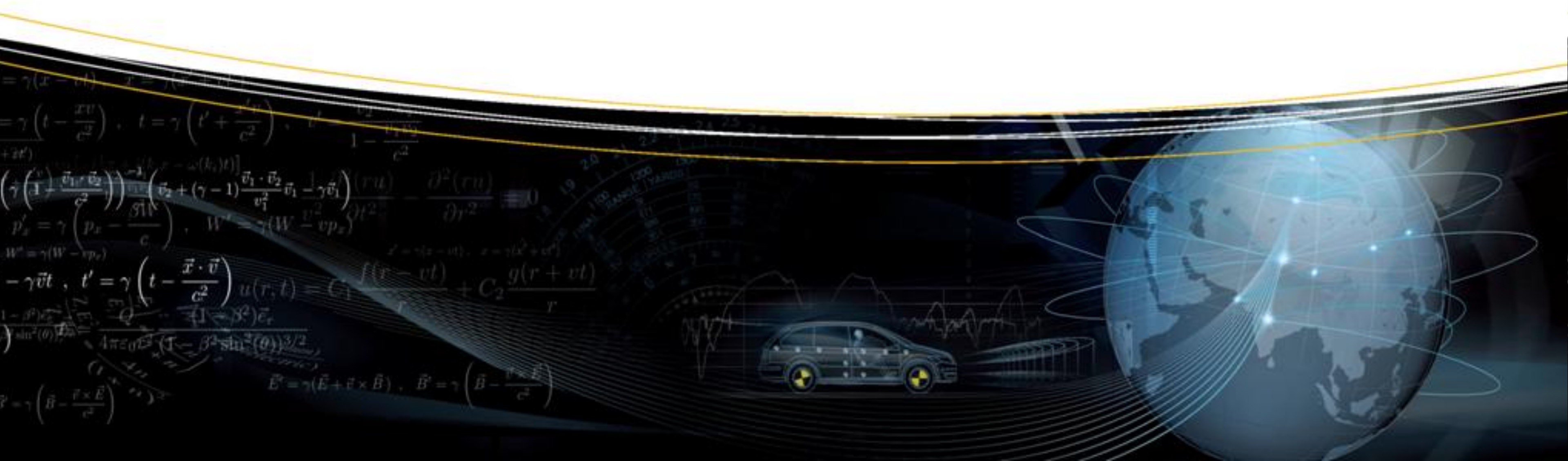
Beyond Safe
Bringing physics into models

TNO innovation for life

Effect of seating height in side impact

gtr Pole Side Impact, Washington 2012, 20-21 september
commissioned and presented by NL - MOT - RDW



Step 1: Comparison WorldSID - Human

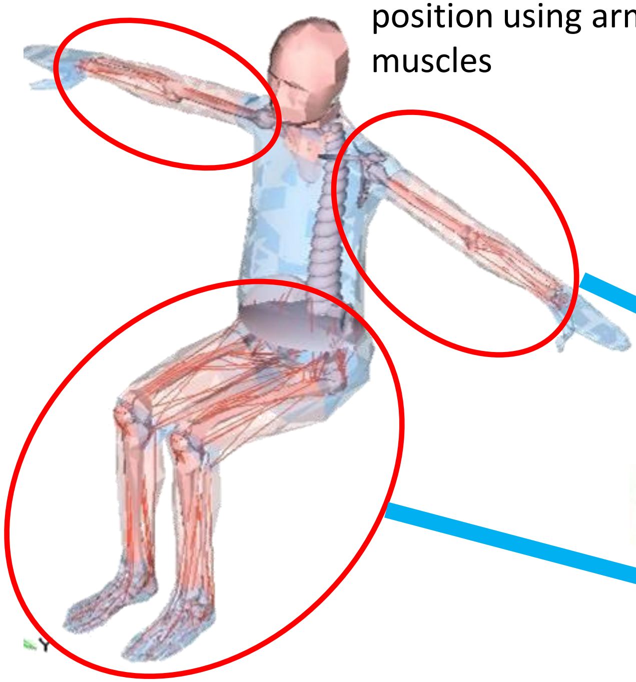
Objective:

- Compare the response of the WorldSID to human responses

- By means of simulations of Wayne State University (WSU) tests at 6.7 and 9.1 m/s with MADYMO (facet) WorldSID model and MADYMO (facet) Active Human Model (used in passive state, since it are PMHS tests)

Development of Active Human Model

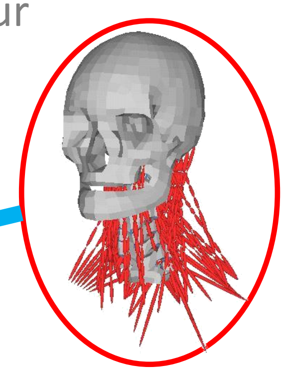
Second step: Predict passive as well as active behaviour



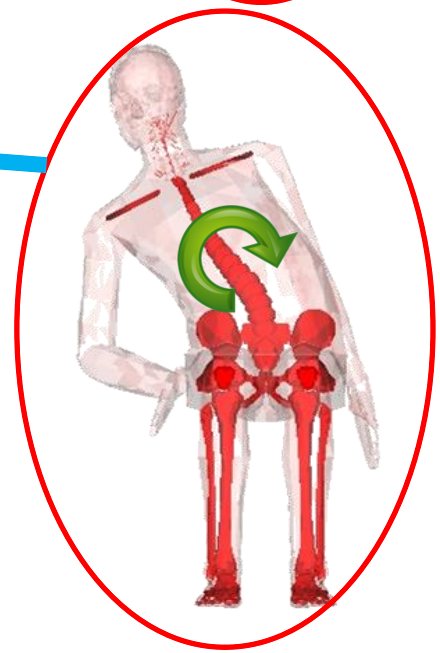
- Controlled elbow position using arm muscles

- Controlled hip position using leg muscles

Facet pedestrian human model MADYMO v7.4



- Controlled head position using neck muscles + balanced muscle recruitment (based on Nemirovsky & van Rooij 2010)



- Controlled spine position using actuators (based on Cappon et al. 2007)

Capabilities of Active Human Model

- Newly released MADYMO 50%ile male Active Human Model
  - Simulates pedestrian as well as occupant impacts
  - Simulates only passive or passive + active (=live) behaviour
  - Simulates stabilising behaviour in seating position automatically

- ‘Active’ via the usage of controlled activated:
  - Muscles in neck / arms / legs to stabilise head / elbows / hips
  - Actuators on vertebral joints to stabilise spine
  - For neck muscles co-contraction can be defined (= the simultaneous tension of all muscles without giving any resultant torques, in reality co-contraction is always there in some extent)

- AHM can be set to 2 different states:
  - ‘Live’: the human is stabilising to its initial position or user defined position
  - ‘Passive’: no stabilisation takes place and the human behaves as a post mortem human subject

