

# Challenges associated with dummy kinematics and booster

GRSP IG, Jan 15, 2014, Brussels

Based on :

Comparison of the submarining behaviors of a 6 years old human model and a Q6 dummy in sled testing



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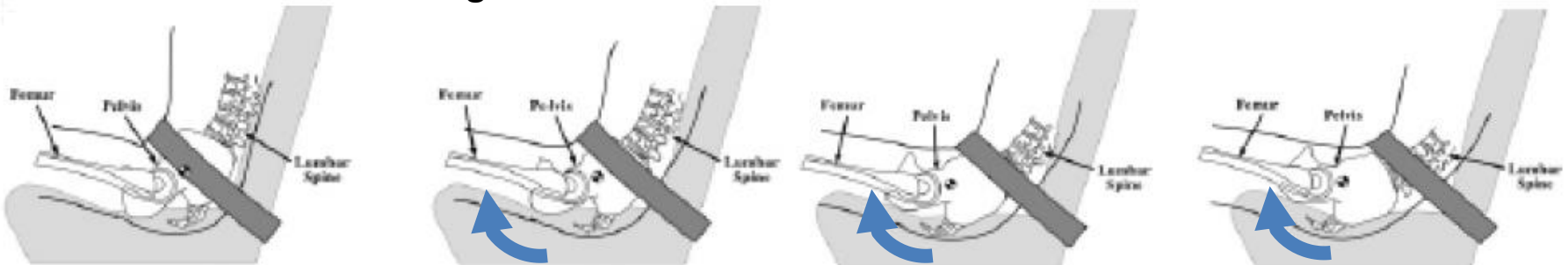
TU Berlin, Germany

Conf Protection of Children in Cars, Munich, Dec 5, 2013

# Introduction

- For older children (e.g. 5-9), the abdomen is among the most frequently injured body regions and risk is higher than for adult occupants
  - e.g. Lesire et al (2012); Javouhey et al (2006)
- Booster seats use reduce the risk...
  - e.g. Durbin et al (2003)
- Common loading mechanism: abdominal loading by lap belt – due to misuse/presubmarining/belt slippage/submarining
  - e.g. Arbogast et al (2007)

Illustration of submarining behavior



# Introduction

- Protection provided by CRS typically evaluated in dynamic testing with crash tests dummies
- For older children: Q6 and Q10 dummies are currently in use or considered (regulation, consumer testing)
- Biofidelity target defined by regional impacts conditions based on scaling (EEVC WG12 Report 2006)
- What about kinematics response and the belt interaction ?
  - Submarining not observed in accident reconstructions (reported in Beillas et al 2012) or sled tests...
  - Biofidelity target not defined explicitly. How to evaluate?



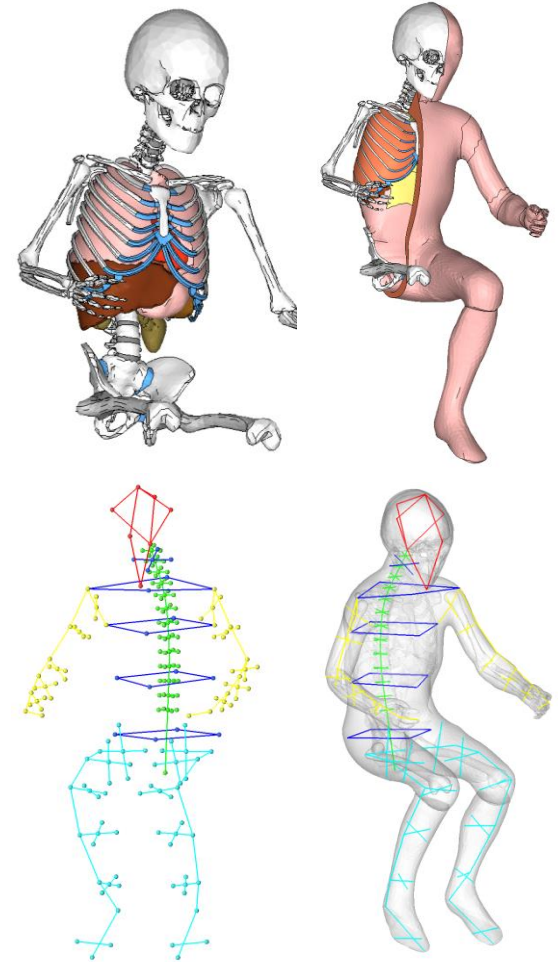
# Introduction

- PMHS tests using pediatric specimen are rare
  - Some historical data collected in the 1970s, including sled tests e.g. Wismans (1979), Kallieris (1976)...
  - New studies on abdominal / thoracic loading Ouyang et al. (2006), Kent et al. (2009, 2011)
- Some volunteer tests (CHOP studies Arbogast et al. 2009)
- Data is scarce but combination represents quite a bit for the 6 YO
- Idea: A human modeling approach can be used to consolidate into a model these known responses, and compare model and dummy responses...



# Methods: human model development & variations

- Development:
  - Based on CT-scan of a 6YO child + Scaling using GEBOD data
  - Simplified head neck, upper extremities, lower extremities
  - Properties: From literature with adjustment



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- Development:
  - Based on CT-scan of a 6YO child + Scaling using GEBOD data
  - Simplified head neck, upper extremities, lower extremities
  - Properties: From literature with adjustment
- “Validation”/check matrix
  - Regional: 6 conditions from PMHS studies on the thorax or abdomen
  - Kinematic response: Wismans et al (1979) and Arbogast et al, (2009).
  - Lumbar flexion (HIII 6YO flexion test)
- Variations: rigidification of lumbar spine, thoracic spine, thorax stiffness, ...

