



Thoracic Injury Assessment for Improved Vehicle Safety

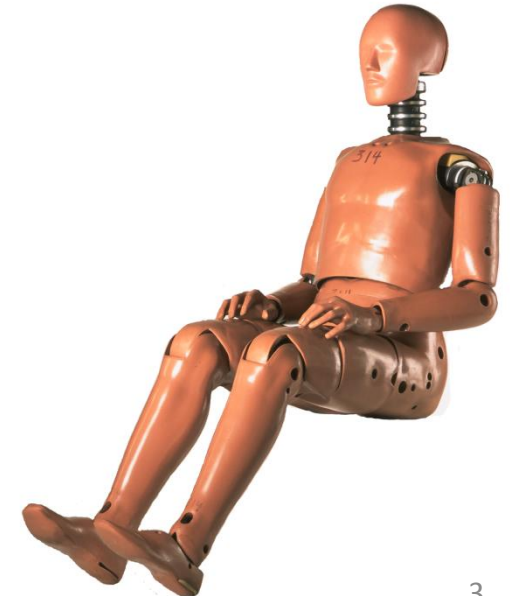
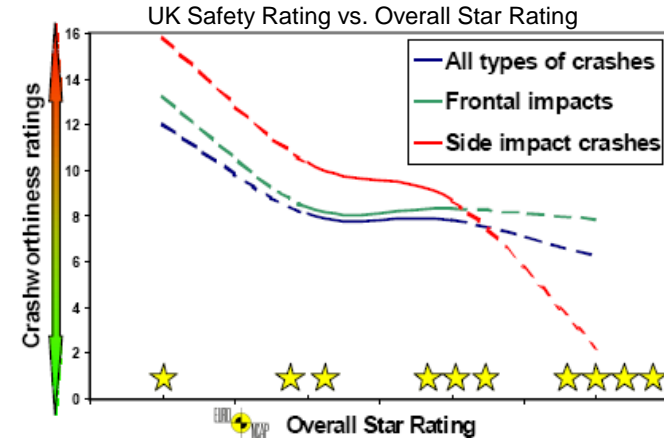
Introduction and Status per April 2012 GRSP IG Frontal Impacts

Paul Lemmen, Bernard Been	(Humanetics)
David Hynd, Jolyon Carroll	(TRL)
Johan Davidsson	(Chalmers)
Boris Steeger	(Continental)



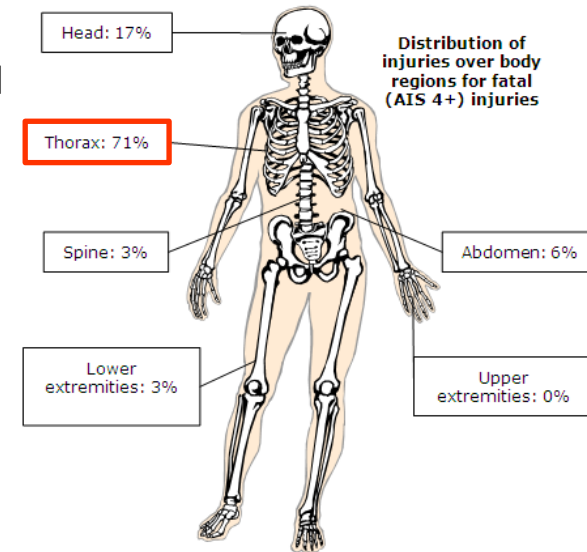


- The trend of increasing performance of vehicles in consumer rating programs is in contradiction with observations from accident data
- This is due to several reasons among which the usage of Hybrid III dummies developed in the late 70ties
- HIII thorax was designed to assess injury risk related to localized hub type loading of an adult male
- State of the art restraints use load limiter belts in combination with multi stage bags which result in a different load case and sensitivity range



The aim of the THORAX project is to develop numerical and experimental tools for the optimisation and assessment of frontal restraints for a wide variety of car occupants (age, gender, size)

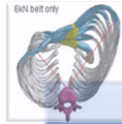
- Identification of the two most relevant thoracic injury types from real world accident data
- Characterization of injury mechanisms and governing parameters for these injury types, quantifying effects of user diversities like age
 - Using PMHS test data and HBM simulations
- Development of hardware demonstrator consisting of a new thorax / shoulder design implemented in THOR NT dummy
- Development of injury risk functions
- Assessment of the sensitivity of the hardware demonstrator to modern vehicle safety systems and usability in safety system optimization





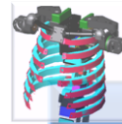
WP1: Accident Analysis

- Prioritisation of thoracic injuries
- Real world accident outcome versus crash test results
- Benefit estimation



WP2: Biomechanics

- Biomechanical requirements
- Volunteer testing
- Injury mechanisms & assessment crit.
- PMHS testing
- Injury risk curves



WP3: Demonstrator design

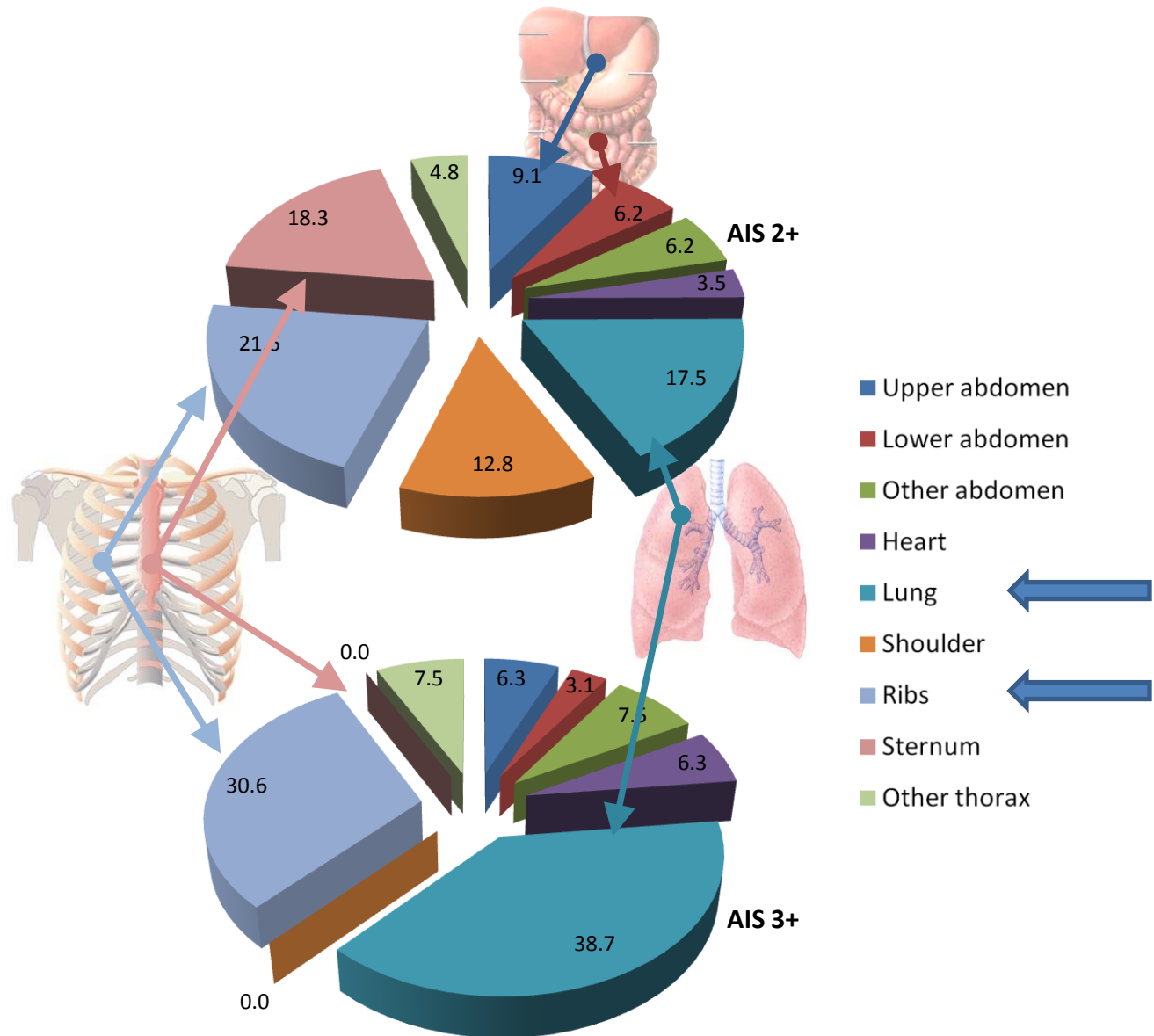
- Requirements
- Dummy concepts
- Design and prototype development
- Validation of biomechanical performance



WP4: Assessment for restraint optimization




- Load cases and evaluation criteria
- Testing
- Data analysis

WP1 Accident surveys




Collision / Accident Data					
Make:	Audi	Model:	A3	Year:	2004
ETS (kph):	34	dV (kph):	31	EES (kph):	39
Object hit:	Car	Overlap:	37	Compartment Intrusion:	none



Loading: O/S longitudinal was loaded, both crumpling and bending. The N/S longitudinal was not directly loaded but was crumpled. The engine was directly loaded.