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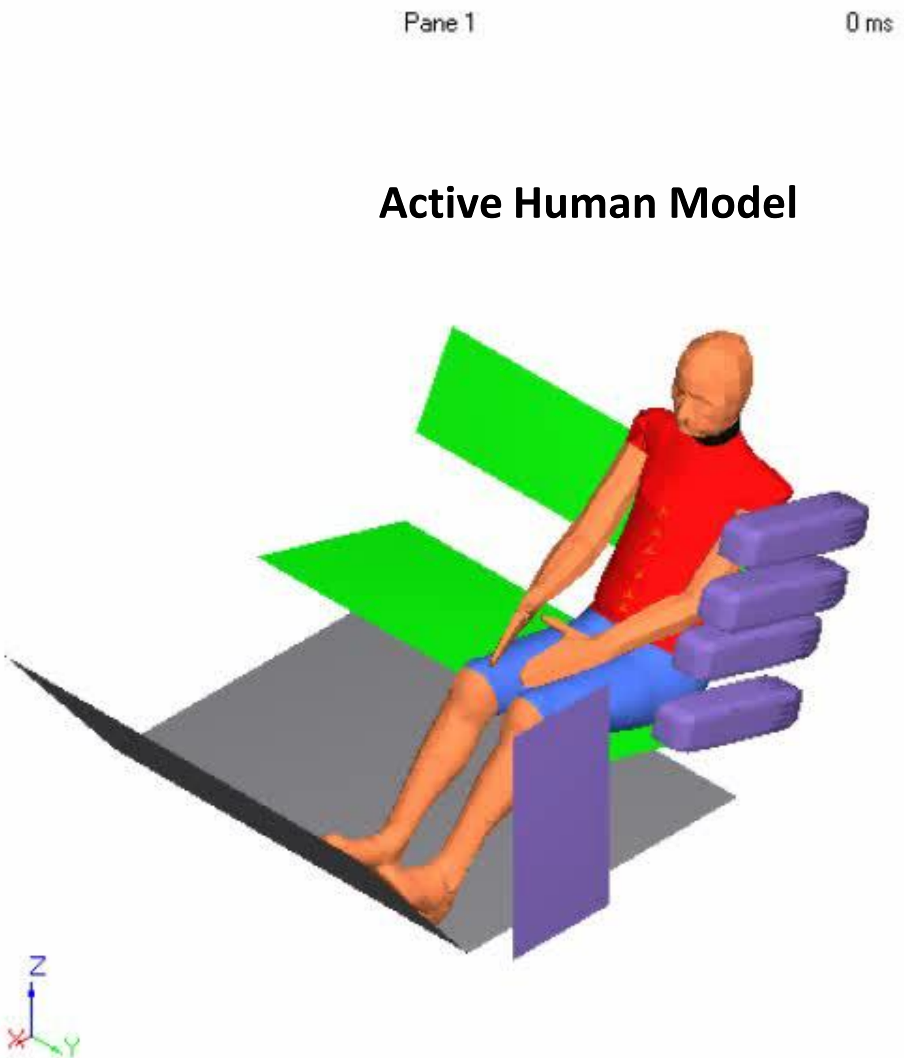
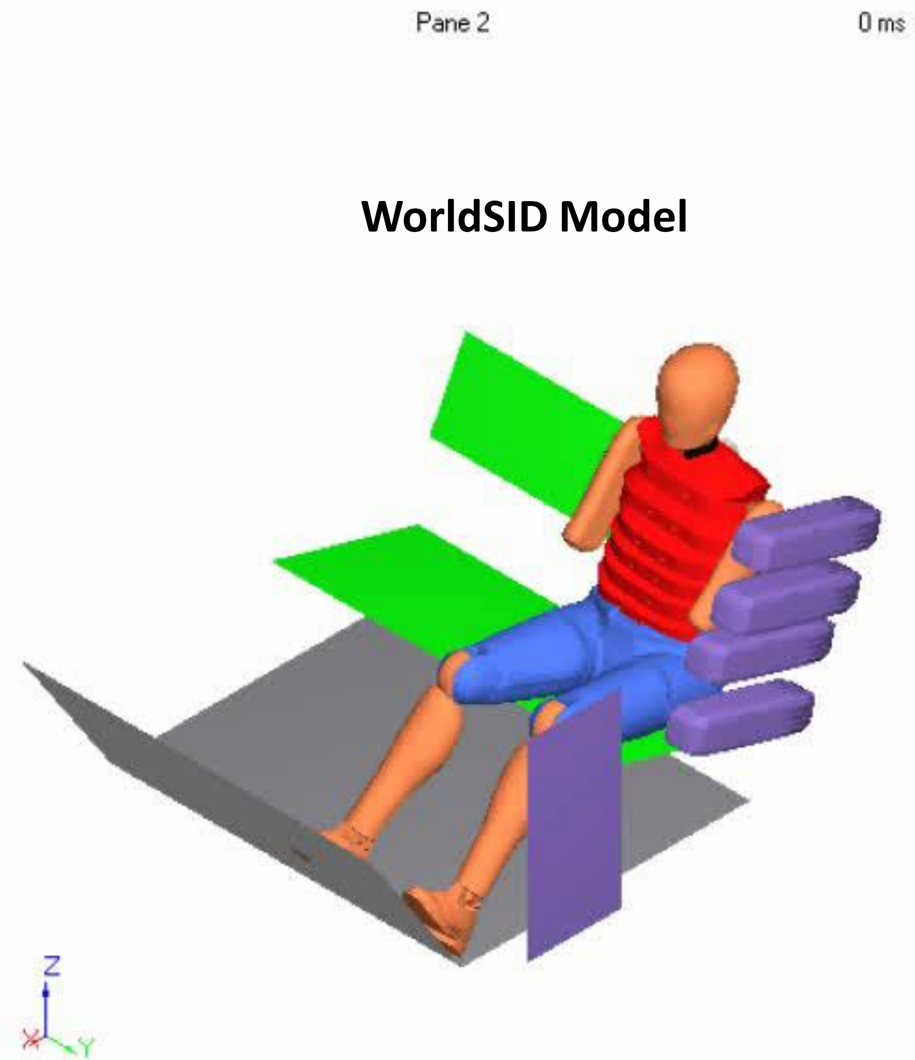
WSU test : v = 6.7 m/s





