Thoracic Injury Assessment for Improved Vehicle Safety

- Introduction and Status per August 2010 -

Meeting: GA Telecall
Date of issue: 25 August 2010
Prepared by: Paul Lemmen (FTSS)

European Framework Project

CHALMERS

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ACCIDENTOLOGY, BIOMECHANICS, HUMAN BEHAVIOR

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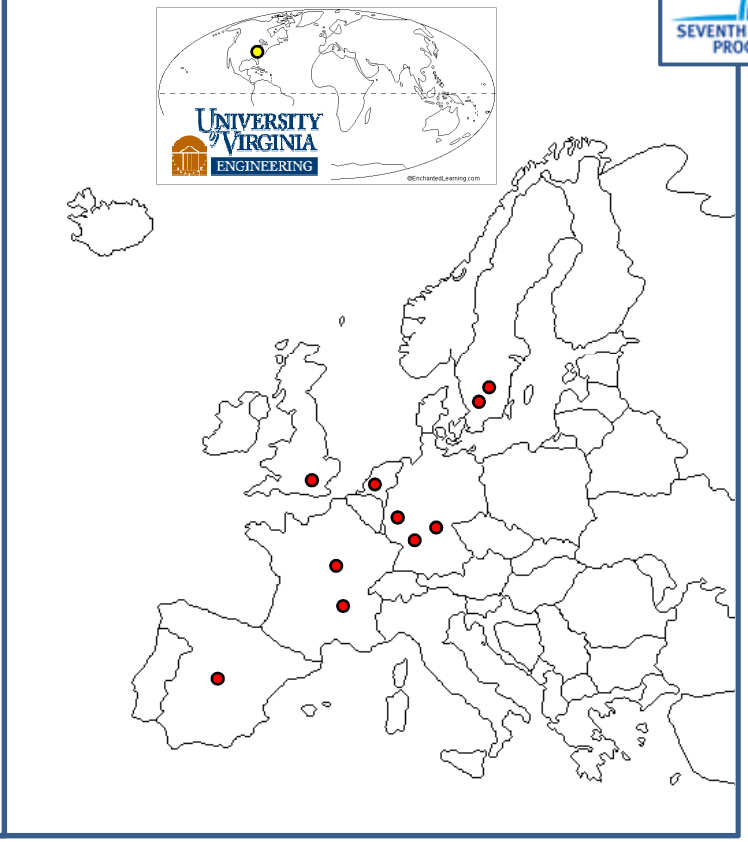
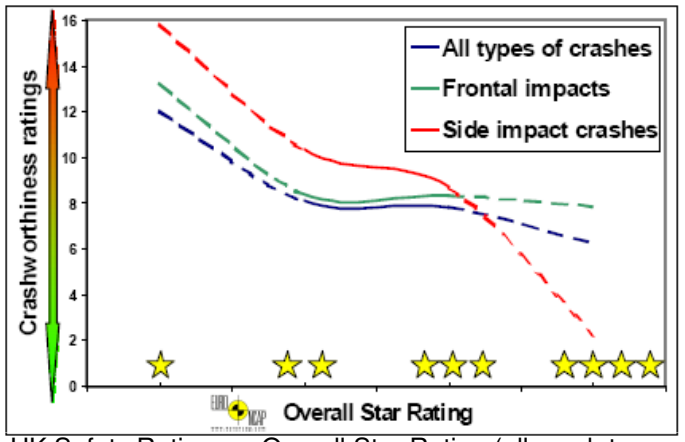