EuroNCap Test:				
Tested model	Audi A3 1.6			
Hand of drive	RHD			
Body type	small family car			
Year of publication	2003			



Frontal Impact Test: The restraint system used single stage tethered airbags teamed with belts fitted with pretensioners and load limiters. These worked well although loads on the occupants' chests were a little high. Unfortunately the driver risked knee injuries from hard points behind the fascia. The body proved very strong after the impact showing minimal distortion around the sill and screen pillar areas, while the footwell suffered only minor deformation.

	Frontal impact driver	Frontal impact passenger	Rating:	Score:
<div style="display: flex; flex-direction: column; align-items: center;"> <div style="width: 15px; height: 15px; background-color: green; margin-bottom: 5px;"></div> GOOD <div style="width: 15px; height: 15px; background-color: yellow; margin-bottom: 5px;"></div> ADEQUATE <div style="width: 15px; height: 15px; background-color: orange; margin-bottom: 5px;"></div> MARGINAL <div style="width: 15px; height: 15px; background-color: brown; margin-bottom: 5px;"></div> WEAK <div style="width: 15px; height: 15px; background-color: red; margin-bottom: 5px;"></div> POOR </div>			ADULT OCCUPANT ★★★★★☆	Front: 12 Side: 16 <div style="text-align: center; font-size: 24px;">29</div>

Driver (right side): Personal data				CCIS severity: slight	
Gender:	Male	Age:	25		
Height (m):	Unknown	Mass (kg):	unknown		

Seating / Restraint data			
Pretensioner:	Fitted and activated	Load limiter:	Fitted and activated
Airbags:	Steering wheel - activated	Seat back angle:	102°
Seat Position:	Mid position		



Injury data				
Injury: None	Body Region	AIS	Injury mechanism	Influenced by intrusion?
unknown				

Passenger (left side): Personal data				CCIS Severity: Serious	
Gender:	Female	Age:	26		
Height (m):	Unknown	Weight (kg):	unknown		

Seating / Restraint data			
Pretensioner:	Fitted and activated	Load limiter:	Present, not activated
Airbags:	Facia - activated, own seat back - not activated, curtain - not activated	Seat back angle:	104°
Seat Position:	Car back		

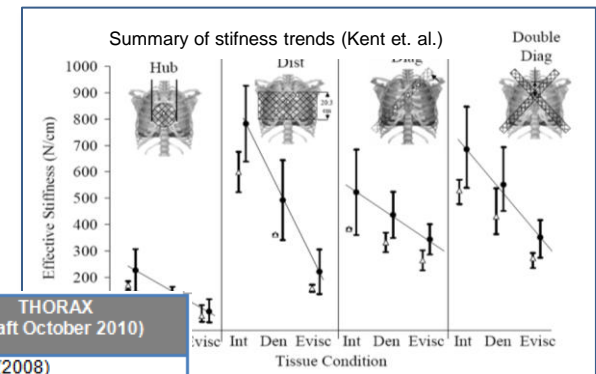
Injury data				
Injury	Body Region	AIS	Injury mechanism	Influenced by intrusion?
Displaced L clavicle mid 1/3	S	2	Seat belt webbing	No
Abrasion R knee	R	1	Facia panel	No

■ AIS 0
■ AIS 1
■ AIS 2
■ AIS 3
■ AIS 4

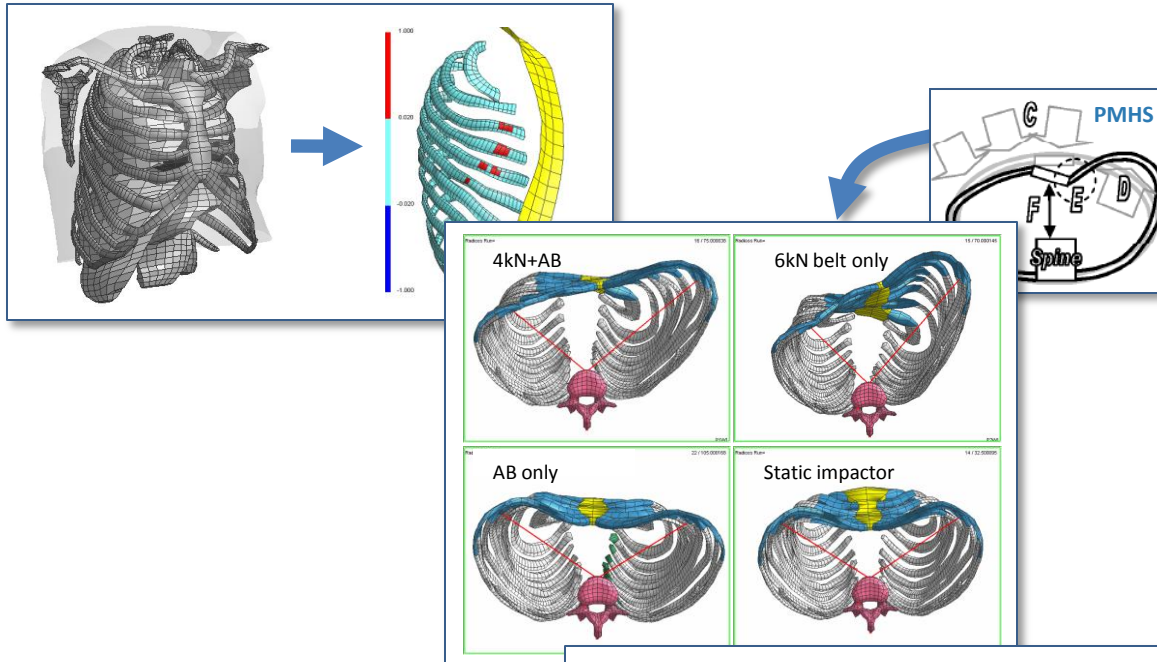
Summary: Euro NCAP predicted adequate protection for the thorax for the front seat passenger. This occupant sustained only one injury to this region; however, a clavicle fracture seems harsh given the age of the occupant and the low delta-v of the crash. The FSP load limiter was not activated and was possibly set too high for clavicle protection. The pretensioner activated.

It is also noted from the photographs that the Audi A3 appears to have over-riden the VW Golf, because the Golf's longitudinal is bent downwards.



