Philipp Wernicke, 2012/09/20
7th GTR PSI Meeting,Washington

WORLDSID 50% SHOULDER ASSESSMENT

INDUSTRY PROPOSAL

BMW GROUP

Rolls-Royce
Motor Cars Limited

CONTENTS

- Background information

- WS50M shoulder in test and simulation

- Conclusion out of analysis

- Proposal for shoulder assessment criteria

BACKGROUND – REVIEW OF LAST MEETING

Statement from Industry:

- In a severe pole crash, loading of the occupant is inevitable.
- In order to protect the occupants well in a PSI the goal is to direct the loads towards the body regions with greater ability to take these loads while limiting forces on sensitive body areas.
- The sensitive thorax area is left at much higher risk by lowering the shoulder forces.

Action for OICA:

- OICA, in liaison with NHTSA and Australia, to investigate WorldSID 50th male dummy pole side impact test shoulder loadings and develop a shoulder criterion that would prevent excessive (i.e. non-biofidelic) shoulder loadings from being used to unrealistically enhance (i.e. in a non-biofidelic way) vehicle pole side impact GTR performance responses.

BACKGROUND – REVIEW OF LITERATURE

Melvin (Biomechanical Analysis of Indy Race Car Crashes, Stapp 1998)

– “The combination of no direct intrusion into the chest, coupled with **stable loading of** the pelvis below the chest and **the shoulder** above the chest **means that chest deformations** other than inertial induced deflections **are minimized.**”

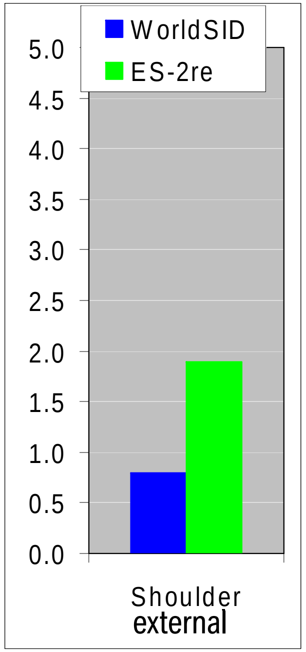
Lessley (Whole-Body Response to Pure Lateral Impact, Stapp 2010)

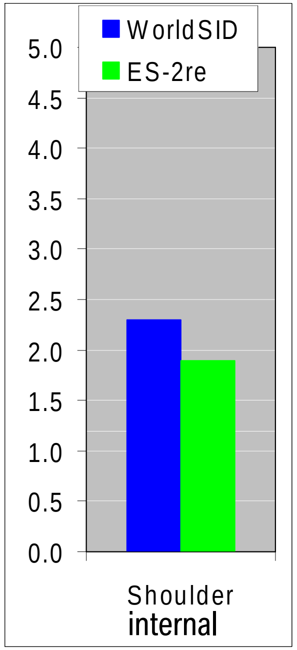
– “The results suggest that **the shoulder presents a substantial load path** and may play an important role in transmitting lateral forces to the spine, **shielding and protecting the ribcage.**”

Iwamoto et al. (Development of a Finite Element Model of the Human Shoulder, 44th Stapp 2000: , page 281–297)

– “Because the lungs and the heart are vital organs in the human, **engagement of the shoulder joint may be a good countermeasure for the reduction of the severity of chest injury**”

BACKGROUND – BIOFIDELITY OF WS50M SHOULDER



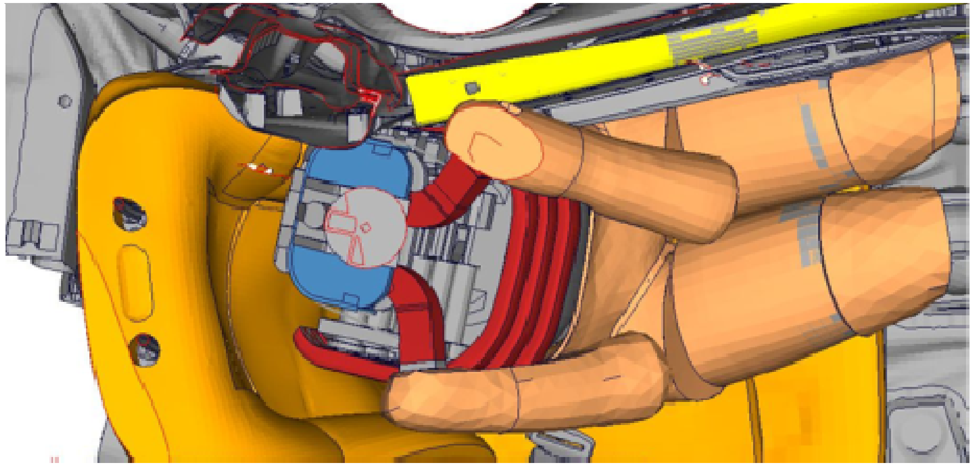
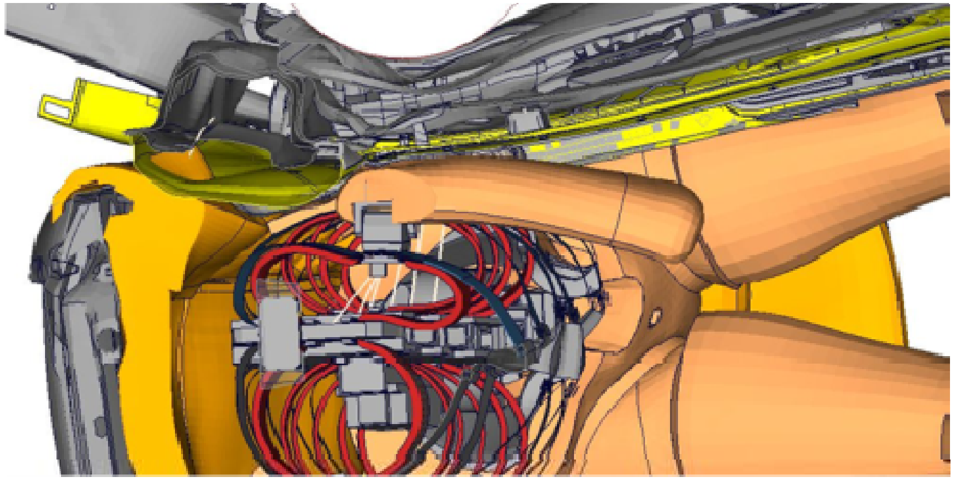
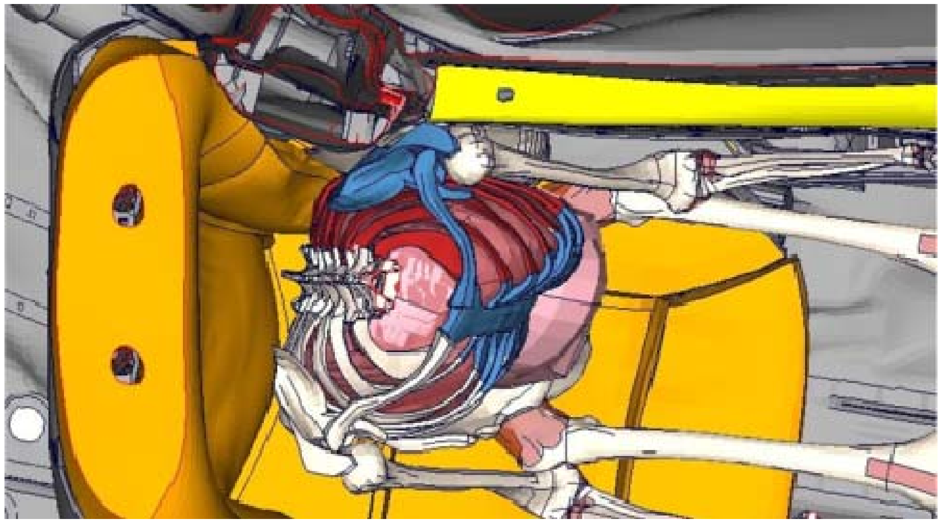


Body Region	ES-2re	WorldSID Ford (OSRP)	WorldSID NHTSA/VRTC
Head	5	10	10
Neck	4.2	5.3	5.5
Shoulder	4.5	10	8.3
Thorax	4.0	8.2	7.5
Abdomen	4.1	9.3	7.3
Pelvis	3.2	5.1	4.8
Overall	4.2	8.0	7.2

Biofidelity Rating according to ISO TR9790

- WSID shoulder biofidelity is better than ES-2re
- WSID shoulder has improved ROM, measures displacement
- WSID shoulder & thorax have improved oblique response