SEVENTH FRAMEWORK PROGRAMME

Background

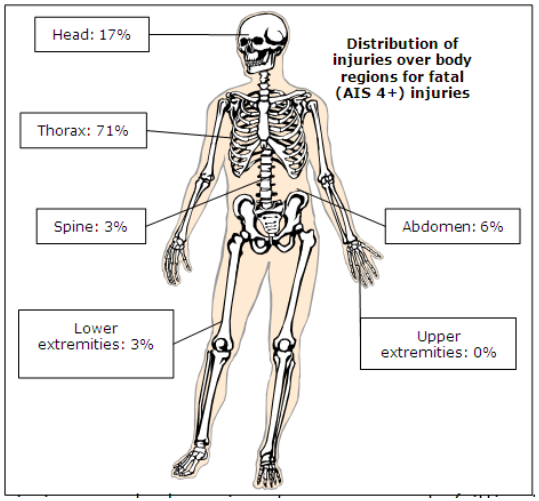
- The trend of increasing performance of vehicles in consumer rating programs is in contradiction with observations from accident data
- This is due to several reasons among which the usage of Hybrid III dummies that were developed in the late 70ties
- HIII thorax was designed to assess injury risk related to localized hub type loading of an adult male



UK Safety Rating vs. Overall Star Rating (all crash types

- 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
- This is also true for combined active / passive systems

Objectives



The aim of the THORAX project is to develop numerical and experimental tools for the optimisation and asessment 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 a THOR NT dummy
- Development of injury risk functions for the hardware demonstrator and HBM's
- Assessment of the sensitivity of the hardware demonstrator to modern vehicle safety systems and usability in safety system optimization