Body region	Type	Absolute / Relative	EEVC (ESV 2003)	NHTSA (GESAC 2005)	ACEA/ISO (Draft June 2010)	THORAX (Draft October 2010)
Shoulder	Sled	Absolute	Vezin (2002) • Two restraint conditions; two speeds	None defined	None defined	Törnvall (2008) • 3-pt belt, three impact directions, 26.5 kph Shaw (2009) • 3-pt seat-belt, 40 kph
	Quasi-static	Absolute	None defined	None defined	None defined	Davidsson (2010) • THORAX tests
	Table-top	Relative	None defined	Schneider (1992) • Quasi-static thorax regional coupling Cesari and Bouquet (1990) Belt loading – relative regional compression	None defined	Cesari and Bouquet (1990) (plus L'Abbe (1982), Riordain (1991), and Cesari and Bouquet (1994) Belt loading – relative regional compression; PMHS and volunteer
Thoracic spine	Sled	Absolute	Vezin (2002) - NB: more tests required • Sled: see shoulder	Cesari and Bouquet (1990) • Belt loading – relative regional compression	None defined	Shaw (2009) • 3-pt seat-belt, 40 kph
	Quasi-static component	-	None defined	Several tentative proposals (mostly embalmed PMHS)	None defined	None defined
Thorax	Impactor	Absolute	Kroell (1971) • Frontal rigid impactor: 23.4 kg; 4.3 and 6.7 m/s Yoganandan (1997) • Oblique padded impactor: 23.4 kg; 4.3 m/s	Neathery (1974) • Frontal rigid impactor: 4.3 m/s Yoganandan (1997) • Oblique padded impactor: 23.4 kg; 4.3 m/s	Lebarbé (2010) • Pendulum impactor tests based on Kroell (1971), INRETS, and CEESAR data • Frontal rigid impactor: 23.4 kg; 4.3 and 6.7 m/s	Lebarbé (2010) • Based on Kroell (1971), INRETS, and CEESAR • Frontal rigid impactor: 23.4 kg; 4.3 m/s Yoganandan (1997) • Oblique padded impactor: 23.4 kg; 4.3 m/s
	Sled	Absolute	Vezin (2002) - NB: more tests required • Sled: see shoulder	None defined	Proposed Shaw (2009) • Sled: lap and diagonal seat-belt, at 40 kph	Bolton (2006) • Lap belt & airbag, two speeds Forman (2006) (not inc. Shaw 2000) • Chest bands with various restraints

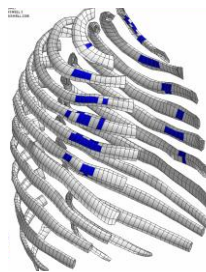




Will be analysed further in future THORAX activities with HBM's and hardware demo and included in risk curve development

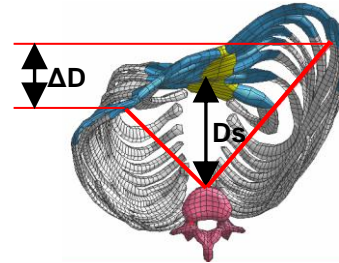
Number of Fractured Ribs

NFR



Deflection Combine

Dc



Combined deflection D_c :

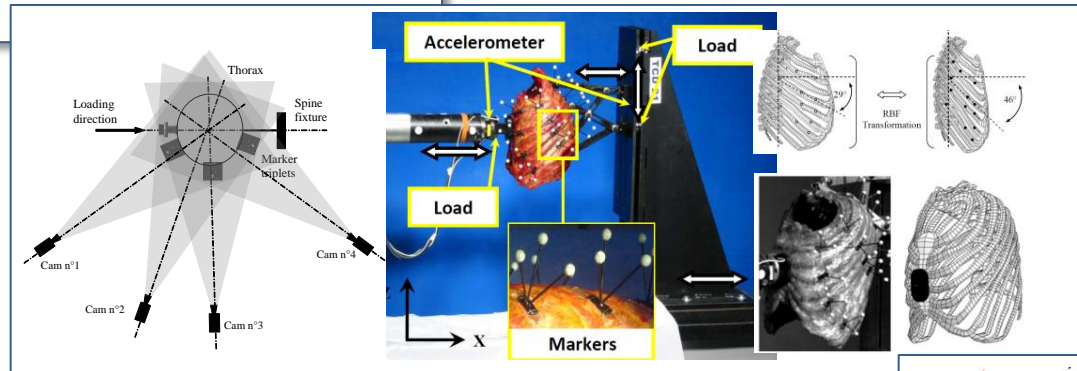
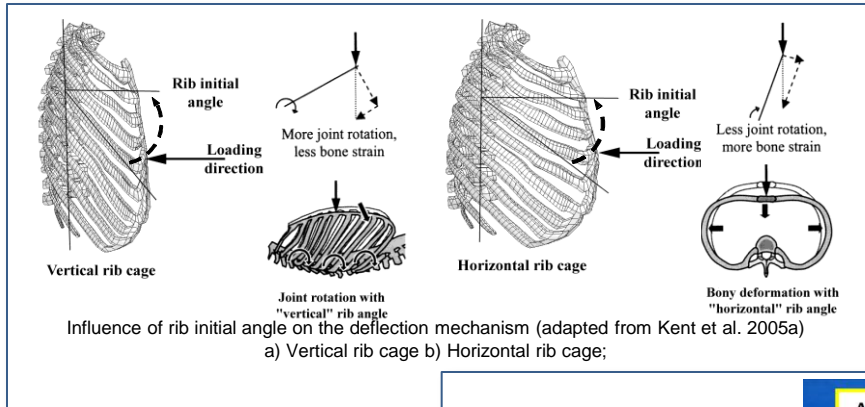
$$D_c = D_s + c_f [(\Delta D - L_c) + |\Delta D - L_c|]$$

D_s = Mid sternal deflection

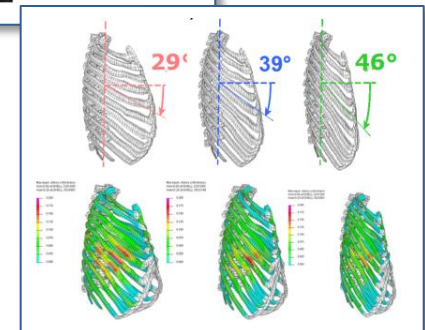
ΔD = Lower thorax differential deflection

L_c = Characteristic length

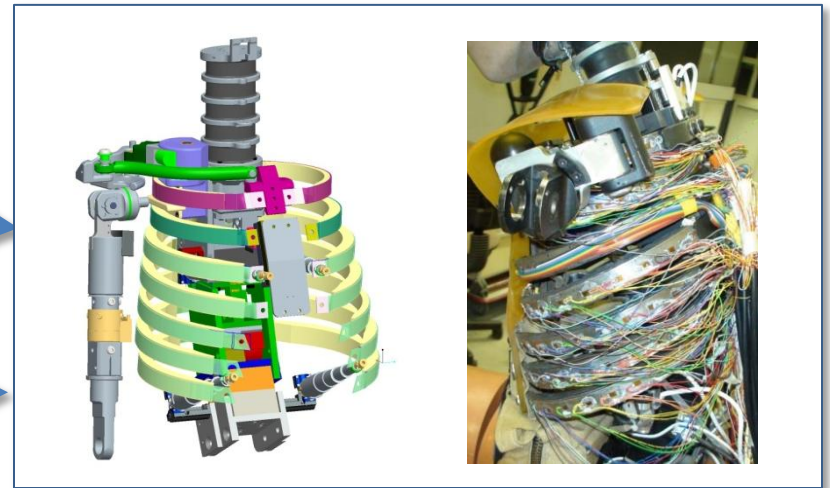
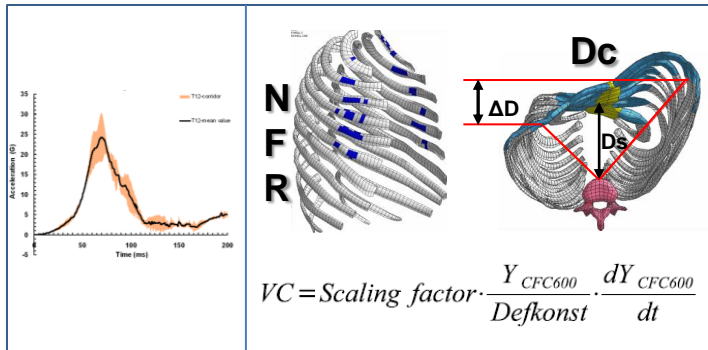
c_f = correction factor

