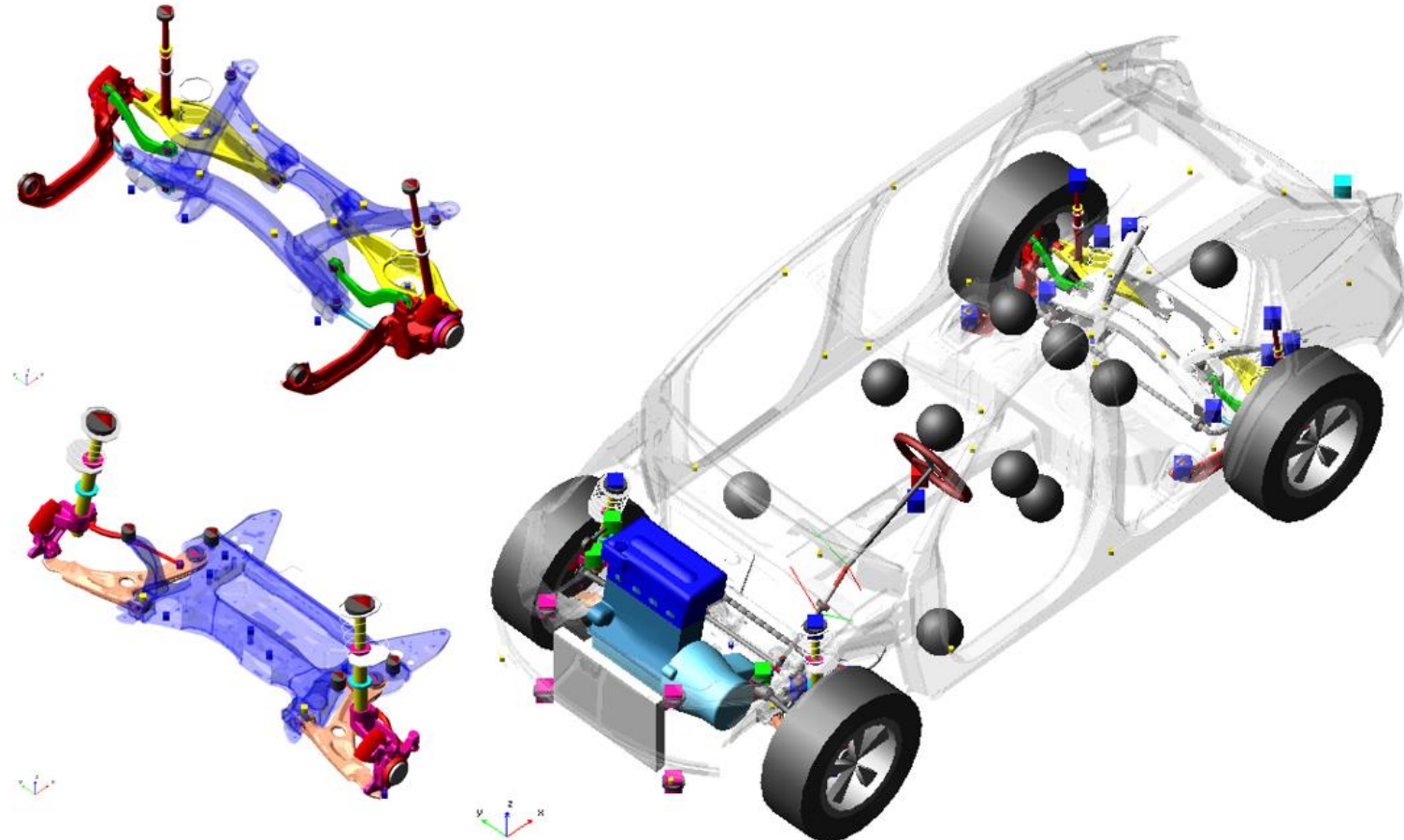
MBD Model





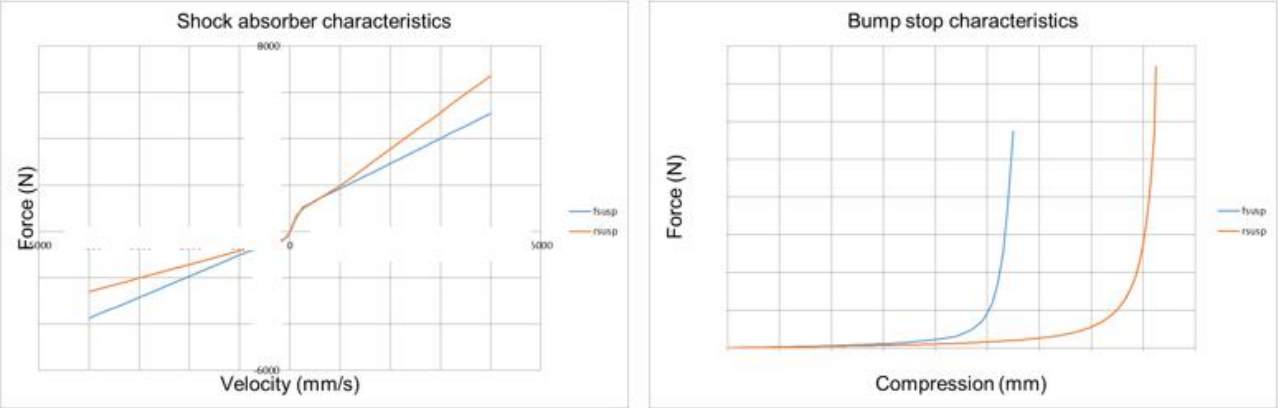
MBD Model

- Modelled based on design specification or measured data
- Suspension and car body as FlexBody
- More than 10 subsystems