Project Structure

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

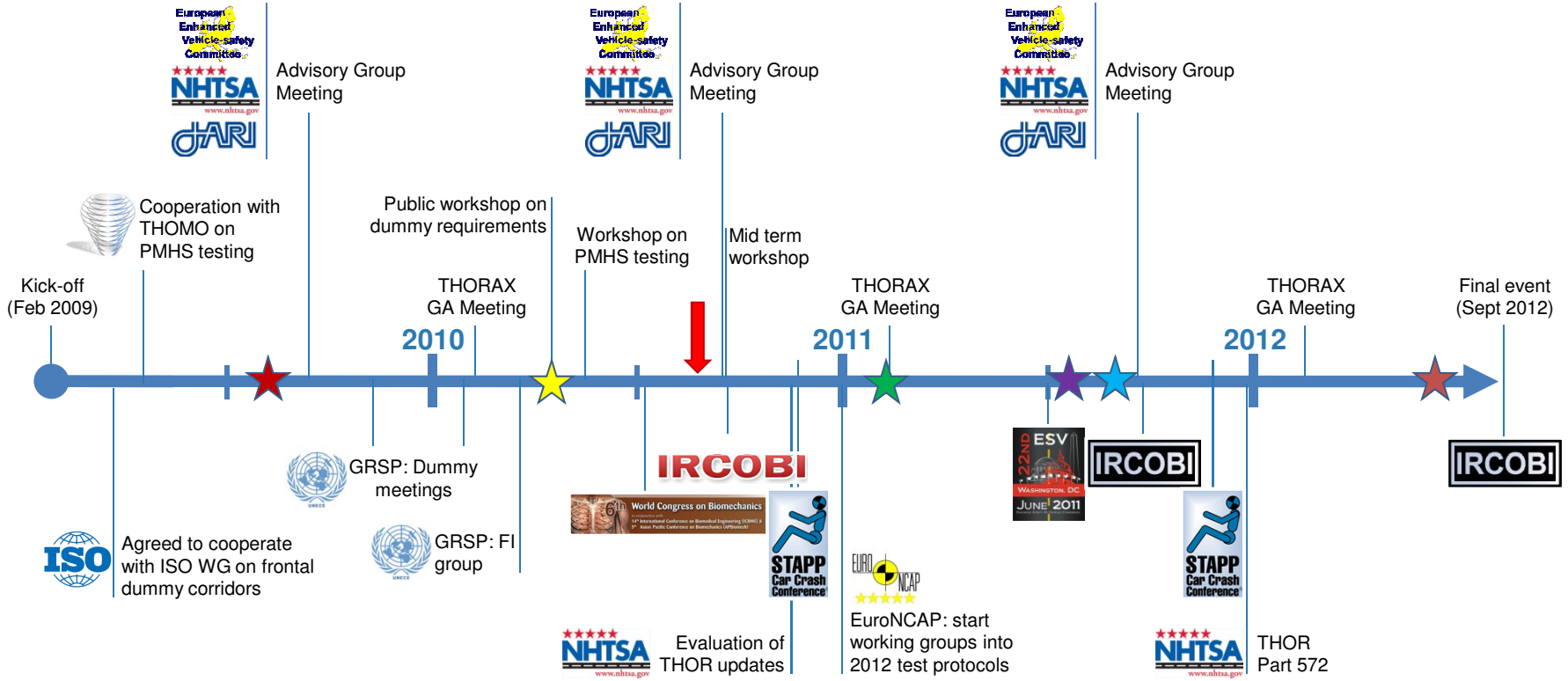
WP3: Demonstrator design

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

WP4: Assessment for restraint optimization

- Load cases and evaluation criteria
- Testing
- Data analysis

Milestones and Timeline



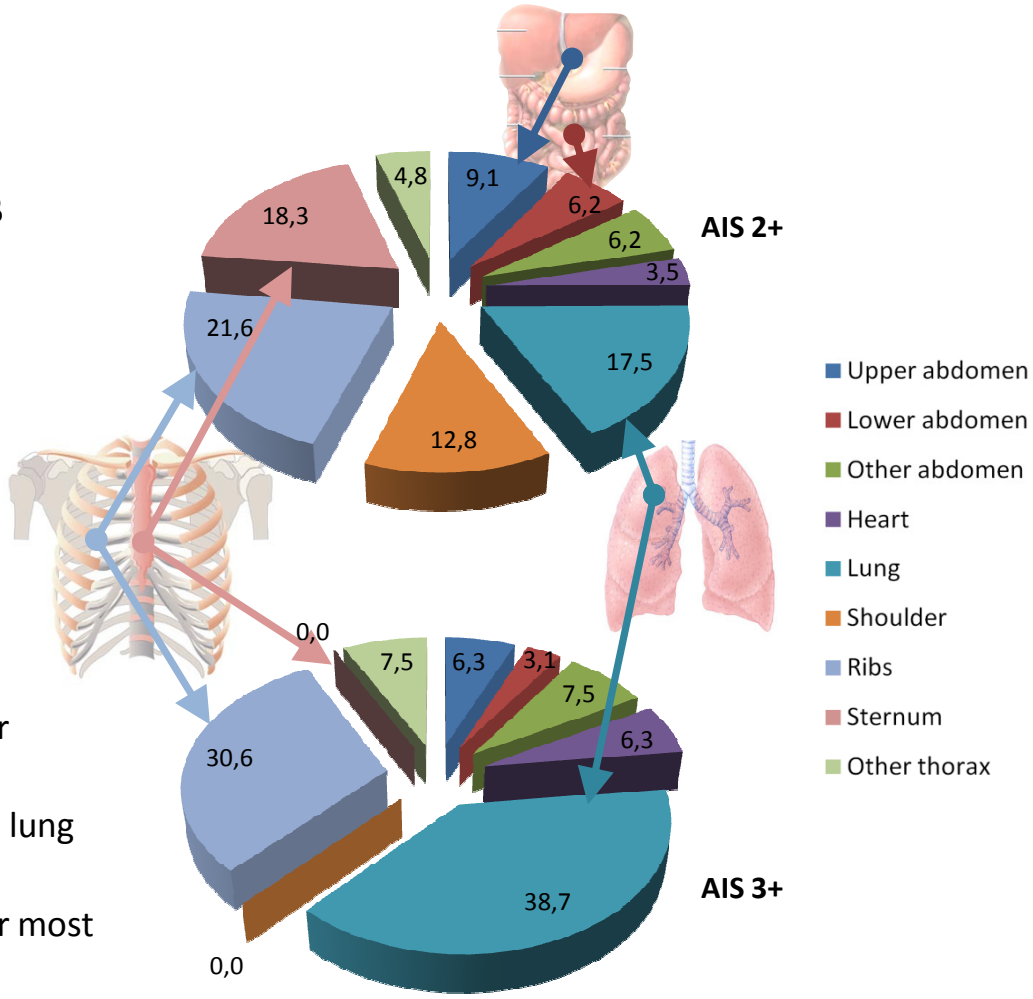
- M1: Two most relevant thoracic injury types identified
- M2: Design specification thorax / shoulder complex
- M3: Prototype thorax / shoulder complex available for testing
- M4: Prototypes validated against biomechanical requirements
- M5: Dummy and HBM injury risk curves available
- M6: Dummy sled tests completed and data analysed