Regional loading on 6YO.

KENT Upper



KENT Distributed



KENT Lower



KENT Diagonal



EEVC Q dummies corridor  
Abdomen compression

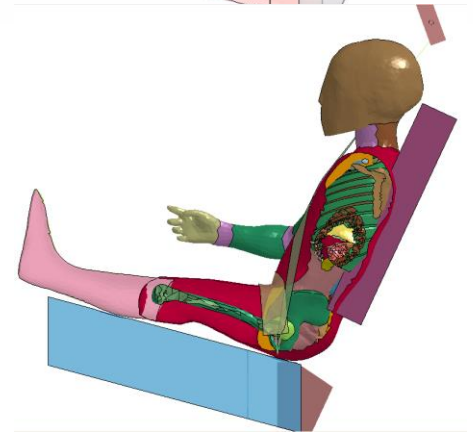
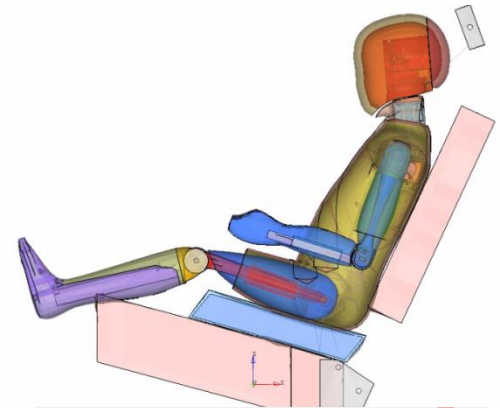


OUYANG thorax



# Methods: sled setup

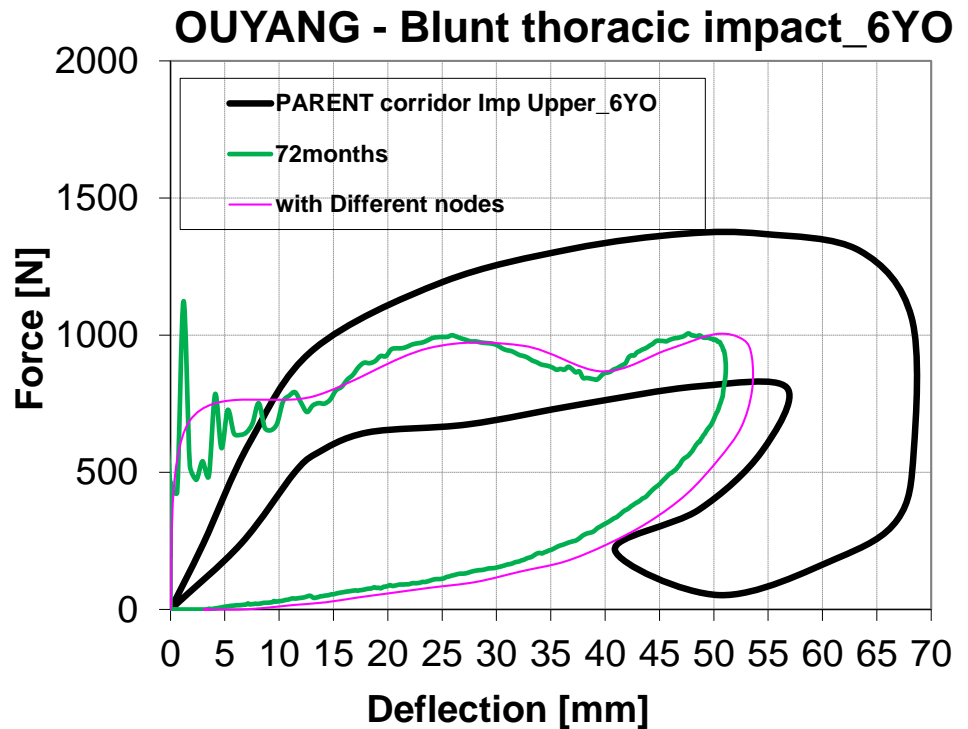
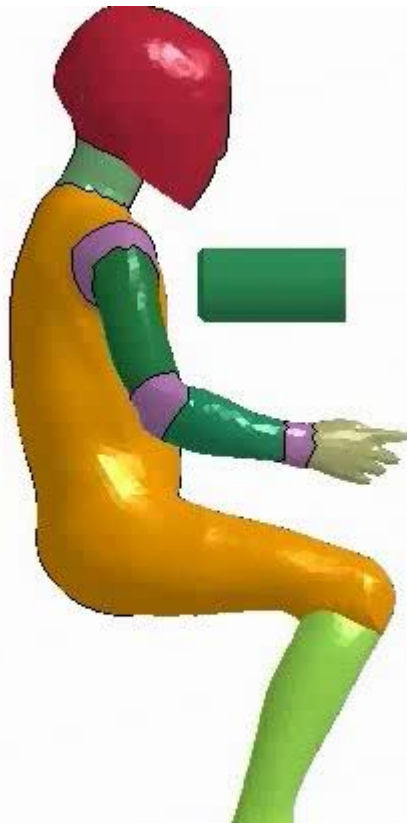
- Surrogates: 6 Y.O. human model + Q6 physical dummy + Q6 numerical model
- Bench:
  - NPACS bench with standard foam (all)
  - NPACS bench with reduced angle (5degree, tilted, dummy model) or modified cushion (5degrees, reduced thickness, all)
  - NPACS bench with modified stiffness (simulation only)
  - Without booster, with simplified booster (simulation only)
- Pulse:
  - R44 pulse (all)
  - NPACS pulse (dummy and human simulations)



# Results: Example of validation

## Thorax impact (Ouyang et al, 2006)

- Sharp force increase
- Close to the corridor after that...