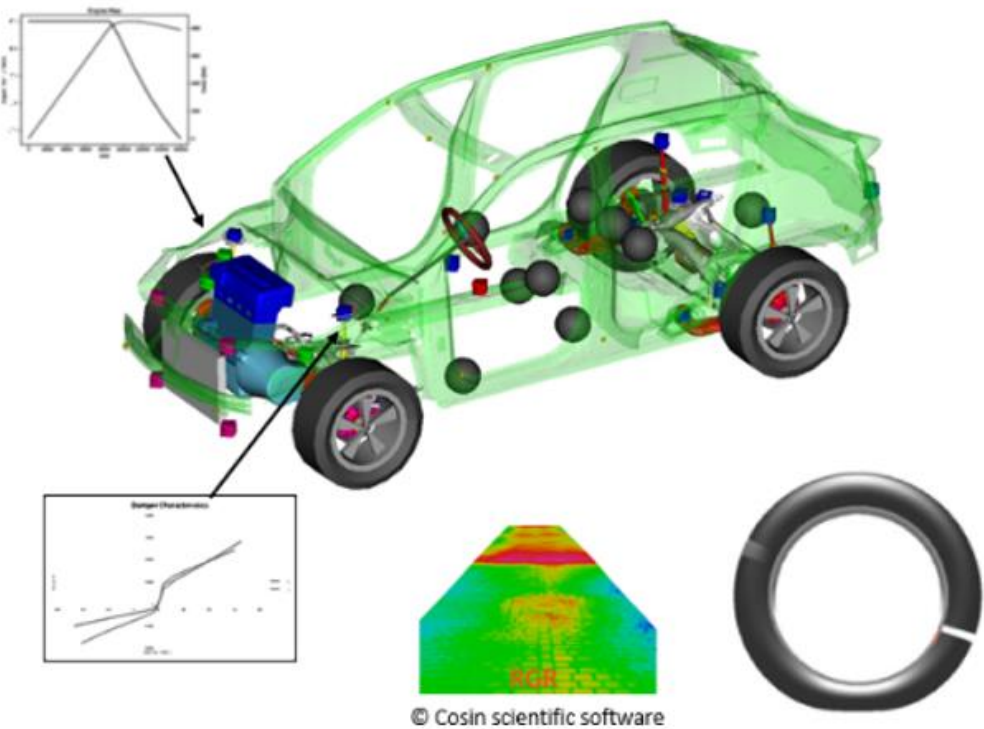




MBD Model

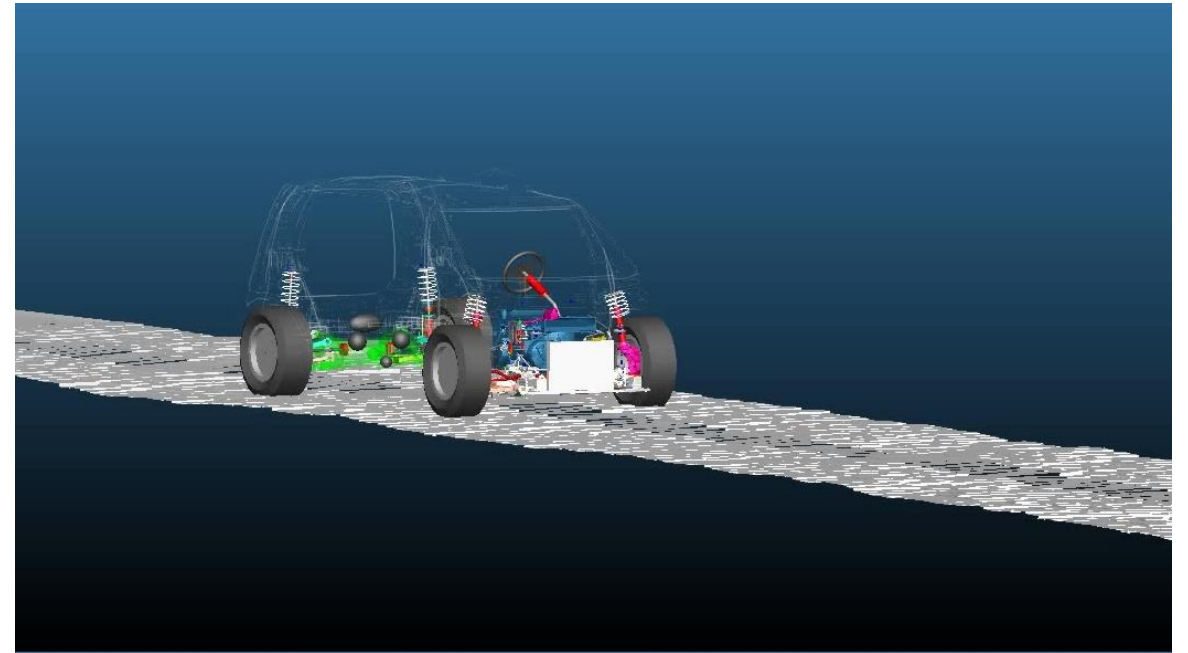


Chassis				
	Shock absorber	Spring [N/mm]	ARB [mm]	Bump clearance [mm]
Fsusp				
Rsusp				
Steering				
Max rack travel [mm]	Rack ratio [mm/rev]	Max steer assist [kN]		





Belgian Pavé





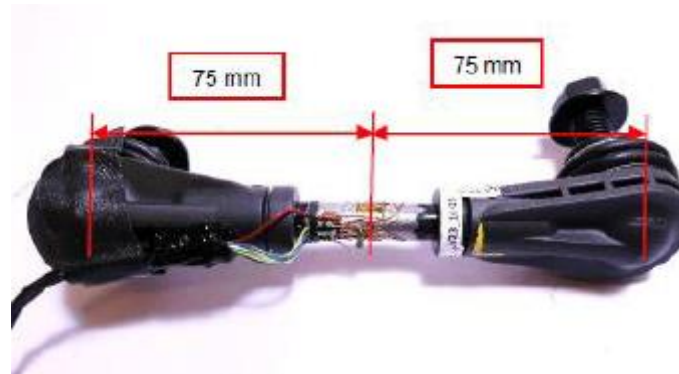
Chassis Rig

- 5 Chassis rig tests during 2022 to 2024
- Servo hydraulic test rig with 12 actuators
- PT-Mount load actuators
- Response signals
- Magna in-house analysis tools





Instrumented parts





Digital Twin Model

Digital Twin model matches with hardware in the rig

Digital twin is a suspension model derived from full vehicle assembly

Actuators are modelled to apply chassis rig loads

- 6 load actuators at WLC on each side
- PT mount load actuators

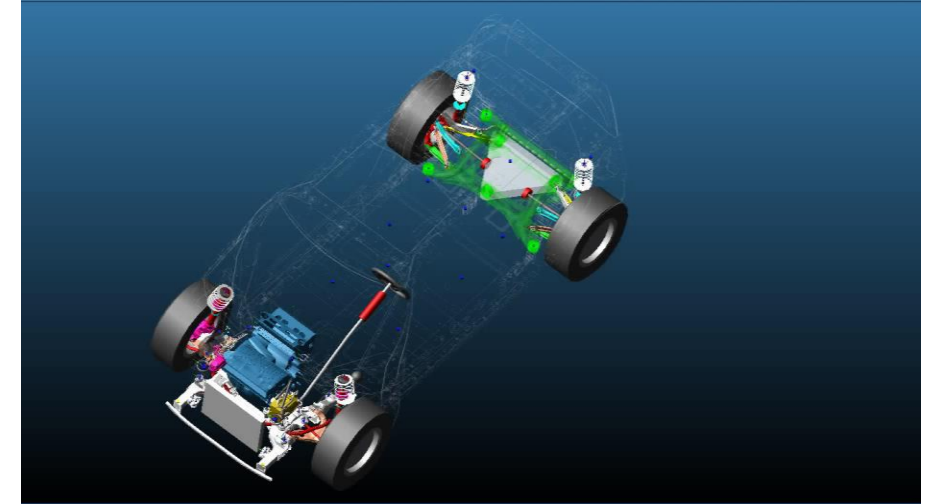
Fixtures to mimic body stiffness

Create requests to match with instrumentation orientation

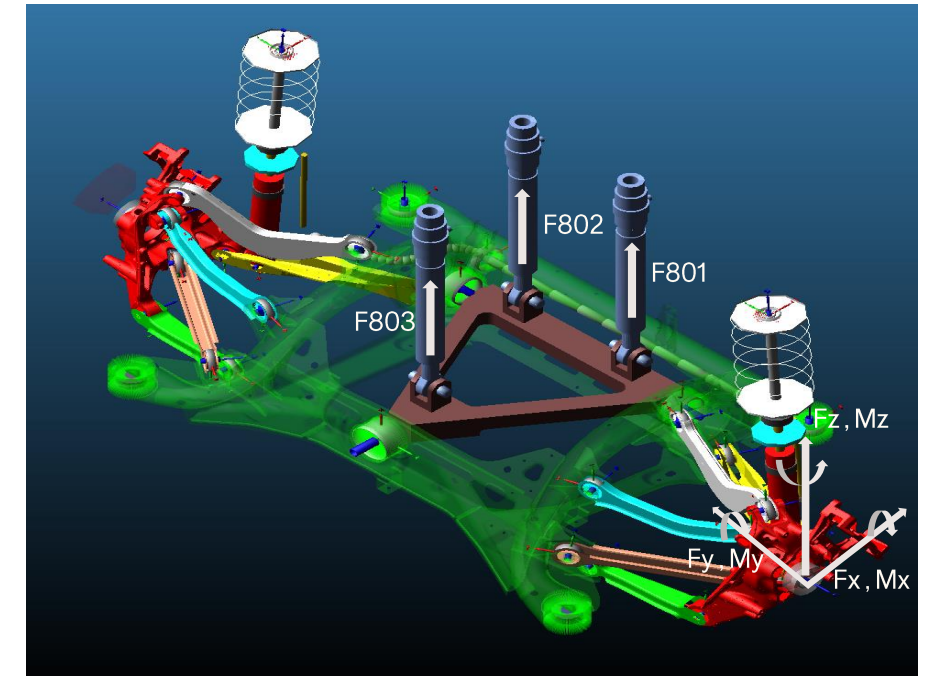
Usage of Digital Twin:

1. Investigate failures in chassis rig test
2. Generate Synthetic regen event

Full Vehicle Rear Suspension System

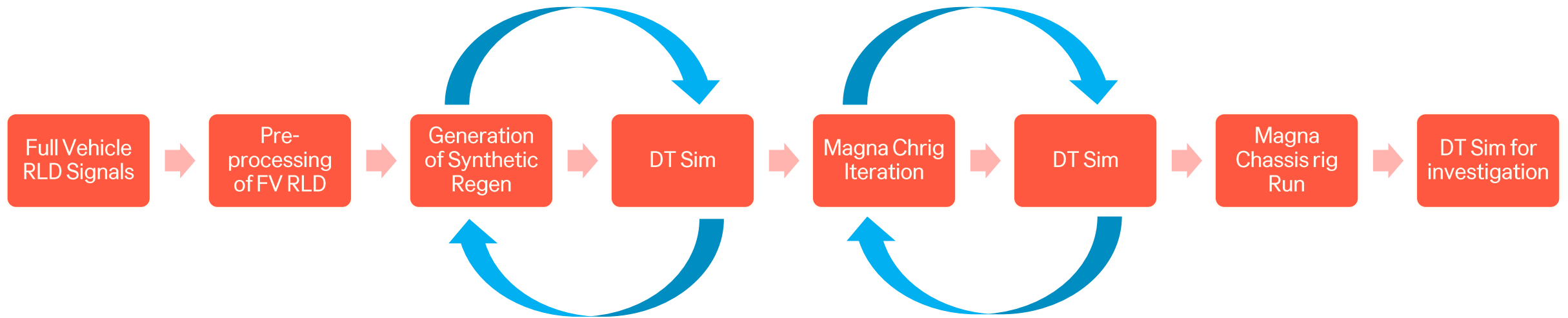


Rear Suspension Digital Twin





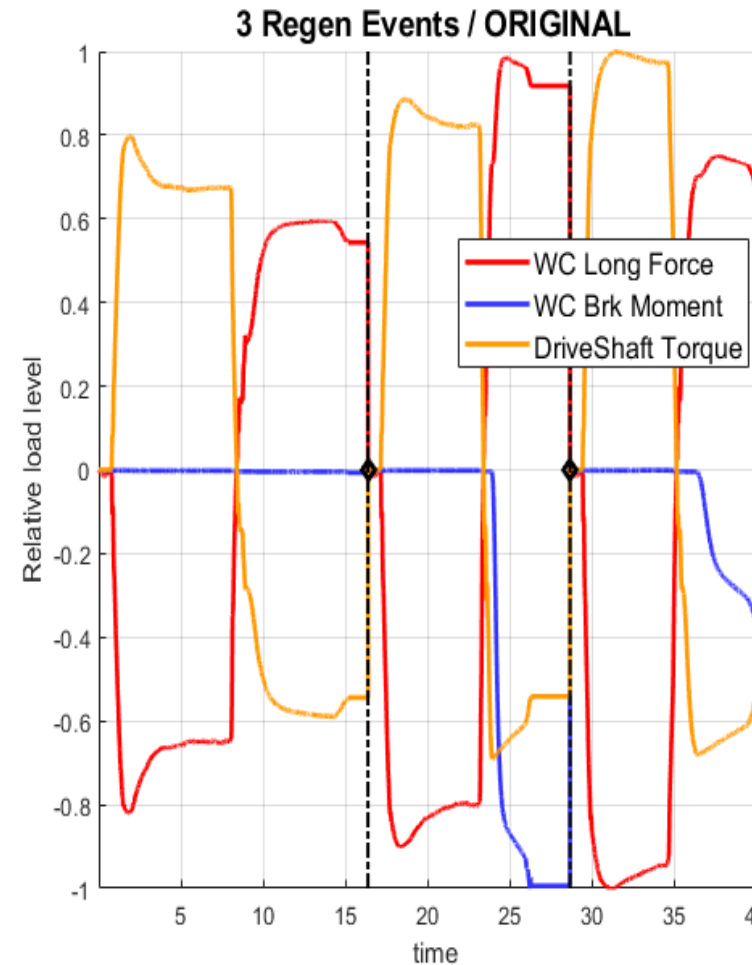
Flowchart: Chassis rig Process



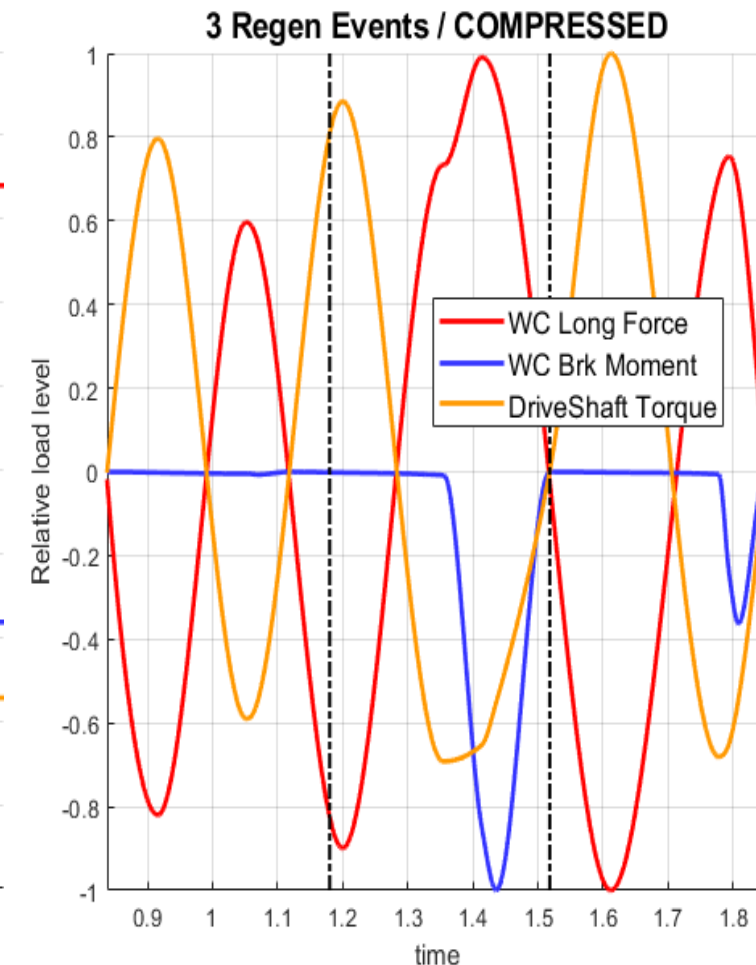


Synthetic Regen

- Long run time without compression
- Multi-axial compression
- Digital Twin Sim :
Compress Loading = Original Loading
Damage Damage
- Practical experience from Magna about
bushing heating issues



Total duty time : 1400 hrs

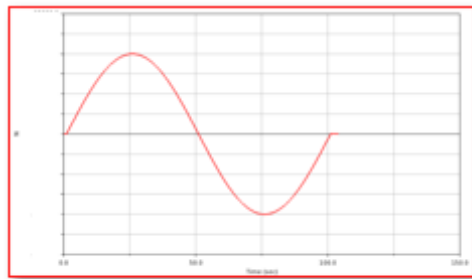


Total duty time : 40 hrs

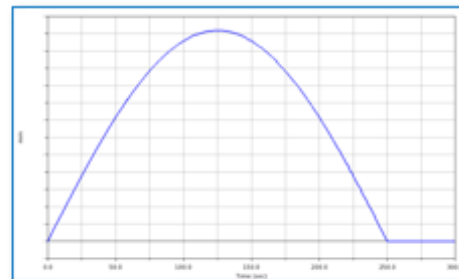


System Correlation events

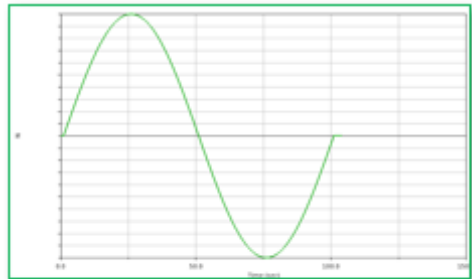
- Qstat X
- Qstat Y
- Qstat Z
- Vert Dyn