BACKGROUND – COMPARISON ES2-WS50M-THUMS 3

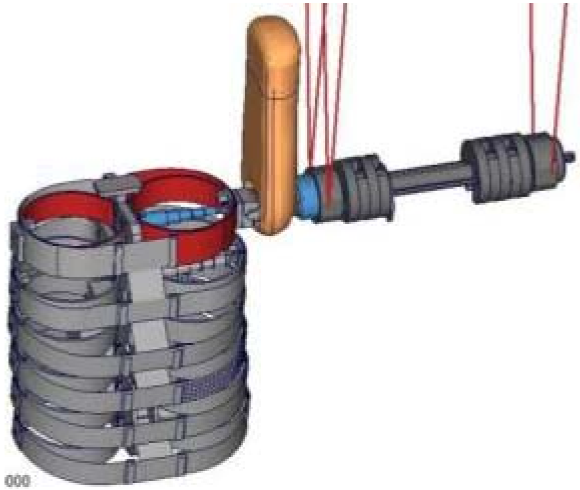
WORLDSID SHOULDER UNDER LOADING

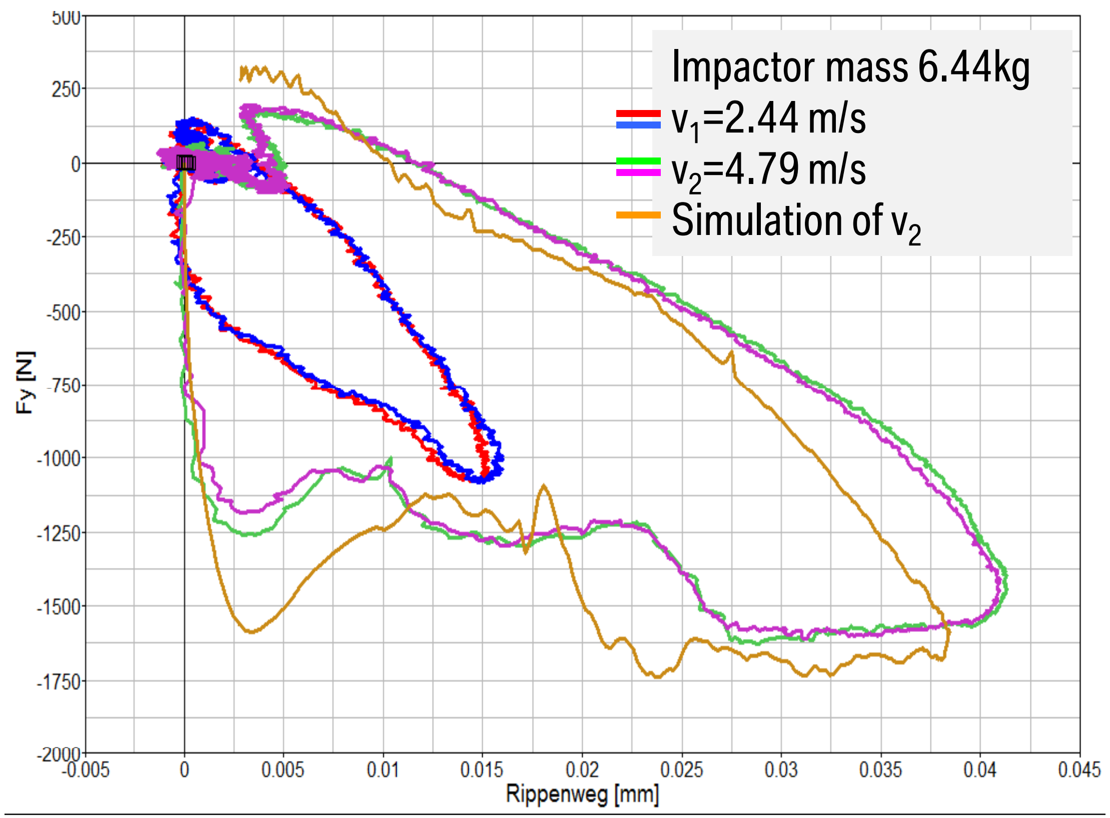
Various loading scenarios and conditions have been analyzed in order to understand the „load path“ in the WorldSID shoulder:

– Numerical pendulum tests based on validation test data
– Pendulum test data from Autoliv
– Numerical and physical crash tests of different passenger cars
– Full scale crash test data of passenger cars

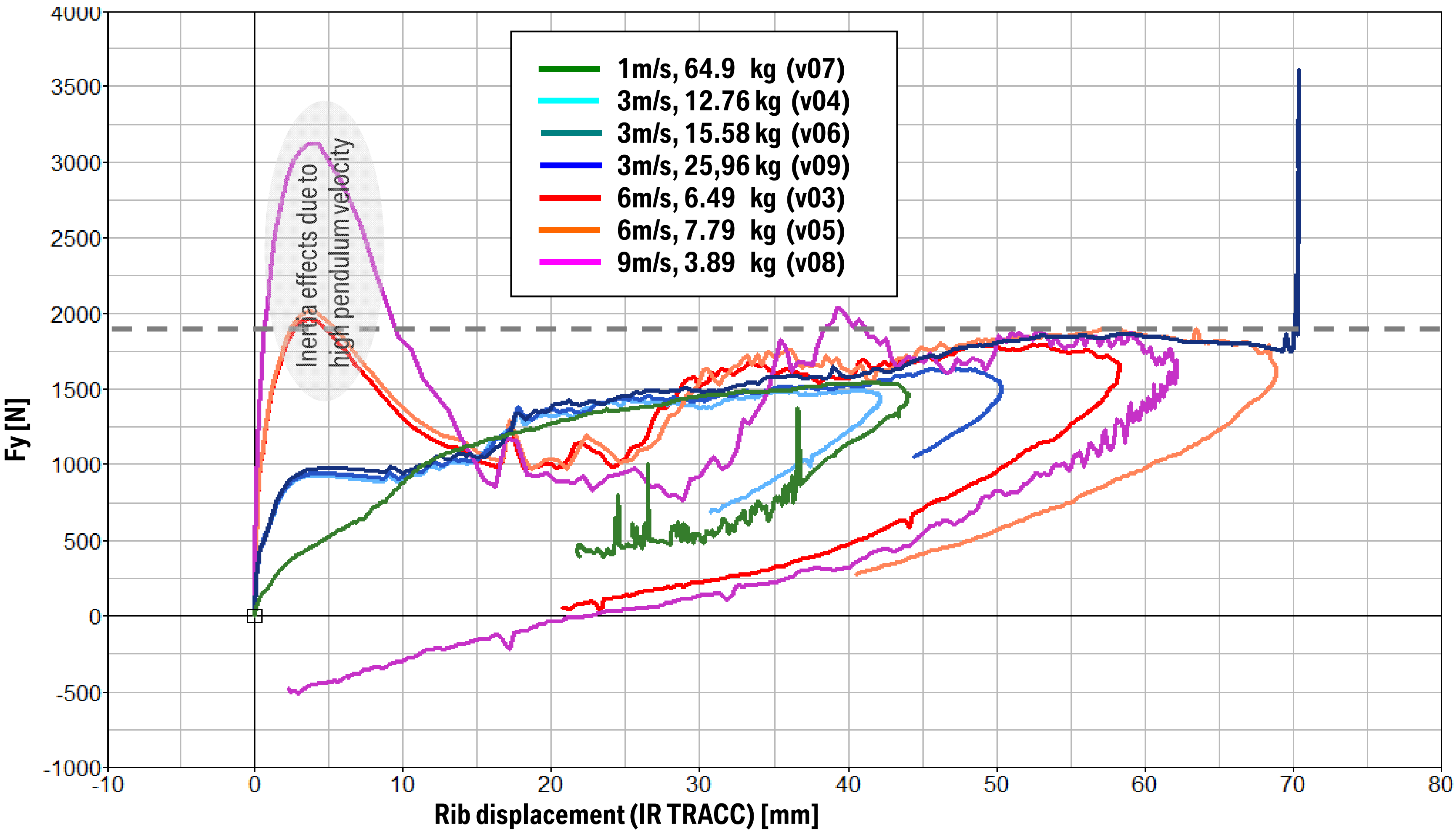
NUMERICAL PENDULUM TESTS (PDB) COMPARISON OF TEST AND SIMULATION

Tests have been condcuted to evaluate the WorldSID FE model.

