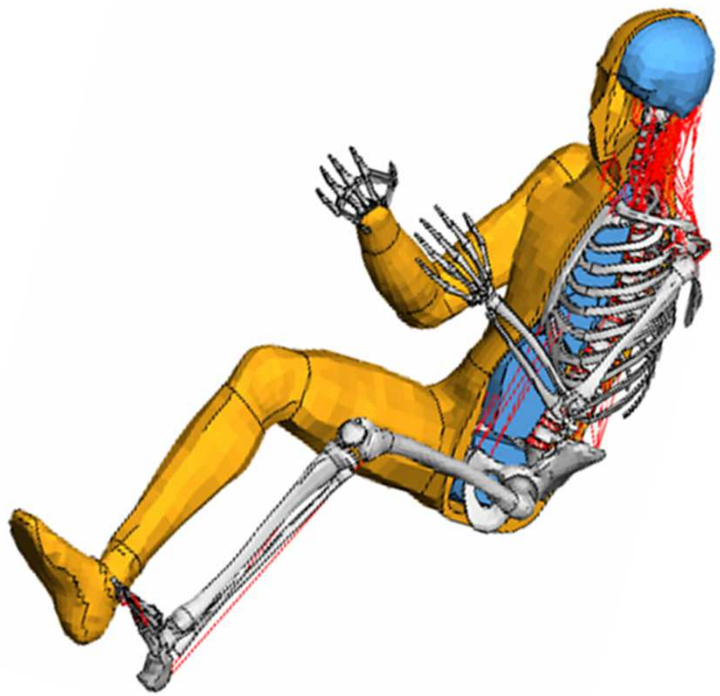
FFI Resultatkonferens 17/9 2019

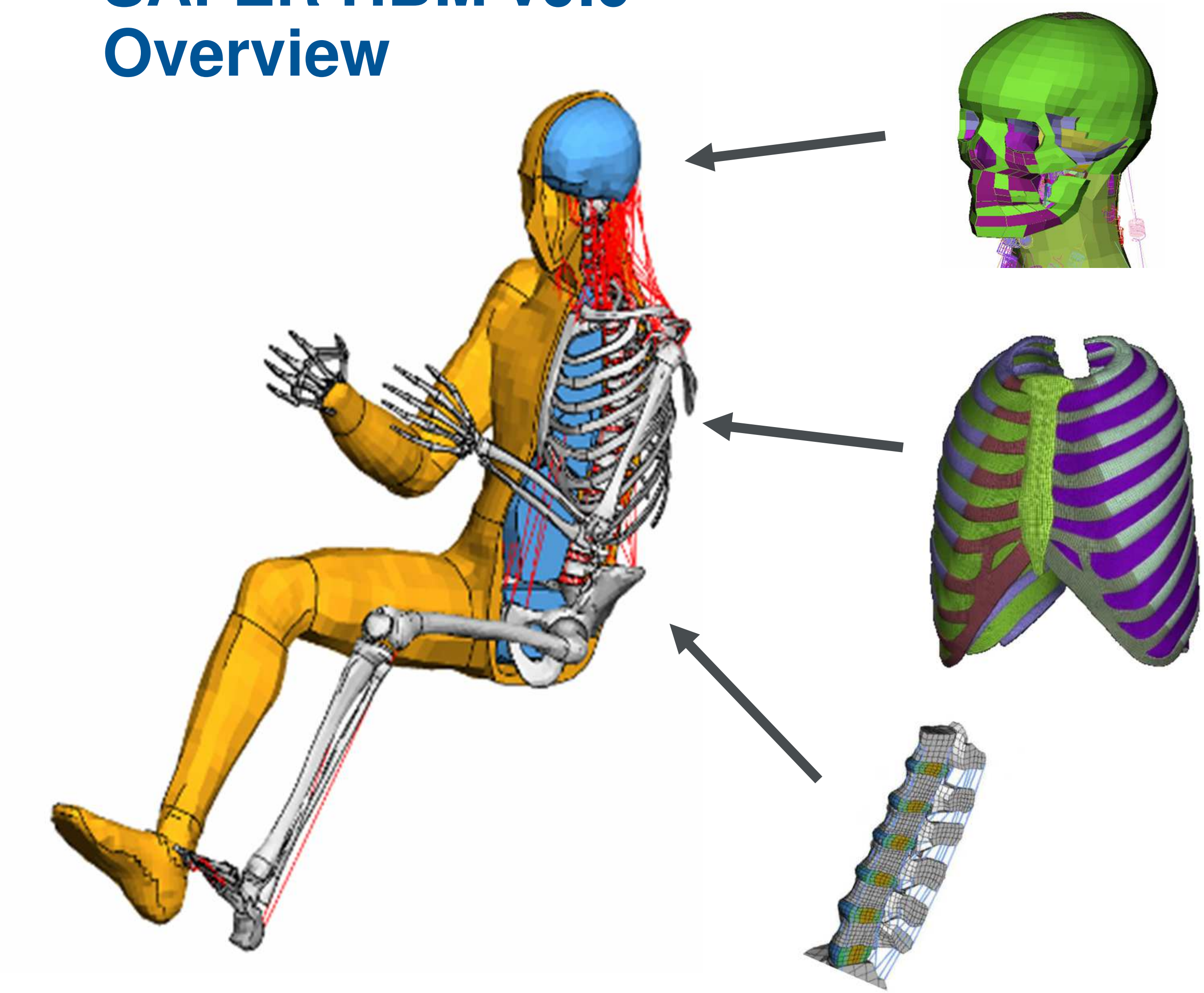
Humanmodellering:
Var är vi och vart är vi på väg?



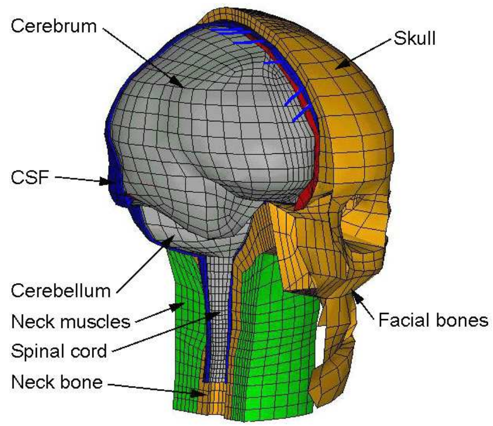
Bengt Pipkorn

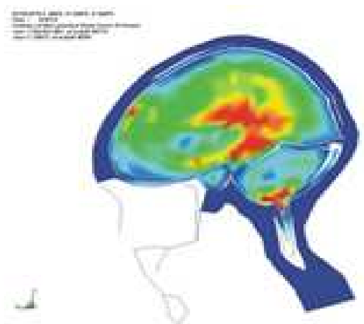
190917

SAFER HBM v9.0
Overview



KTH head modell

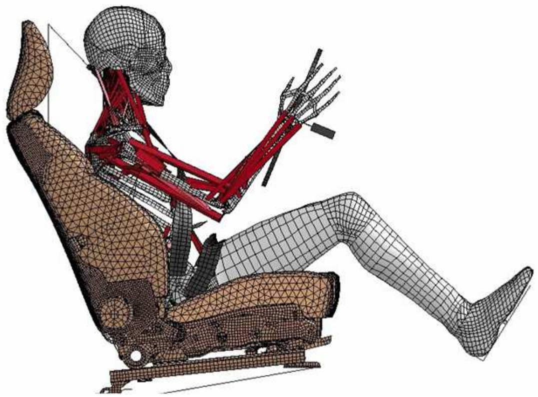


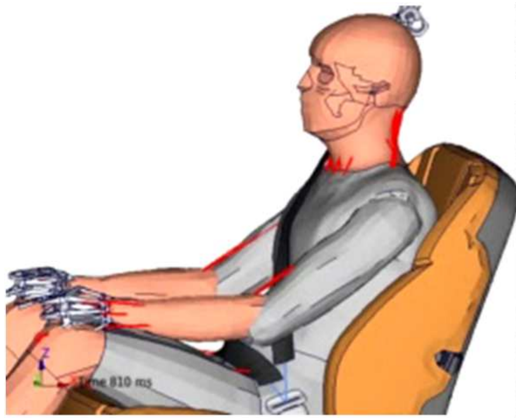


Status SAFER HBM v9.0

The SAFER HBM is a 50%-ile morphable Human Body Model with active and passive properties for combined pre-crash and in-crash and only in-crash analysis

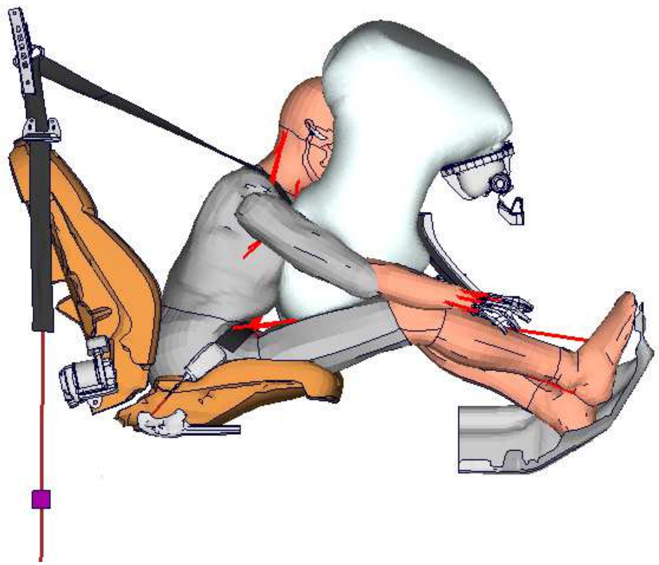
Standardised pre- and postprocessing to minimize analysts influence on results and conclusions