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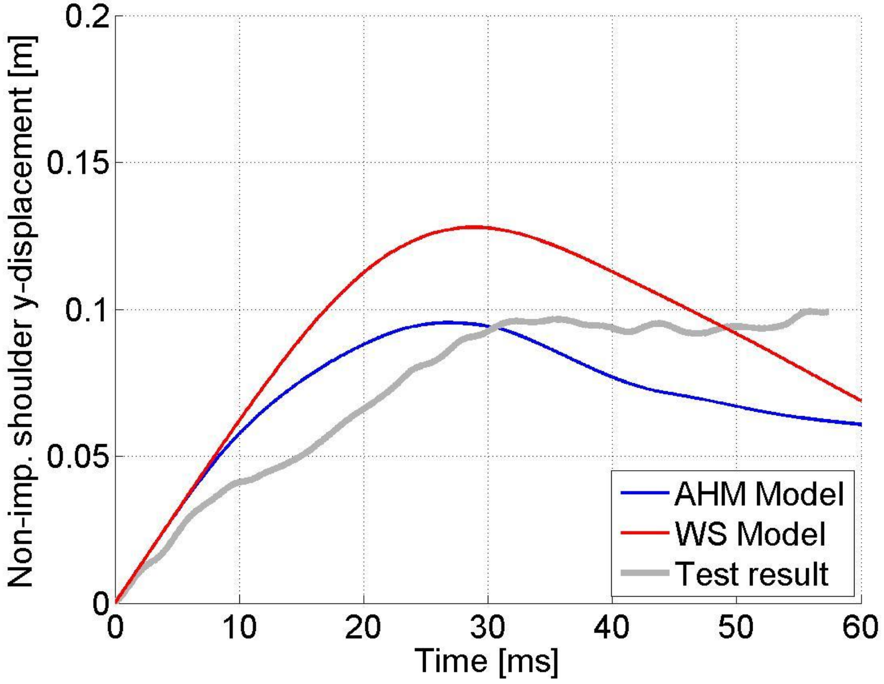
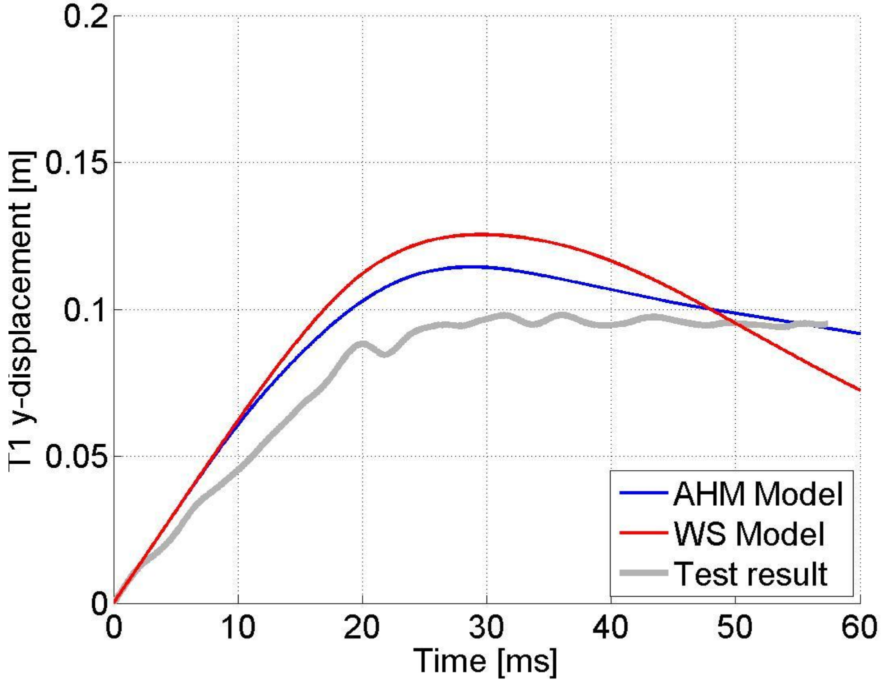
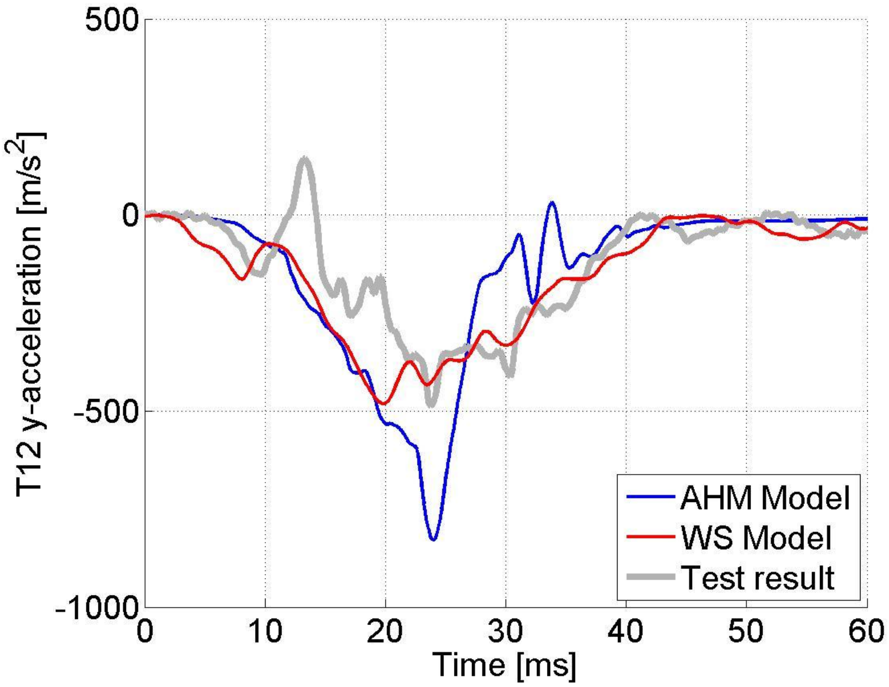
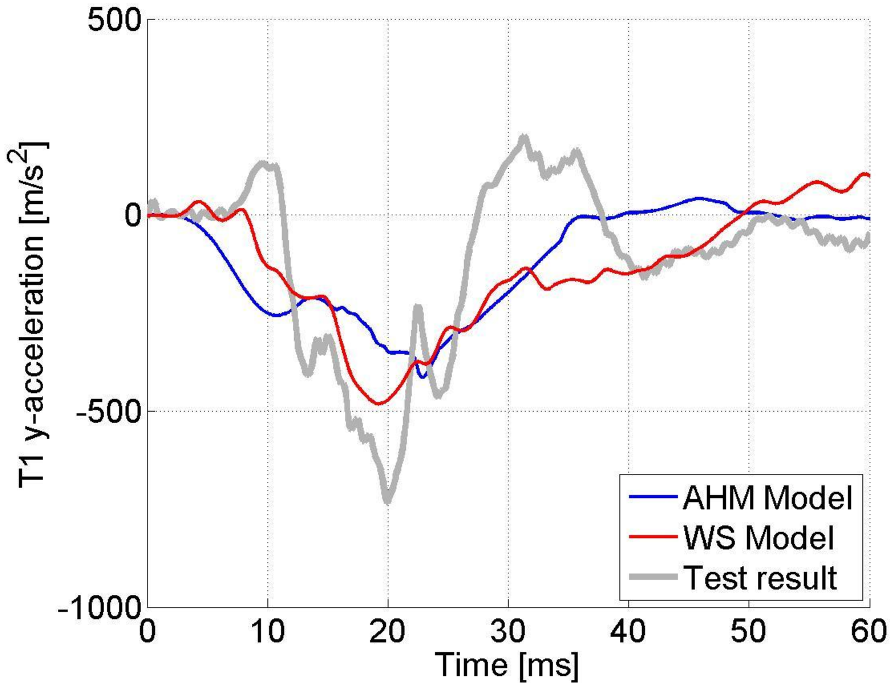
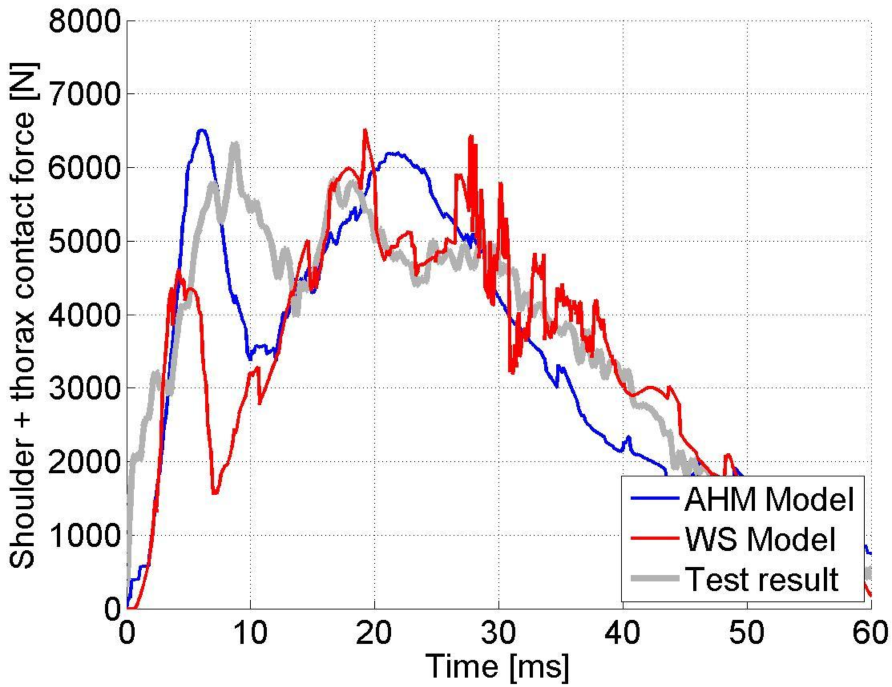
Simulation results versus Test results