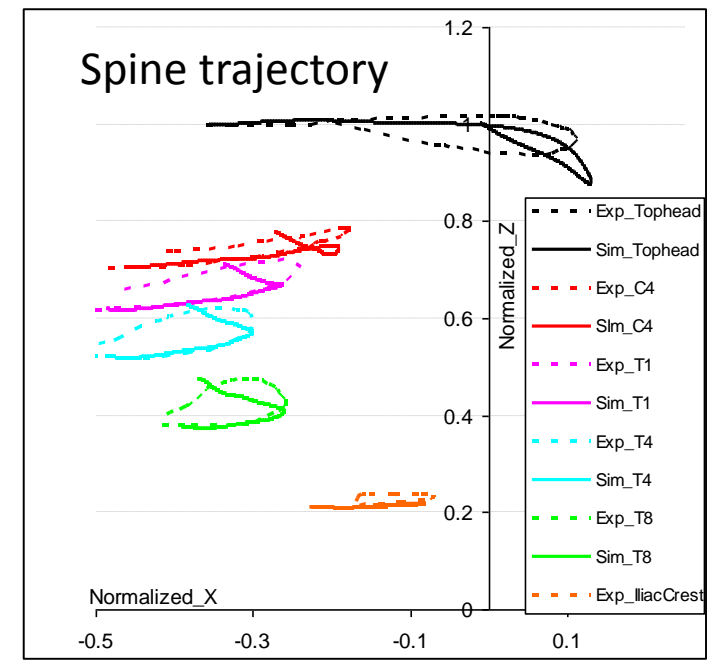
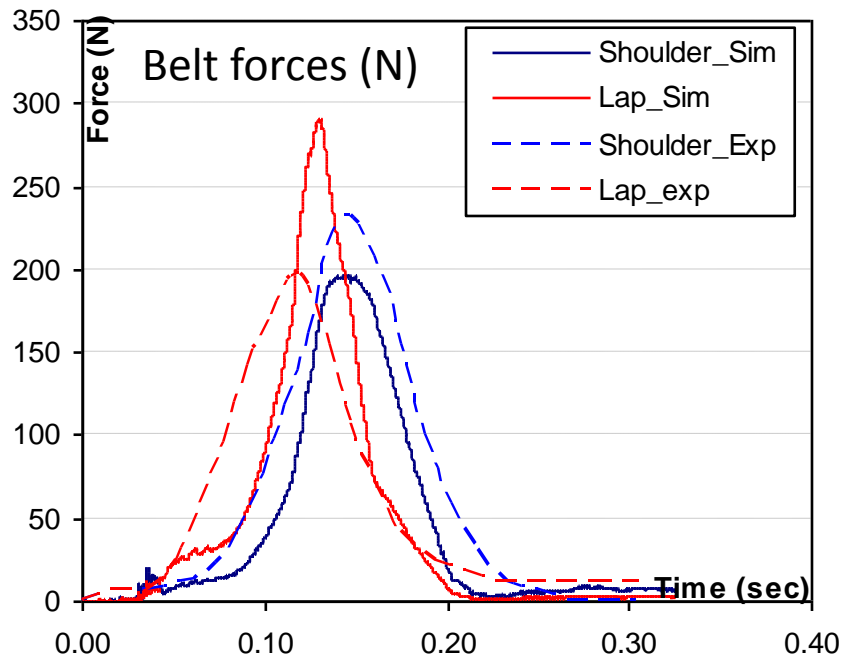
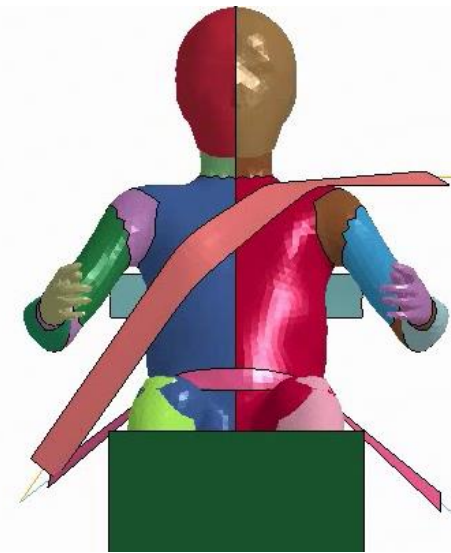
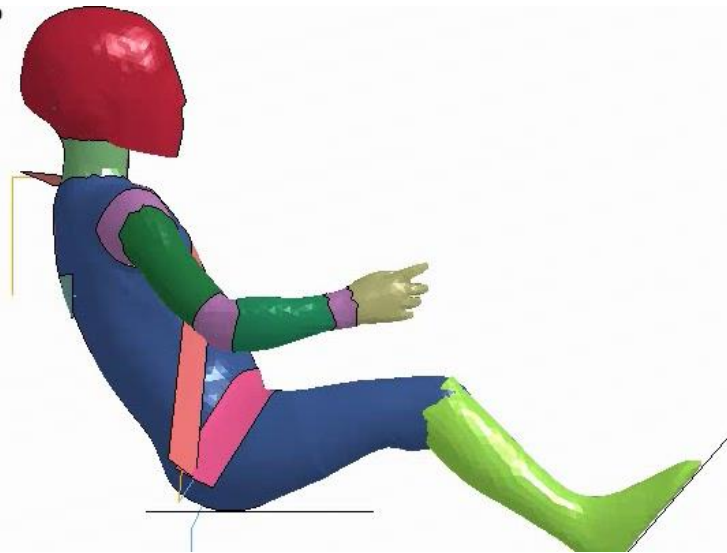
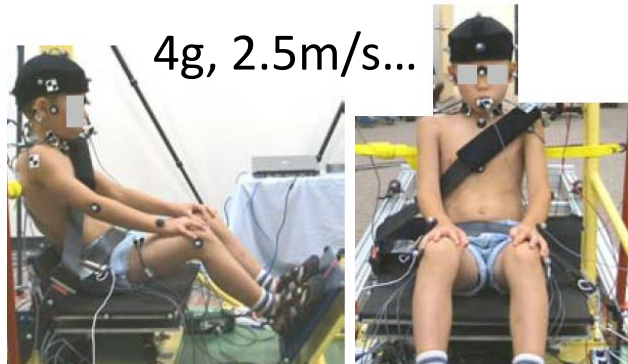