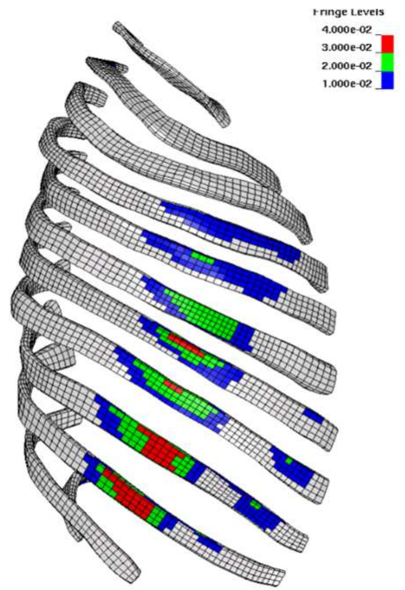
Status Active SAFER HBM v9.0 – Capabilities
In-Crash Analysis

- Predicts both driver and passenger kinematics
- Omnidirectional – Predicts occupant kinematics for frontal to lateral load
- Predicts the risk of
  - rib fractures based on occupant age
  - concussions (AIS1 & AIS2)
  - lumbar spine fractures

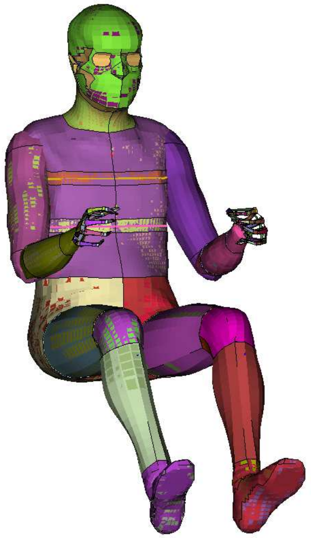


Status SAFER HBM v9.0 - Capabilities
Combined Pre-Crash and In-Crash Analysis

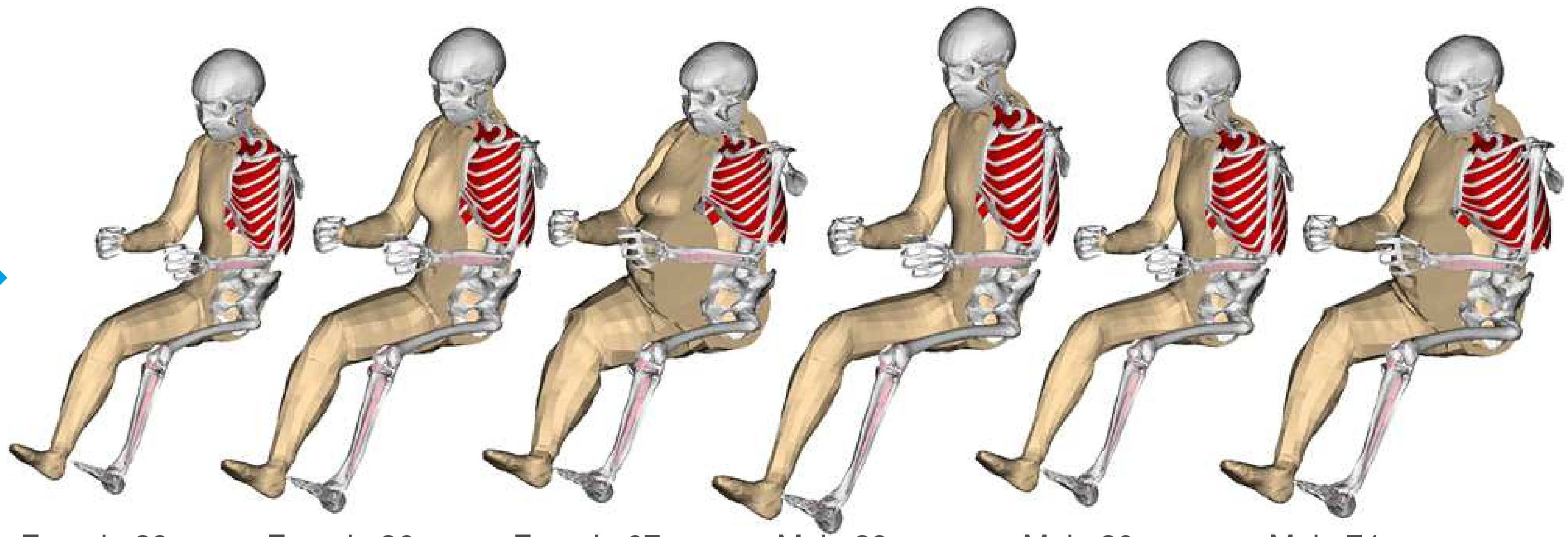
- Predicts driver and passenger kinematics in pre-crash braking followed by crash (from frontal to lateral crash)
- Predict passenger kinematics in pre-crash avoidance maneuvers followed by crash (from frontal to lateral crash)
- Predict the risk of
  - rib fractures based on occupant age
  - concussions (AIS2 & AIS2)
  - lumbar spine fractures



Status SAFER HBM v9.0 - Capabilities
Seamlessly Morphable to Any Adult Human Anthropometry

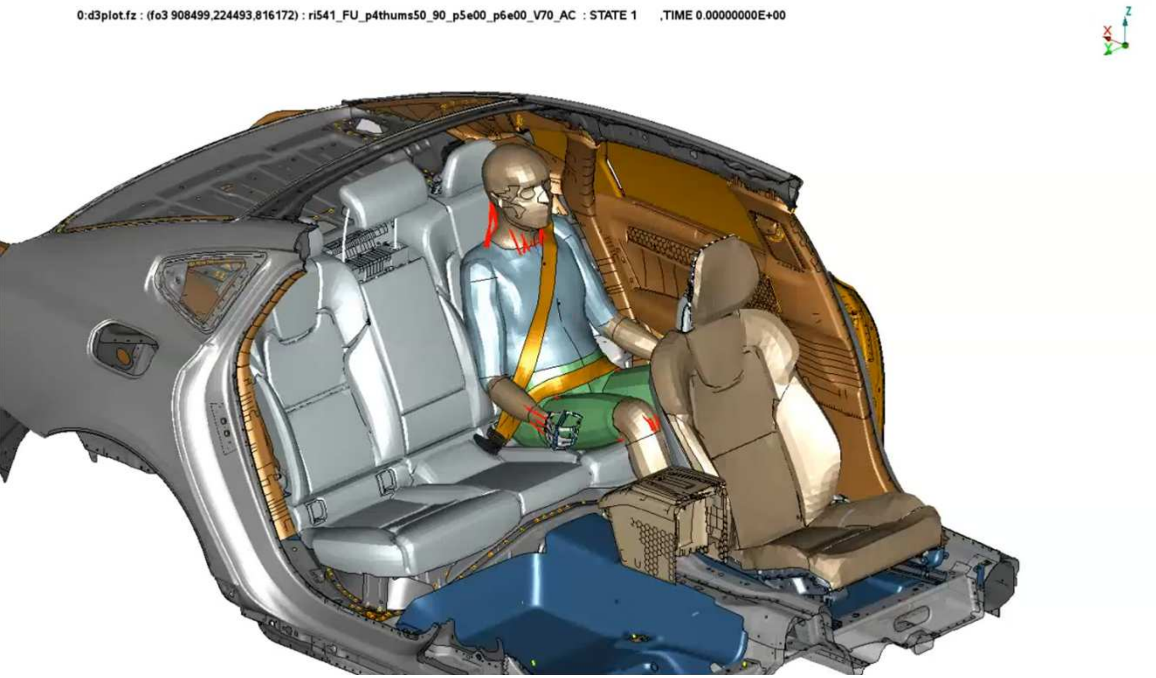


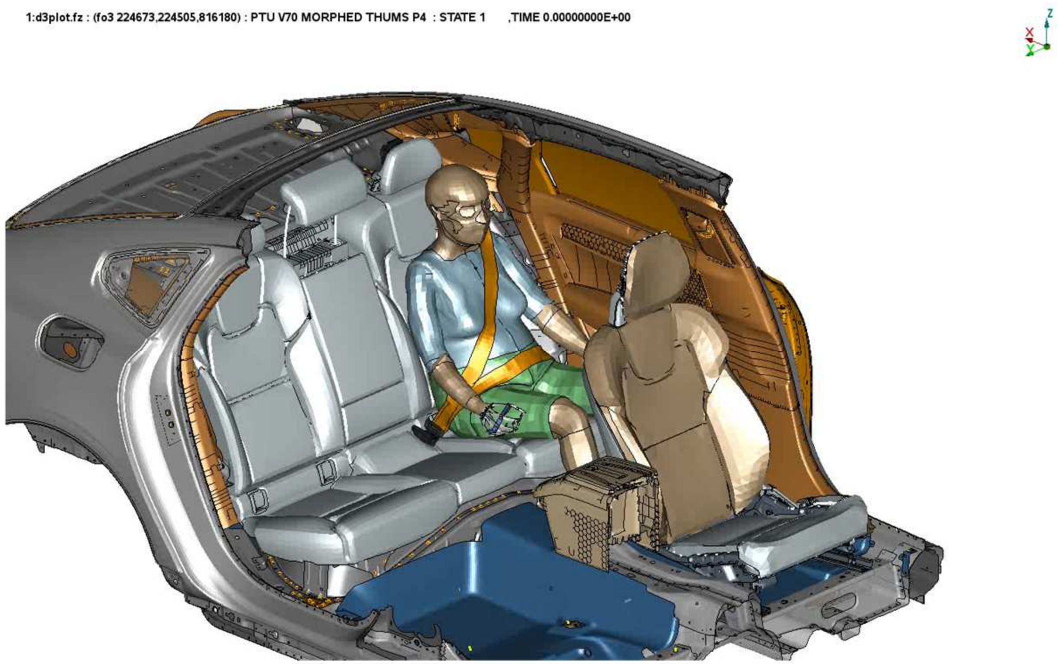
50th percentile male HBM



Female 29yr	Female 36yr	Female 67yr	Male 29yr	Male 20yr	Male 74yr
149cm 48kg	163cm 77kg	153cm 107kg	192cm 74kg	161cm 52kg	166cm 109kg

Example Morphed SAFER HBM:
85 Year Old, Female, 153 cm, BMI of 26





Long Term Goal
Human Body Modelling

A biofidelic tool to predict human complex pre-crash and crash kinematics incl multiple impacts and run off road events.