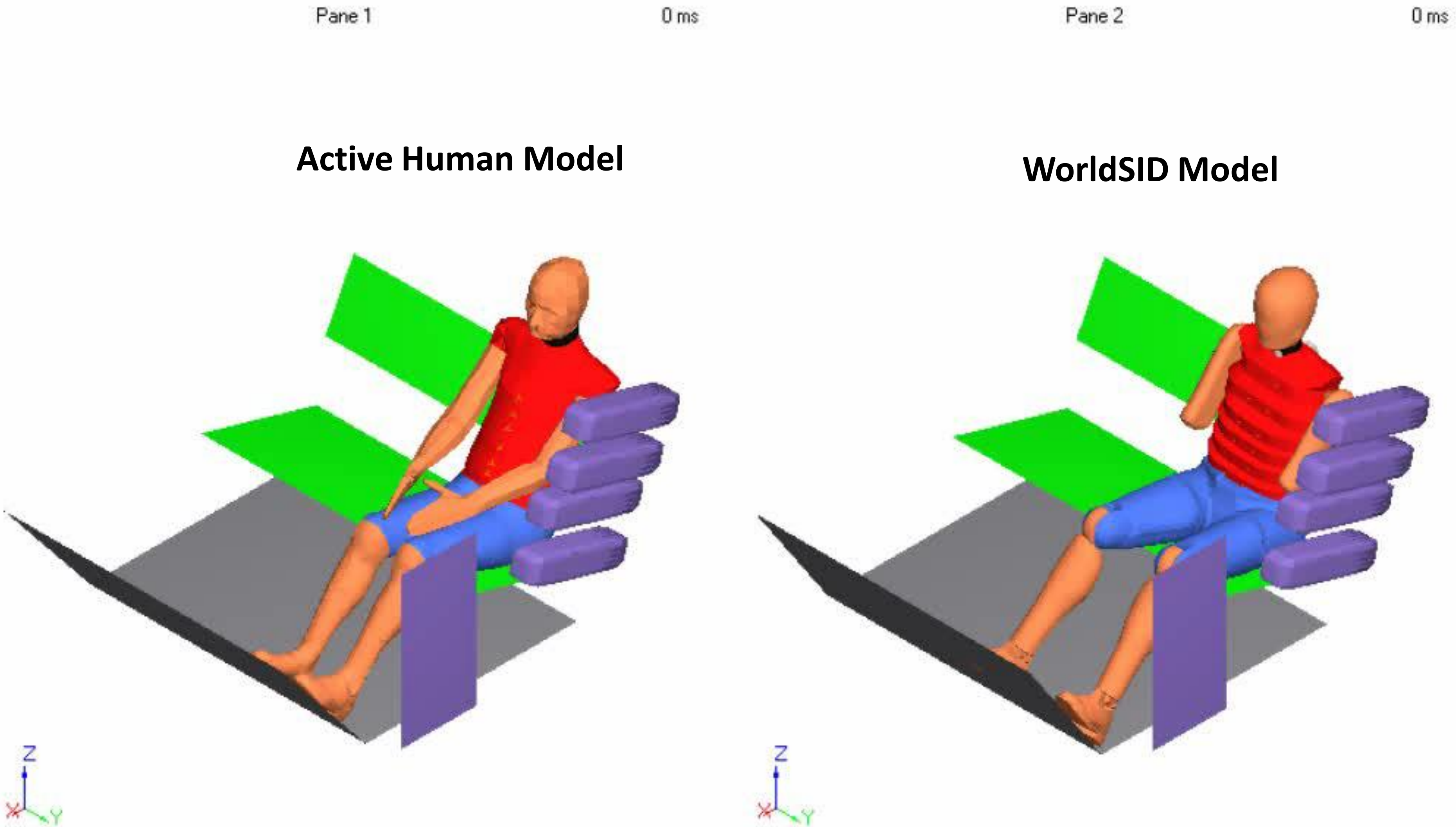

T12 y-acceleration [m/s2]
500
0
-500
-1000
0
10
20
30
40
50
60
Time [ms]
AHM Model
WS Model
Test result


T1 y-acceleration [m/s2]
500
0
-500
-1000
0
10
20
30
40
50
60
Time [ms]
AHM Model
WS Model
Test result

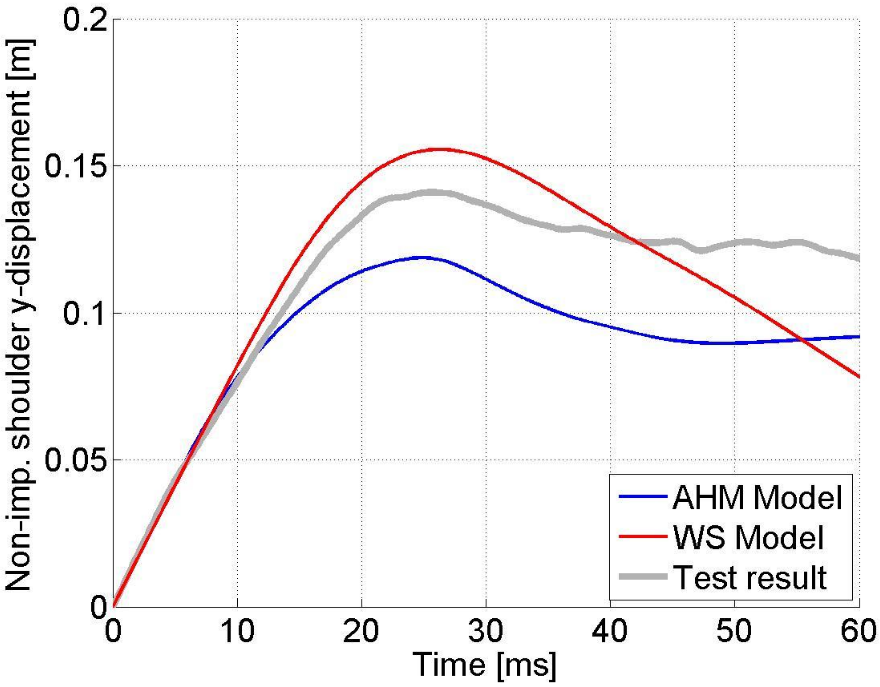


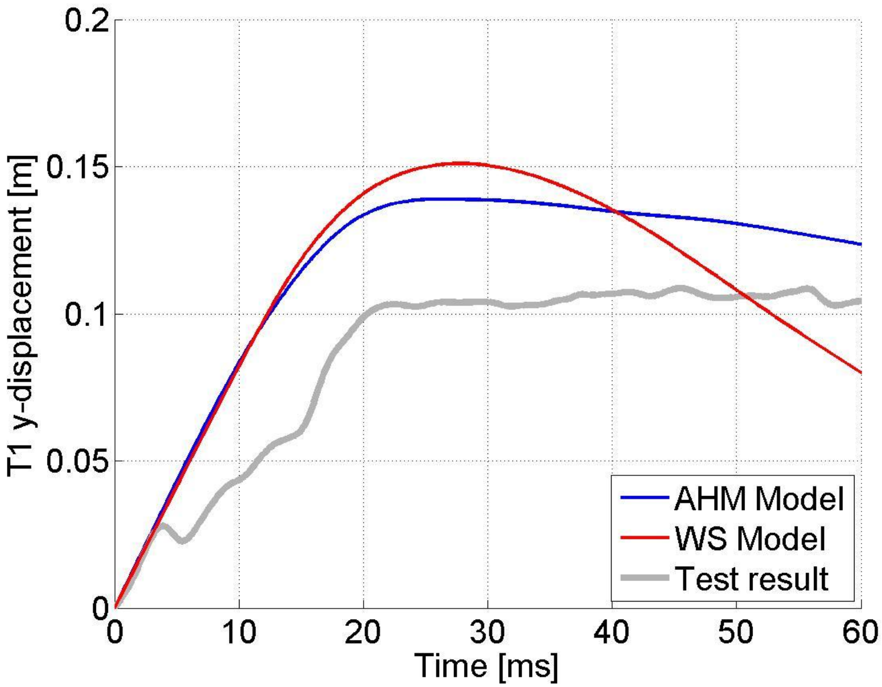
Contact forces are measured at the shoulder bar and the thorax bar of the sled separately.