WP1 Accident surveys

Accident survey in GIDAS, CCIS, OTS and LAB

- Two most frequent thoracic injuries are:
  - Rib fractures
  - Lung injuries
- Of secondary importance are:
  - Shoulder injuries
  - Sternum fractures

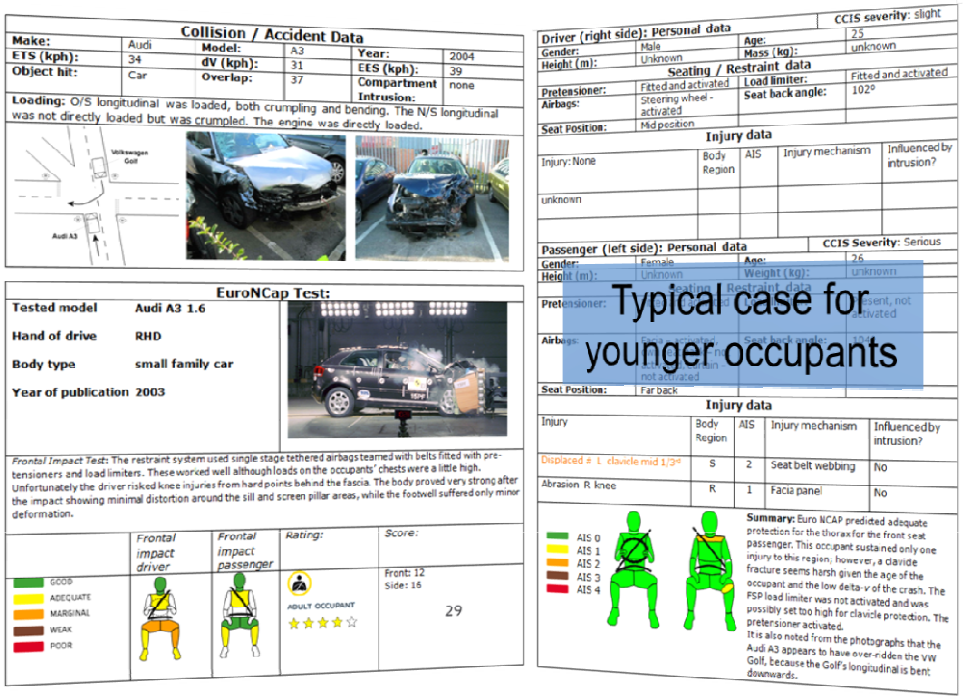
- Also
  - Risk of thoracic injury is greater for older occupants than younger occupants
  - Younger occupants can sustain a serious lung injury without serious rib fractures
  - Load limiters reduce the risk of injury for most AIS3+ injuries
  - 4kN load limiters are much more efficient than 6kN load limiters
  - Accidents with widely distributed loading to the car front are most likely to cause torso injuries



Distribution of thoracic injuries AIS 2+ (top) and AIS 3+ (bottom)