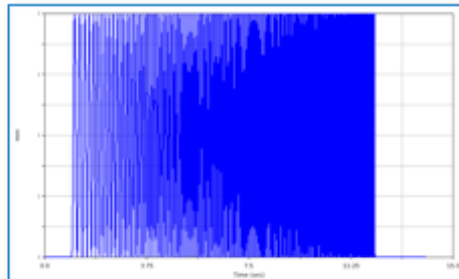
Qstat X



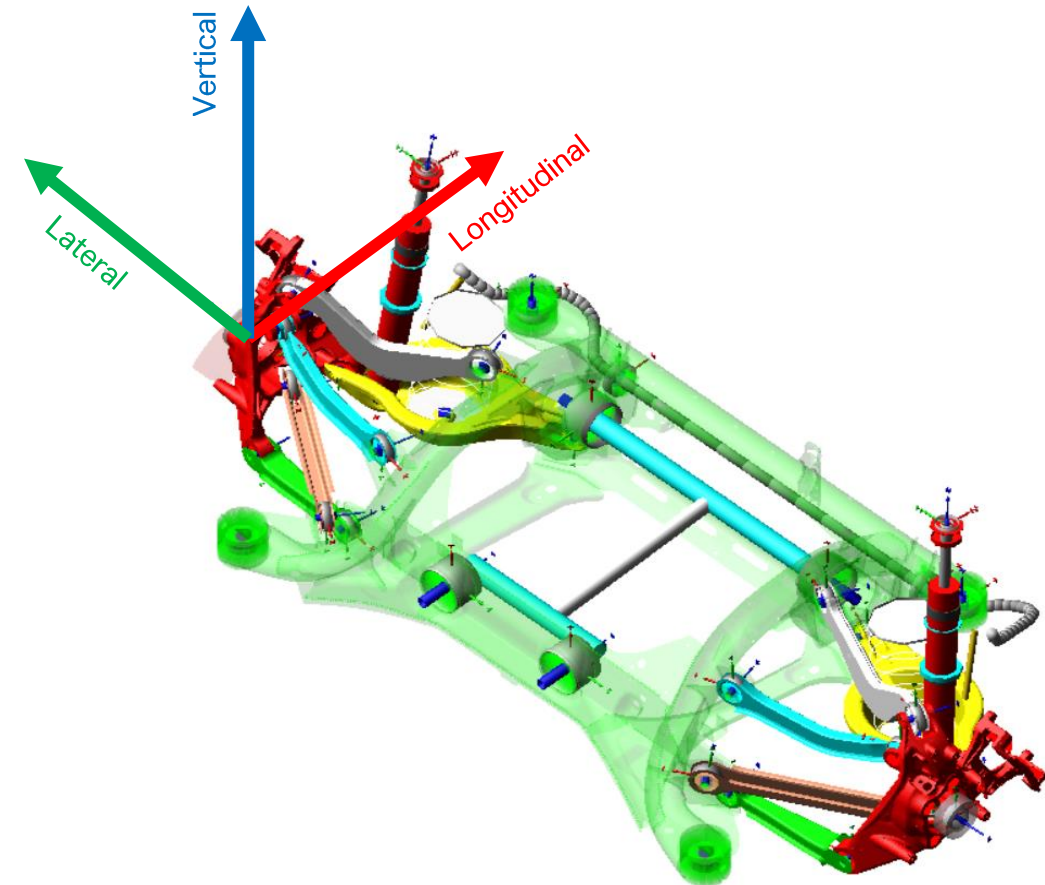
Qstat Z



Qstat Y

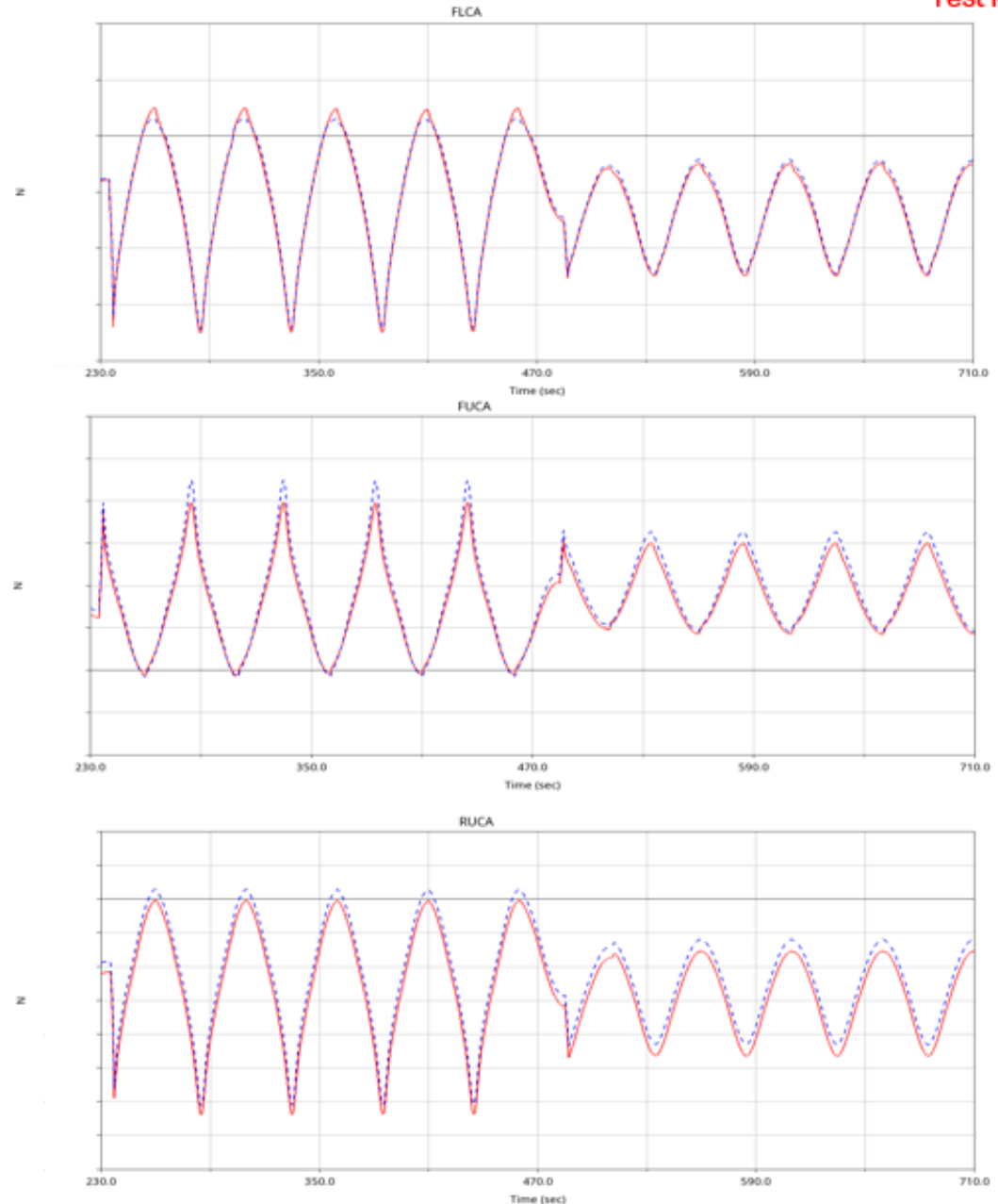


VertDyn



System Correlation events

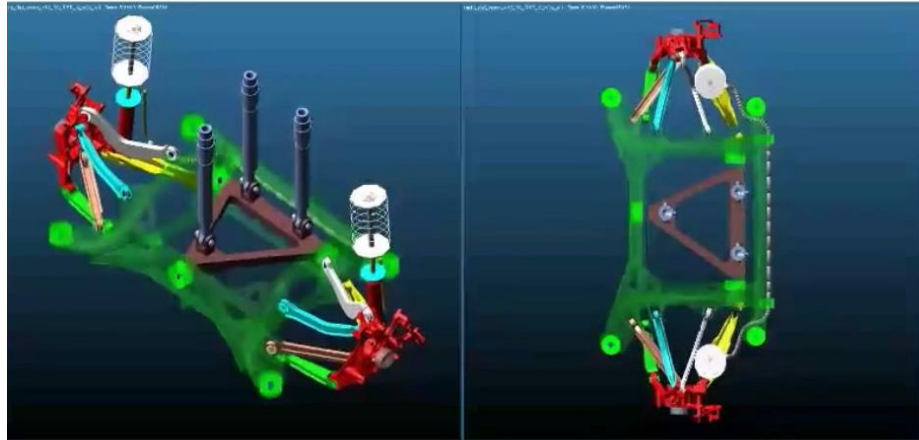
- Good correlation between Digital Twin simulation results and Test rig measurements
- Simulation model is investigated further if correlation is not good.