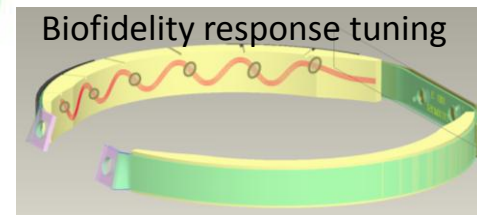
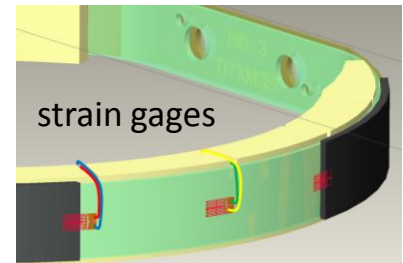
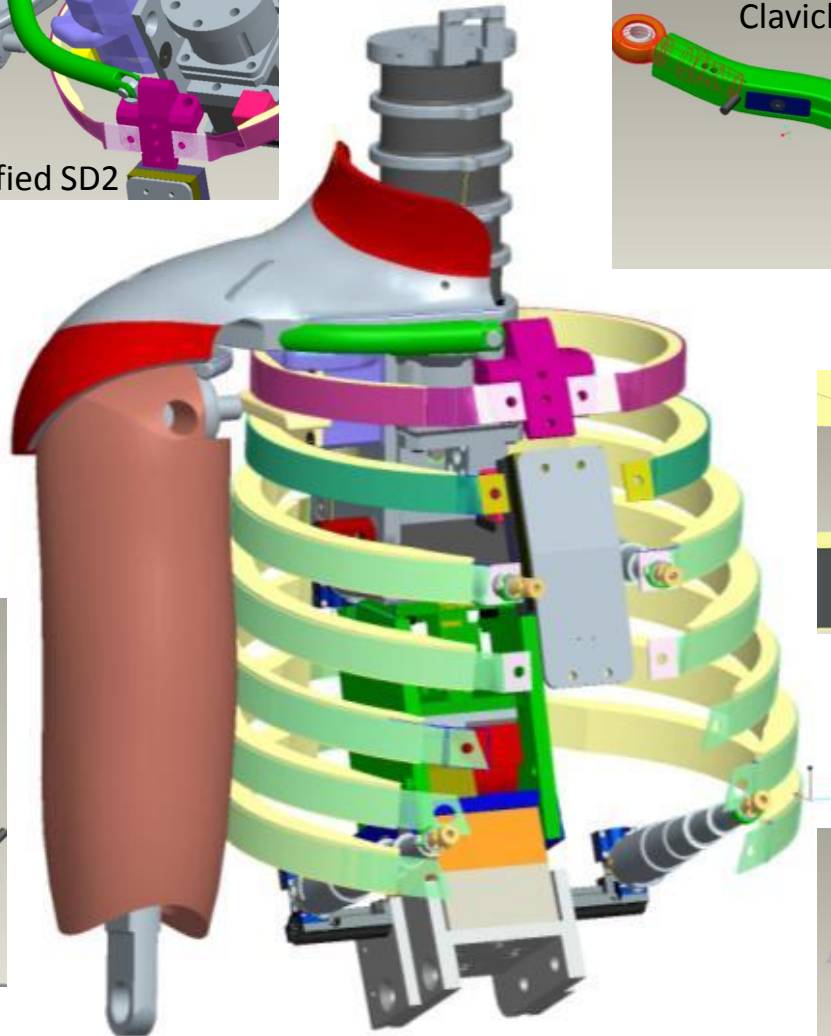
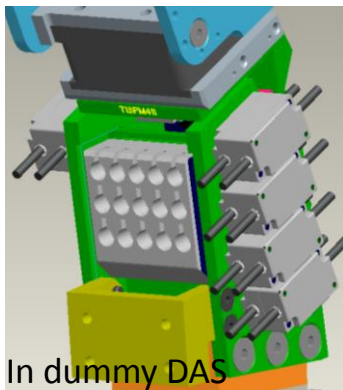
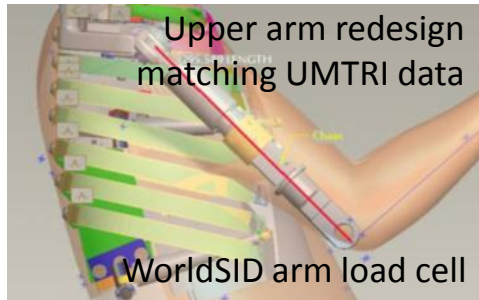
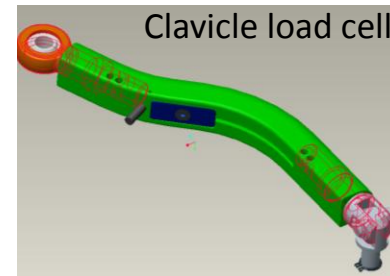
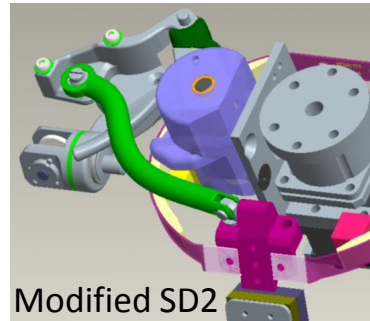


Approach will be used to support further studies into the injury assessment criteria and development of risk curves



- Base design 2010 THOR NT with updated pelvis, femur, knee, neck installed
- Include instrumentation to study proposed & existing assessment criteria
- Minor updates in chest stiffness
- Using updated SD2 shoulder and adjusted arms
- In dummy DAS





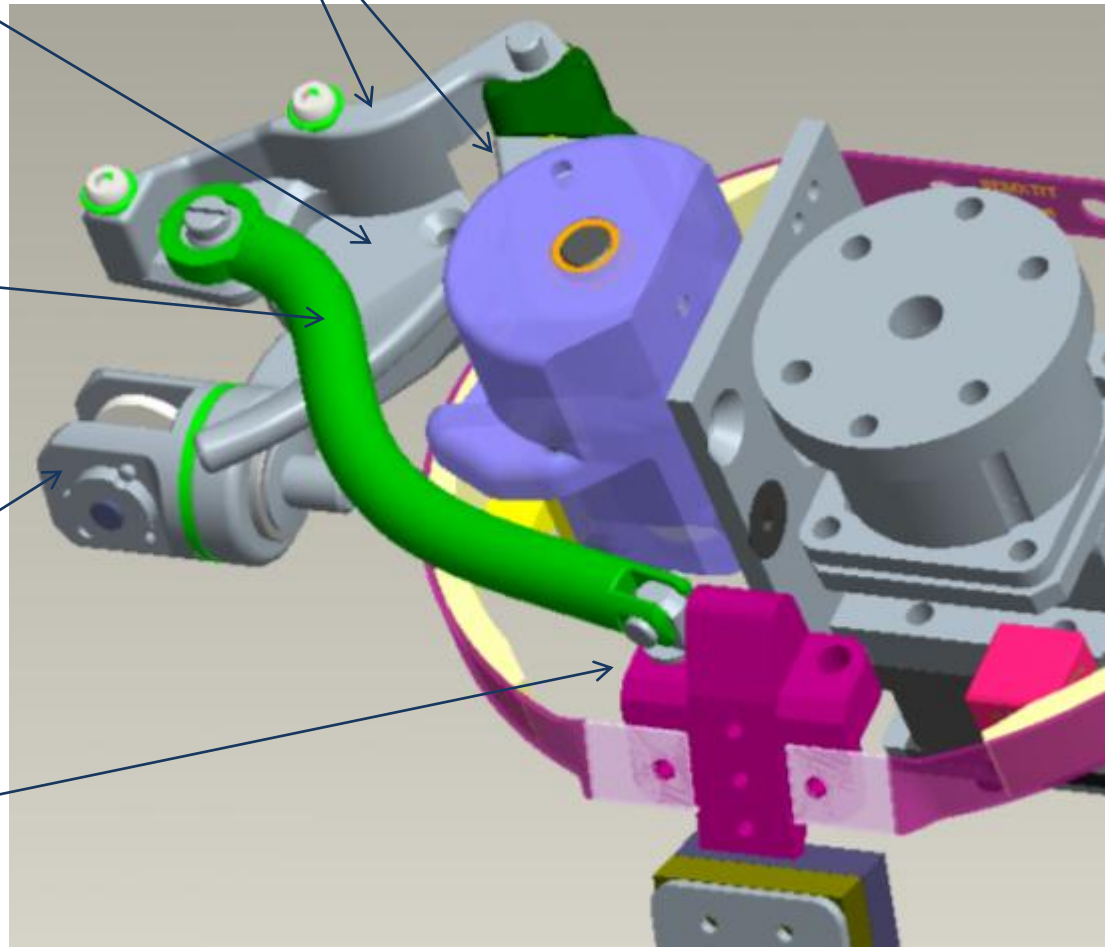
Coracoid and scapula parts
now combined into one