WP1 Comparison accident cases / EuroNCAP test

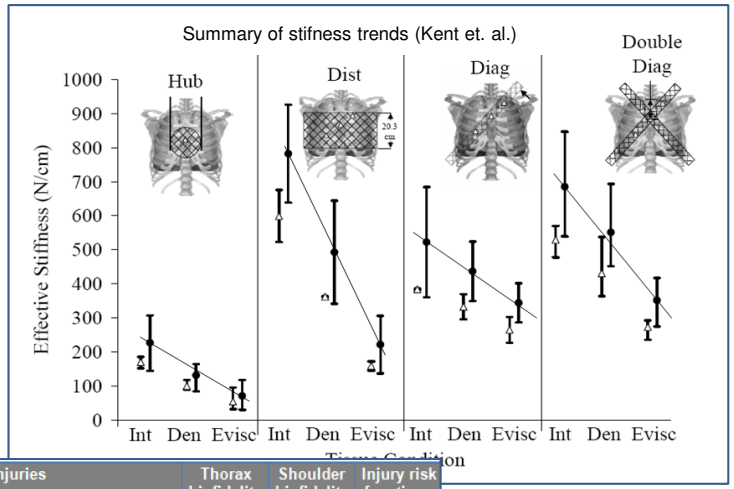
34 cases from GIDAS & CCIS selected based on their similarity with EuroNCAP test



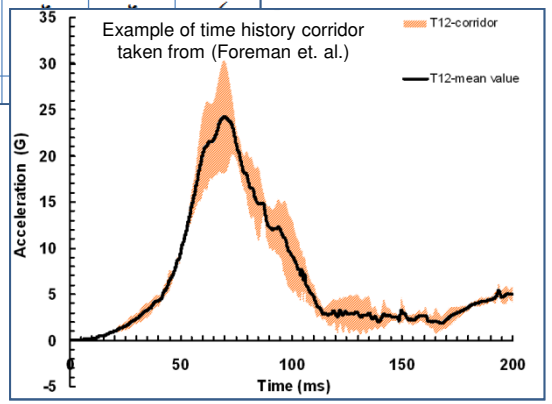
- Thoracic injuries mainly result from belt loading
- Front seat passengers are at higher risk than drivers
  - As front seat passengers are mostly female a "female" dummy should be used at the passenger position in combination with a "male" driver
- Protection of younger occupants in offset frontal crashes is generally good
  - Positive influence of Regulation 94 and Euro NCAP
  - There is an effect of age and injury risk curves for various ages should be developed

WP2 Biomechanical requirements

- Dependency of thoracic response to loading type
- Large number of datasets checked on their applicability
  - 13 sets found to be relevant ➔ some provided with corridors
  - 11 sets potentially relevant
- Issue: scaling method to be applied
- Cooperation with ISO group on frontal dummy corridors