The tool is to predict the most common moderate to fatal and disabling injuries for the diverse population.

A tool useful for development of countermeasures and support of rating and legal programs

Summary of Development of Implementable omni-directional chest and spine criteria for human body models

Aim

To validate on a multi-scale level the capability of the SAFER HBM to predict the risk for an occupant to sustain two or more fractured ribs (NFR 2+)

Data Sources for Validation of the Capability of the Model to Predict 2 or more Fractured Ribs

PMHS Tests

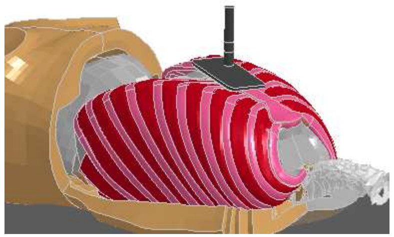
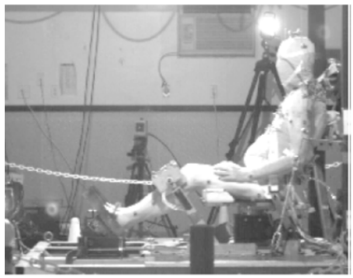
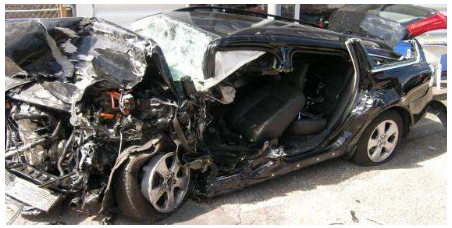


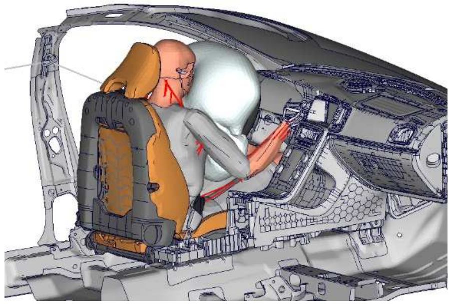
Table Top



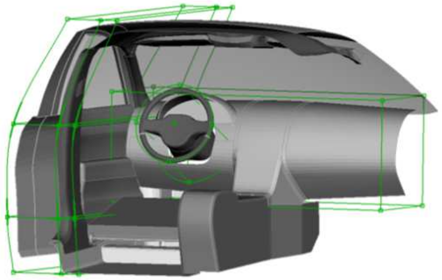
Sled

Detailed Reconstructions

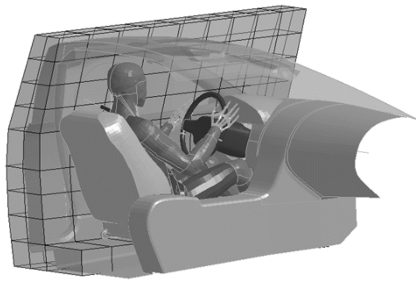




Population Reconstructions

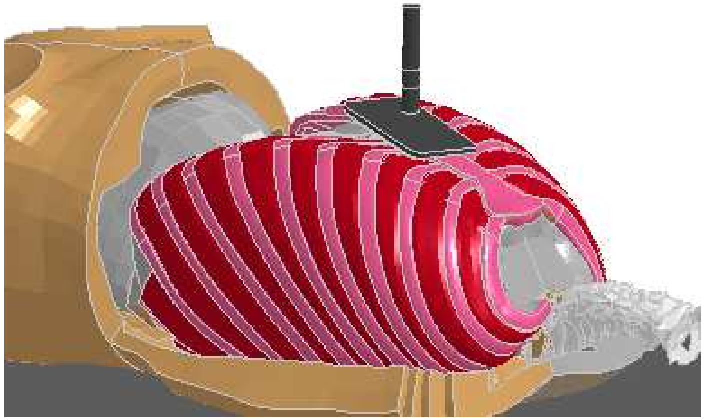


Frontal Impact



Side Impact

PMHS Table Top Tests



5 denuded PMHS thoraxes

Rigid indentors, covered by rubber

indentor speed was 1 m/s

Strokes were either 18-30mm (non-injurious) or 80mm (injurious)