# Results: Example of validation

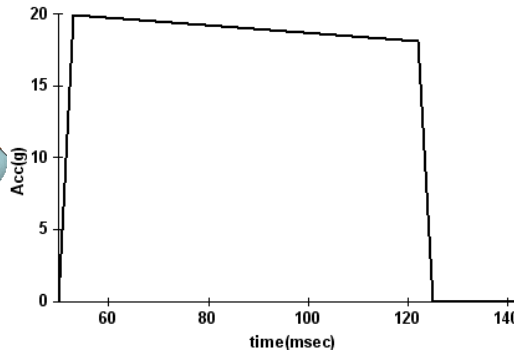
## Volunteer sled

(Arbogast et al, 2009)



# Example of validation tests – Sled with harness Wismans et al (1979)

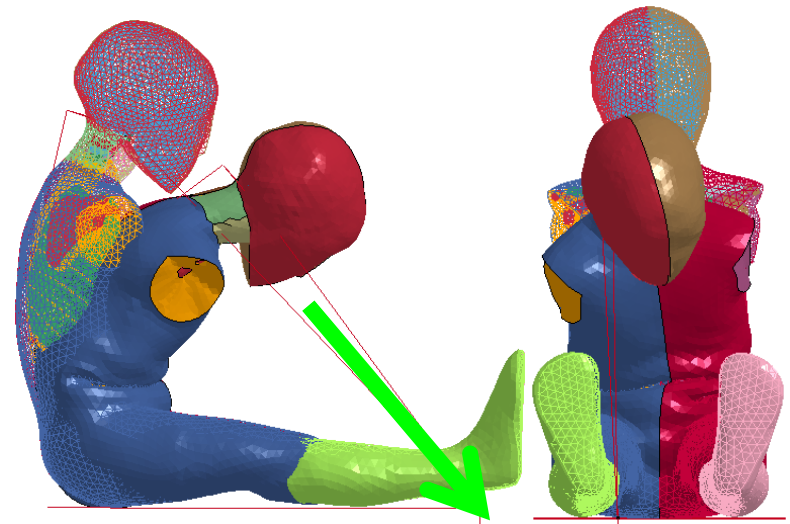
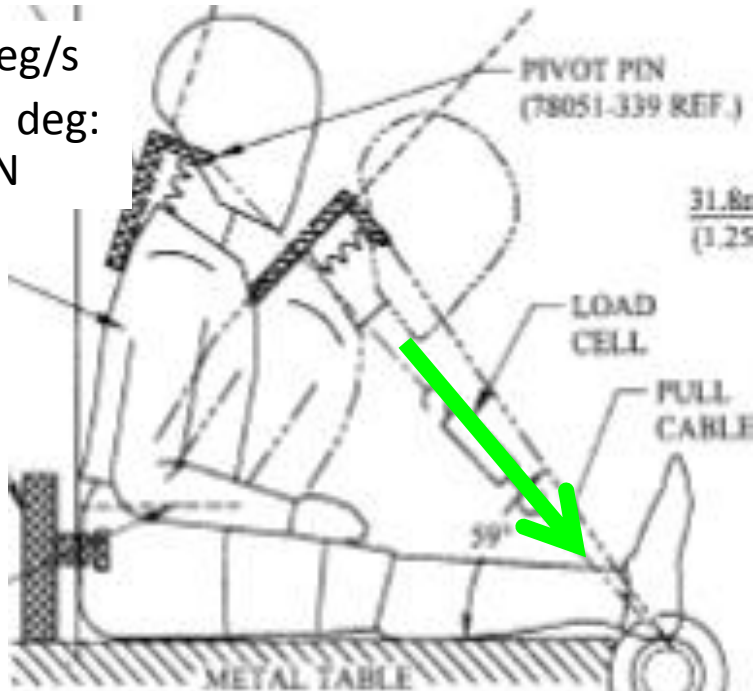
- 6 Y.O. PMHS (anthro near 4YO)
- Acc. Pulse: 20 to 15g in 120ms