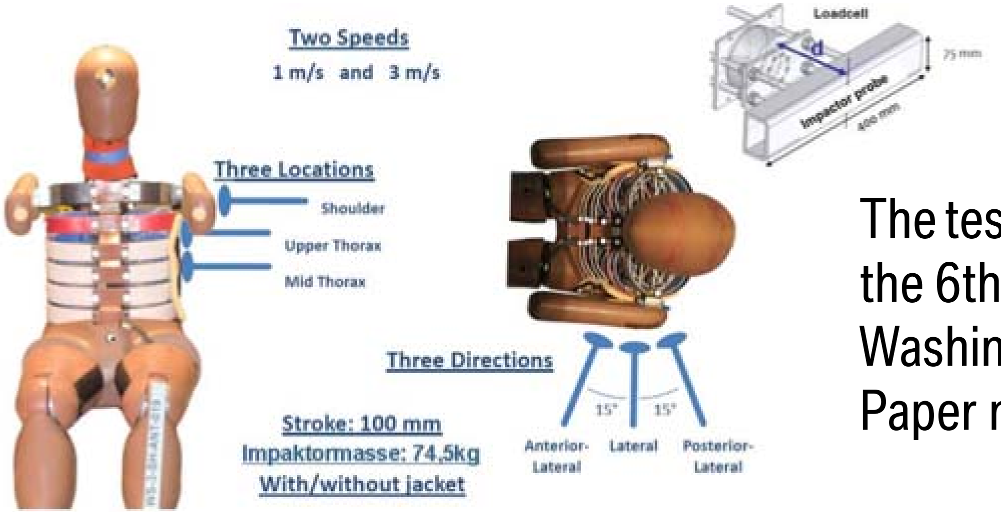




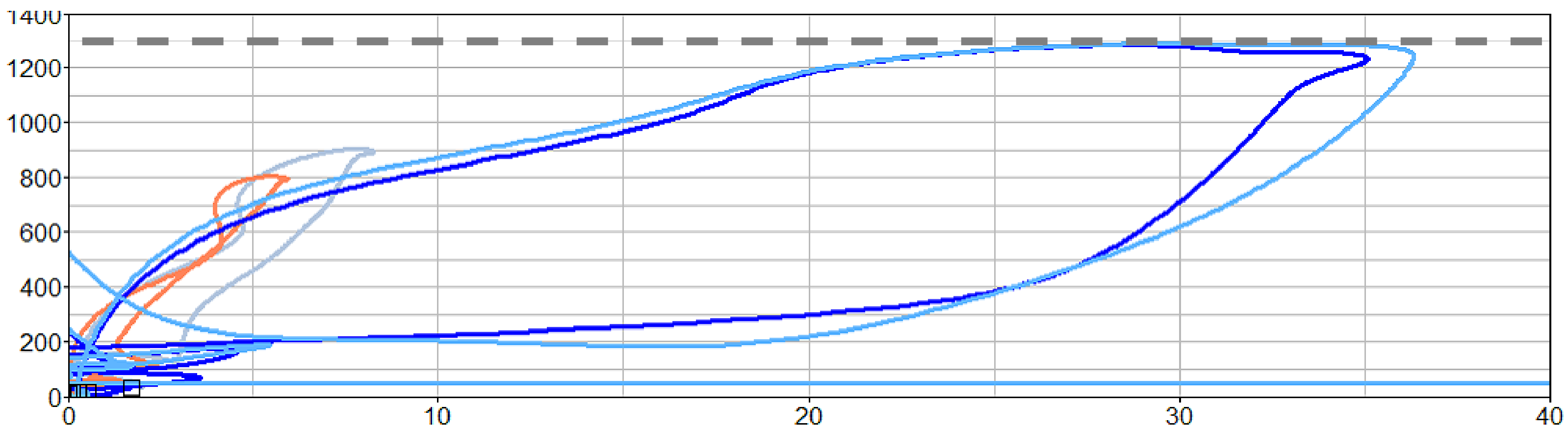
NUMERICAL PENDULUM TESTS (PDB) SHOULDER: FORCE - DEFLECTION



PENDULUM TESTS BY AUTOLIV
TEST SET UP / FORCE – DEFLECTION

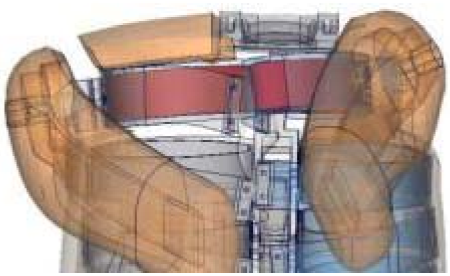


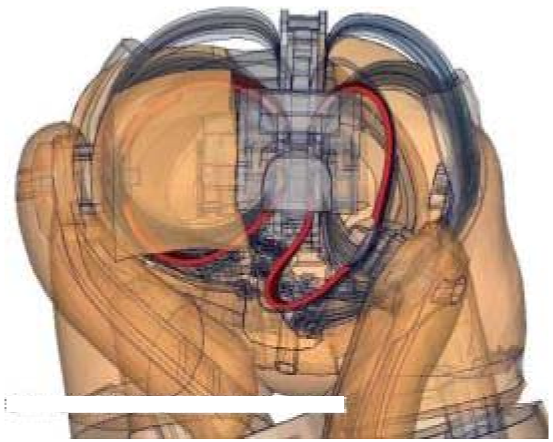
The test series was presented at the 6th IWG WorldSID meeting in Washington 2011.
Paper number WS-06-05e.

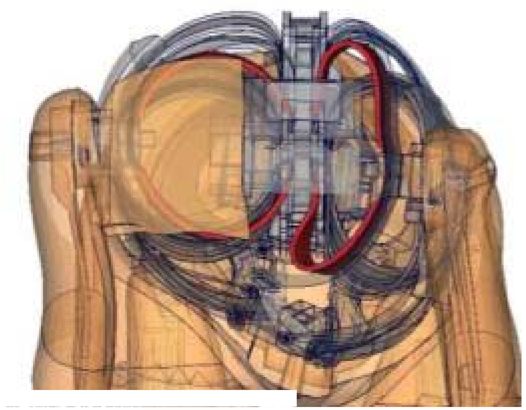


NUMERICAL CRASH TESTS
SHOULDER: RIB DEFORMATION

Shoulder rib deformation in FMVSS 214 CtP with WorldSID 50%.