Injurious tests at least 2 fractured ribs were received by both test subjects

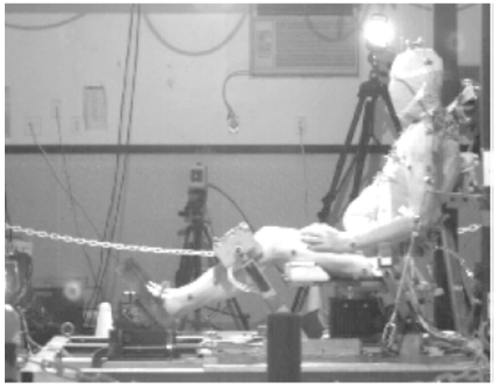
PMHS Sled Tests

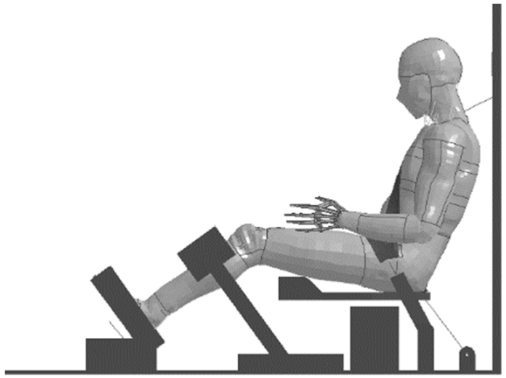
Ford Taurus 1999

3 Subjects

Dv 30km/h

3-pt belt



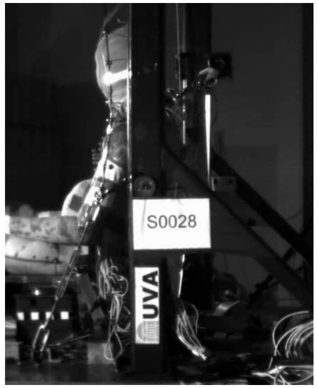


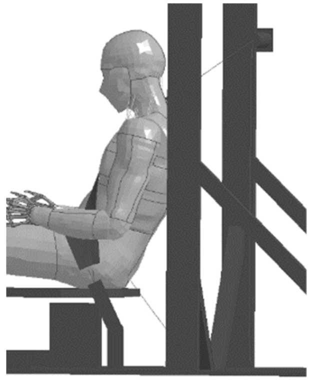
Gold Standard

8 Subjects

Dv 40km/h

3-pt belt





Gold Standard Modified

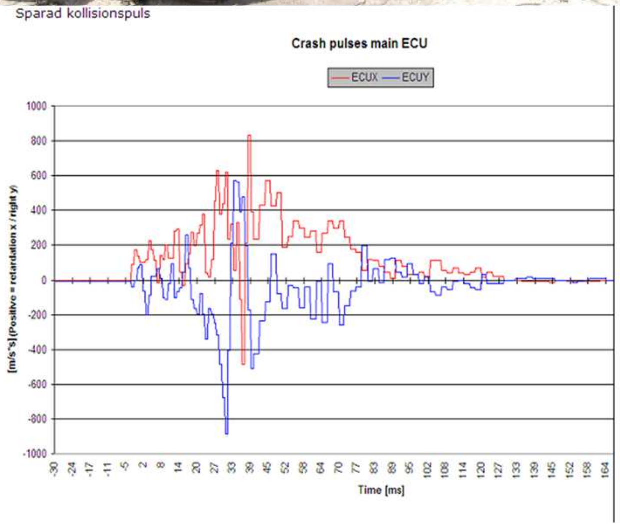
2 Subjects

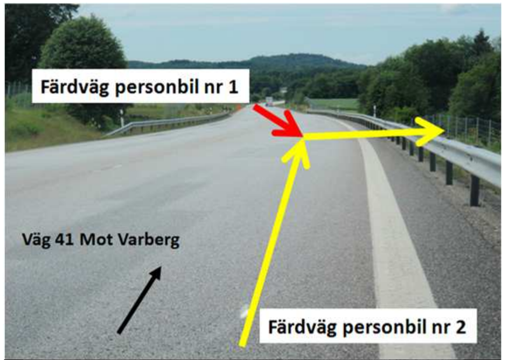
Dv 30km/h

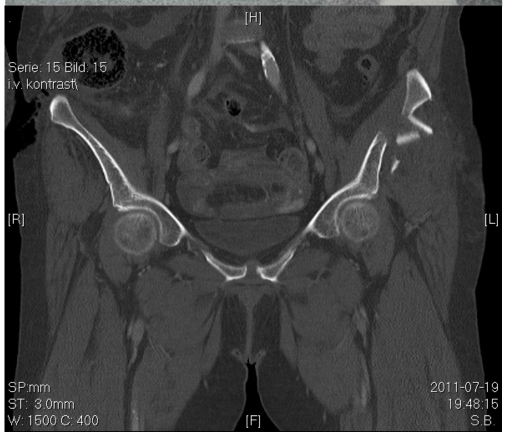
3-pt belt

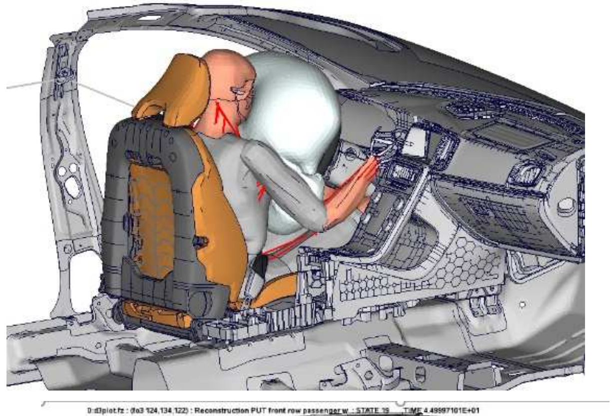
Pretensioner & Load Limiter

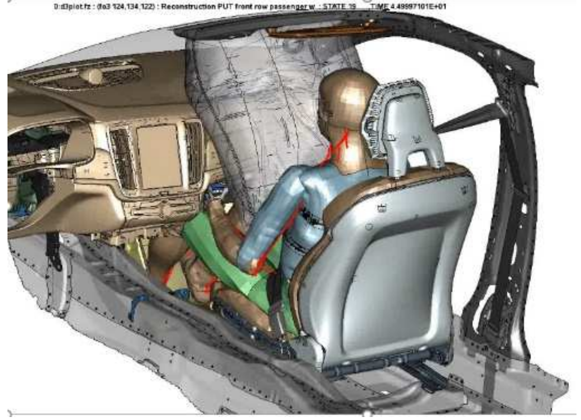
Detailed Reconstructions







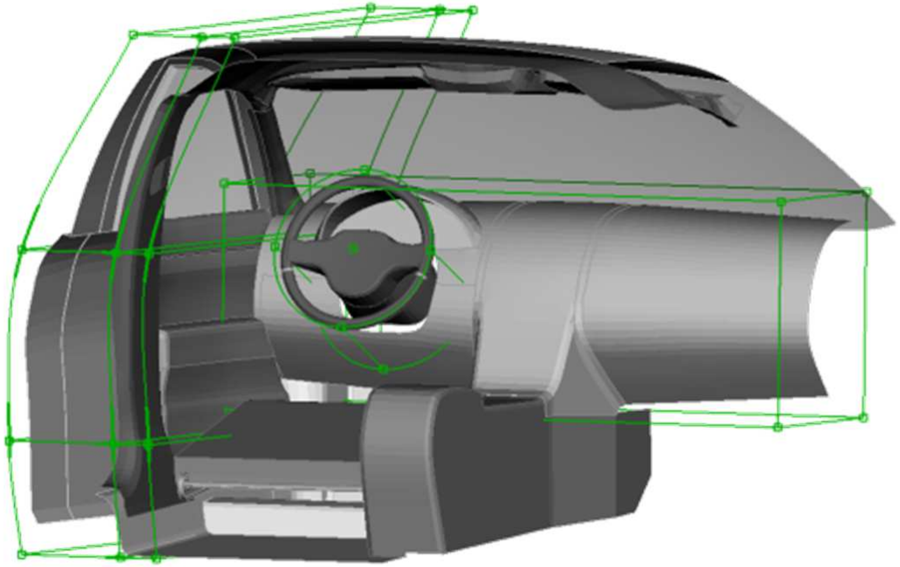


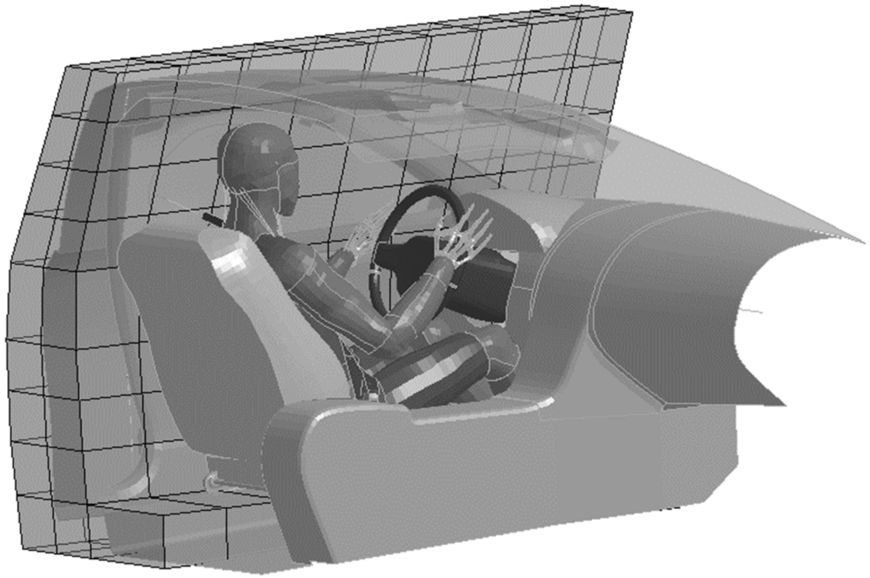


Detailed Reconstruction Cases
50%-ile SAFER HBM

	Sex	Position	Age	Height (cm)	Weight (kg)	BMI	Impact Type	DV (km/h)	Overlap (%)	Direction
1	Male	Driver	67	178	79	25	Frontal	49	25	12
2	Male	Driver	81	-	84	-	Frontal	53	25	11
3	Female	Passenger	82	-	70	-	Frontal	53	25	11
4	Male	Driver	44	180	80	25	Frontal	58	80	12
5	Male	Driver	44	165	65	24	Frontal	53	30-50	11
6	Male	Driver	67	-	-	-	Frontal	77	100	-
7	Female	Passenger	62	-	-	-	Frontal	83	30-50	11
8	Female	Rear Seat	85	153	61	26	Frontal	83	30-50	11
9	Male	Driver	79	186	91	26	Frontal	42	30	-
10	Male	Driver	42	-	-	-	Frontal	64	34	11
11	Male	Driver	19	-	-	-	Side	75		
12	Male	Driver	42	170	80	28	Frontal	70	65	9
13	Male	Driver	46	-	-	-	Frontal+Run-Off	34	80	12
14	Female	Driver	52	168	67	24	Frontal	54	70	11
15	Male	Driver	39	182	70	21	Frontal	64	65	-
16	Female	Passenger	37	163	63	24	Frontal	64	65	-
17	Female	Driver	38	170	90	31	Frontal+Run-Off	39	20	11
18	Male	Passenger	34	188	94	27	Frontal+Run-Off	39	20	11
19	Male	Driver	42	-	-	-	Frontal	65	-	-
20	Male	Driver	22	-	-	-	Frontal	90	Mid (Tree)	-

Population Based Reconstructions





NASS/CDS database containing cases with both injured and uninjured occupants
one for frontal impacts and one for lateral impacts
Model year later than 1999

n=5083 cases (1,474,869 cases weighted)
185 occupants (17,810 occupants weighted)
rib fractures (AIS2+)

Belted front seat occupants, near side, deployed bag.

n=569 cases (166,209 cases weighted)
60 occupants (3,495 occupants weighted)
rib fractures (AIS2+) for the lateral analysis

Population Based Reconstructions
Statistical Distributions

Interior safety system parameters:

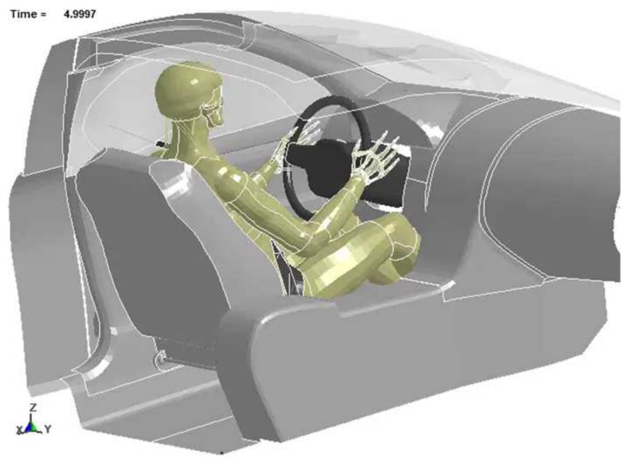
- Airbag size
- Airbag pressure
- Airbag TTF
- Steering column collapse force
- Belt pretensioner force
- Belt load limiter force

Boundary condition parameters:

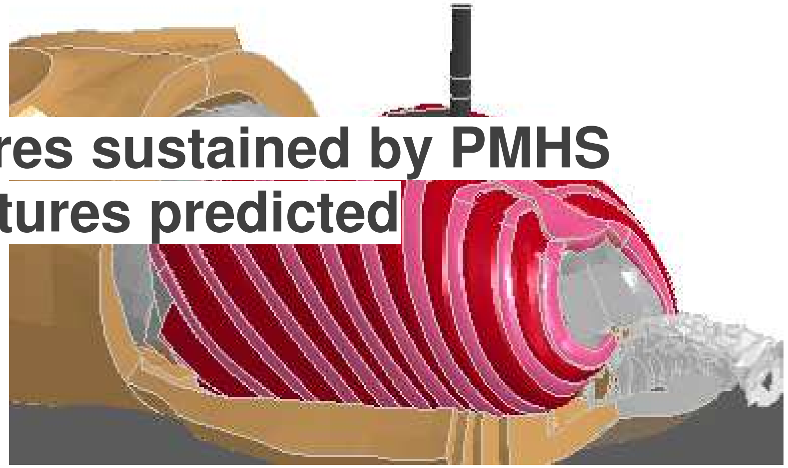
- Delta velocity
- PDOF
- Pulse duration
- Pulse shape
- IP intrusion
- Footwell intrusion

Vehicle parameters:

- Steering wheel position
- Distance to IP
- Distance to side structure
- IP stiffness
- Friction