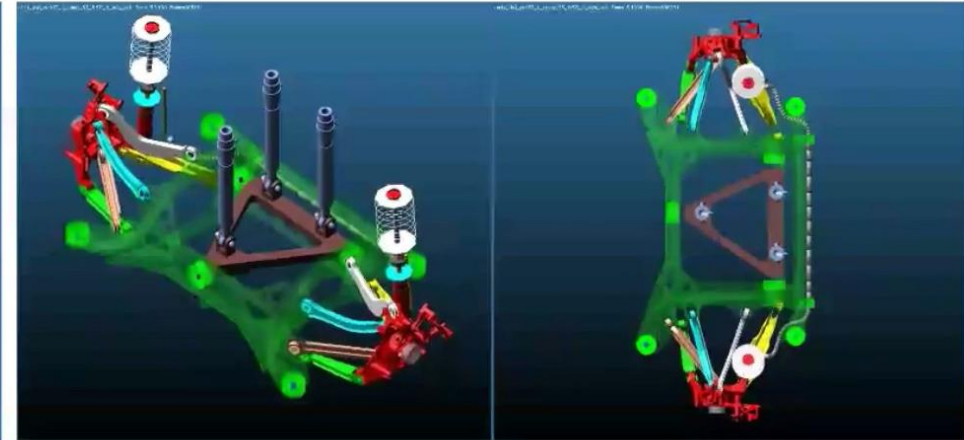


Animation Results: Chassis Rig

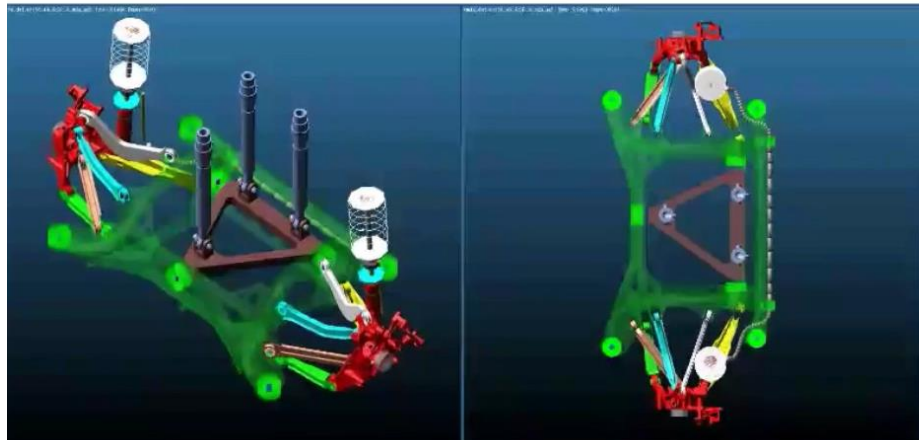
Synthetic Regen



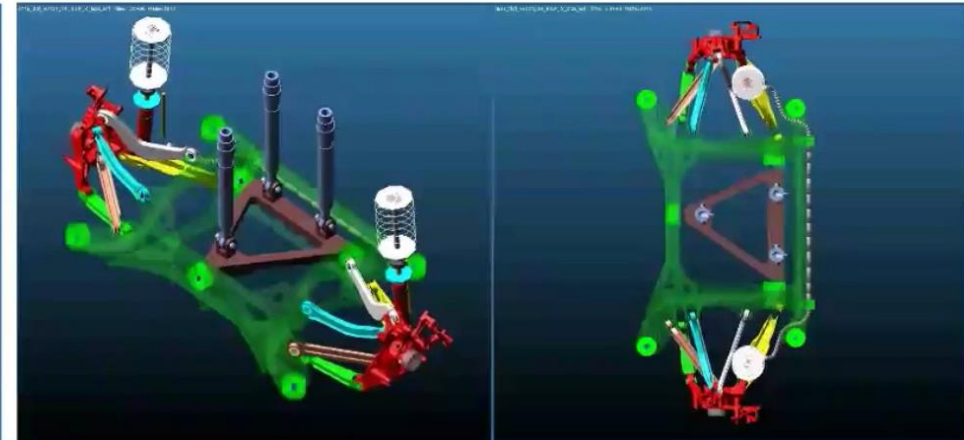
Belgian Pave



Country Road ABS Braking



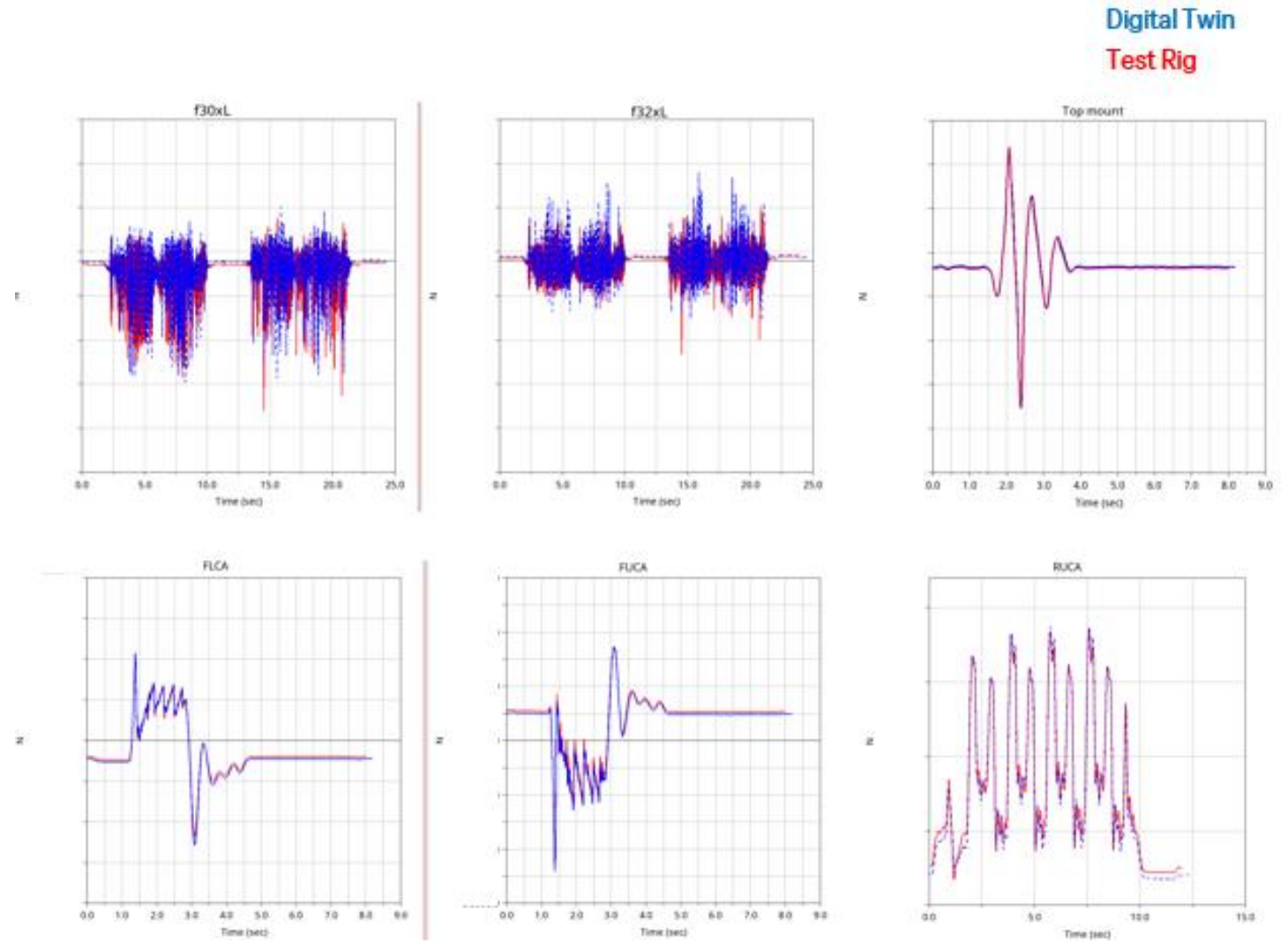
Pothole





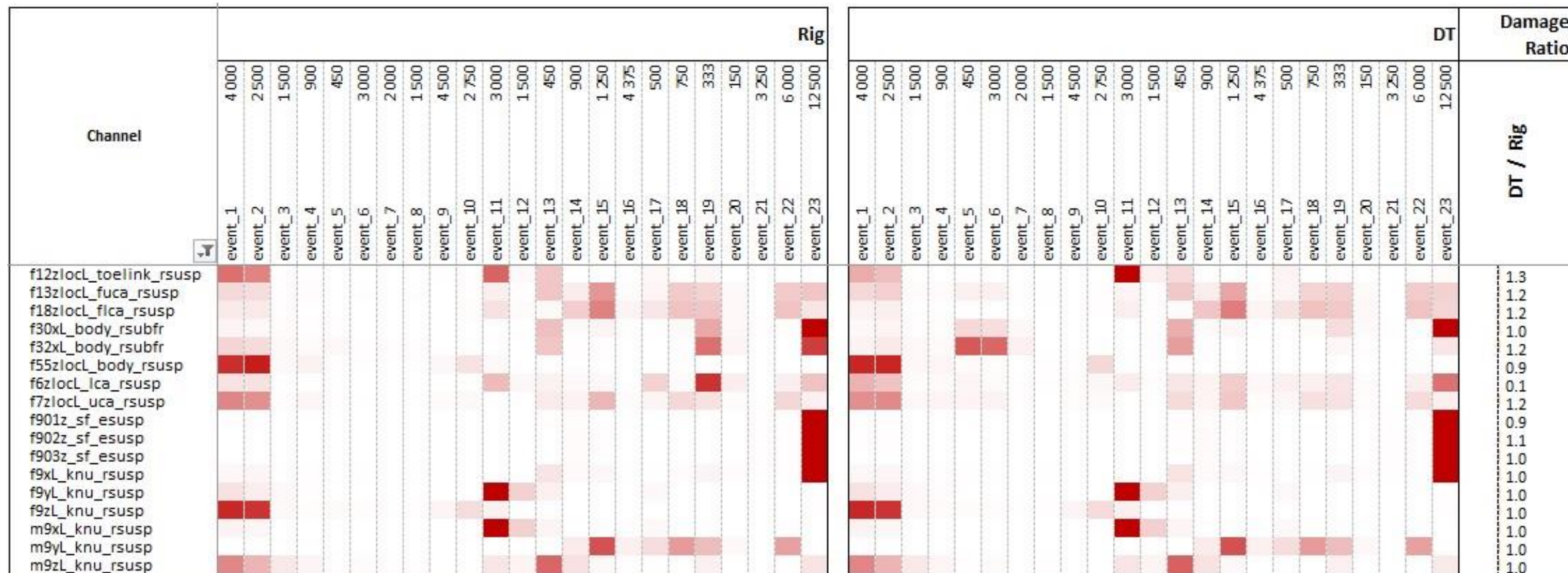
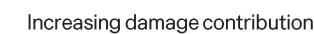
Correlation

- Measured loads on instrumented components.
- Good correlation between chassis rig measurement and Digital Twin simulations.





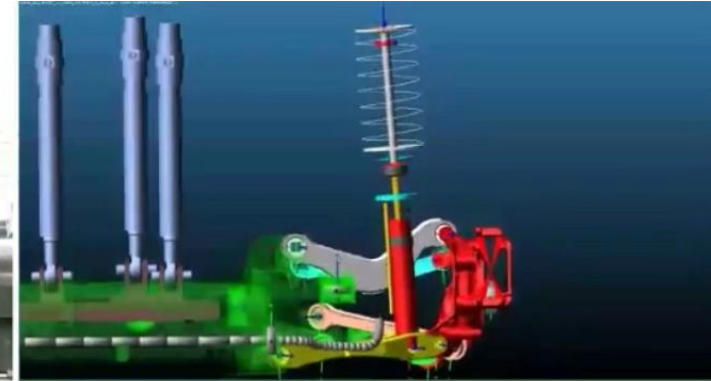
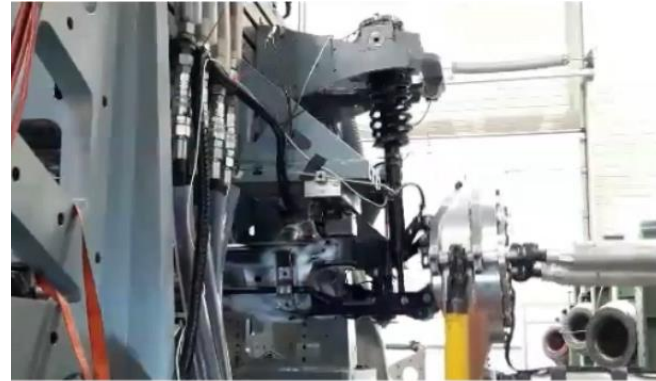
Correlation