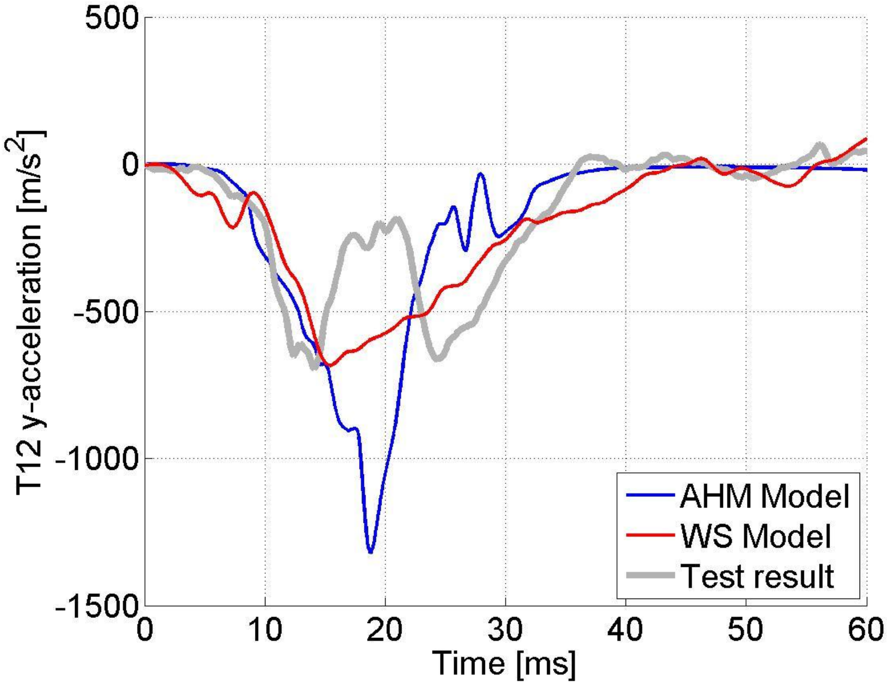
WSU test: v = 9.1 m/s

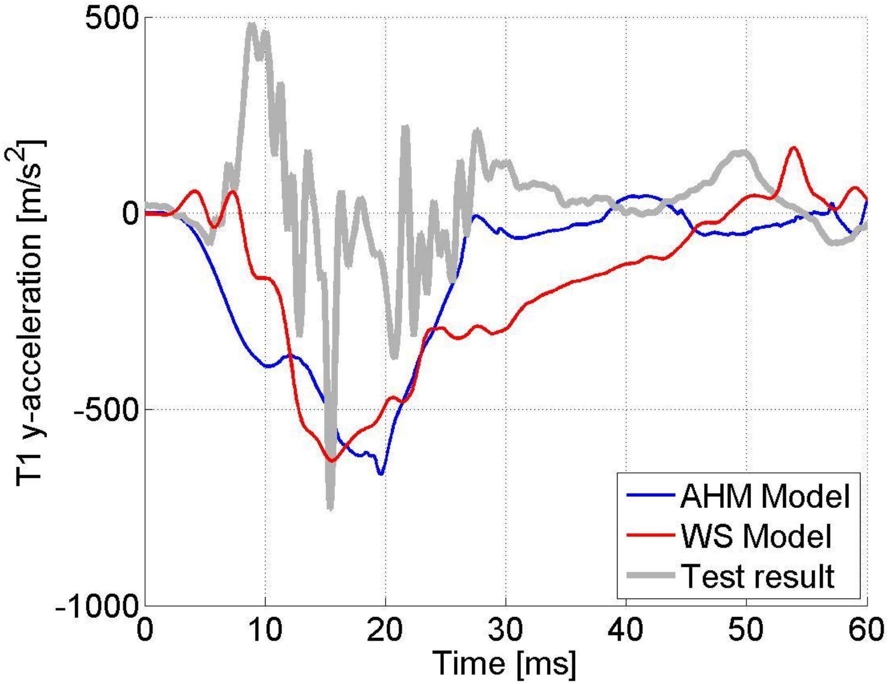


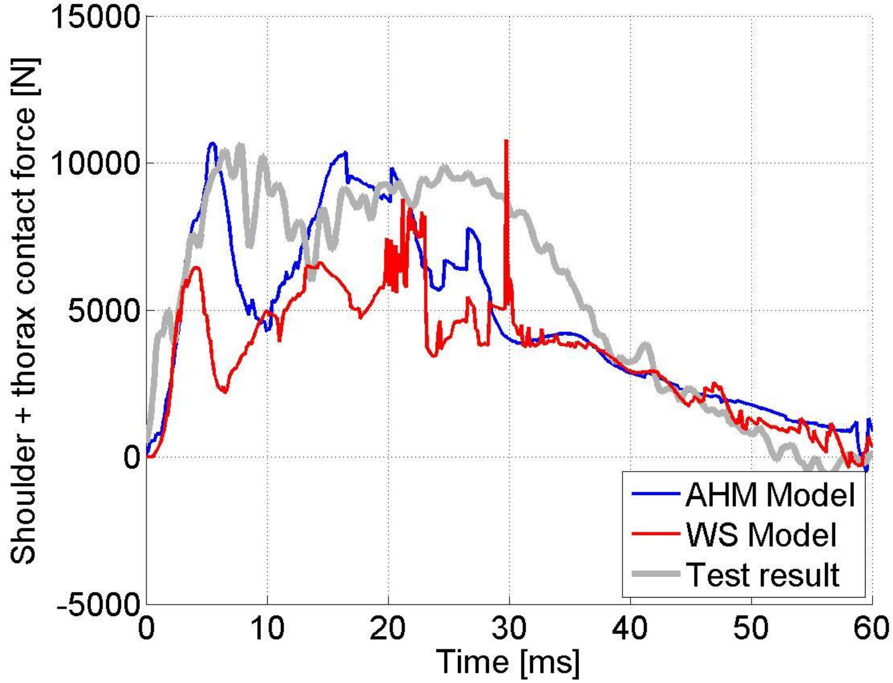
Simulation results versus Test results






T12 y-acceleration [m/s^2]
500
0
-500
-1000
-1500
0
10
20
30
40
50
60
Time [ms]
AHM Model
WS Model
Test result


T1 y-acceleration [m/s^2]
500
0
-500
-1000
0
10
20
30
40
50
60
Time [ms]
AHM Model
WS Model
Test result


15000
10000
5000
0
-5000
Shoulder + thorax contact force [N]
0
10
20
30
40
50
60
Time [ms]
AHM Model
WS Model
Test result

Step 2: Parameter variations in side impact

Objective:

- Investigate the effect of the seating height in comparison to other possible parameter variations

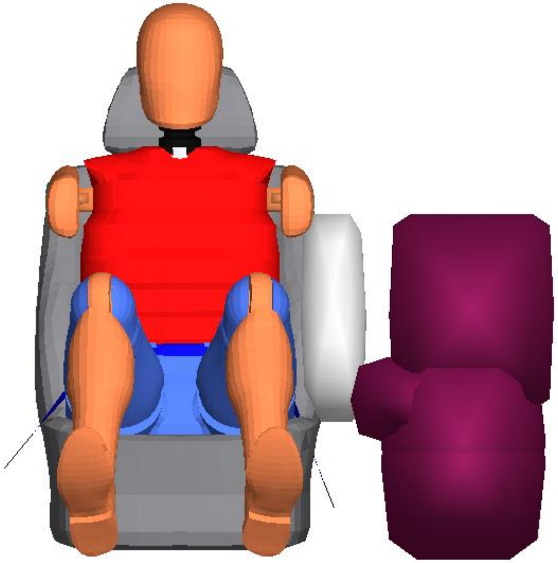
- By means of simulations with MADYMO (facet) WorldSID and MADYMO (facet) Active Human Model with parameter variations

- Simulation model is based on crash test with the AE-MDB side-impact barrier (APROSYS)