Results
PMHS Table Top Tests Validation



Numerous rib fractures sustained by PMHS
0 Risk for 2+ rib fractures predicted

5 denuded PMHS thoraxes

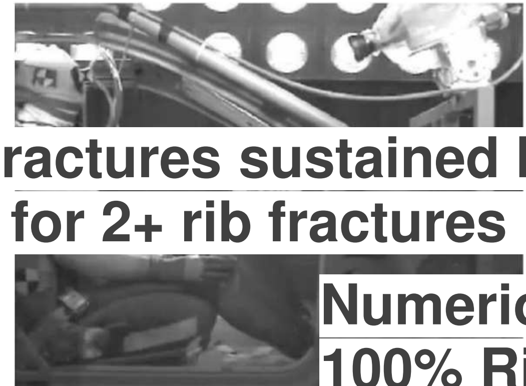
Rigid indentors, covered by rubber

indentor speed was 1 m/s

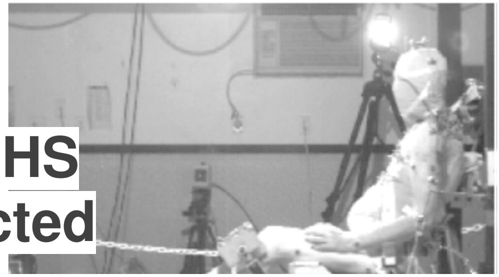
Strokes were either 18-30mm (non-injurious) or 80mm (injurious)

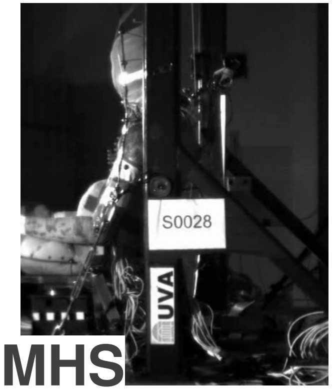
Injurious tests at least 2 fractured ribs were received by both test subjects

Results
PMHS Sled Tests Validation



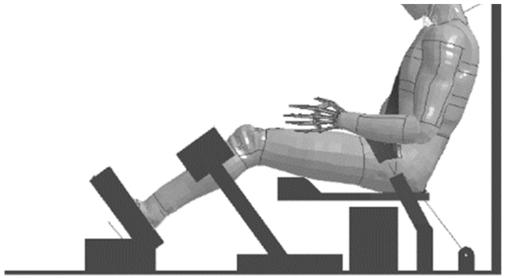
0 Rib fractures sustained by PMHS
0 Risk for 2+ rib fractures predicted





Numerious Rib fractures sustained by PMHS
100% Risk for 2+ rib fractures predicted

0 Rib fractures sustained by PMHS
0% Risk for 2+ rib fractures predicted



Ford Taurus 1999
3 Subjects
Dv 30km/h
3-pt belt

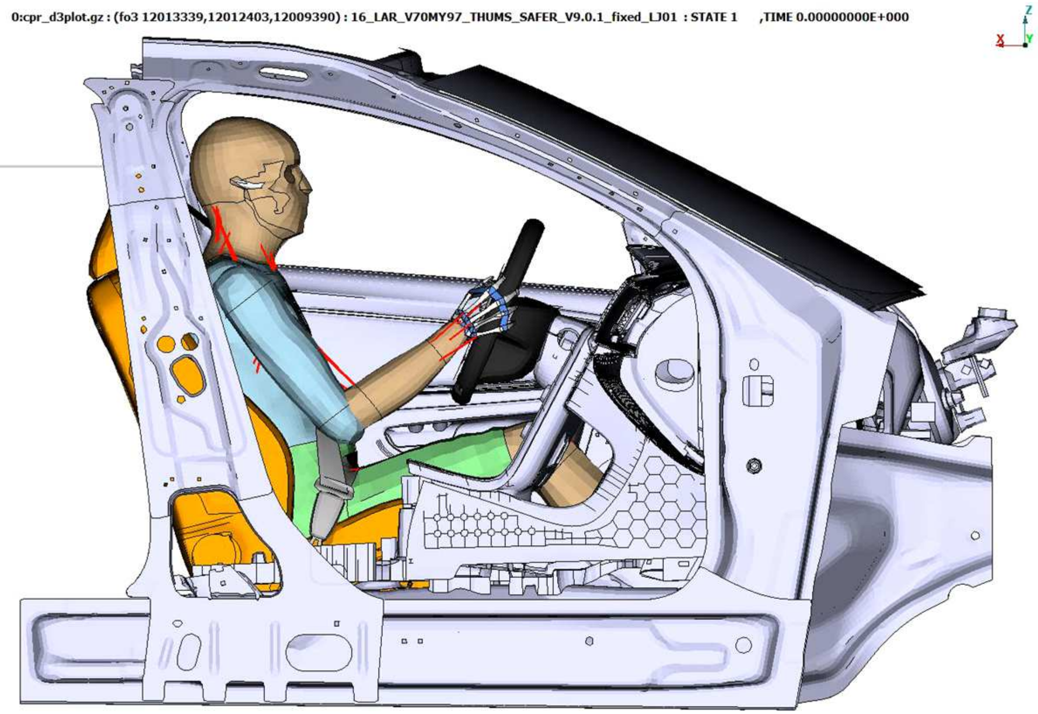
Gold Standard
8 Subjects

3-pt belt

Gold Standard Modified
2 Subjects
Dv 30km/h
3-pt belt
Pretensioner & Load Limiter

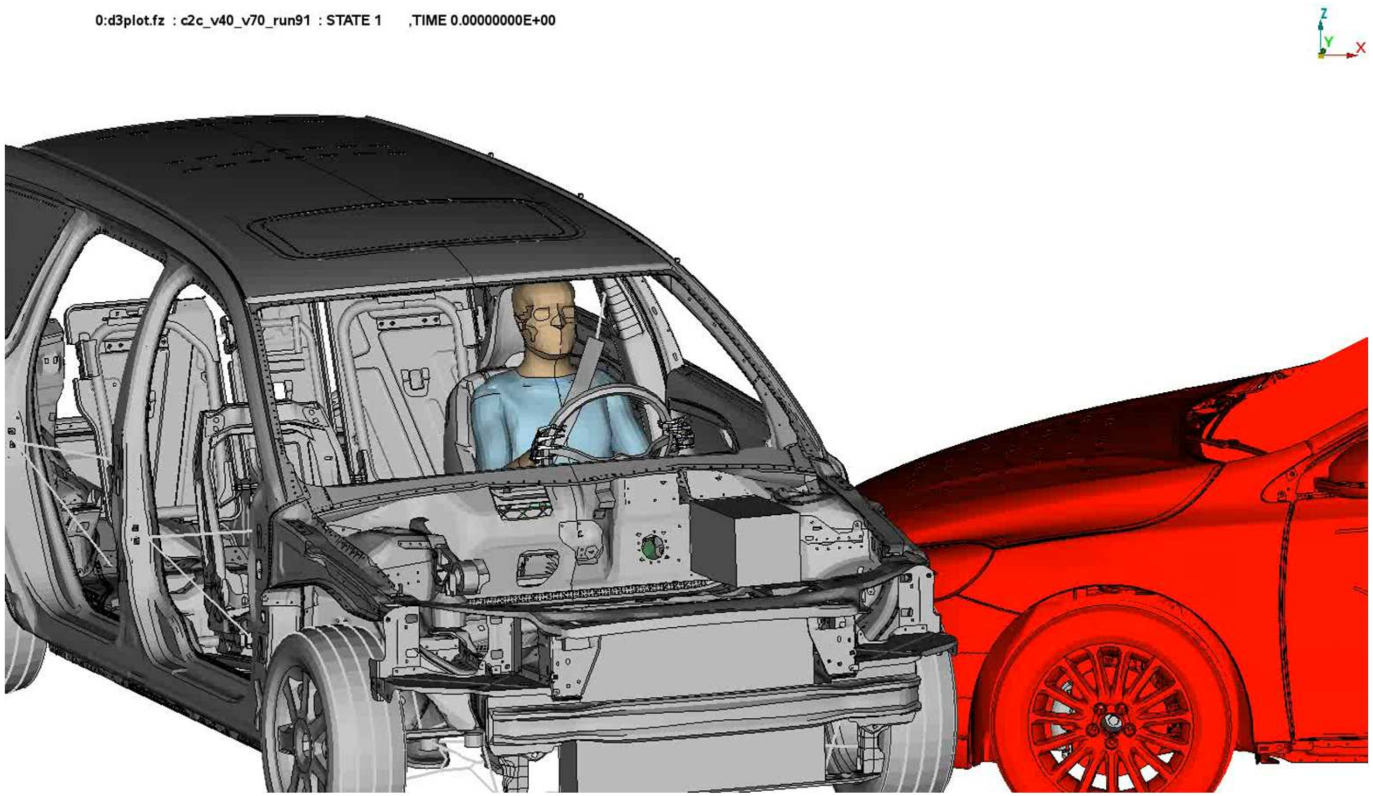
Results
Detailed Reconstructions Male 67 Year Old

Nr	Age	Chest injuries sustained by the occupants	NFR 2+ Risk
6	67	1-2 rib fractures right side (AIS2)	94.7%