Head	Max Excursion	Max Acc
Wismans	37cm @ 82ms	40g @ 75ms
Simu.	35cm @ 85ms	36g @ 75ms

# Example of simulation check: Torso-Flexion Test: (H3 part 572 style)

- Pull @ ~1 deg/s
- Force @ 45 deg:  $147 < F < 200N$

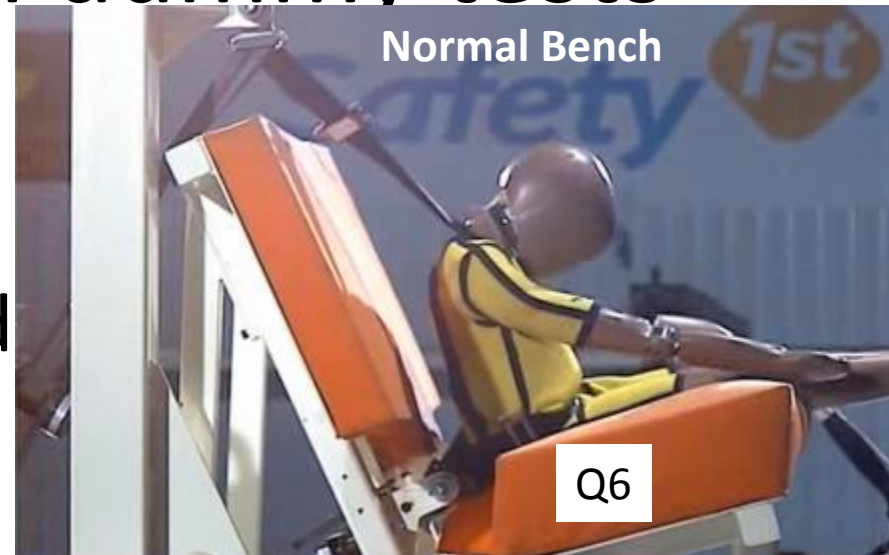


Simplified setup: 0.5m/s  
 Model Response: 160 N @ 45 degrees



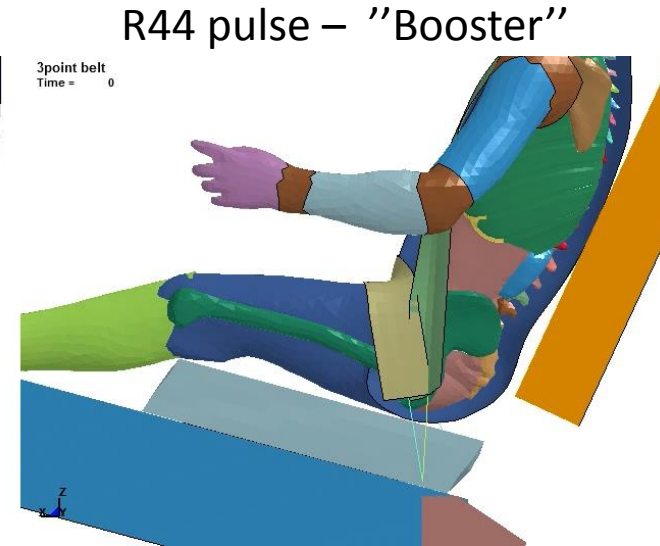
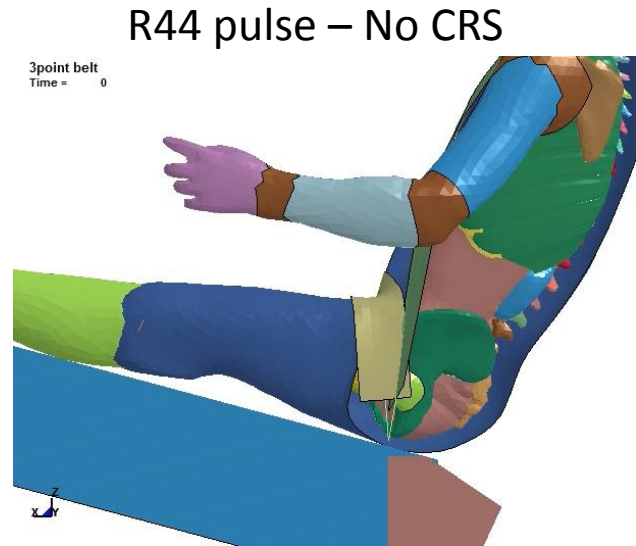
# Results: physical dummy tests

- No abdominal loading without booster
- A booster is not needed to protect the Q6
  - Criteria OK, kinematics OK, ANY CRS would pass...
  - Same results for Q10 already shown (Beillas et al., Icrash 2012)