- F063401_Cam01.AVI
- F063401_Cam04.AVI

WorldSID Side Impact simulation

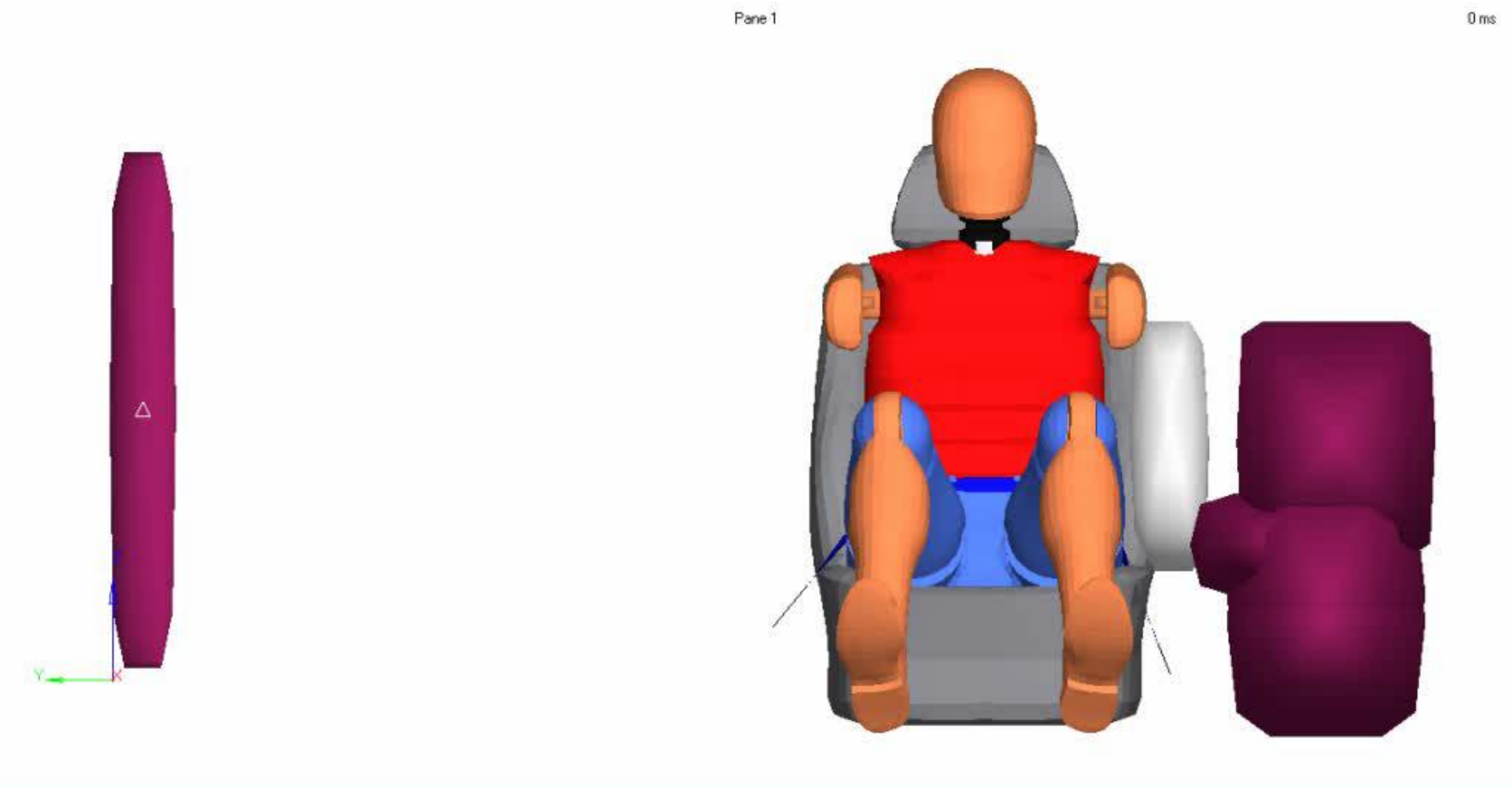
- WorldSID simulation model:
  - General facet seat model
  - FE lapbelt
  - Ellipsoid door model with arm rest
  - Ellipsoid airbag



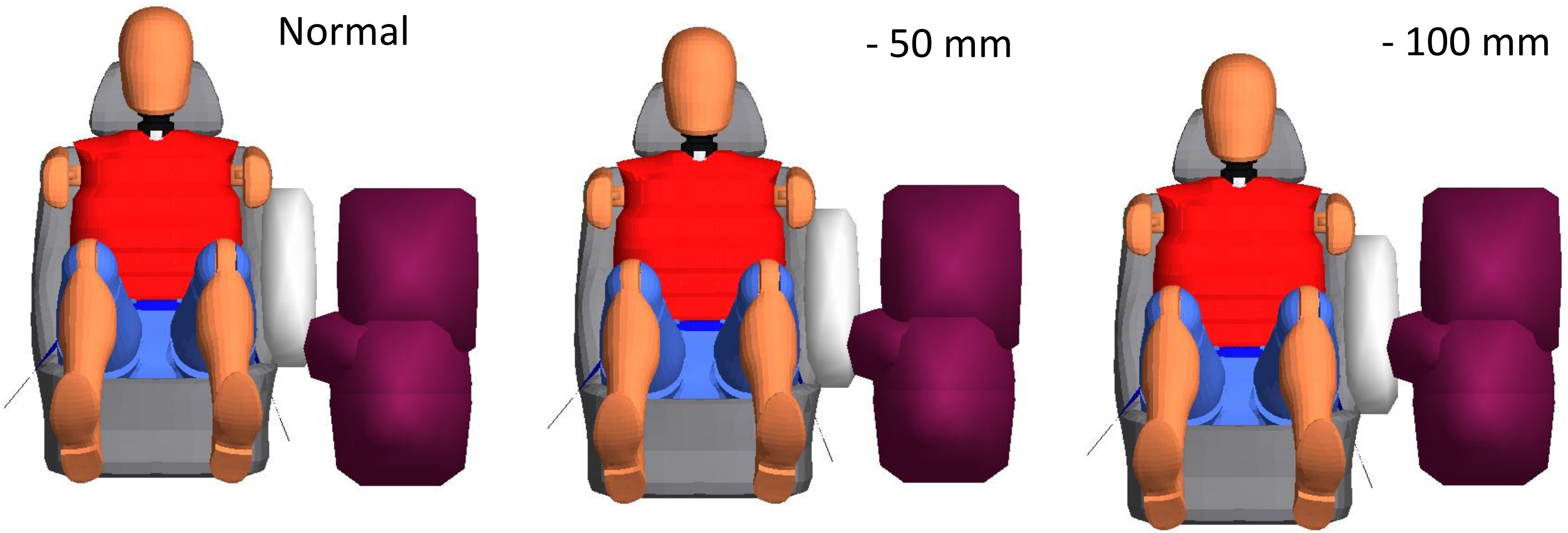
Output:

- Shoulder force
- Shoulder deflection
- Chest deflection (max of 3 ribs)
- VC (max of ribs and shoulder)