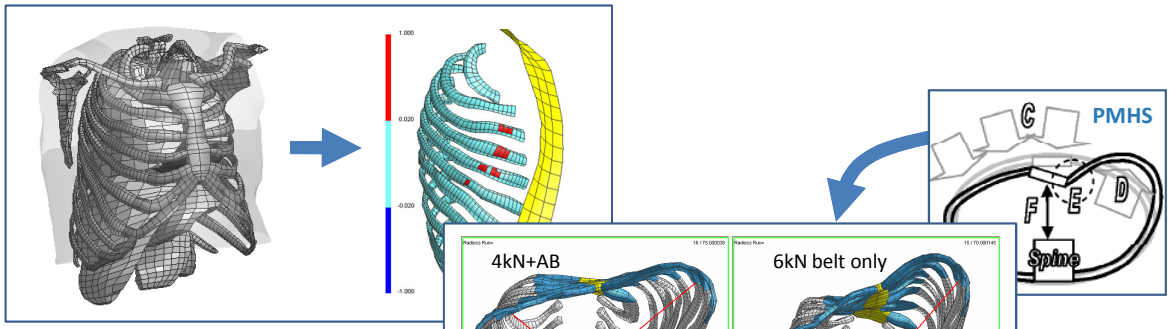
Author / Appendix	Description	Restraints	Chest compression measurement	Shoulder displacement measurements	Injuries	Thorax biofidelity requirements	Shoulder biofidelity requirements	Injury risk functions
Shaw *et al.* (2009) / App A	Sled tests. 8 PMHS, of which 6 meets the inclusion criterion, at 40 km/h in rigid/cable seat	3-point belt (separate lap and shoulder belt)	Multiple 3D-film targets on rib cage, sternum and along the spine and accelerometer arrays	Three-dimensional film targets on shoulder (left and right acromion)	5 rib fractures in average, clavicle fractures in 2 and 1-2 sternum fractures in all but one subject	✓	✓	✓
Petitjean *et al.* (2002)	Sled tests. 4 PMHS at 64 km/h using production seat and restraints	Force limited 3-point belt and airbag combinations	Not available	Not available	15 rib fractures on average	×	×	✓
Vezin *et al.* (2002)	Sled tests. 6 PMHS, of which 5 PMHS meets the inclusion criterion, at 30 km/h and 50 km/h using a and rigid seat and commercial restraint systems	Force limited 3-point belt (separate lap and shoulder belt) and force limited 3-point belt with an airbag	Spine accelerometer data only	Not available	6 rib fractures in average for the airbag test and 2 rib fractures in average for the belt only tests			
Cavanaugh	Table top tests. Static.	Chest loading plate;	Chest	None	Sub-injury and injury level			

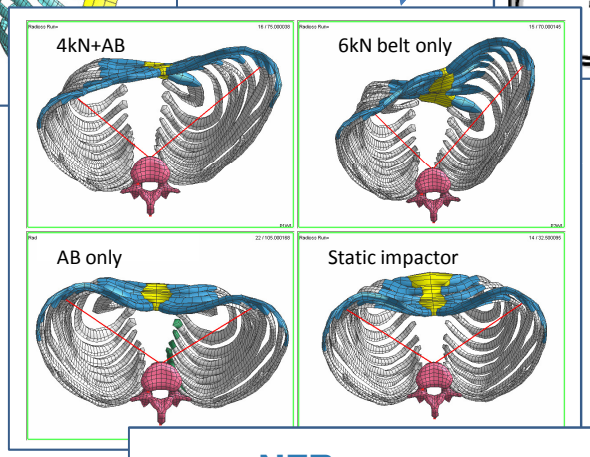


Full set of response corridors to be delivered February 2011

WP2 Injury mechanism and assessment criteria

Studies into rib fractures using validated Human Body Models

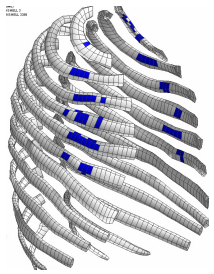




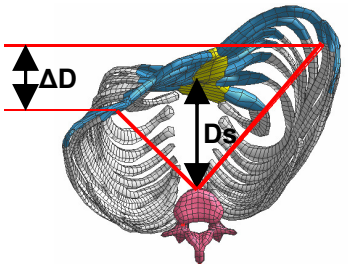
- bending is the main loading mode leading to rib fracture
- Analysis of various load cases resulted in proposals for two new criteria:
  - Combined Deflection Dc
  - Number of Fractured Ribs NFR