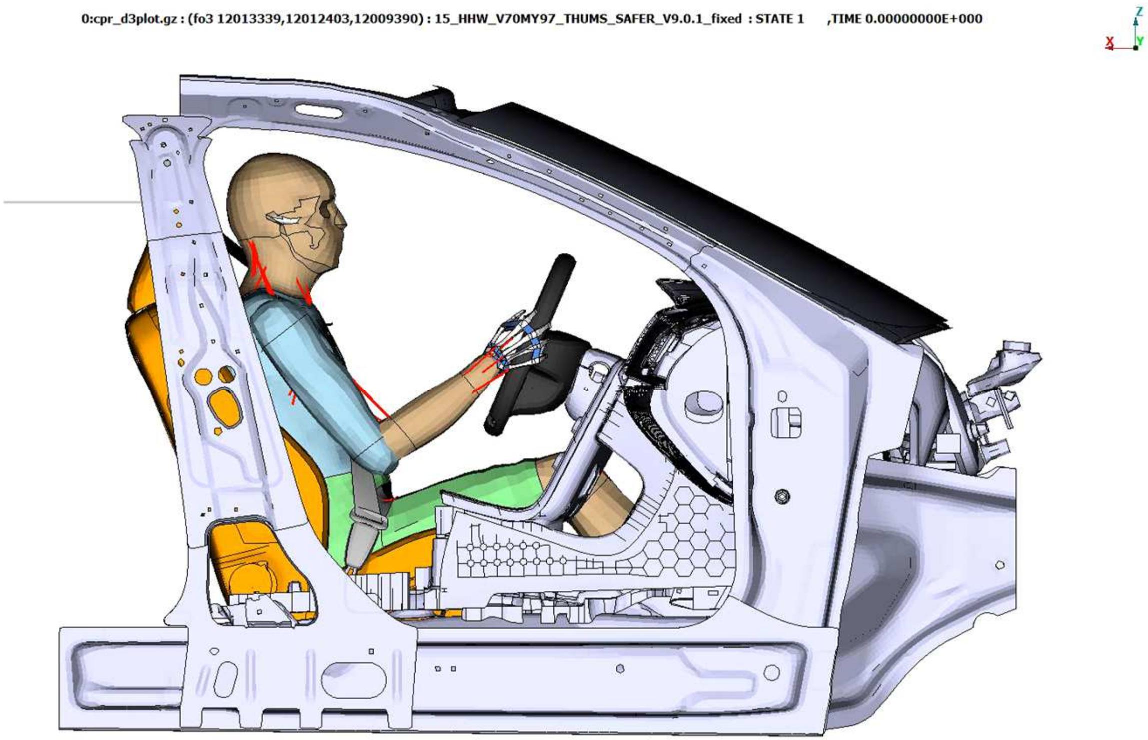
Results
Detailed Reconstructions Male 19 Year Old

Nr	Age	Chest injuries sustained by the occupants	NFR 2+ Risk
11	19	Spleen rupture (AIS3)	34.0%



Results
Detailed Reconstructions Male 42 Year Old

Nr	Age	Chest injuries sustained by the occupants	NFR 2+ Risk
12	42	9 rib fractures (AIS3), 2 sternum fractures (AIS2)	92.8%

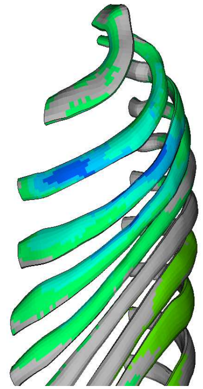


SAFER HBM v 9.0
- Validation of generic ribcage fracture prediction (detailed reconstructions)

Results
Rib Fracture Predictions Detailed Reconstructions

Nr	Age	Chest injuries sustained by the occupants in the accident	NFR 2+ Risk
1	67		0.10%
2	81	Sternum fracture (AIS2)	0.2%
3	82		1.1%
4	44		98.4%
5	44	Lung contusion (AIS3)	86.7%
6	67	1-2 rib fractures right side 1-2st (AIS2)	94.7%
7	62	1 rib fracture left side (AIS1), pneumothorax (AIS2)	76.0%
8	85	Chest contusion (AIS 1), 4 rib fractures right side (AIS 3), pneumothorax (AIS4)	97.0%
9	79		0.3%
10	42		21.7%
11	19	Spleen rupture (AIS3)	34.0%
12	42	9 rib fractures (AIS3), 2 sternum fractures (AIS2)	92.8%
13	46		0.0%
14	52	Chest contusion (AIS1)	6.1%
15	39		5.2%
16	37		28.0%
17	38	1 sternum fracture (AIS2), chest contusion (AIS1)	0.8%
18	34		0.1%
19	42		29.9%
20	22	Bleeding left lung (AIS3)	5.8%