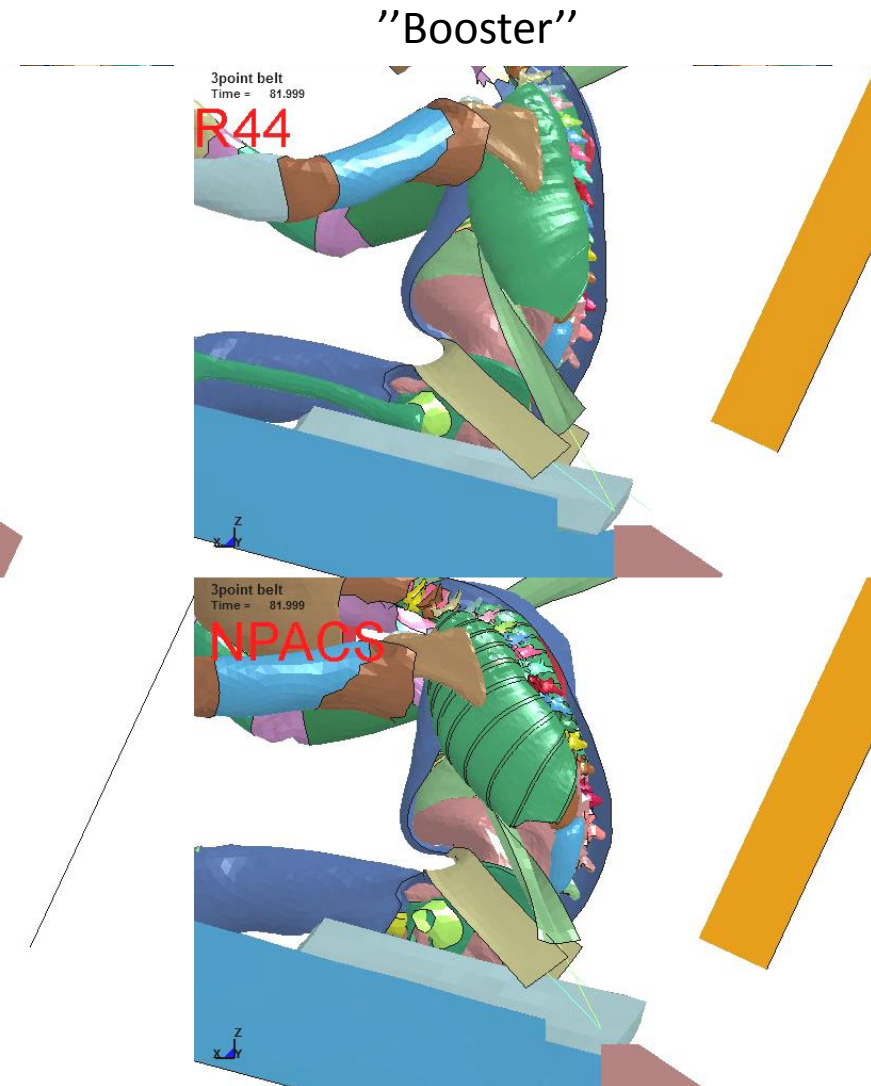
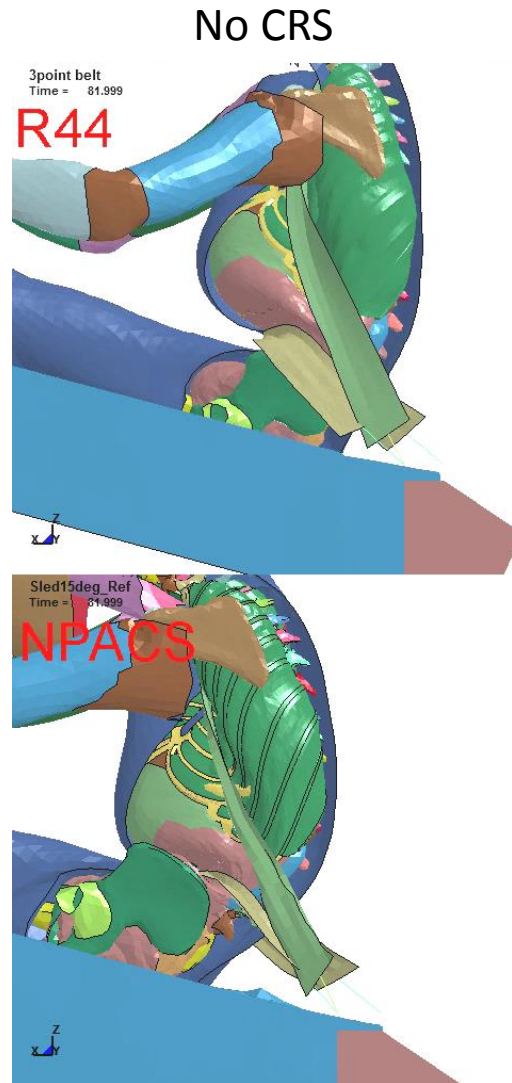
# Results: human simulations

- No CRS:  
submarines
  - And also rigid lumbar spine, ribcage, ...
- Rigid foam or complete spine or CRS: no submarining