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

NFR



Dc



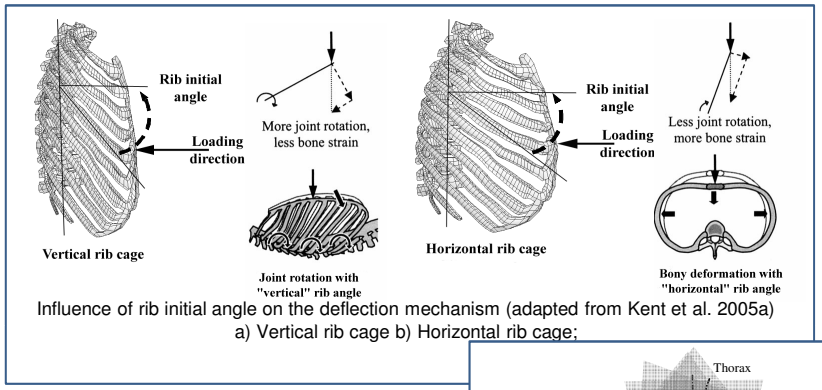
Combined deflection Dc:

$$Dc = Ds + c_f\,[(\Delta D - L_c) + |\Delta D - L_c|]$$

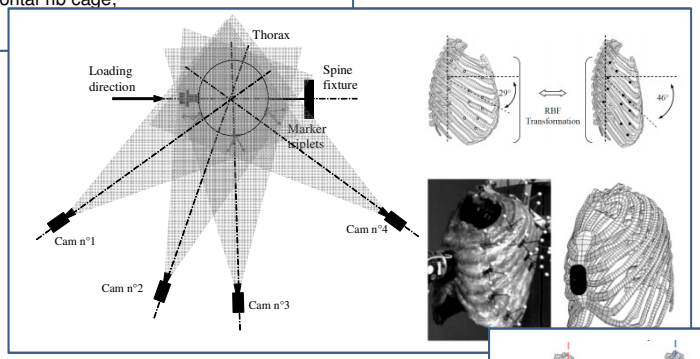
Ds = Mid sternal deflection
ΔD = Lower thorax differentail deflection
L_c = Characteristic length
c_f = correction factor

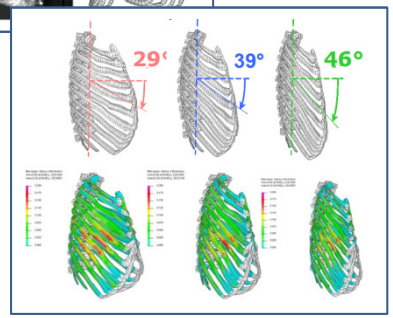
WP2 Influence of rib cage geometry

Combined experimental – numerical approach to study influence of internal thorax (rib cage geometry and joints) parameters on the injury mechanism



Influence of rib initial angle on the deflection mechanism (adapted from Kent et al. 2005a)
a) Vertical rib cage b) Horizontal rib cage;



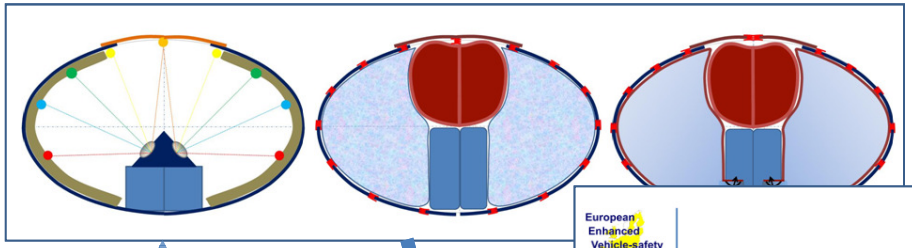


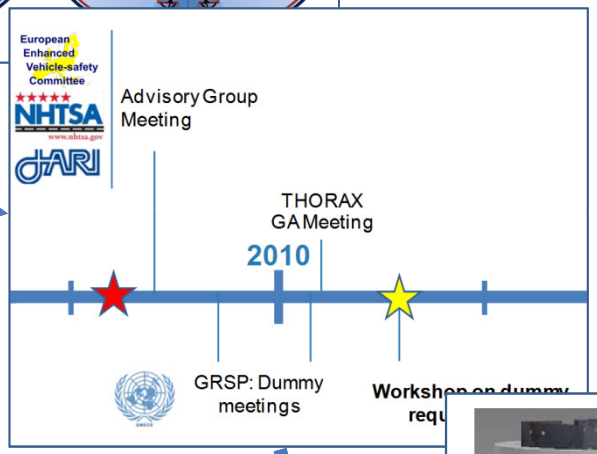
Approach will be used to support further studies into the injury assessment criteria and development of risk curves