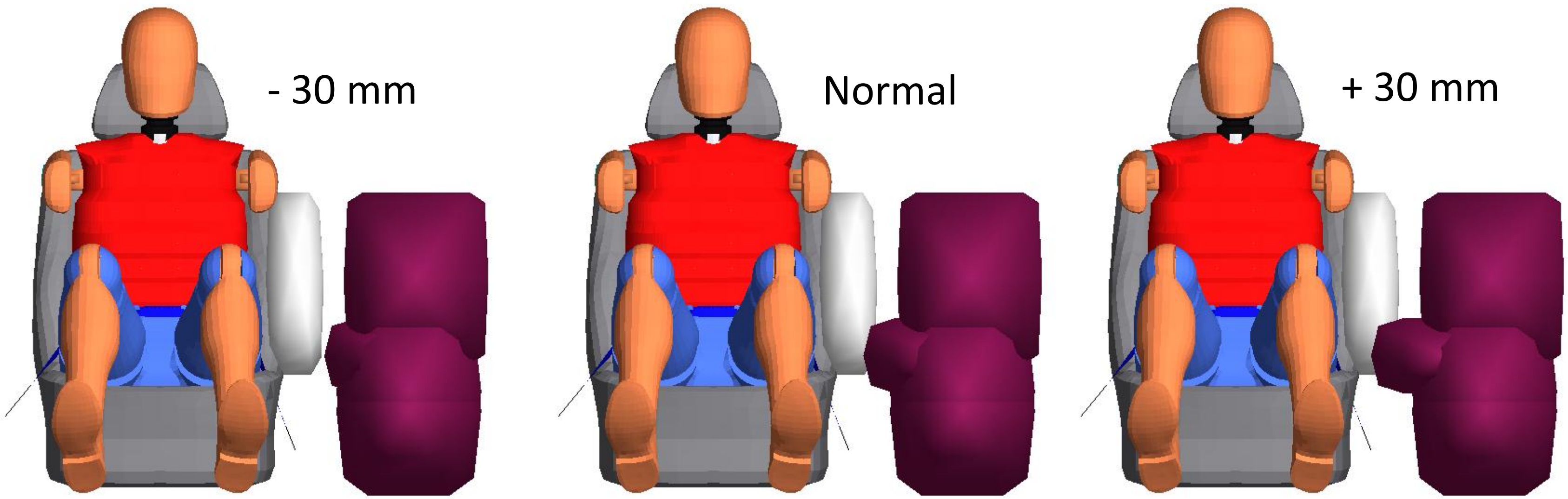
Standard simulation WorldSID



- Simulation model variations:
  - Seat height



- Simulation model variations:
  - Lateral arm rest position



- Simulation model variations:
  - Door deformation

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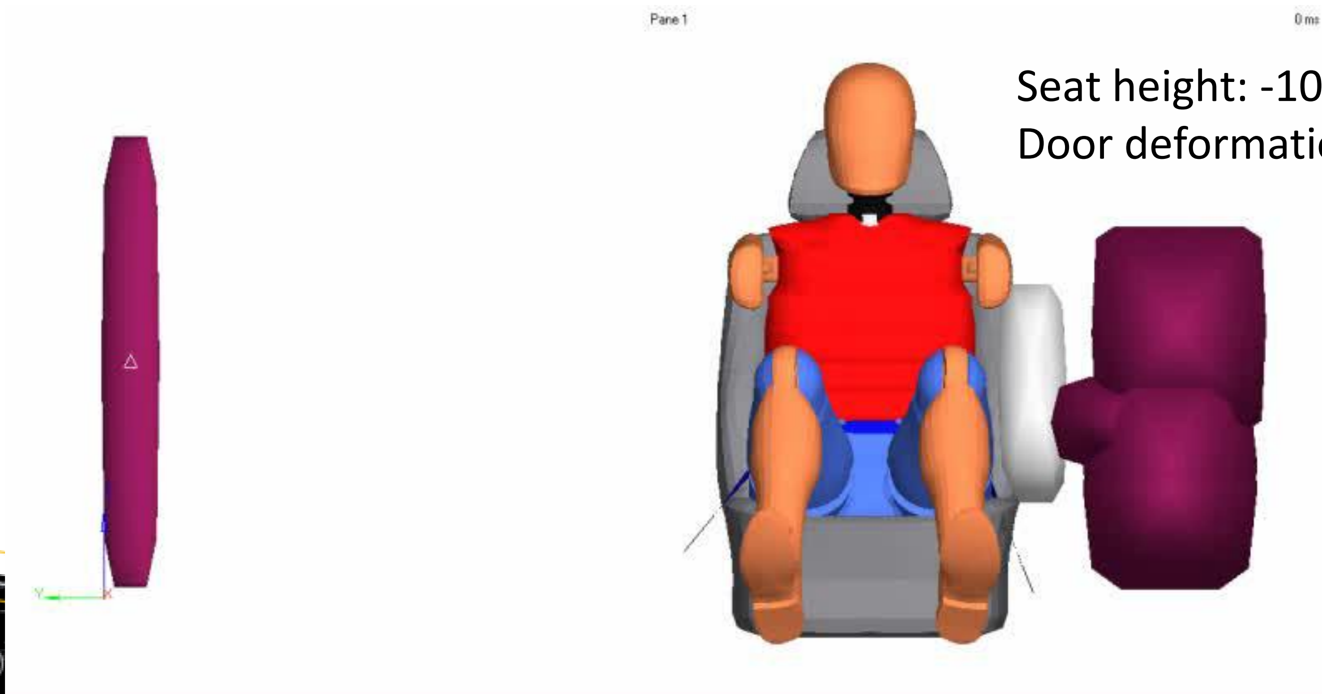
WorldSID results

Simulation			Maximum injury values			
Seat height	Arm rest displacement	Door deformation	Shoulder Rib Deflection [mm]	Chest Deflection [mm]	Shoulder Force [N]	VC [m/s]
-	+30 mm	-	21.0	29.3	1548.2	0.5
-	-30 mm	-	32.8	36.5	2025.3	0.8
-	-	up +10%	33.0	47.9	2021.6	1.3
-	-	down +10%	20.6	22.2	1557.4	0.2
-	-	-	28.1	33.3	1855.1	0.6
-50 mm	+30 mm	-	57.0	25.1	3232.9	1.2
-50 mm	-30 mm	-	70.3	28.8	3313.3	1.5
-50 mm	-	up +10%	77.2	38.4	3546.9	1.8
-50 mm	-	down +10%	52.0	28.0	3037.1	1.0
-50 mm	-	-	64.9	28.1	3272.2	1.4
-100 mm	+30 mm	-	63.5	64.7	3294.7	1.6
-100 mm	-30 mm	-	77.2	38.5	3333.6	1.6
-100 mm	-	up +10%	85.7	48.9	4086.8	1.9
-100 mm	-	down +10%	57.4	58.6	3103.8	1.5
-100 mm	-	-	71.9	52.3	3338.8	1.4
Average			54.2	38.7	2837.8	1.2
SD			21.8	13.0	803.8	0.5
Average+SD			76.0	51.7	3641.6	1.7

Preliminary conclusions WorldSID simulations

- Seat height -100 mm
  - Most severe shoulder deflection and force → full shoulder impact
  - Most severe chest deflection → armrest impacts close to chest
- Seat height normal
  - Less severe shoulder deflection and shoulder force → shoulder above door
- Door deformation up +10%
  - Higher shoulder force → more severe impact of shoulder



Seat height: -100 mm
Door deformation: up +10%

Active Human Model Side Impact simulation

- Active Human Model simulation model:
  - General facet seat model
  - FE lapbelt
  - Ellipsoid door model with arm rest
  - Ellipsoid airbag

Output (equal to WorldSID):

- Acronium force
- Acronium deflection
- Chest deflection (max of 3 ribs)
- VC (max of ribs and shoulder)