Clavicle same profile as SD2
Durable ball and clevis joint

Revised humerus joint based on
THOR adjustable friction and
stable position

Corrected
Sterno-Clavicular joint position
to match UMTRI

Simplified shapes
for machining



SD2 changes

Improved bearing material on all shafts

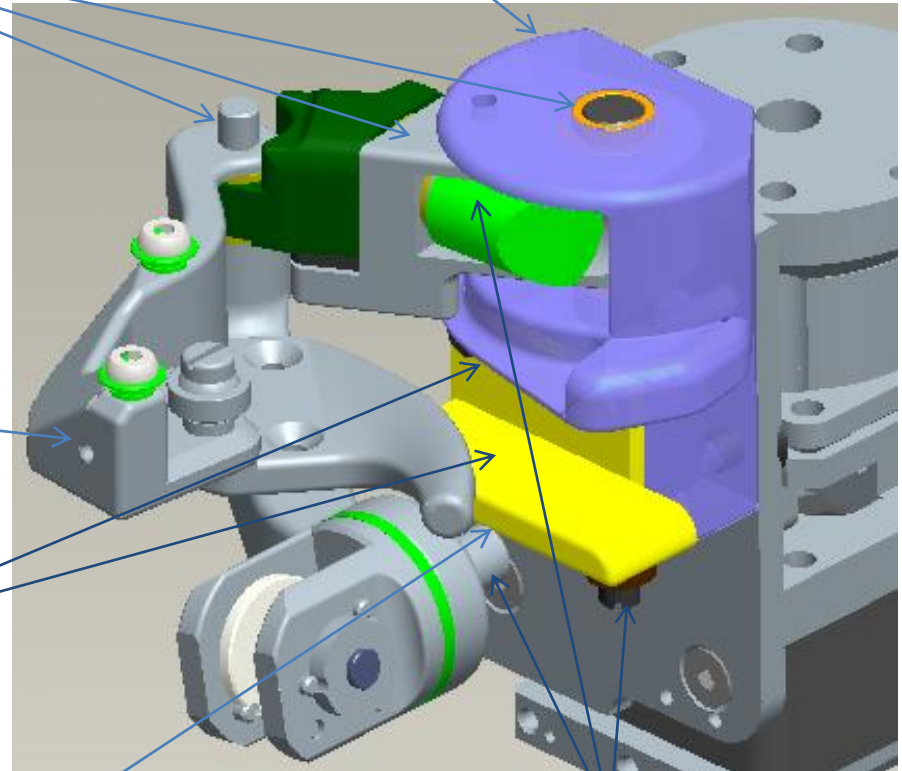
Shoulder pivot, spring housing, rib shelf integrated

Threaded hole for position measurement and film target mount

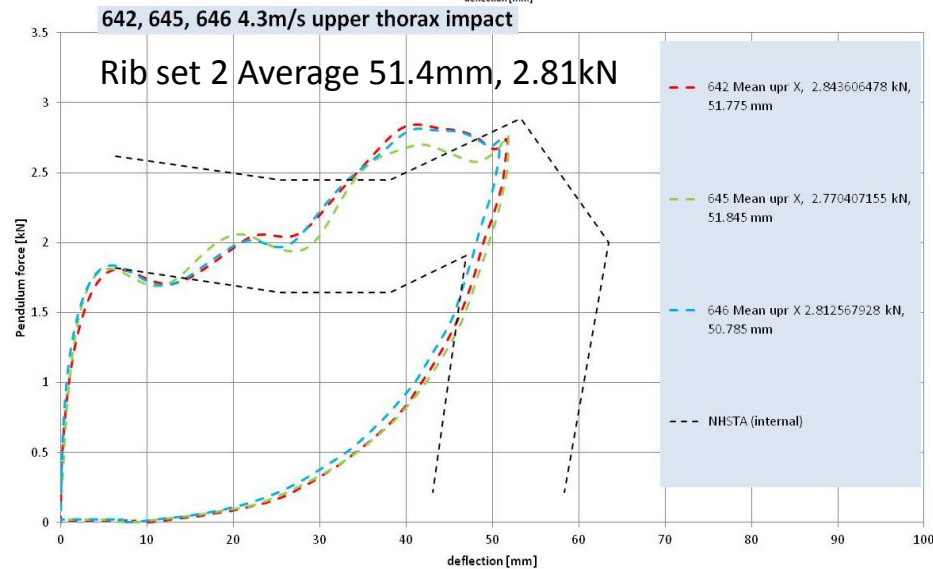
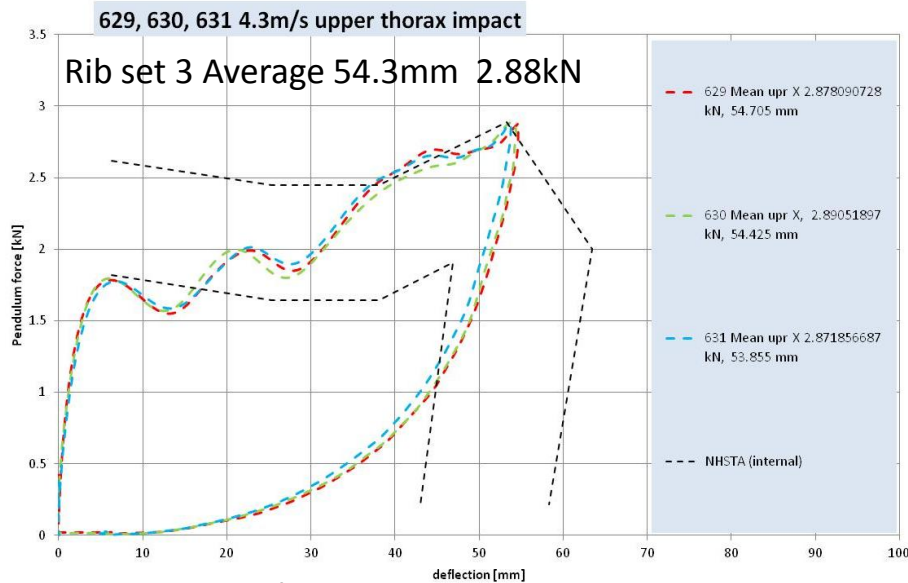
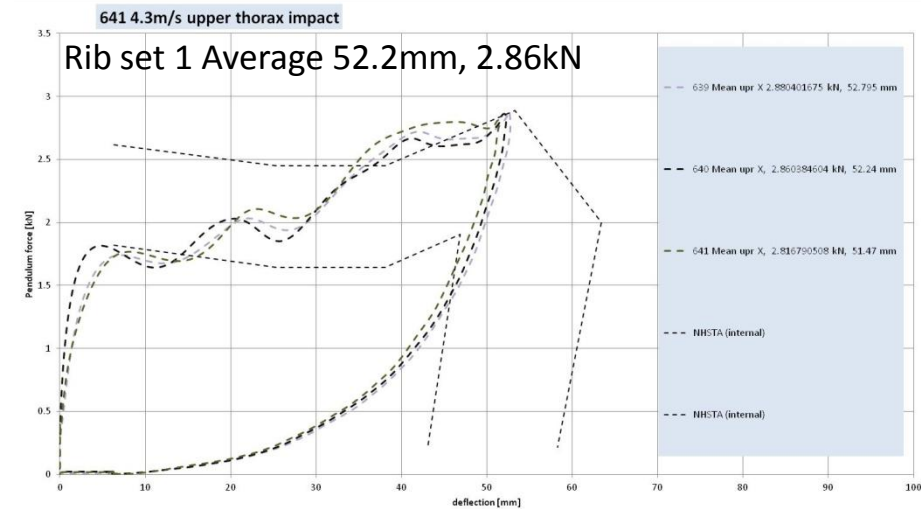
PTFE pad removed metal parts to have low friction coating