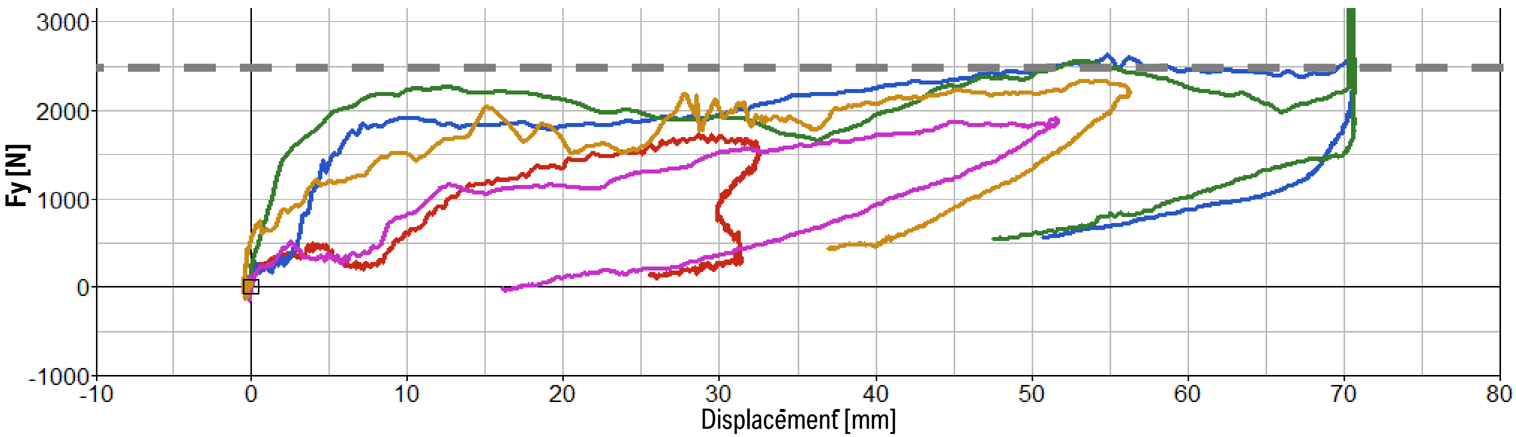




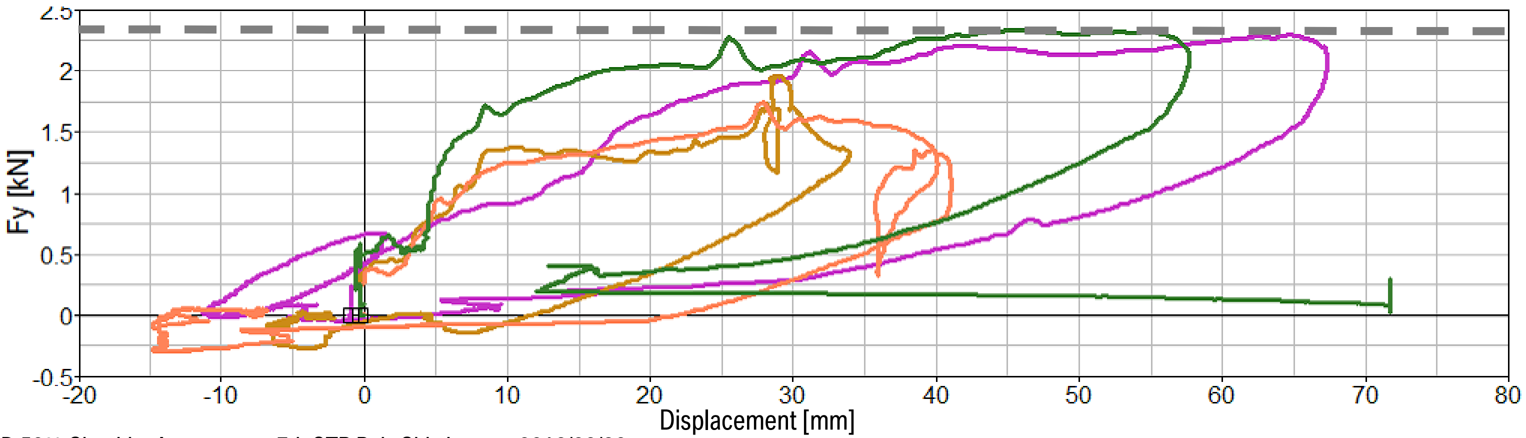


FULL SCALE CRASH TESTS
SHOULDER: FORCE - DEFLECTION

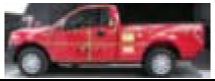
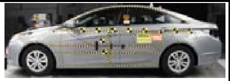
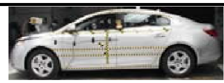
Force – Deflection of the WS50M shoulder in different vehicle simulations



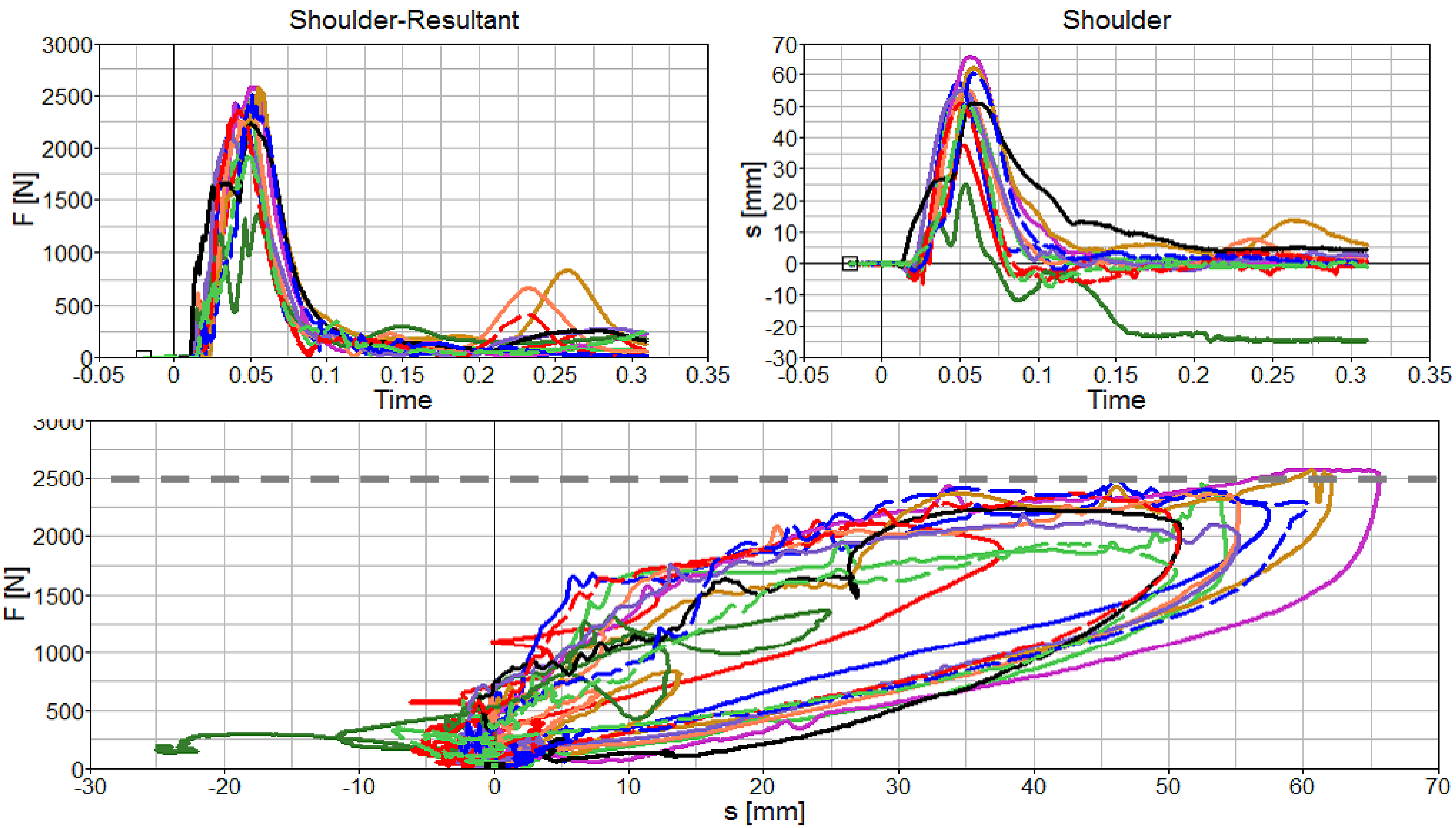
Force – Deflection of the WS50M shoulder in different full scale tests



NHTSA FULL SCALE CRASH TESTS DATA BASE

Test No.	Contractor Study Title	(degrees) Test	Speed (kph)
7652	2010 FORD F150 LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	31.2
7653	2011 HYUNDAI SONATA LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	32.2
7654	2010 BUICK LACROSSE LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	31.8
7655	2010 CHEVROLET TRAVERSE LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	32.3
7656	2010 ACURA MDX LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	32.1
7657	2010 KIA FORTE LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	32.1
7658	2010 SUZUKI SX4 LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	31.8
7659	2011 HYUNDAI TUCSON LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	32.2
7660	2011 JEEP GRAND CHEROKEE LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	32.1
7661	2011 CADILLAC CTS LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	32.5
7662	2011 FORD EXPLORER LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	32.2
7663	2011 HONDA ODYSSEY LEFT SIDE FMVSS 214 POLE IMPACT AT 32 KPH 	285	31.9

FULL SCALE CRASH TESTS
SHOULDER: FORCE - DEFLECTION



SUMMARY
SHOULDER: FORCE - DEFLECTION

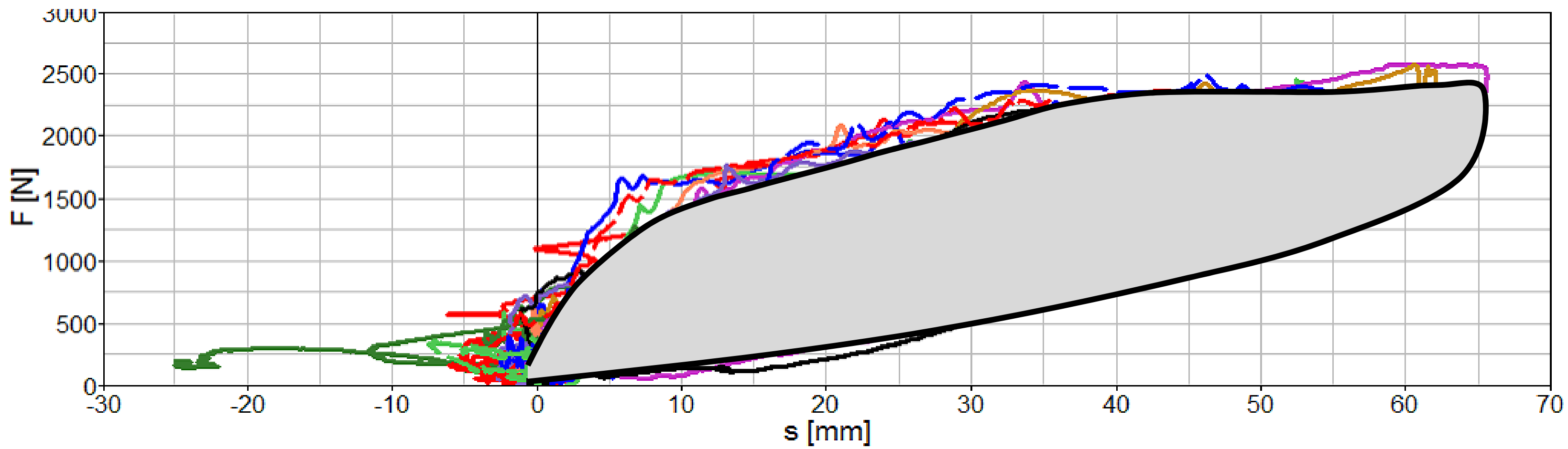
Behavior of the WS50M was analyzed under various loading conditions and environments, as well as in Simulation as in Testing.