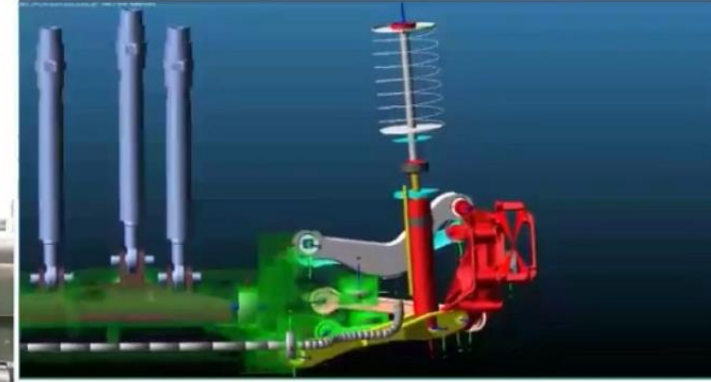


Test vs Sim

Belgian Pave



Country road ABS Braking



Synthetic Regen



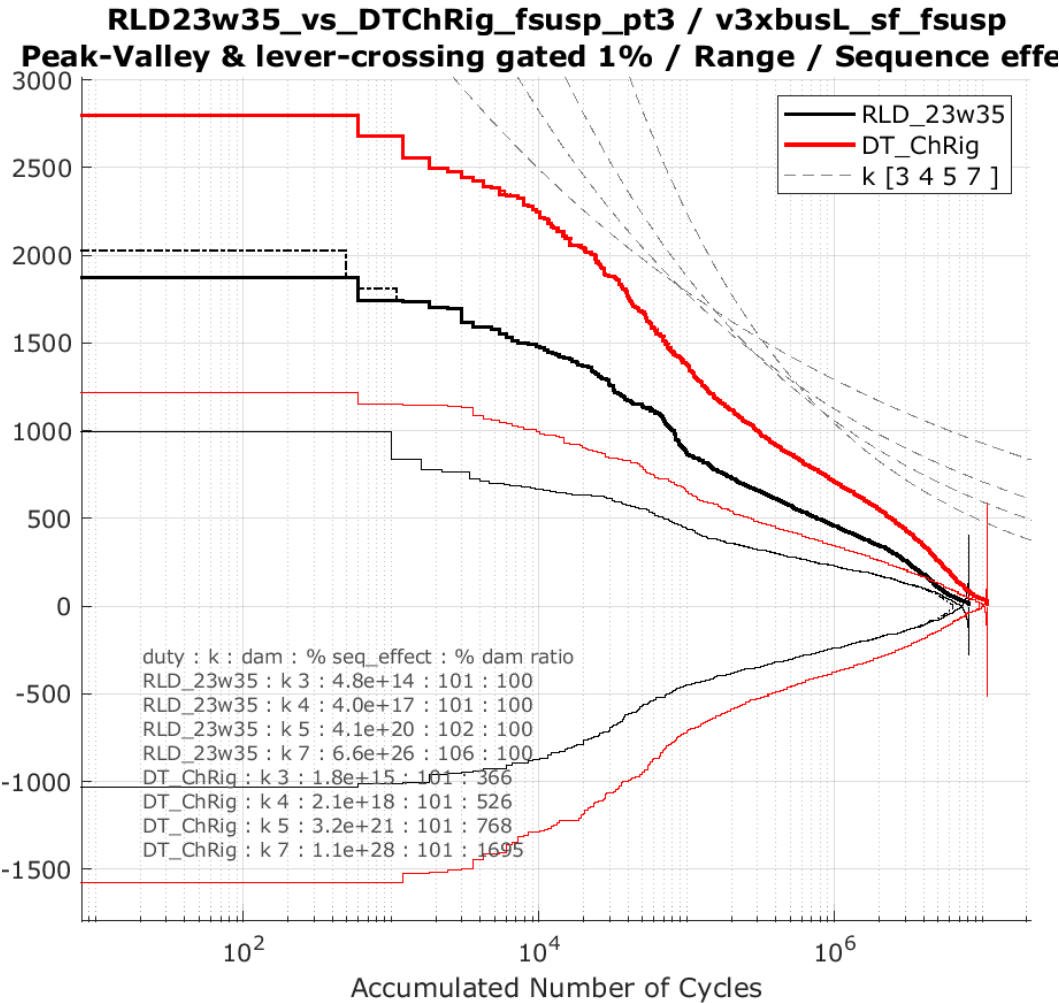
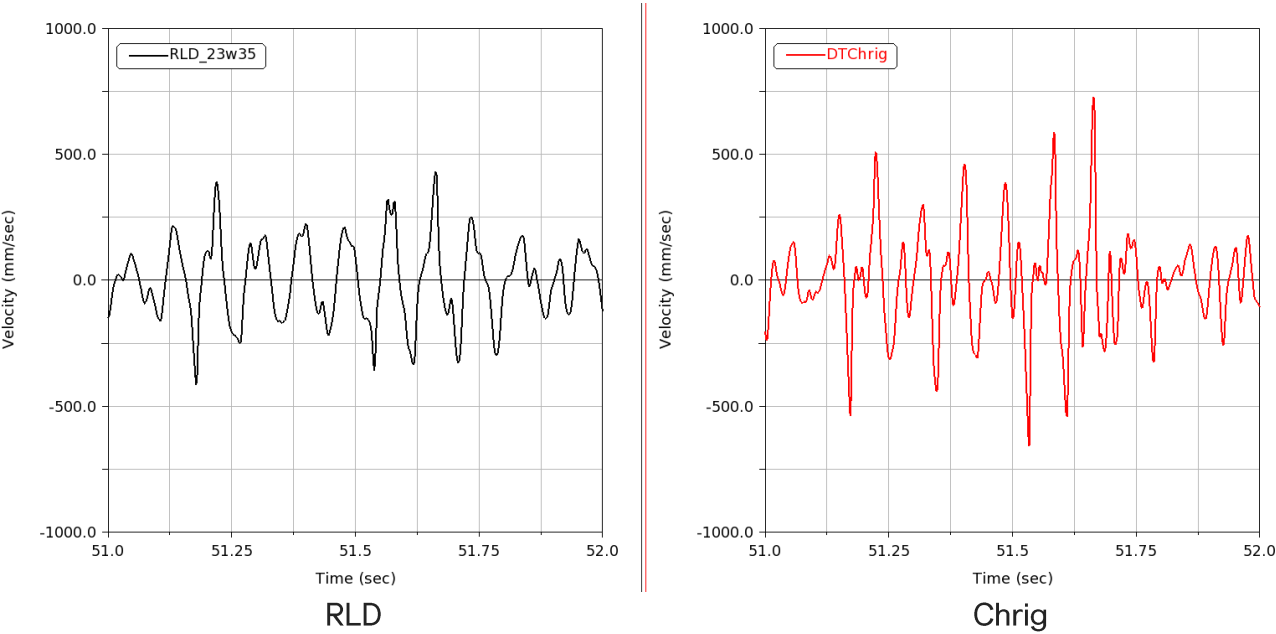


Hydro Bushing Failure





Hydro Bushing Failure



The highest contribution comes from pave and cobblestone.