rib 2 Interference removed

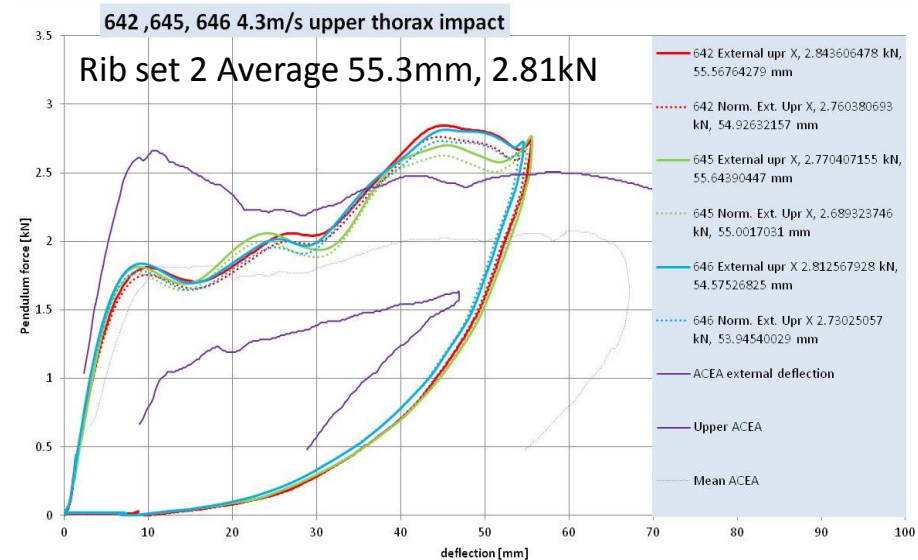
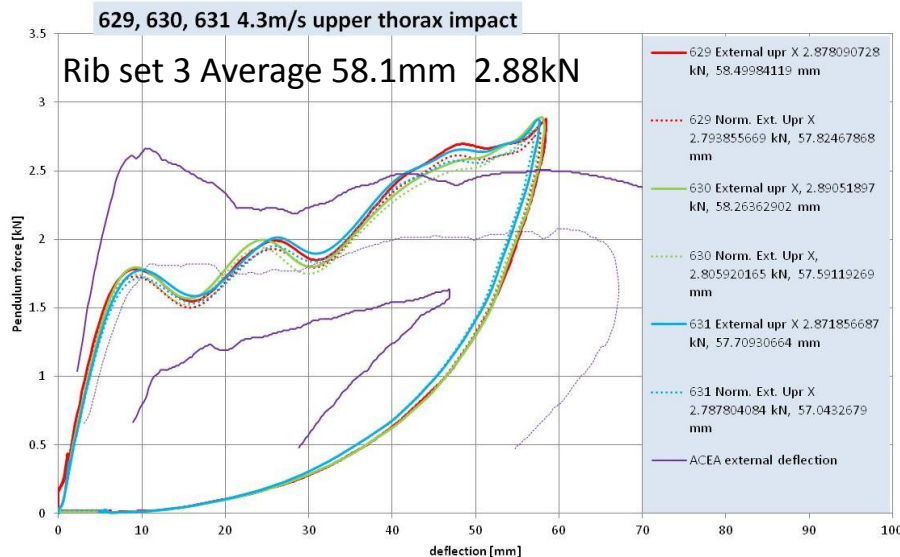
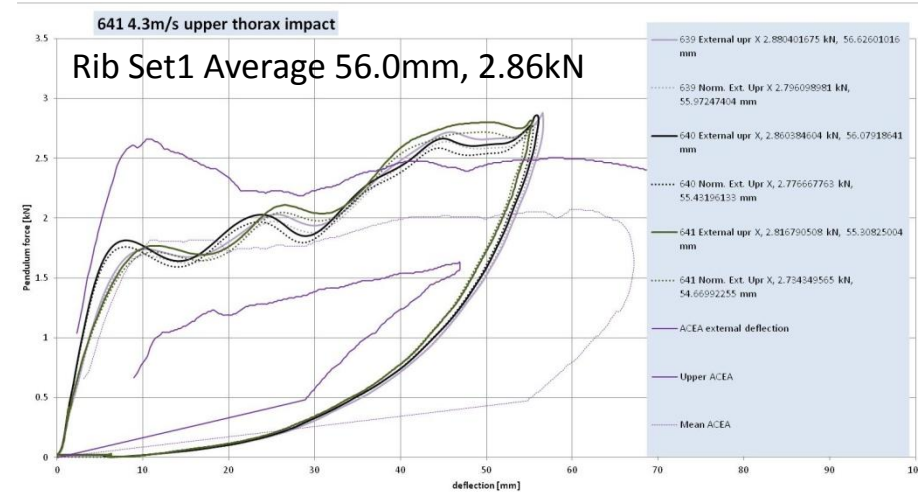
Adjustable joint friction with Belleville washers



- Based on NHTSA 2005 Biofidelity 4.3m/s pendulum test corridor without muscle tension
- Changes include
 - Reduction of damping material thickness
 - Ensolite foam ¼" inside jacket
- Mean upper CRUX X displacement
- 3 repeats on 3 rib sets