The force-deflection curve seems to have a similar shape in each analyzed data set.

No linear dependency between force and deflection can be found for the shoulder rib.

The force - deflection curve is degressive and builds up a force plateau between 40 - 70 mm deflection.

The force level is between 2- 2.5 kN.



CONCLUSION
SHOULDER LOAD PATH

Based on this analysis it seems that the shoulder rib of WorldSID 50% does not have the attributes to be misused as an non-biofidelic load path.

Dependent on the environment, the shoulder can take up to 2.5 kN lateral force till the deformation of the rib reaches its geometrical maximum.

As soon this force level is reached, the shoulder only takes more deformation without any significant rise in the load.

Therefore, the shoulder does not offer itself as the “hidden” load path as it may be the case in other dummy types. It deforms on a biofidelic load level till the rib bottoms out.

PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA PRINCIPLES

Loading the shoulder in a PSI event in a "biofidelic" way seems to be a good way to protect the ribcage without risking serious injury.

What is "biofidelic" loading?

- The WorldSID shoulder has a good biofideliy rating both in NHTSA and ISO methods.
- This indicates that as long the shoulder does not experience severe loading leading to deformations greater than its design specifications, the WorldSID shoulder can be seen as a "good" load path.

Proposal for assessment criteria:

- Non-biofidelic loading is not permitted.
- Therefore, severe loading has to be detected.

PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA DETECTION OF "SEVERE LOADING"

Based on the analysis of the force-deflection characteristic of the WorldSID50M shoulder, a defined force level seems not to be the right measurement to detect such loading.

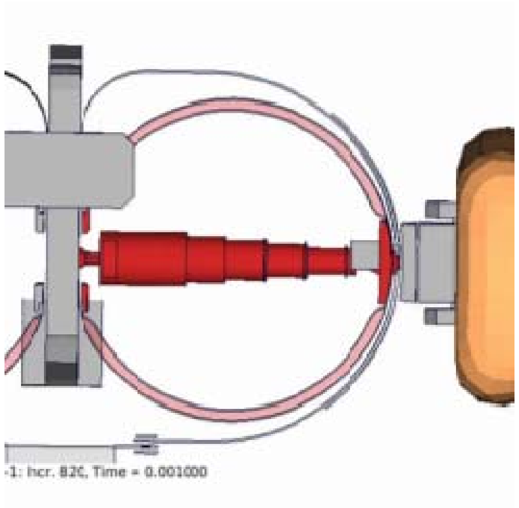
Similarly, the detection of a bottoming out using the IR-TRACC also has its limitations concerning exactness and reliability.

- The deformation of shoulder rib has shown variations in its maximum deflection range (67-73 mm).
- Overloading the shoulder leads to destruction of the IR-TRACC fixation without noticeable peak force.

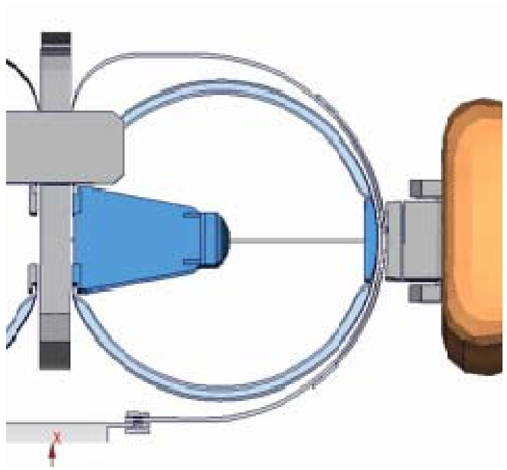
Proposal:

Detection of peak force in the shoulder load caused by a bottoming out on a rib stop, which replaces the IR-TRACC in the WorldSID shoulder.

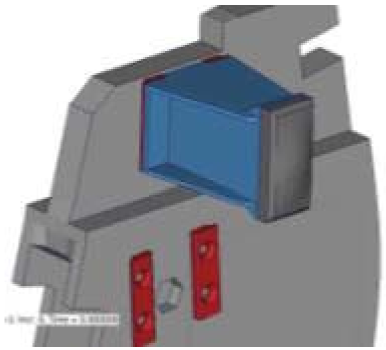
PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA
PROPOSAL OF NEW SHOULDER RIB STOP