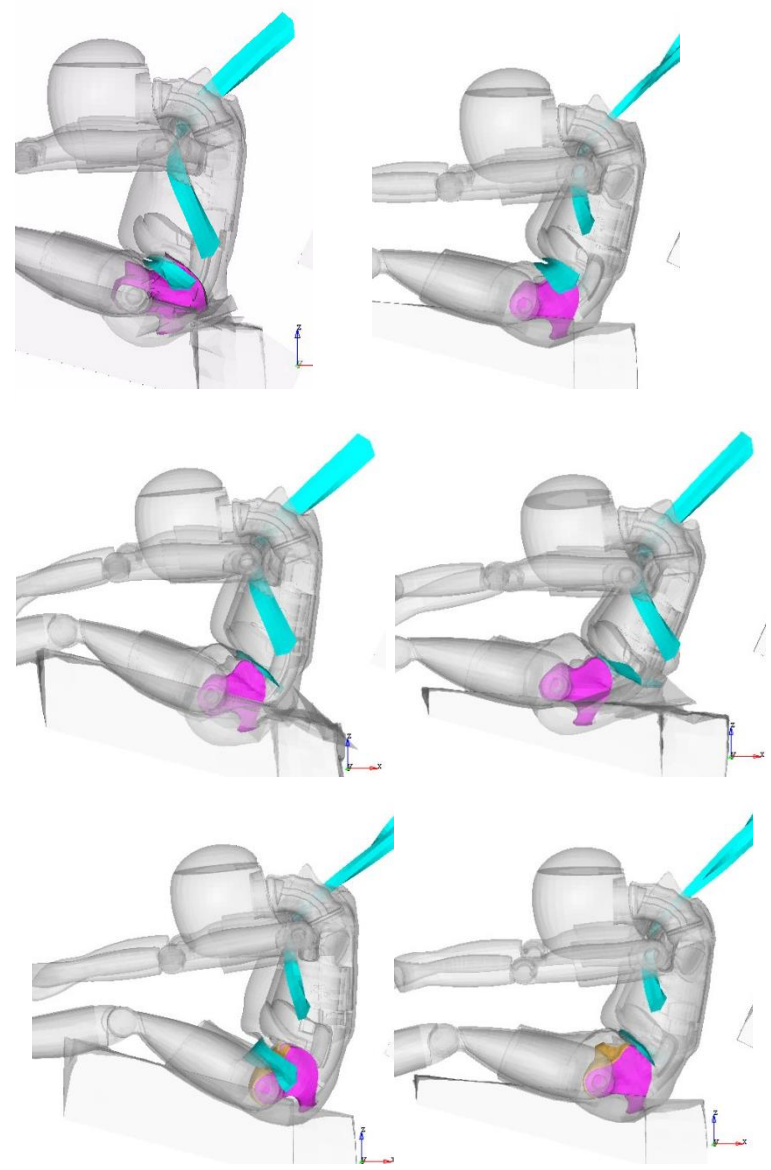
# Results: human simulations

- No CRS:  
submarines
  - And also rigid lumbar spine, ribcage, ...
- Rigid foam or complete spine or CRS: no submarining
- Pulse has an effect



# Results: dummy simulations

- No CRS, normal or modified cushion ECE R44 pulse: no submarining
  - And also softer lumbar spine, no abdomen, etc.
- NPACS + rigid pelvis flesh (x10), or NPACS + reduced angle: submarines
- ECE R44 pulse + filling of gap between casting and flesh (flesh mat): flat cushion submarines, standard cushion no submarining



# Results: dummy modification attempts

- Change gap at hip / R44: kinematic change but still no submarining or no obvious submarining
  - APTS used in few tests: pressure remains low...

Standard dummy



Dorel reinforcement



Ifsttar insert (for Q3...)



# Result summary: submarining???

	Baseline: NPACS bench, no CRS	Human model	Q6 model	Q6 test
R44	baseline	YES	NO	NO
NPACS	baseline	YES	NO	-
R44	<b>WITH CRS</b>	NO	-	<i>NO</i>
NPACS	<b>WITH CRS</b>	NO	-	-





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NPACS	<b>WITH CRS</b>	NO	-	-
NPACS	stiff spine or stiff bench	NO	-	-



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NPACS	<b>WITH CRS</b>	NO	-	-
NPACS	stiff spine or stiff bench	NO	-	-
R44	horiz bench	YES	NO	NO
R44	dummy modif	-	NO (filling, softer lumbar...)	NO (Dorel, Ifsttar modif)
R44	horiz bench, dummy modif	-	YES (filling)	NO (Dorel modif)



# Result summary: submarining???

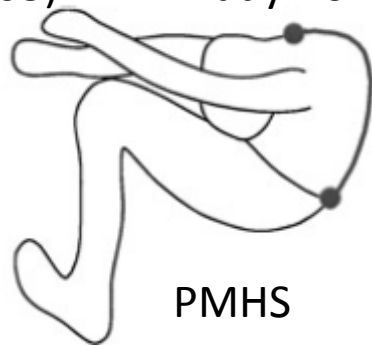
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NPACS	<b>WITH CRS</b>	NO	-	-
NPACS	stiff spine or stiff bench	NO	-	-
R44	horiz bench	YES	NO	NO
R44	dummy modif	-	NO (filling, softer lumbar...)	NO (Dorel, Ifsttar modif)
R44	horiz bench, dummy modif	-	YES (filling)	NO (Dorel modif)
NPACS	horiz bench	-	YES	-
NPACS	stiffer pelvic flesh	-	YES	-



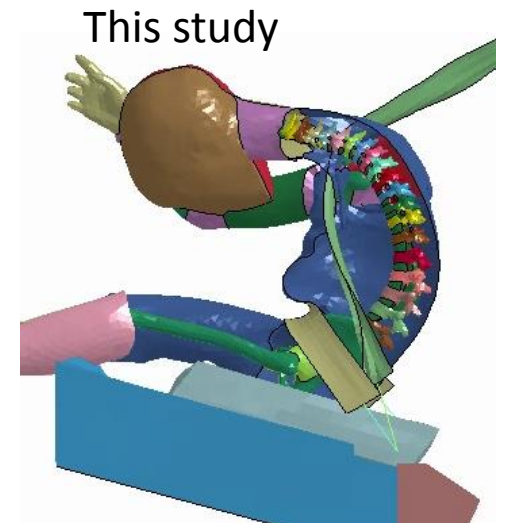
# Discussion and conclusions

- Spine seems to have an effect (also leads to diagonal belt slippage and increased neck force?)