Standard simulation Active Human Model

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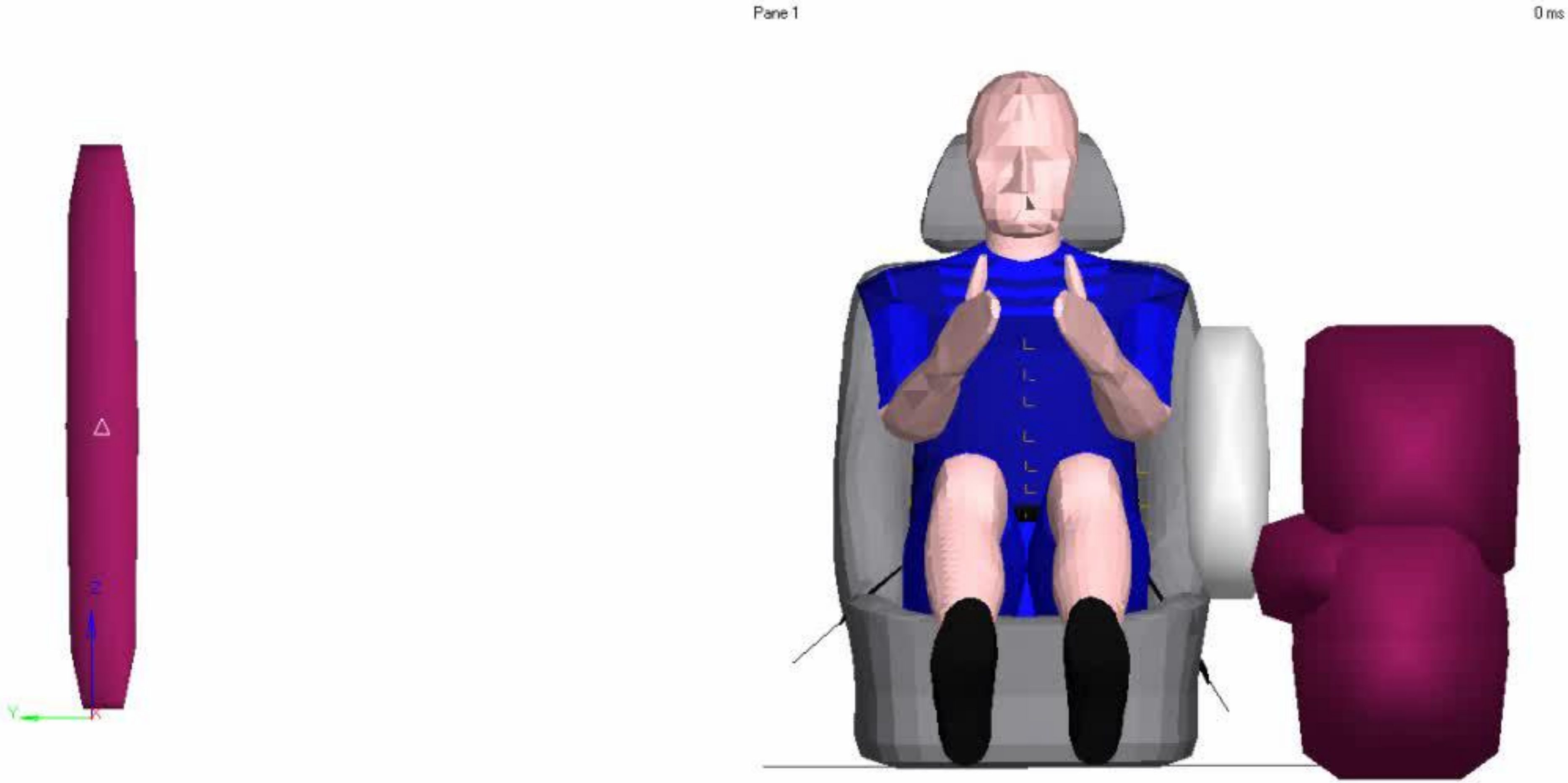

Results Active Human Model

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Simulation			Maximum injury values			
Seat height	Arm rest displacement	Door deformation	Shoulder Rib Deflection [mm]	Chest Deflection [mm]	Shoulder Force [N]	VC [m/s]
-	+30 mm	-	53.5	63.2	1136.8	0.9
-	-30 mm	-	46.1	64.5	974.4	0.9
-	-	up +10%	51.3	68.1	1167.6	1.4
-	-	down +10%	48.1	61.0	1116.6	0.8
-	-	-	47.0	65.3	1033.6	0.9
-50 mm	+30 mm	-	80.2	53.7	2072.5	0.9
-50 mm	-30 mm	-	83.4	53.6	2095.8	0.6
-50 mm	-	up +10%	90.2	57.1	2262.2	1.2
-50 mm	-	down +10%	72.6	53.1	1842.6	0.7
-50 mm	-	-	83.3	57.6	2101.7	0.7
-100 mm	+30 mm	-	88.7	54.1	2194.9	0.8
-100 mm	-30 mm	-	101.6	50.5	2261.3	0.7
-100 mm	-	up +10%	107.6	53.6	2508.1	1.1
-100 mm	-	down +10%	85.2	53.7	1896.2	0.8
-100 mm	-	-	95.7	54.6	2279.4	0.8
Average			75.6	57.6	1796.2	0.9
SD			21.1	5.4	544.7	0.2
Average+SD			96.8	63.0	2340.9	1.1

Preliminary conclusions Active Human Model

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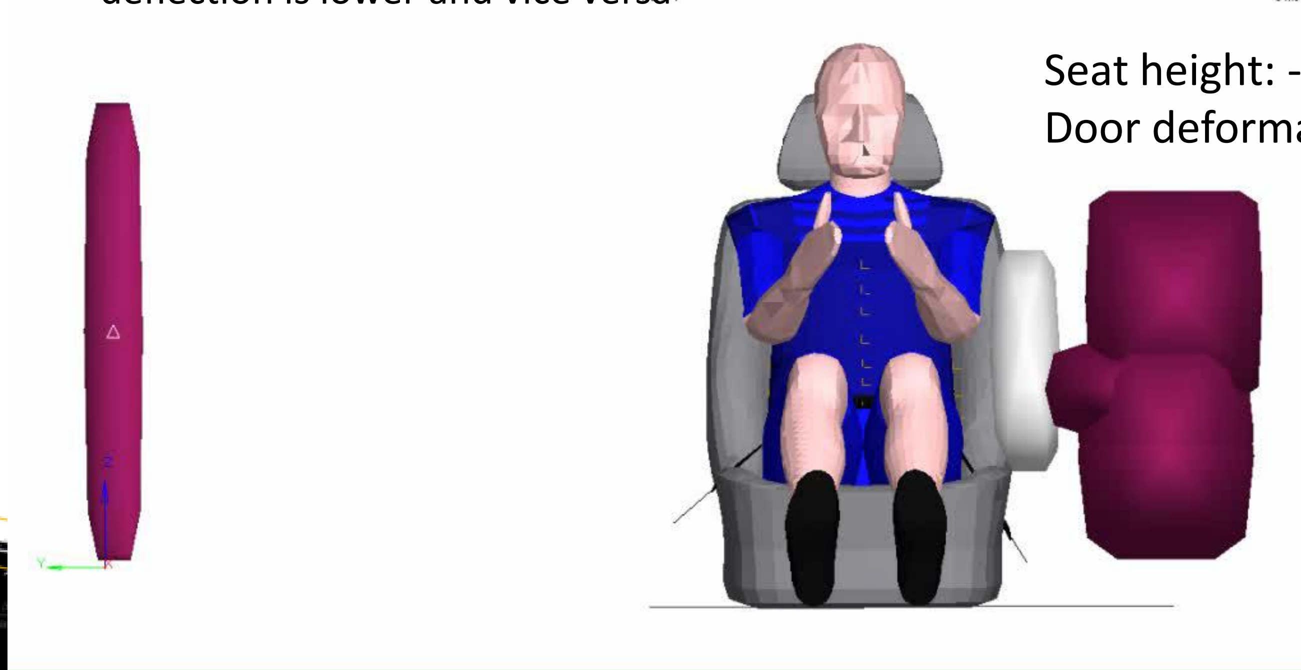
- Seat height -100 mm
  - Most severe shoulder deflection and shoulder force → Full shoulder impact
- Seat height normal
  - Most severe chest deflection → Upper part of door impacts chest
  - Low shoulder deflection and forces → Shoulder above door
- General
  - In case of seat height variations: when shoulder deflection is higher, chest deflection is lower and vice versa



Seat height: -100 mm
Door deformation: up +10%

Conclusions

- Comparison WorldSID and Active Human Model in WSU tests:
  - Generally the WorldSID and Active Human Model kinematics are comparable to each other as well as to the human subjects responses
- WorldSID side impact simulations:
  - Seat height has a significant effect on shoulder deflection and force
  - Door design influences chest deflection
- Active Human model simulations:
  - Seat height has a significant effect on shoulder deflection and force
  - Seat height variation:
    - Shoulder deflection higher → Chest deflection lower and vice versa
- Difference WorldSID versus Active Human model
  - Chest and shoulder deflection are generally higher for Active Human Model
  - Shoulder force is generally higher for WorldSID
  - Chest deflection shows more variation for WorldSID
    - WorldSID seems more sensitive for door design variation