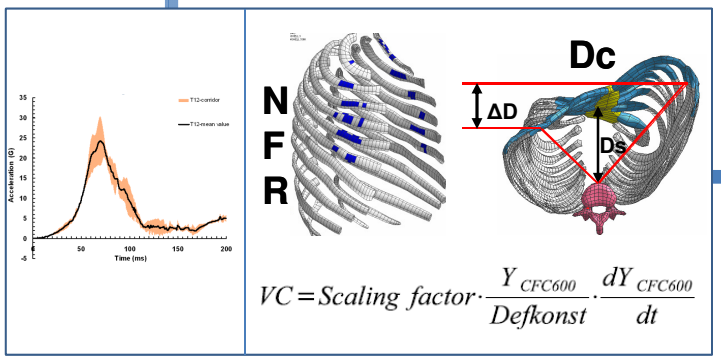
- PMHS testing with advanced tracking system for 3-D deformation measurements
- Personalised FE models for each subject
- Allow to isolate geometry from other parameters like material properties and cross section thickness
- Initial studies on isolated rib cages show that the rib cage morphologie (e.g. orientation, curvature spine, curva rib and their distribution) is influencing the response
- Influence of internal organs investigated by future PHMS tests in THORAX

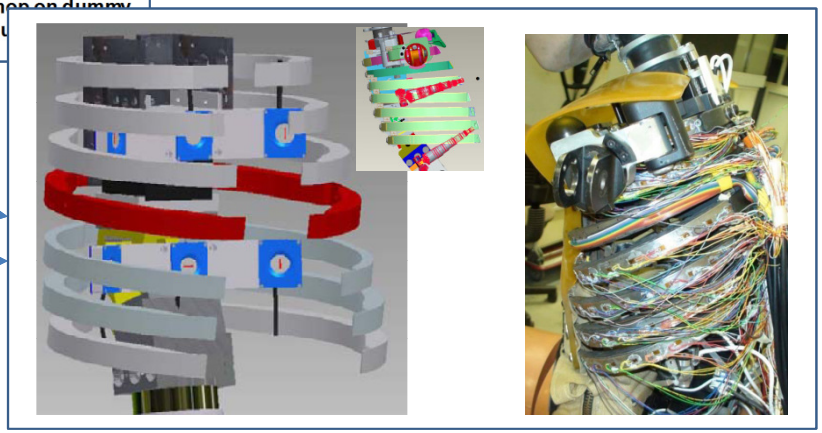
WP3 Dummy concept design

Concepts of different level of complexity developed and discussed with Stakeholders from Governments & Industry









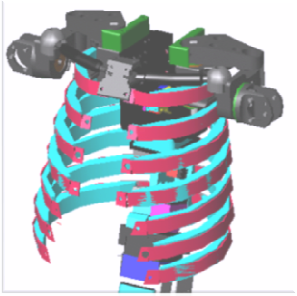
Recommendations:

- Base design on 2010 THOR NT
- Include instrumentation to study proposed & existing assessment crit.
- Allow for minor updates like chest stiffness redistribution and shoulder design (introduce SD Shoulder)

Outlook

Key work items for next period

- Completion of the biomechanical requirements by Jan 2010
- WP3 to deliver 2 prototype dummies to partners for testing of biomechanical performance in Jan 2011
- Development of Injury Risk curves by Dec 2011
  - Risk functions of humans (considering diversities)
  - Risk functions HBM's
  - Risk functions of hardware demonstrator
- Sled testing to assess dummy performance for restraint optimisation Aug 2011 – June 2012



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