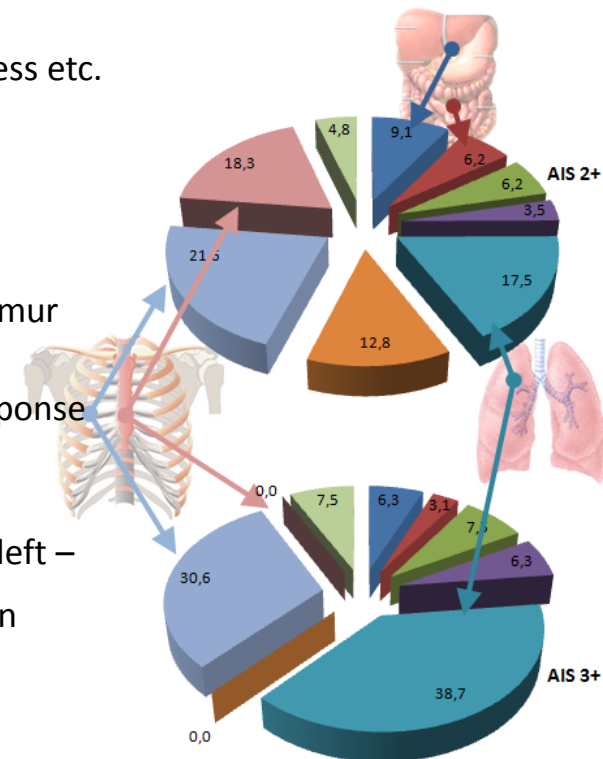


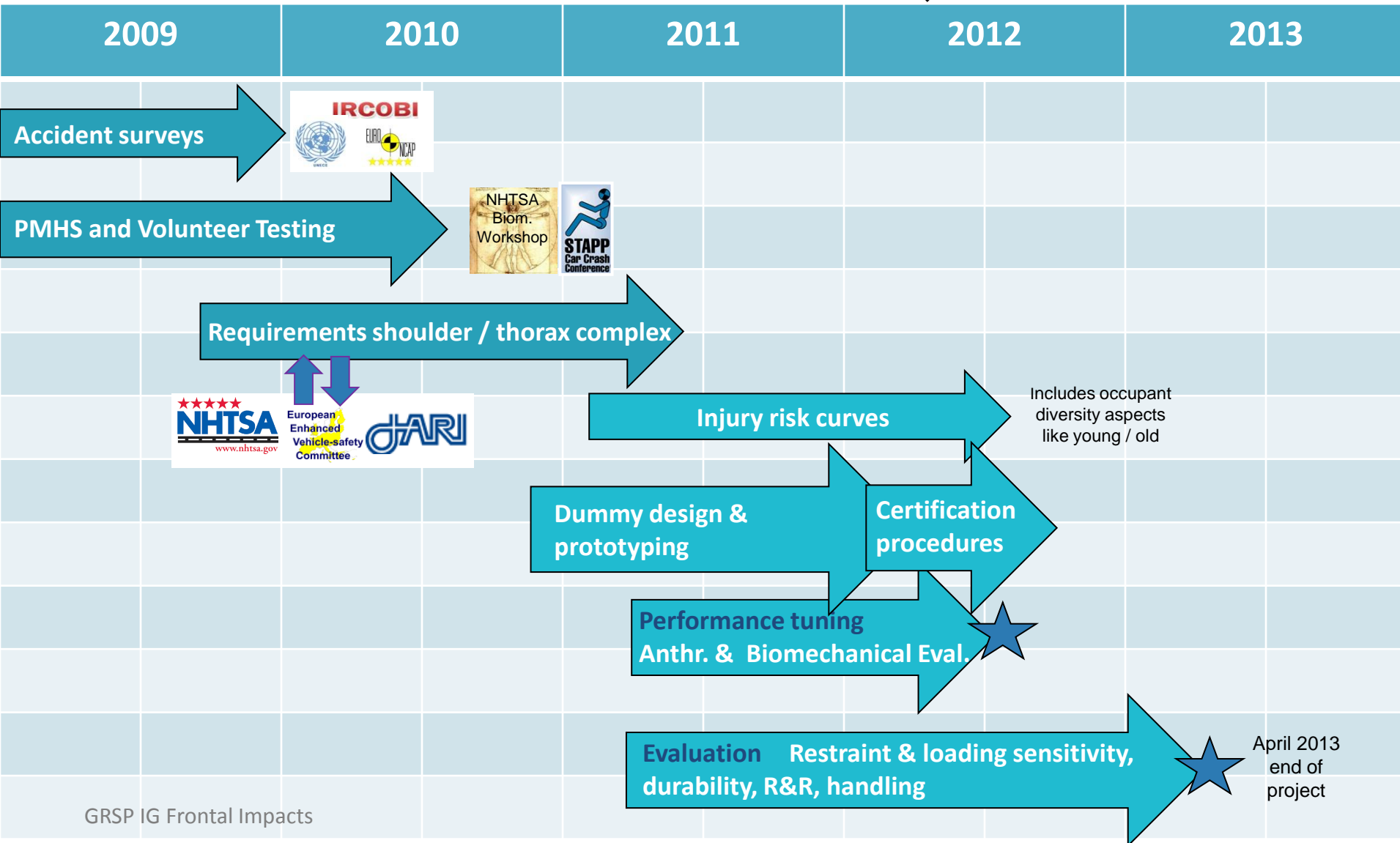
- Lebarbe frontal Biofidelity corridors 4.3m/s pendulum test corridor without muscle tension, based on external chest deflection
 - (includes soft tissue compression outside the ribs)
- Summation of CRUX X displacement and calculated jacket compression
- 3 repeats on 3 rib sets



Harmonization NHTSA / FP7 THORAX

- Good exchange of info EU FP7 THORAX and NHTSA
- Thorax
 - Chest stiffness aligned
 - Both using 4 3-D IRTACC's for multiple point assessment criteria
 - EU FP7 THORAX also uses strain gages for local strain based assessment criterion
- Shoulder
 - EU FP7 THORAX has updated the SD2 shoulder to improve robustness etc.
 - Taking into account remarks from US
 - Updated shoulder will be provided to UVa for testing
 - First evaluation meeting UVa / NHTSA planned for July timeframe involving THORAX partners
- Other dummy parts
 - EU FP7 THORAX uses THOR dummies with upgrade kit for pelvis, femur and knee
 - Neck not included as this is minor detail only
 - Lower leg not included as this part is not influencing the thorax response
- Assessment criteria
 - Open dialogue between US and THORAX on criteria
 - French proposals: local NFR and global Dc (sternum deflection and left – right differential in lower thorax)
 - UVa studying extended version of Dc (using left – right differential in lower and upper thorax)



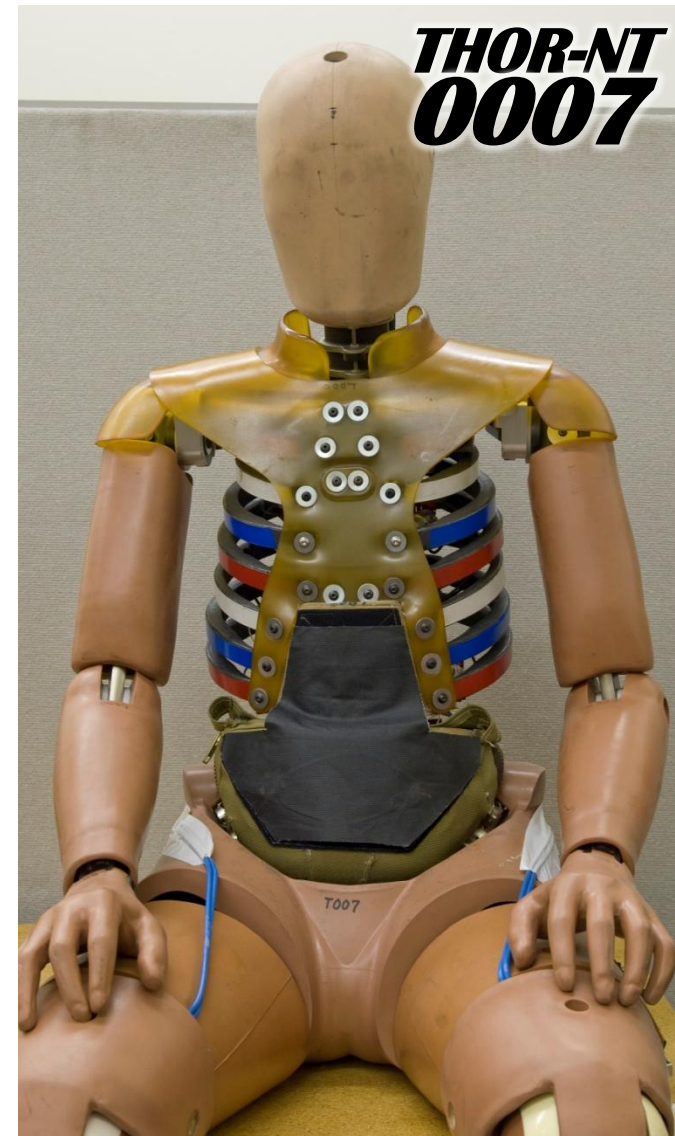
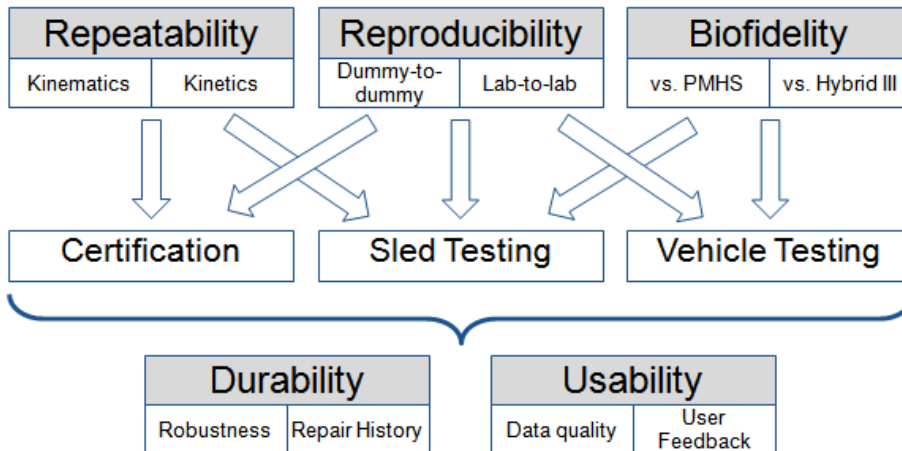