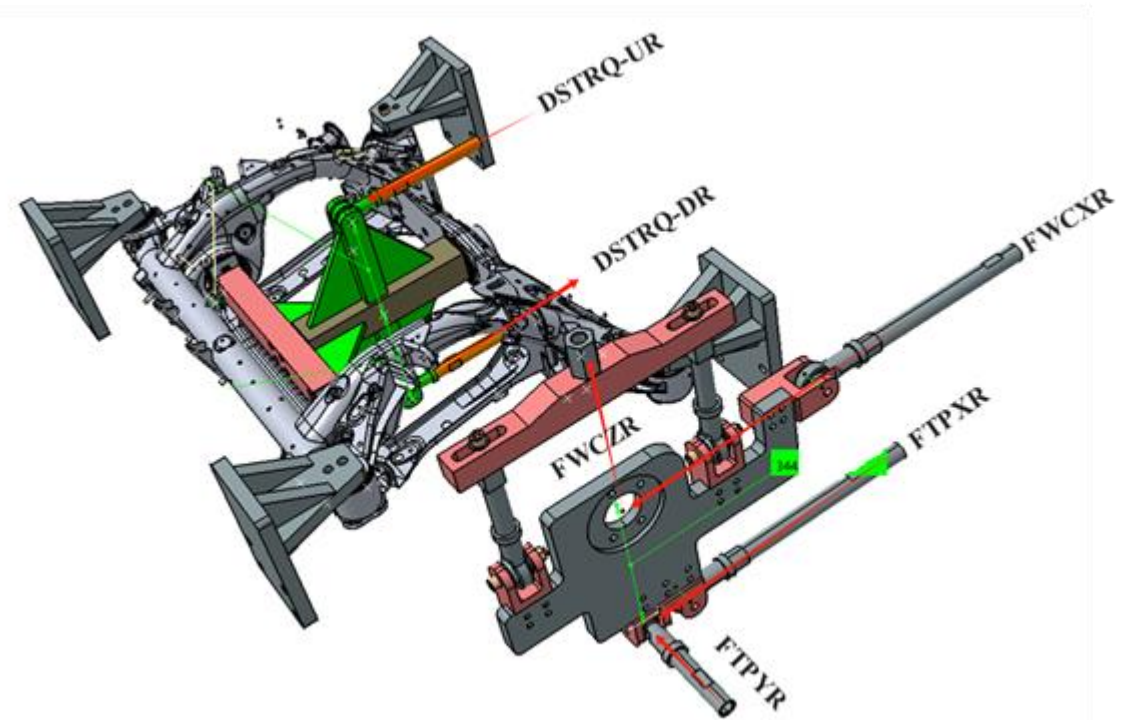


Hydro Bushing Failure



Subframe mini-module test

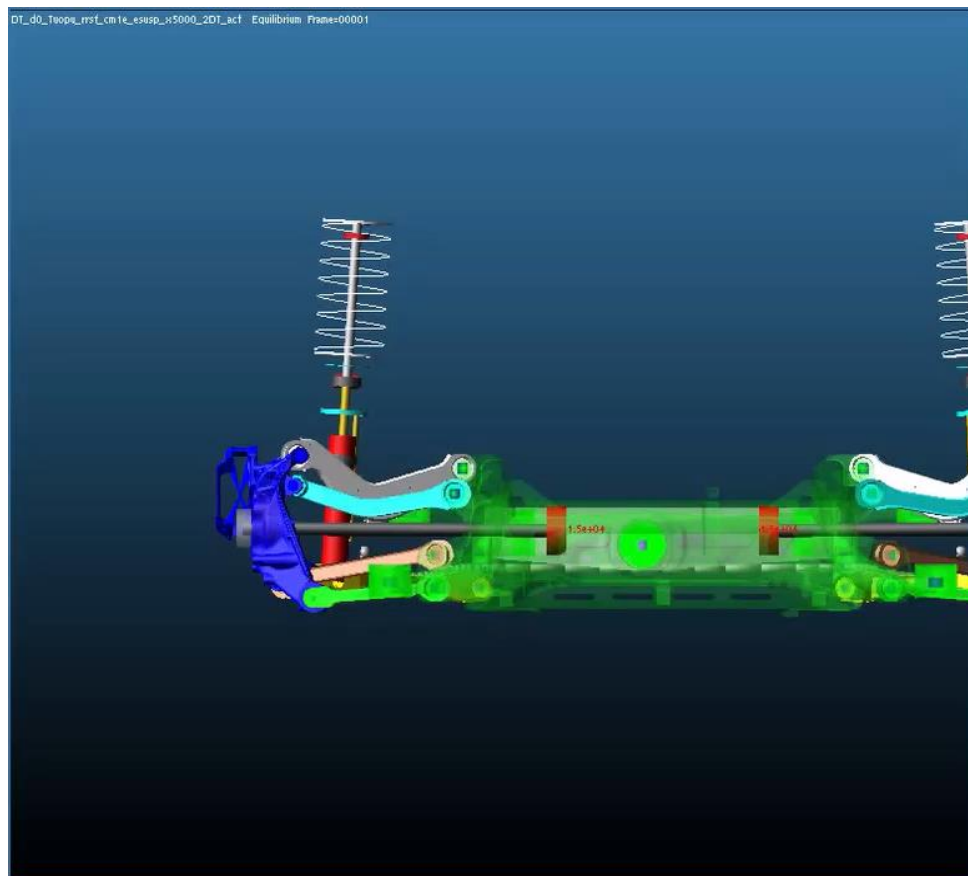
- Test run with 6 actuators
 - 4 actuators on WLC on one side
 - 2 actuators for powertrain mounts
- 6 Loads at WLC converted into 4 force actuators at WLC and contact patch by supplier
- Goal is to achieve same damage as FV RLD
- Issue: Too many unexpected failures





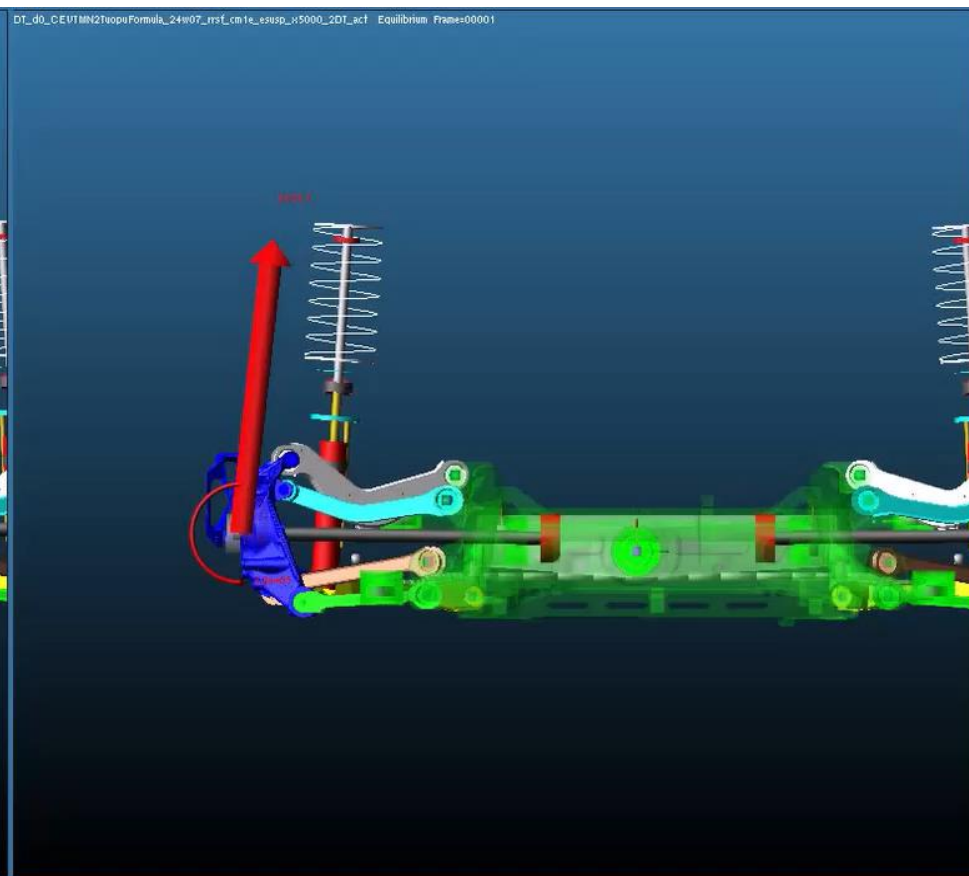
Subframe mini-module test

Digital Twin Simulation with supplier Rig Response Signals



Forces and moments can be seen in wrong directions.

Digital Twin Simulation with Full Vehicle RLD Signals

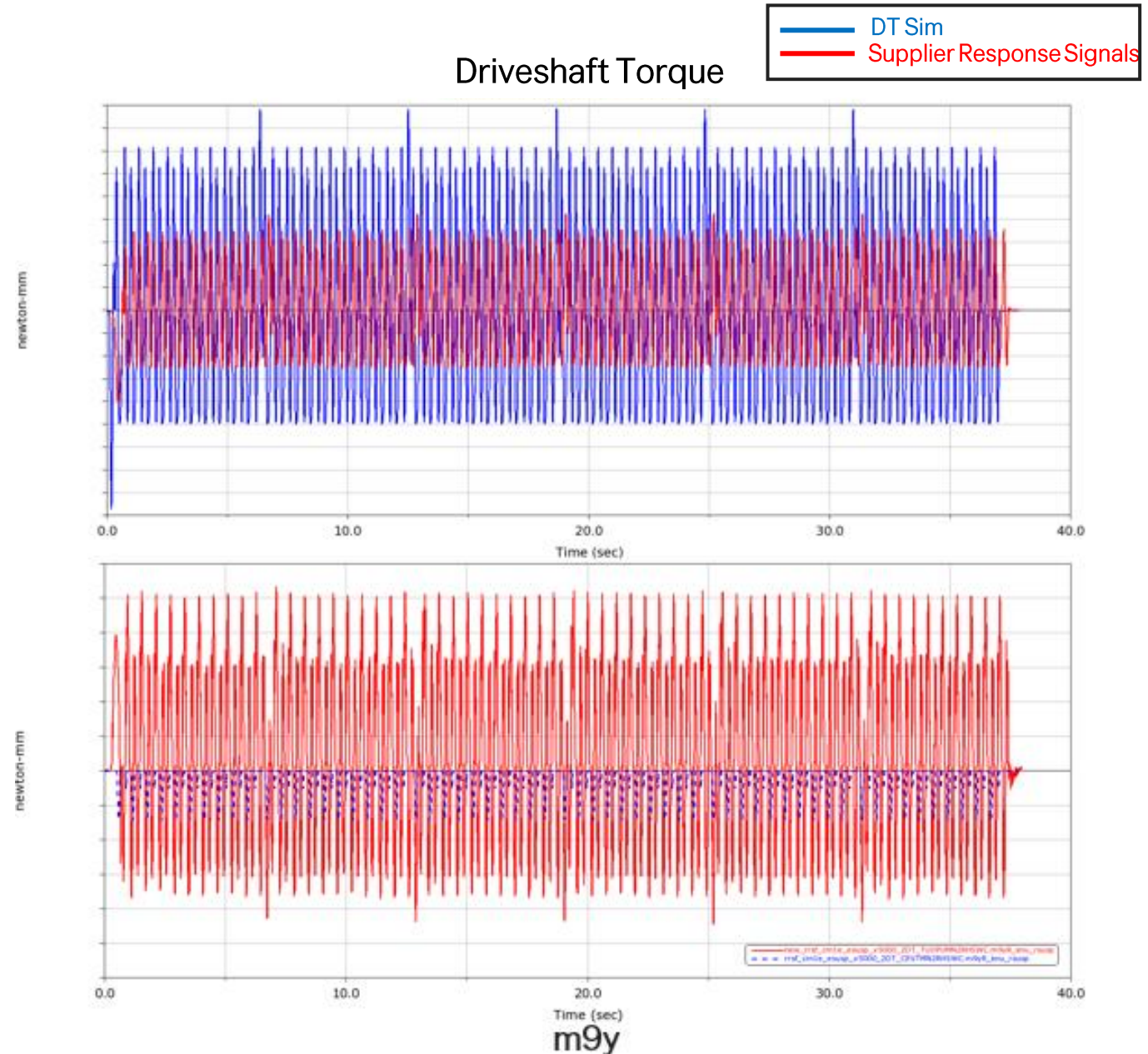


Forces and moments can be seen in correct directions.