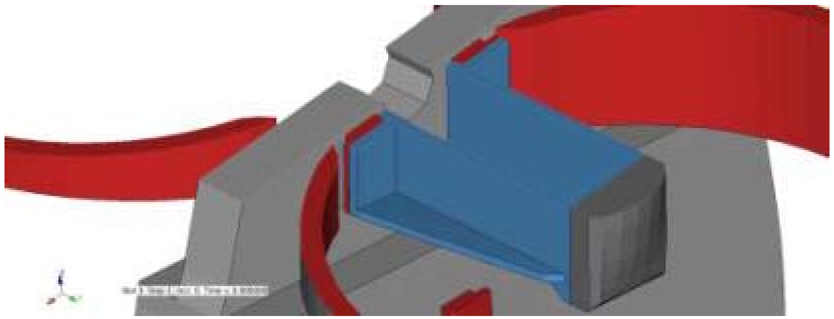


Current WS50M design



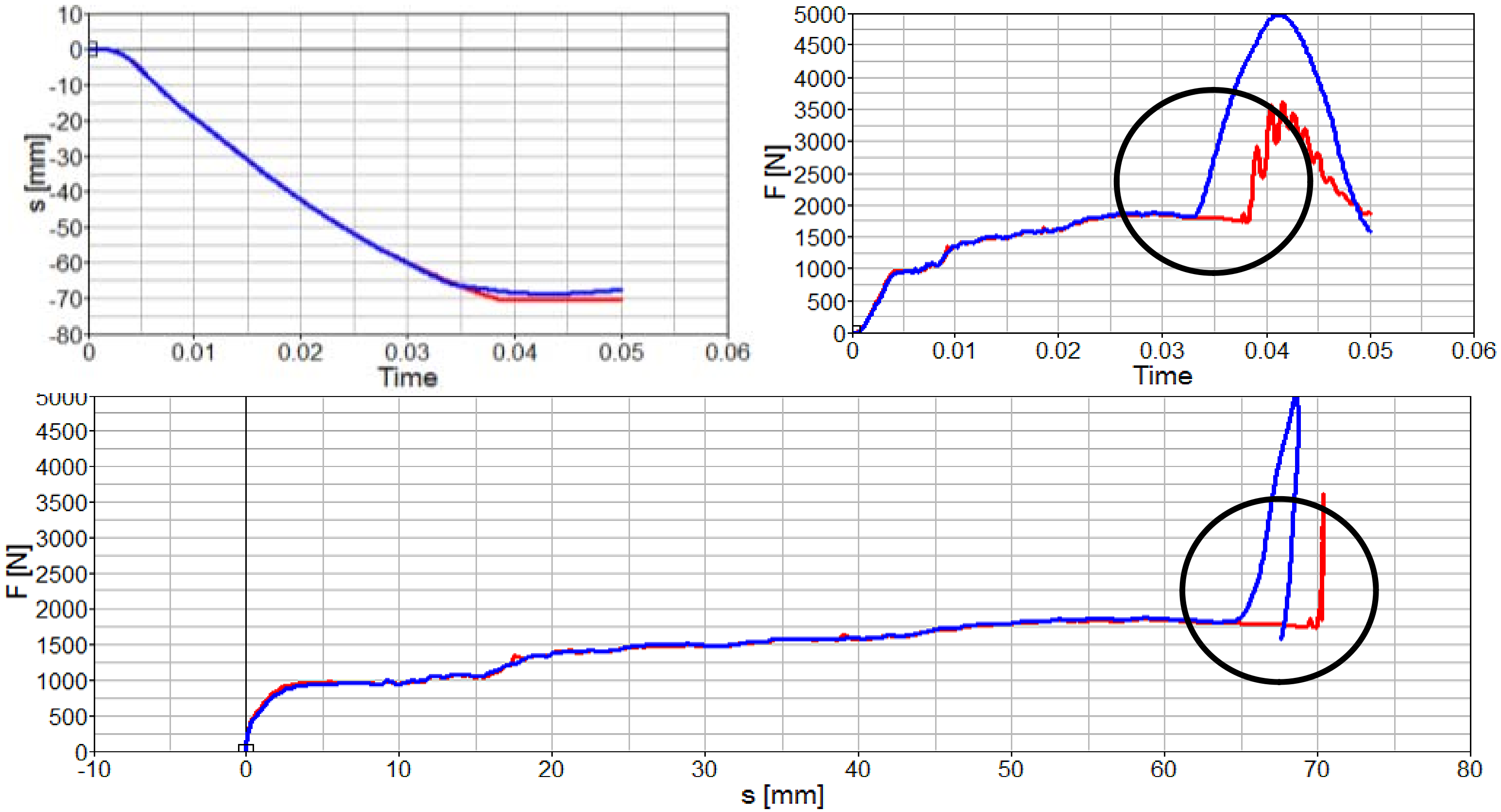
Proposal for a shoulder rib stop





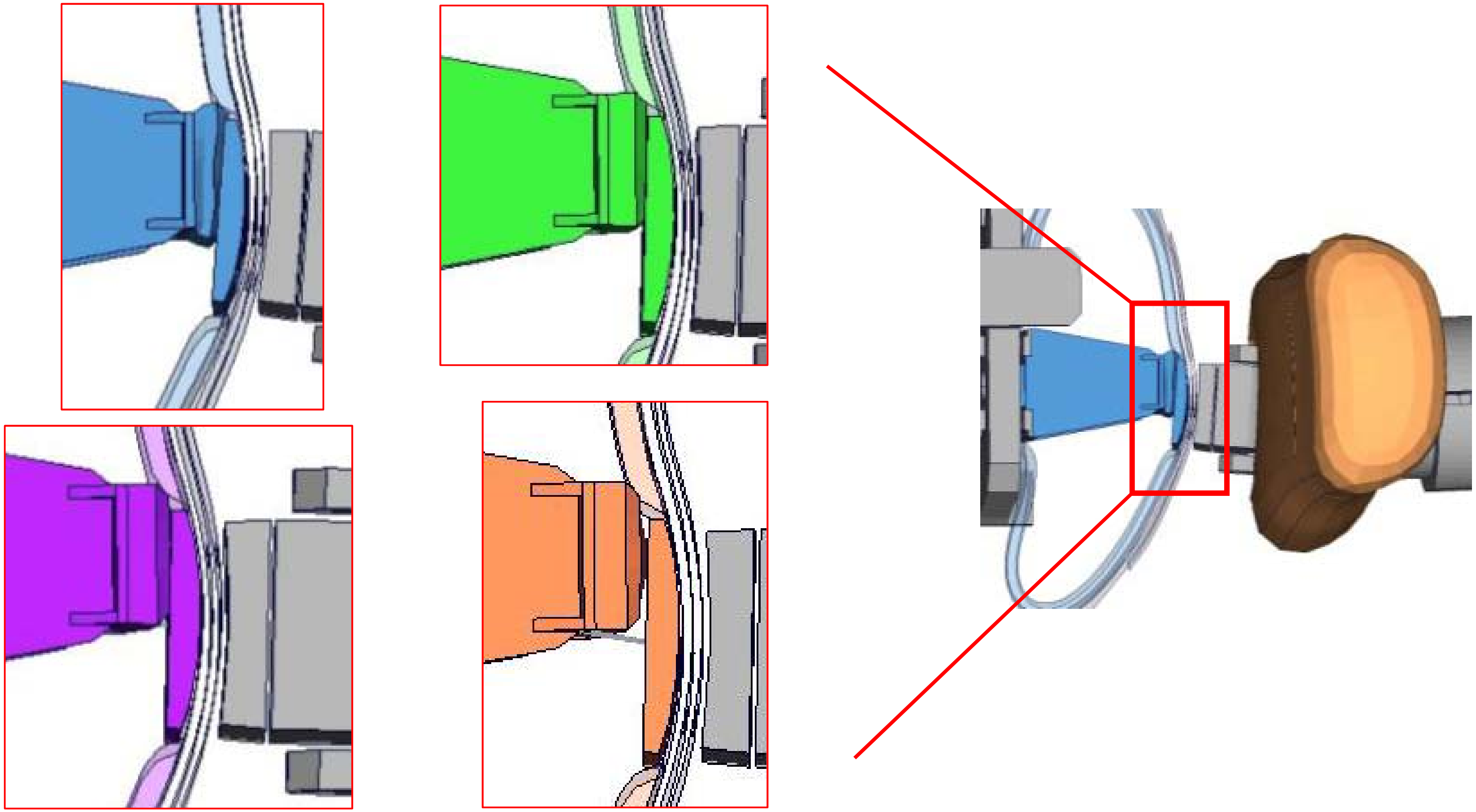
PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA
SHOULDER STOP: PDB PENDULUM TESTS

Reliable detection of the bottoming out at a defined shoulder rib deformation.



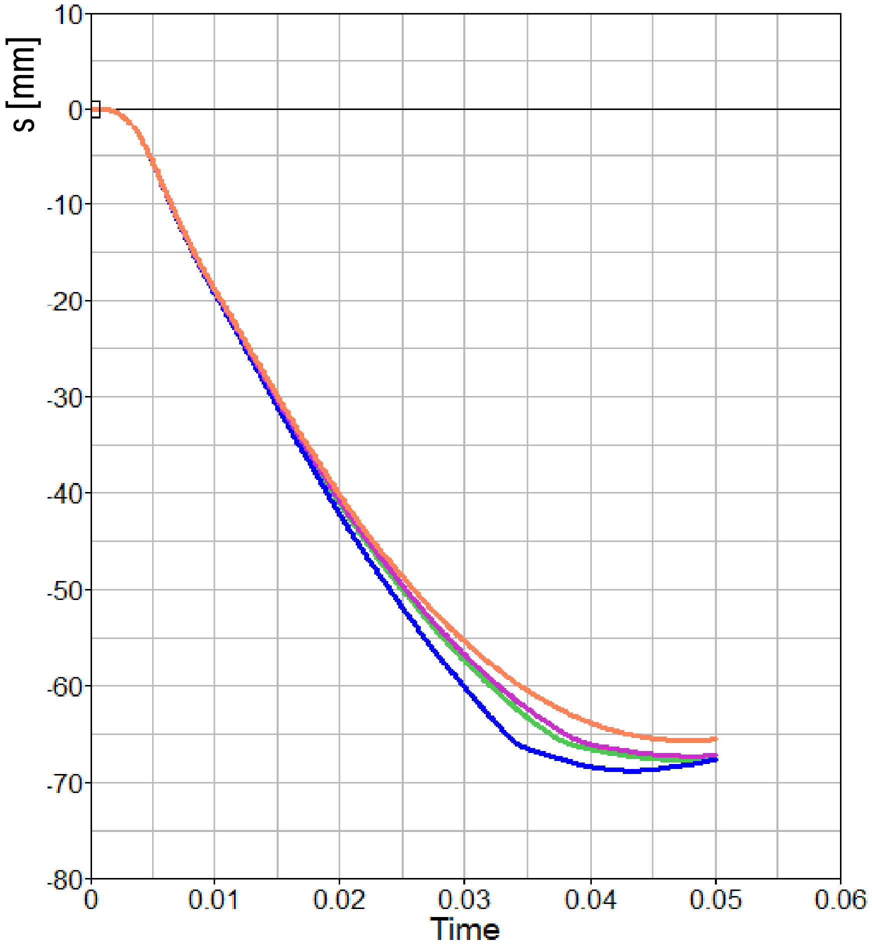
PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA
SHOULDER STOP: PDB PENDULUM TESTS