THOR Activities NHTSA

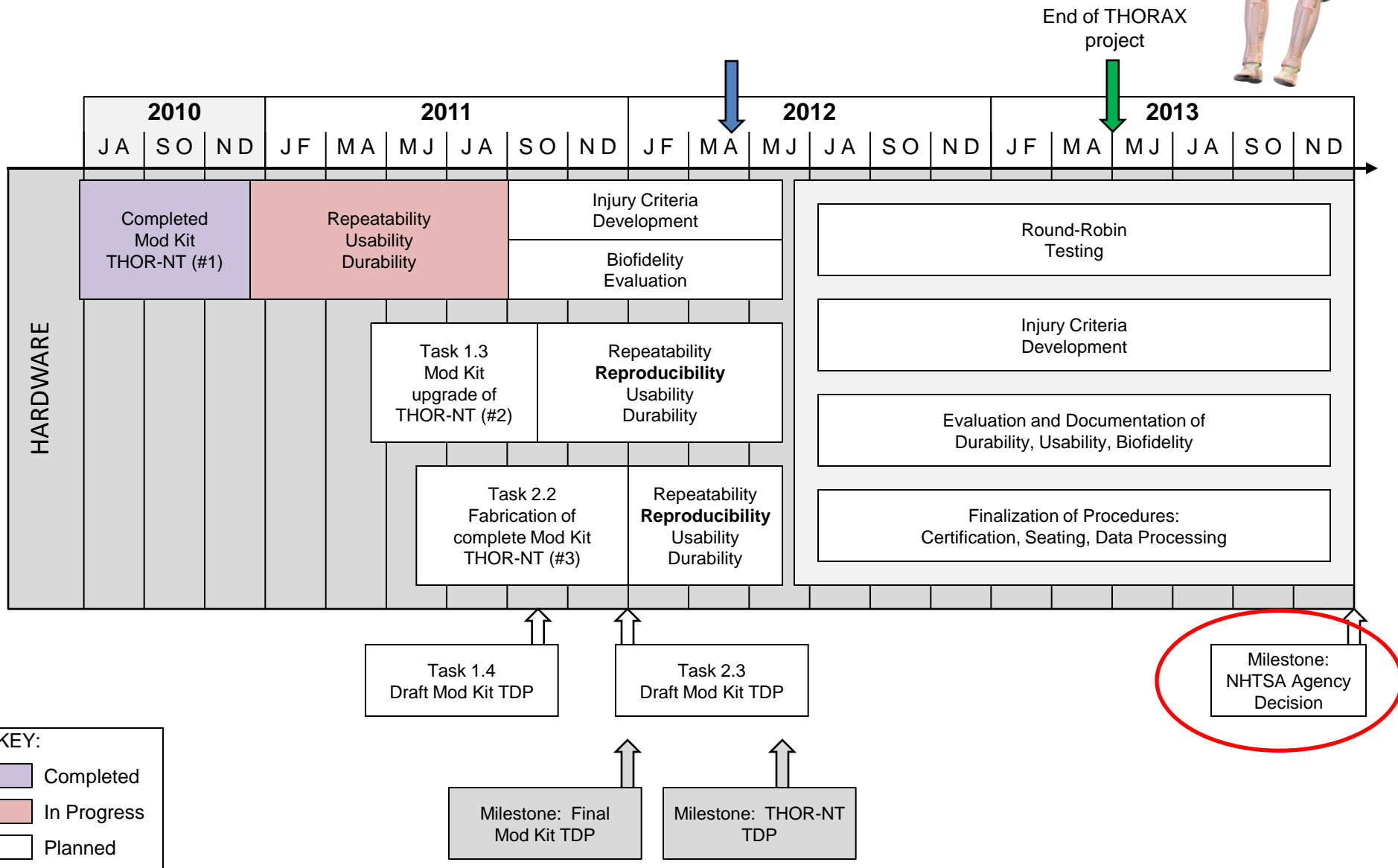
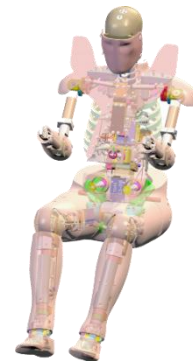
Upgraded dummies



Fully metric dummy

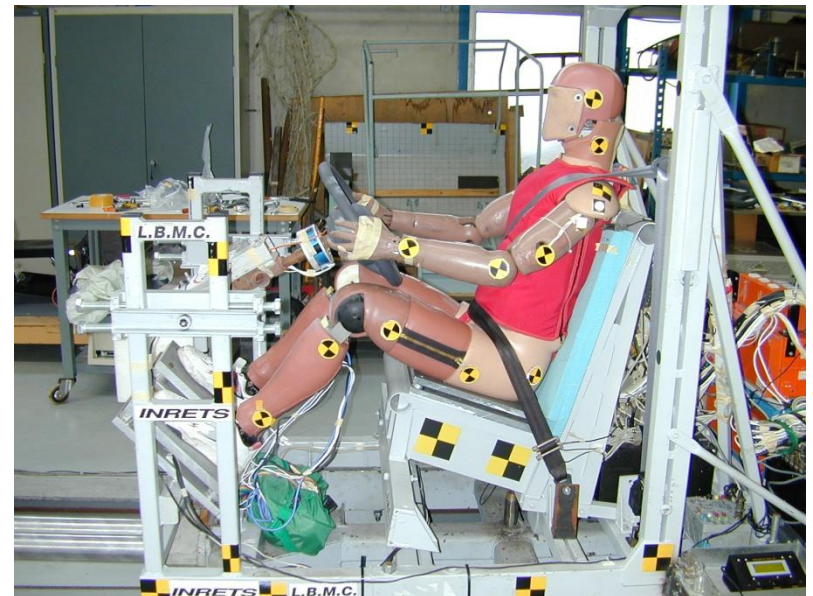


Timeline THOR Activities NHTSA




Key work items for next period

- 3 prototype dummies shipping to partners next week for testing
 - Currently being tested at Humanetics
- Evaluation biomechanical performance May – July 2012
- Development of Injury Risk curves by Sept 2012
 - Including consideration of age
- Sled testing to assess dummy performance for restraint optimization Aug 2012 – Jan 2013
- 1 set of shoulders being provided to US for evaluation








Please visit www.thorax-project.eu for more information



Thoracic injury assessment for improved vehicle safety

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Project summary

Thoracic injuries are one of the dominant causes for fatalities and injuries in car crashes today. The tools available today for studying these injuries are not up to par with the latest implementation of restraint systems and airbags.

The THORAX Project will focus on reduction and prevention of thoracic injuries through:

- Understanding the thoracic injury mechanisms
- Implement this understanding in numerical computer models and
- Implementation of an updated THORAX design in a crash test dummy

The models and dummy will enable the design and evaluation of advanced restraint systems for a wide variety (gender, age and size) of car occupants.

[Learn more about THORAX project »](#)

Events

ISN & COVER Workshop on Biomechanical Experiments with Human Subjects
September 14, 2010
Hanover, Germany
information and call for papers: [PDF](#)

17th Congress of the European Society of Biomechanics 2010
July 5-8, 2010
University of Edinburgh, UK

[View all events »](#)



News

- [Presentation during the 6th World Congress of Biomechanics available](#)
- [Second COVER Newsletter](#)
- [THORAX Stakeholder Workshop on Dummy Demonstrator Requirements](#)
- [ISN & COVER Workshop on Biomechanical Experiments on Human Subjects, Call for Papers](#)

Facts & Figures

About 41,600 people were killed and more than 1.7 million injured in European road accidents in 2005. Although the number of road fatalities has declined by more than 17% since 2001, more efforts will have to be made to meet the EC's target of halving the number of deaths in the period between 2001 and 2010.

Co-funded under 7th FP (Seventh Framework Programme)



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