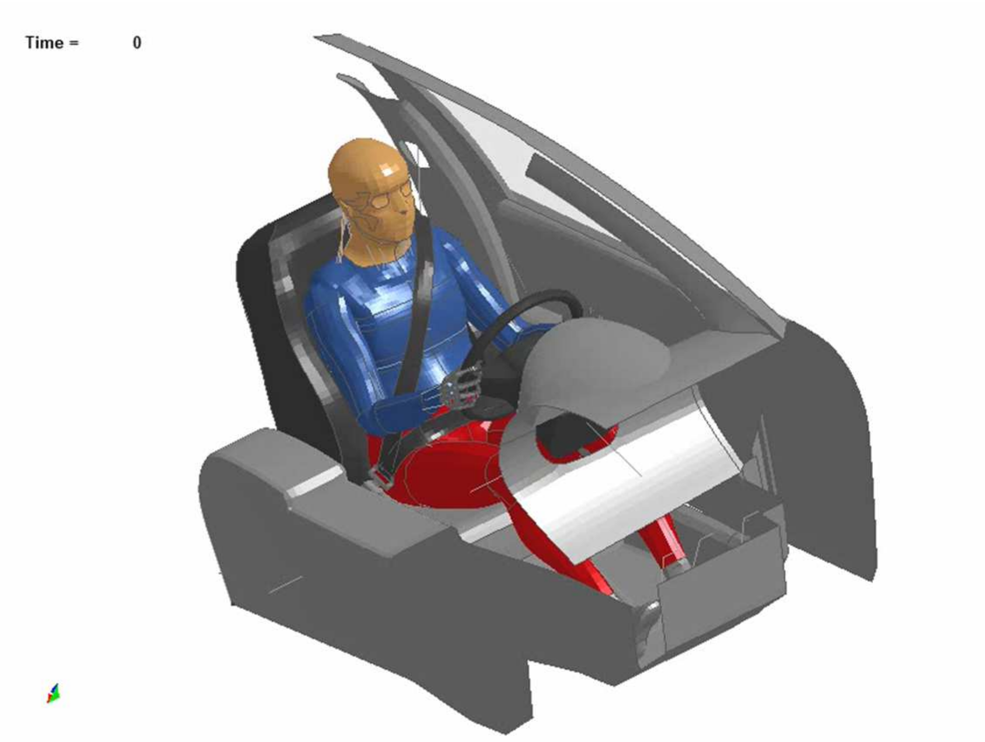
DV 58km/h

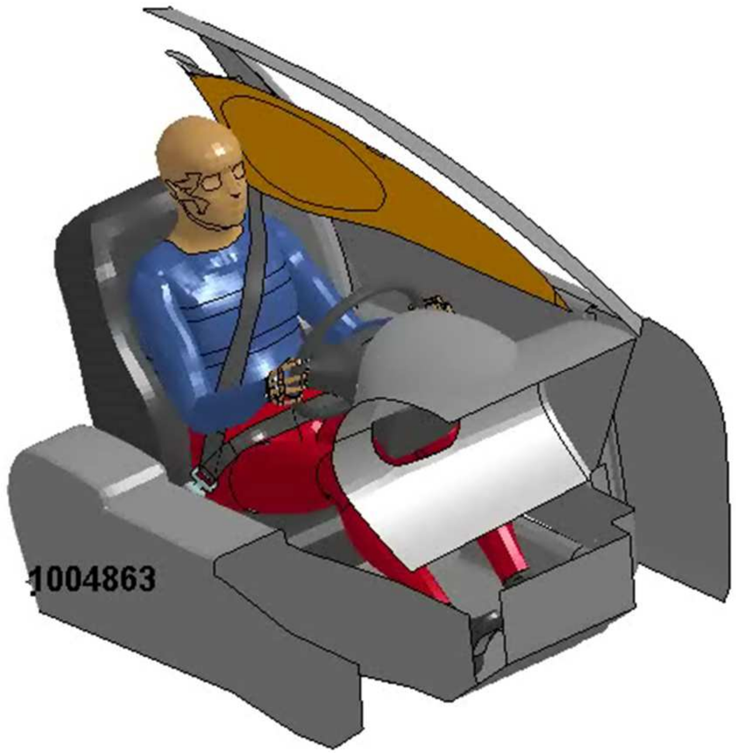


DV 64km/h

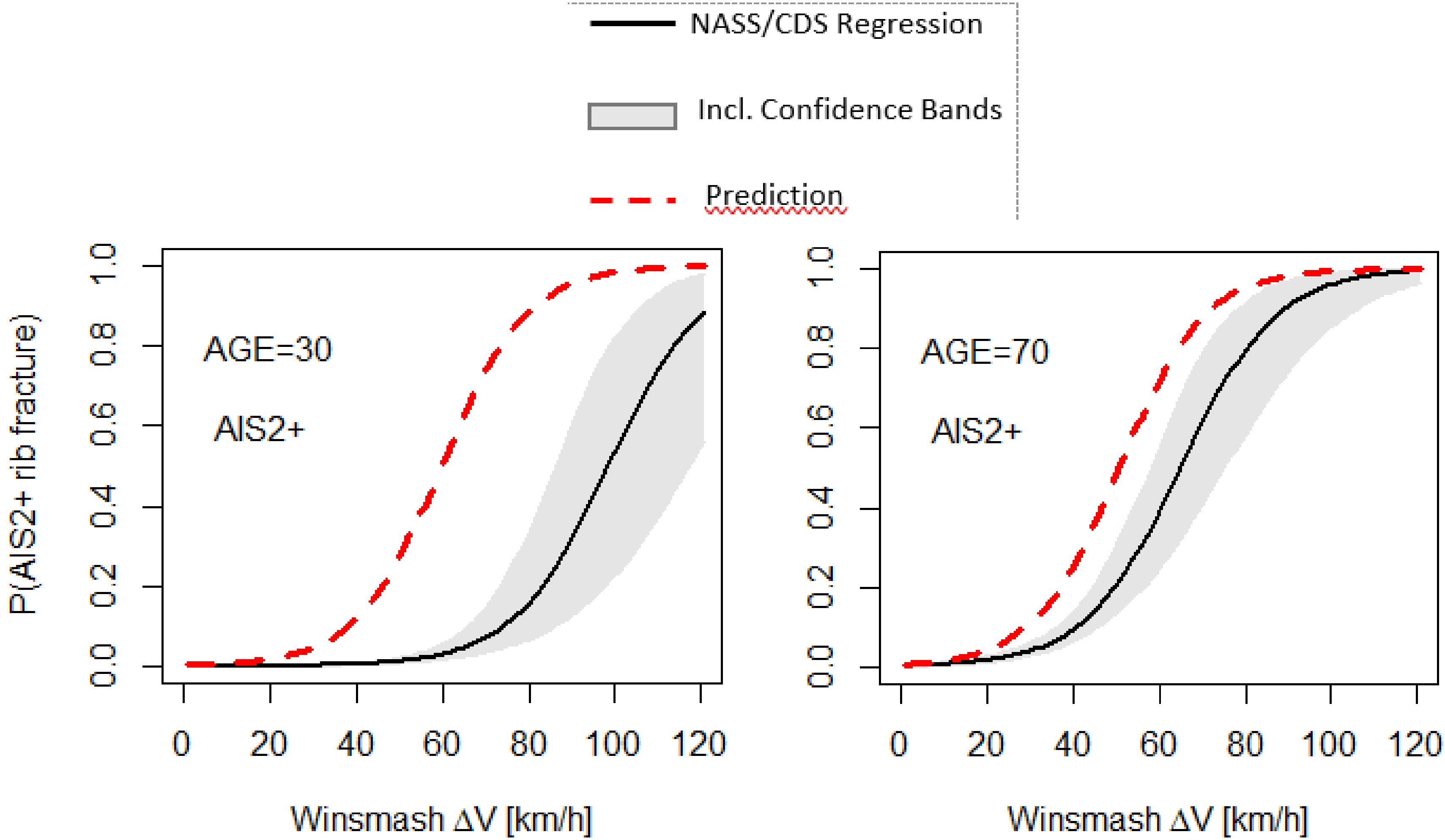
DV 65km/h

Results
Population Based Front and Side Impact

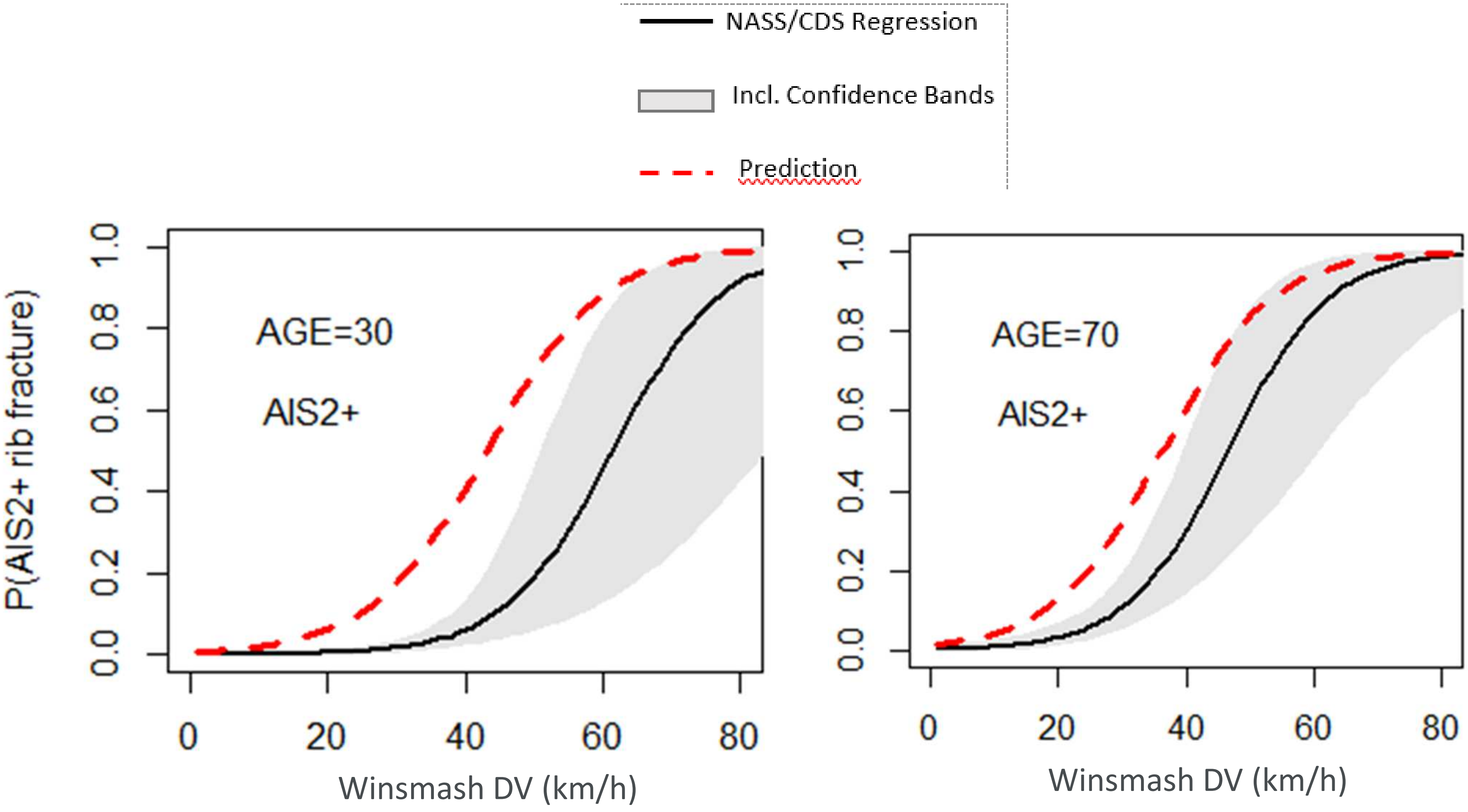




Results
Population Based Reconstructions - Frontal Impact



Results
Population Based Reconstructions- Side Impact

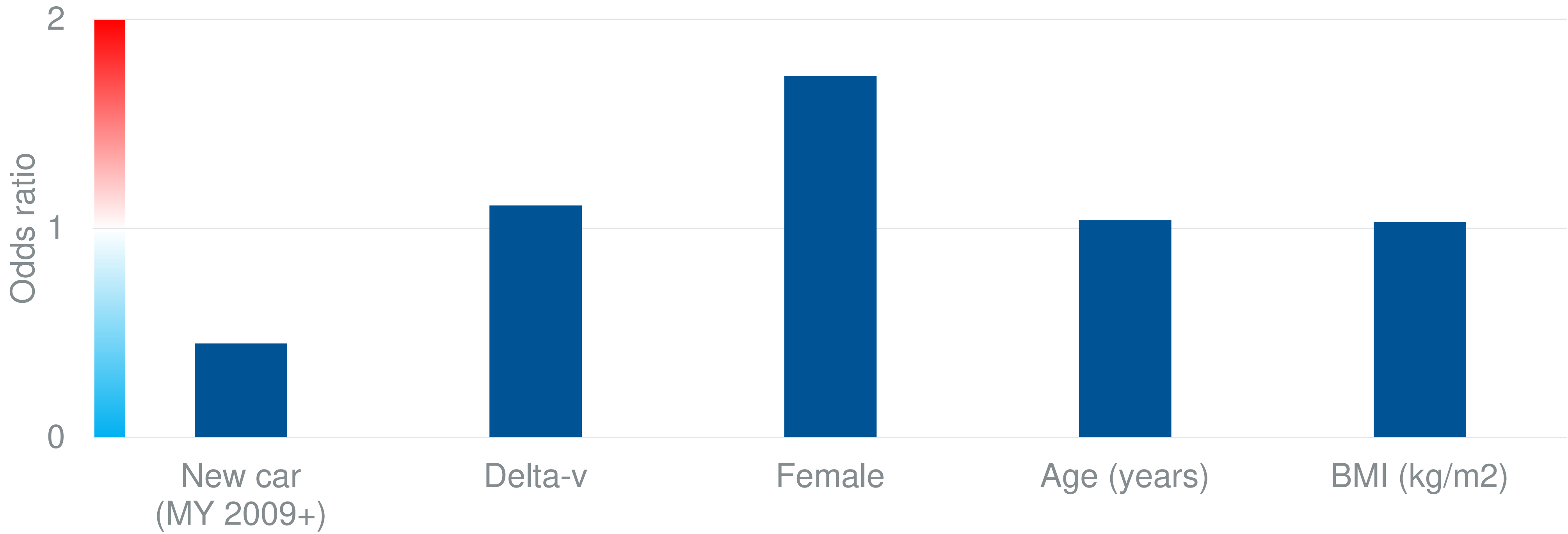


Conclusion

SAFER HBM predicted the risk of AIS2+ rib fractures in PMHS sled tests and in detailed accident reconstructions. In the population based reconstructions the risk was overpredicted.

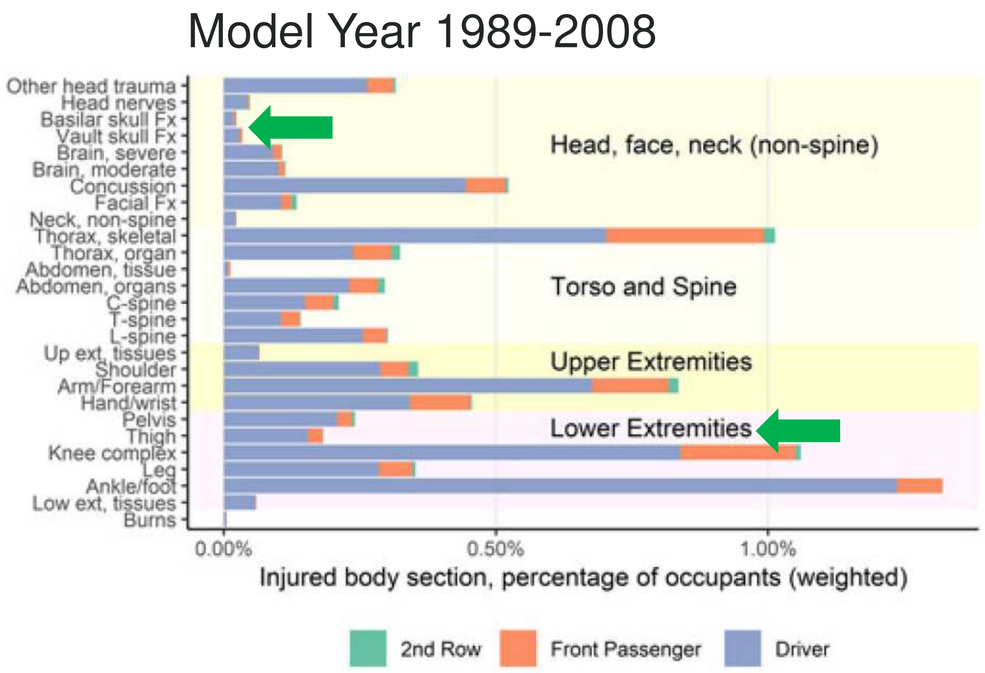
What is next?