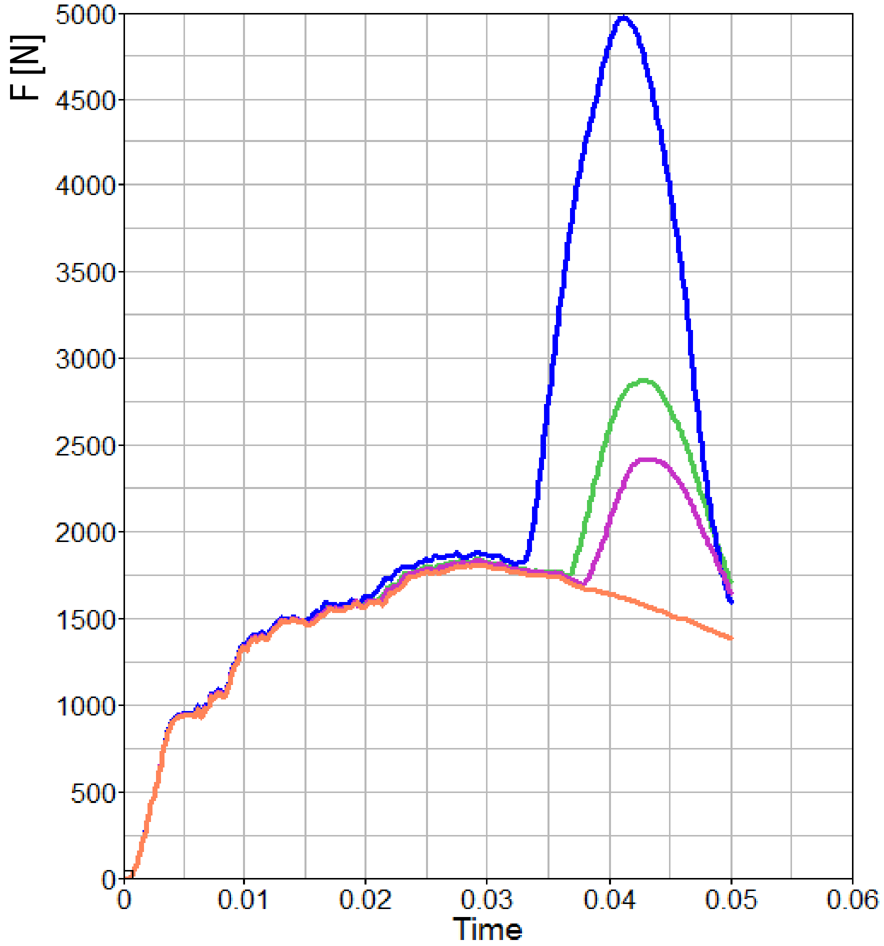
Pendulum mass variation in order to get variations in shoulder rib deformations.



PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA SHOULDER STOP: PDB PENDULUM TESTS

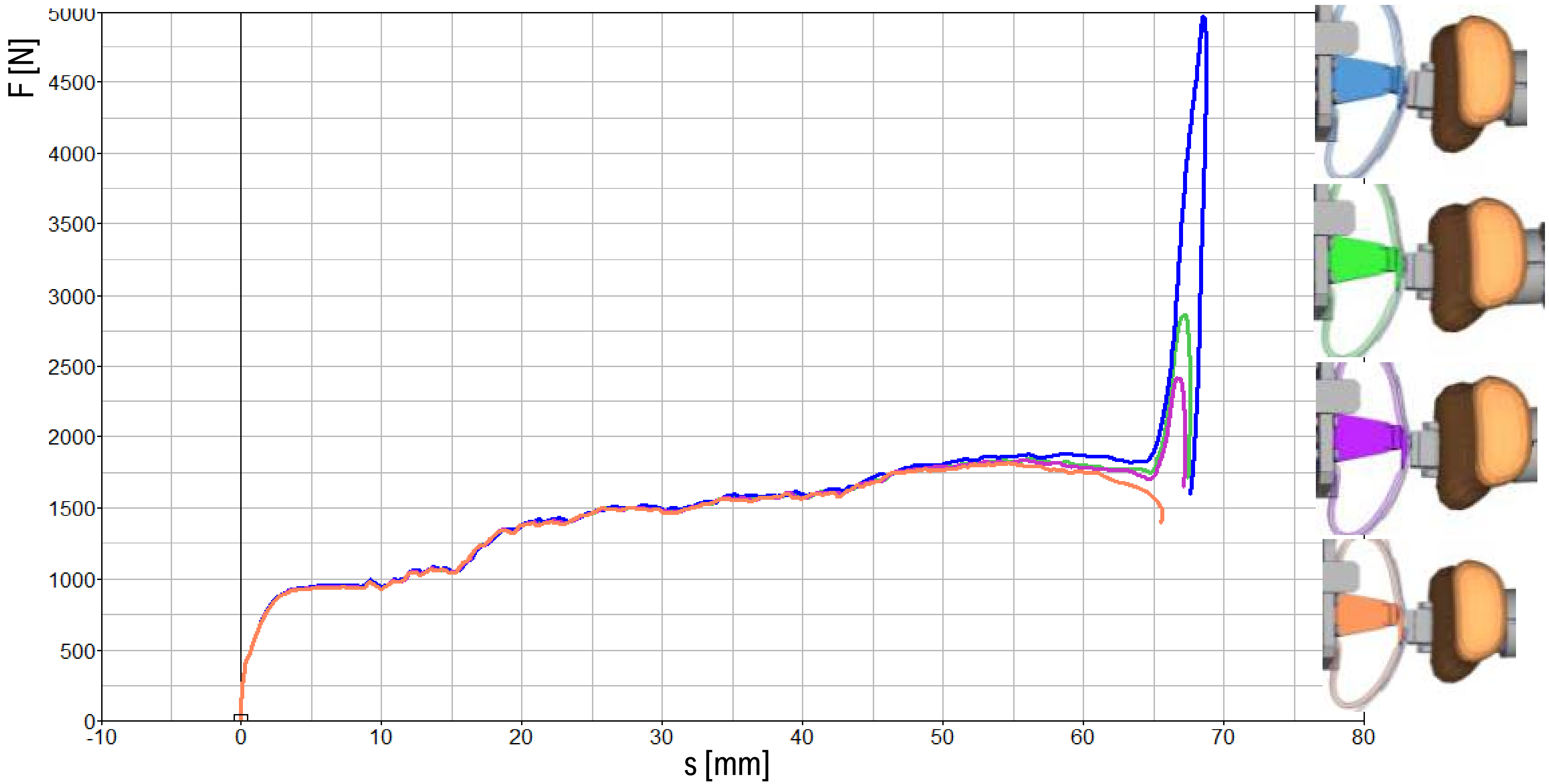
Pendulum mass variation in order to get variations in shoulder rib deformations.





PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA
SHOULDER STOP: PDB PENDULUM TESTS

Pendulum mass variation in order to get variations in shoulder rib deformations.

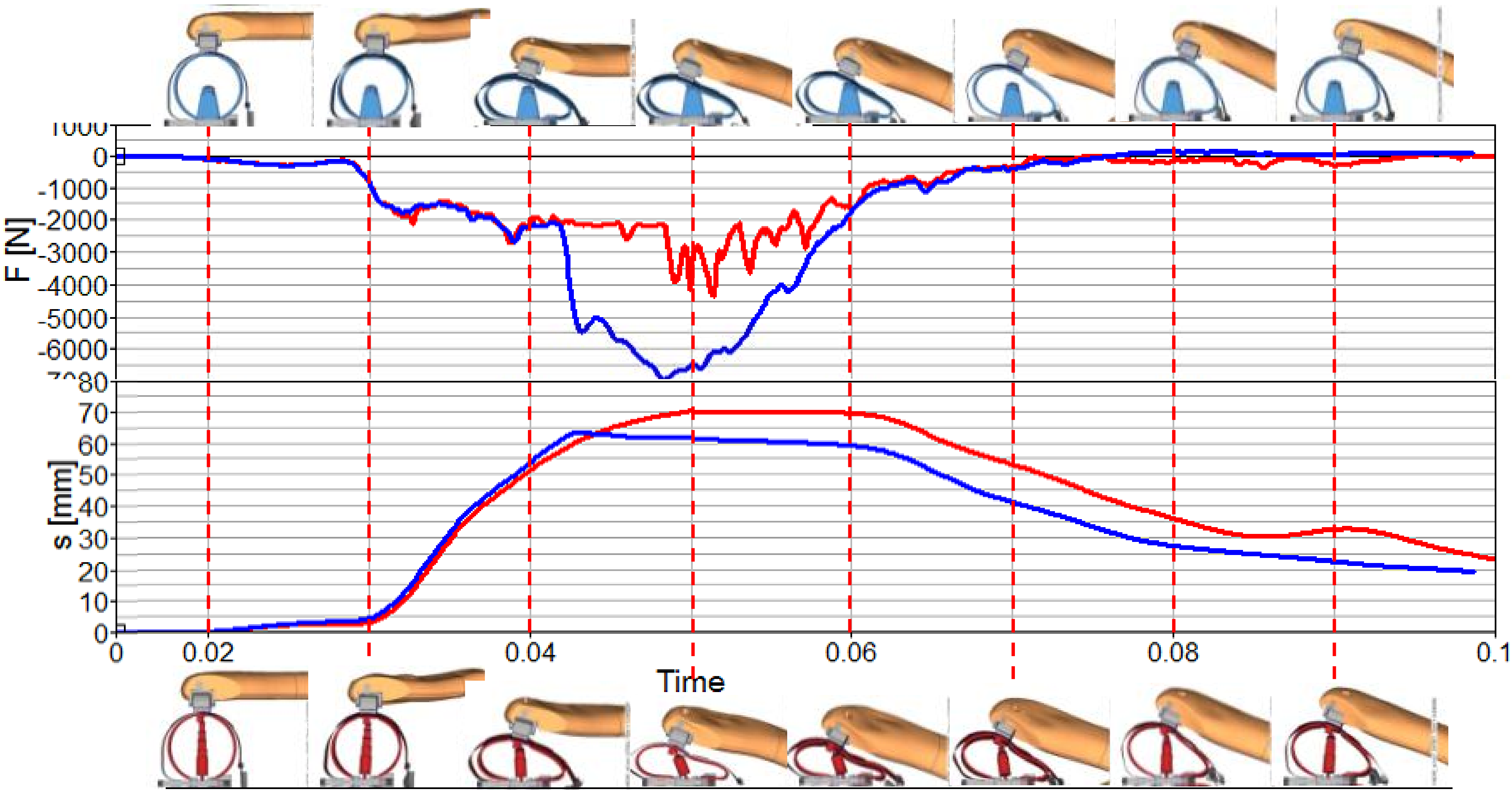


PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA SHOULDER STOP: FULL SCALE VEHICLE SIMULATION

Results of vehicle simulation with/without the new shoulder stop are compared to have a first feasibility check in real loading conditions and look for any effects on other dummy measurements.