Subframe MM Test

- Driveshaft torque applied is significantly lower in regen events of supplier Response Signal
- Braking torque is applied significantly higher in regen events of supplier Response Signal





Subframe mini-module test

- Significant difference in damage between supplier rig test and full vehicle RLD. This explains failures in link-arms.
- Test was performed again with correct signals verified in Digital Twin.

Channel	k	CORRECTED Test Setup / RLD	ORIGINAL Test Setup / RLD
driveshaft_torque	4 7	1.0 1.0	0.1 0.1
f901z_sf_esusp	4 7	1.0 1.0	0.2 0.1
f902z_sf_esusp	4 7	1.0 1.0	0.1 0.1
f903z_sf_esusp	4 7	1.0 1.1	0.1 0.1

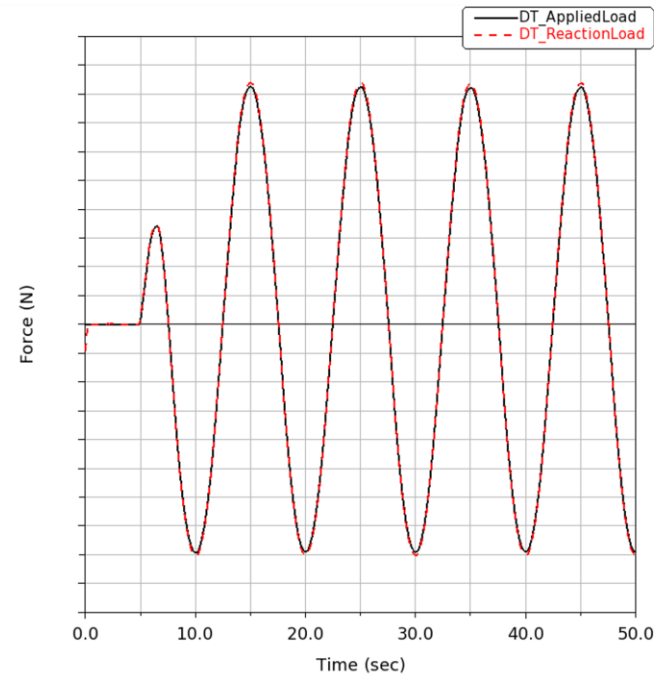
Channel	k	CORRECTED Test Setup / RLD	ORIGINAL Test Setup / RLD
f12zlocR_toelink_rsusp	4 7	1.1 1.3	2.2 4.0
f13zlocR_fuca_rsusp	4 7	3.7 13.3	16.3 60.8
f18zlocR_flca_rsusp	4 7	0.1 0.0	29.5 48.5
f4zR_sf_rsusp	4 7	1.0 1.0	10.3 49.1
f6zlocR_lca_rsusp	4 7	0.4 0.0	10.0 22.7
f7zlocR_uca_rsusp	4 7	1.7 4.6	7.3 25.3
f9xR_knu_rsusp	4 7	1.0 1.0	1.9 2.8
f9yR_knu_rsusp	4 7	1.1 1.1	1.7 2.9
f9zR_knu_rsusp	4 7	1.0 1.0	0.4 0.4
m9xR_knu_rsusp	4 7	1.0 1.0	0.9 1.0
m9yR_knu_rsusp	4 7	1.0 1.0	60.0 106.3



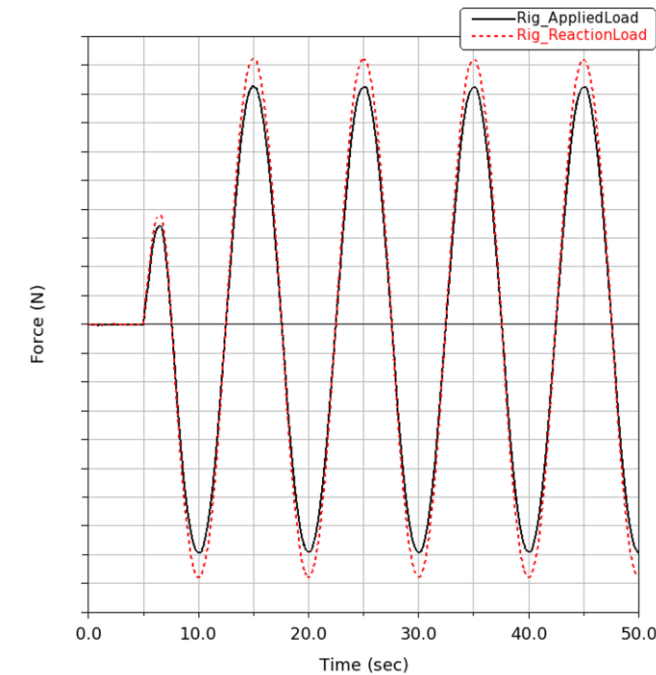
Subframe Mount Loadcell

- Digital Twin results show force equilibrium.
- Rig measurement do not show force equilibrium. Reaction loads are higher than applied loads at wheel center ($f_{9x} < f_{30x} + f_{32x}$).
- Further investigation carried out.

Quasistatic Analysis – Digital Twin



Quasistatic Analysis – RigMeas

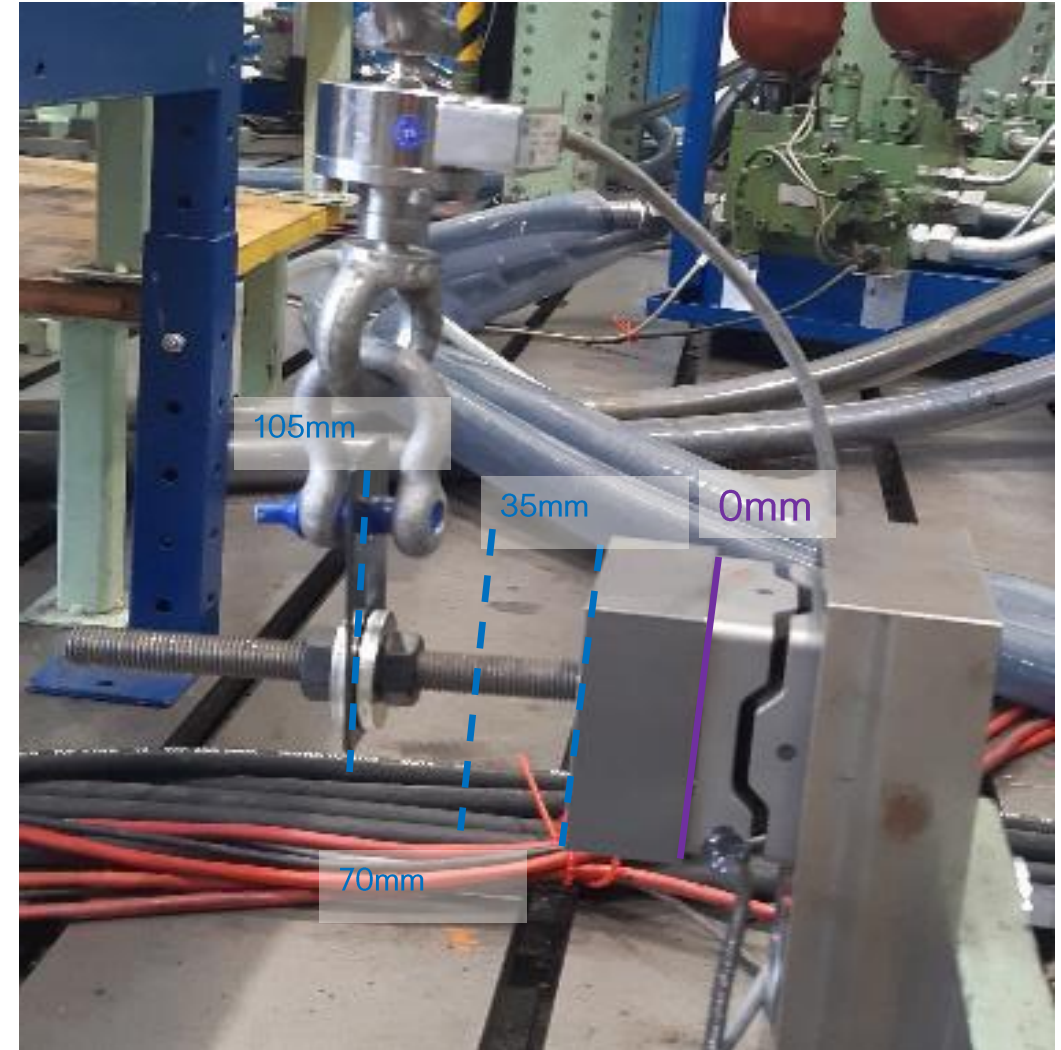


Input Channel
Output Channel

Subframe Mount Loadcell

- Test was carried out by changing applying loads at different offset.
- Offset has significance influence on measured load.

Distance [mm]	factor f_{x-3d}/F_{ref}
35	1,08
70	1,14
105	1,19





Summary

- Historical need to get deeper insight in chassis rig test failures
- Digital Twin helps us :
 - to improve various test set up
 - to understand iteration drive signals and its correlation to dimensioning RLD
- Access to loads at all locations which can not be measured in the rig
- Continuous model improvements are required and are ongoing

Thank you.
Questions?