Sherwood (2003): HIII+Madymo vs. Kallieris test

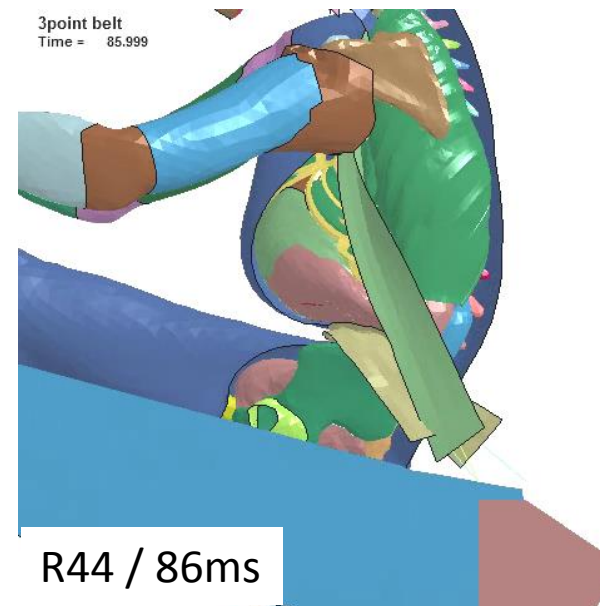
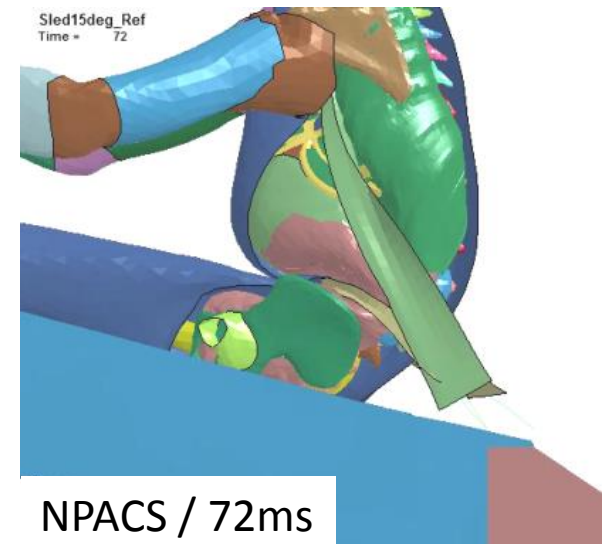


Wismans et al (EEVC report, 2008)



# Discussion and conclusions

- Pulse + bench have an effect in simulations...
- Overall, the baseline human model behavior seems in line with epidemiological data. However, the results question the ability of the dummy to evaluate the submarining behavior in the sled conditions...
  - Pulse or bench not sufficient
  - Seems dummy issue → modification needed?
- Impact on future procedure???



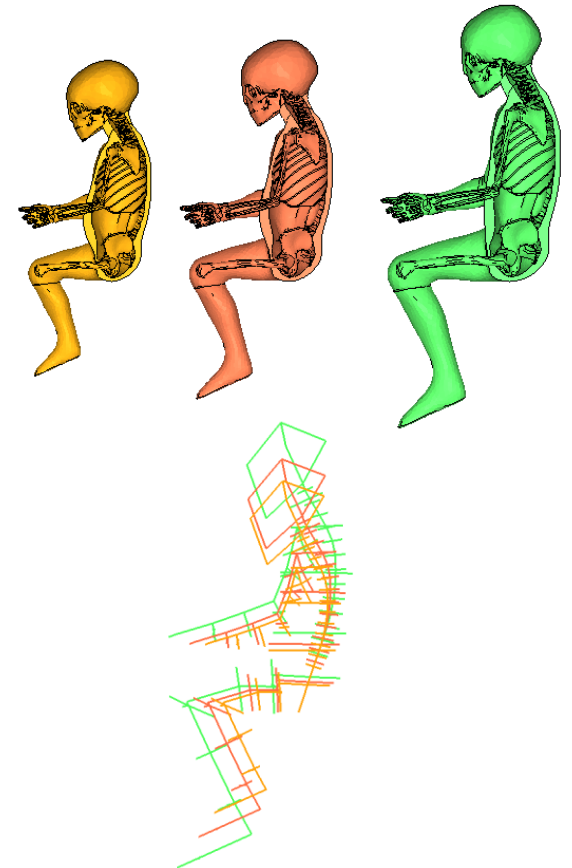
# Additional material: inflatable CRS/10YO.

- P10, R44 bench/pulse, (video provided by Britax): submarine → fail
- Q10, NPACS bench/R44 pulse (video provided by Dorel) → pass (other criteria ok)



# Perspectives

- Continue work to understand dummy behavior and define test procedure
- Human modeling:
  - Non-linear scaling to 6, 3 and 1.5 Y.O. using GEBOD + literature → done
  - Work on the simulation of Kallieris et al (1976) tests (need Golf 1)
  - Improvements will continue (Proetech project and new EC Project PIPER)
  - PIPER Models will be licensed for wide access
    - (full models coming)



- Acknowledgements
  - Funding from the Proetech Project
  - Initiation of the modeling effect with funding from the CASPER EC Funded Project (2008-2012)





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