30ms 40ms 50ms 60ms 70ms 80ms

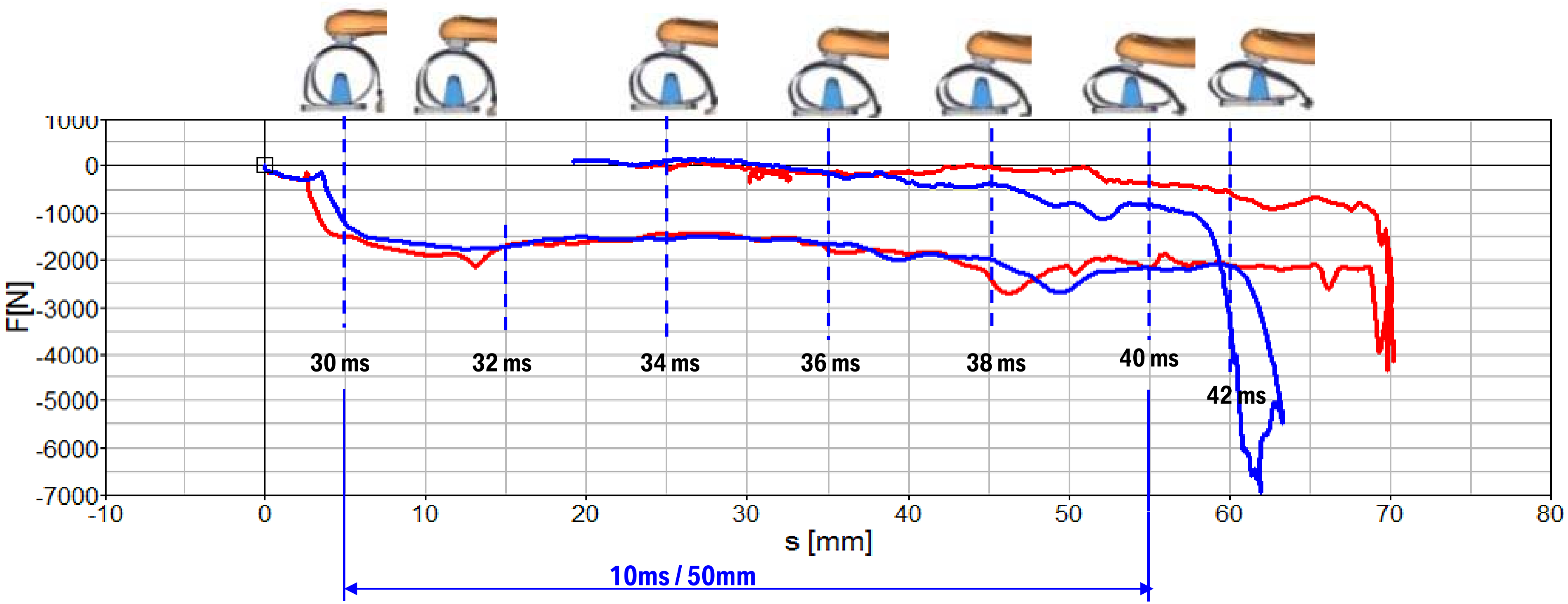
PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA SHOULDER STOP: FULL SCALE VEHICLE SIMULATION



PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA SHOULDER STOP: FULL SCALE VEHICLE SIMULATION

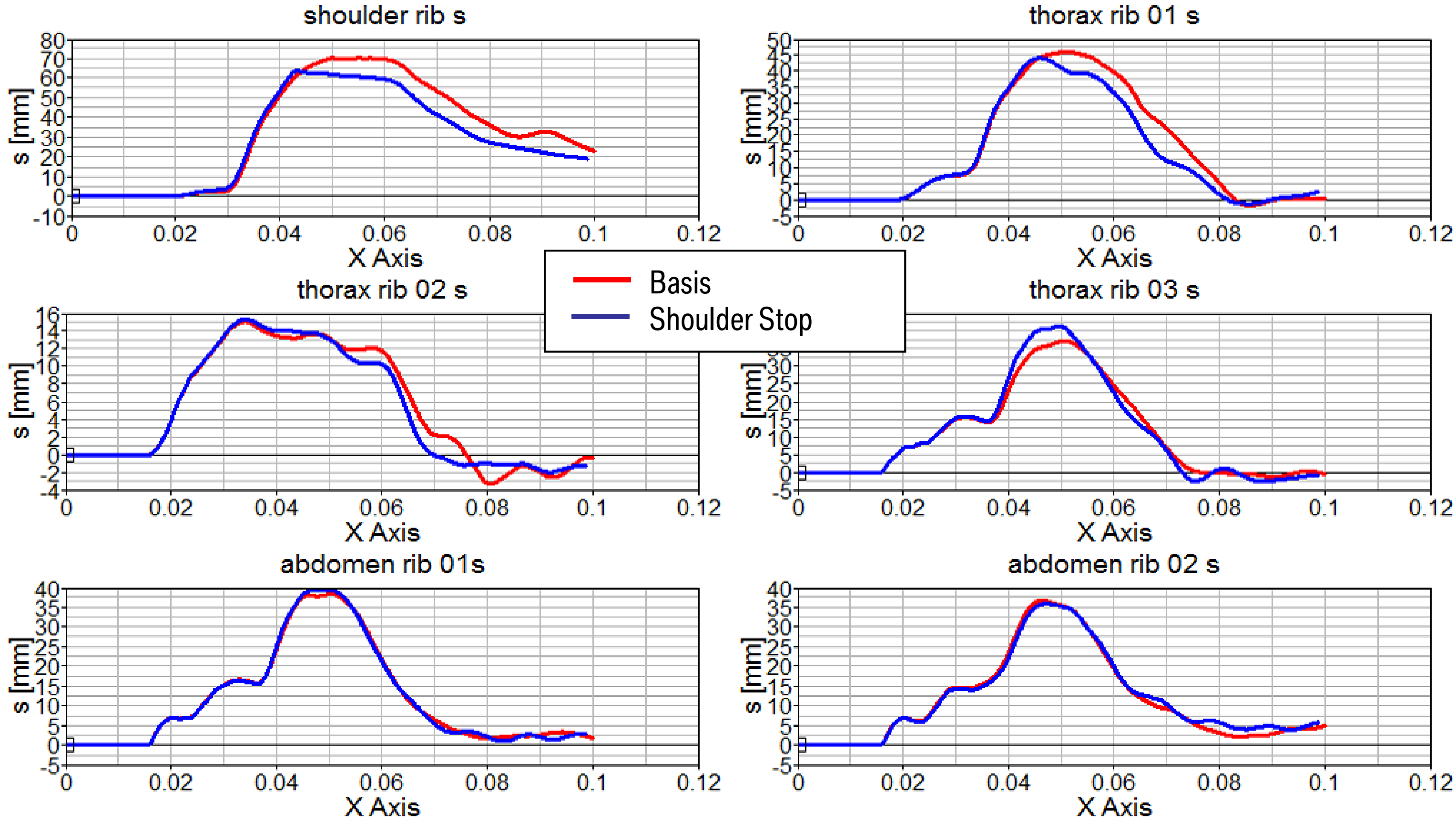
A reliable detection of the bottoming out can be done within the biofidelic ranges of shoulder displacement.

Additionally, this design will "solve" the issue overloading the shoulder in development tests leading to broken IR-TRACC systems.



PROPOSAL FOR SHOULDER ASSESSMENT CRITERIA SHOULDER STOP: FULL SCALE VEHICLE SIMULATION

The influence of the new shoulder stop on the other rib measurements is negligible.



THANK YOU!
QUESTIONS?