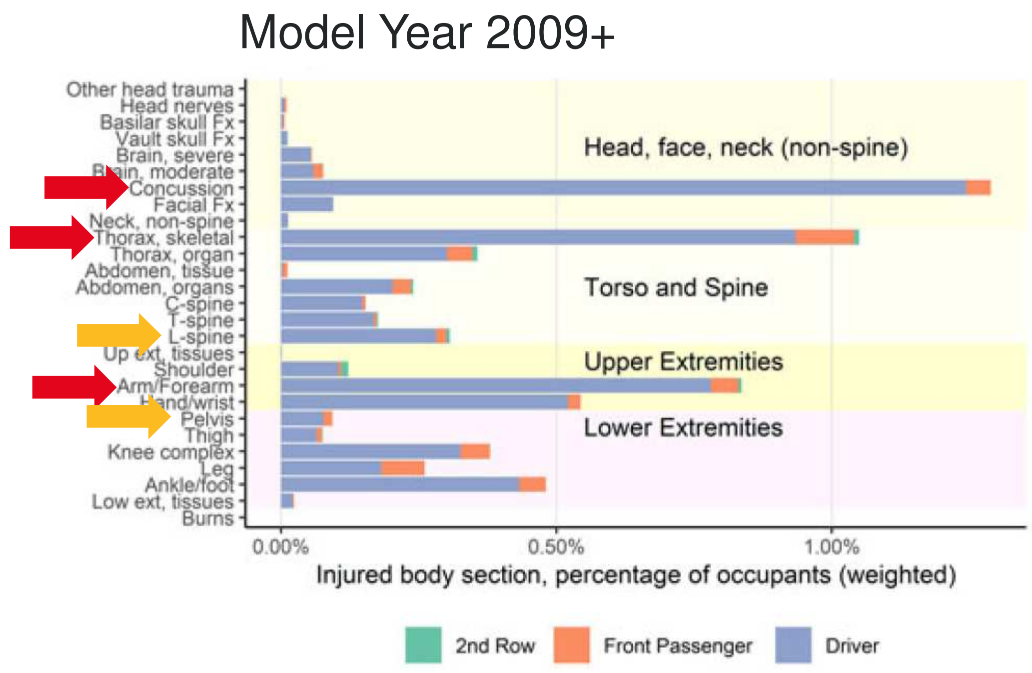
Modern Cars
At risk for AIS3+ Occupant Injuries: Female, Elderly, Obese



J. Forman, G. S. Poplin, C. G. Shaw, T. L. McMurry, K. Schmidt, J. Ash & C. Sunnevang (2019). Automobile injury trends in the contemporary fleet: Belted occupants in frontal collisions, *Traffic Injury Prevention*

Modern Cars
AIS2+ Occupant Injuries in Modern Cars





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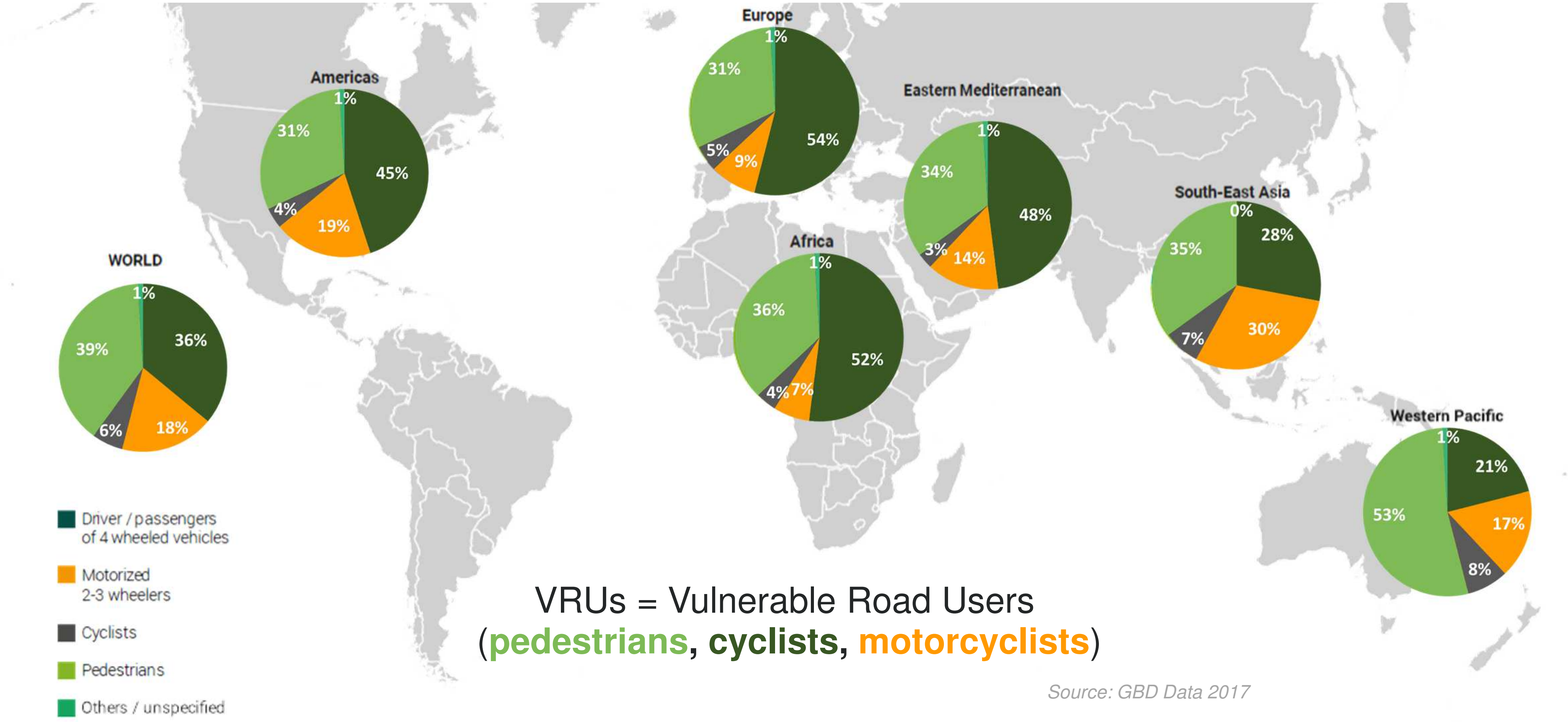
VRUs dominate Road Fatalities across world with > 60% share



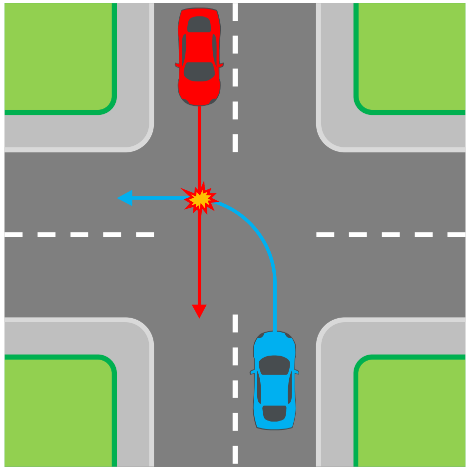
VRUs = Vulnerable Road Users
(pedestrians, cyclists, motorcyclists)

Source: GBD Data 2017

Future Cars
Four Scenarios Cover 90% of Future Accidents (AIS2+ car-to-car)

TAP

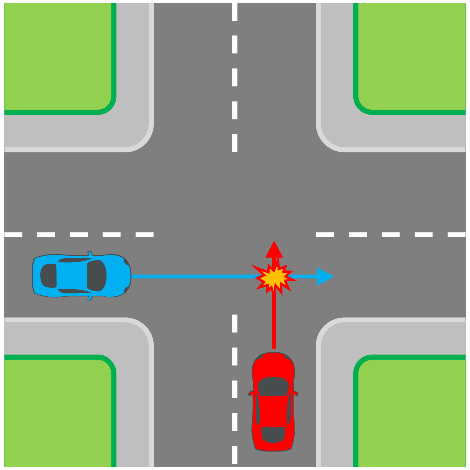
Turn Across Path



NASS CDS: 46%

SCP

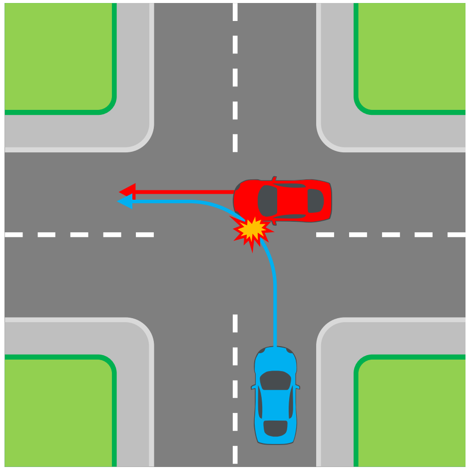
Straight Crossing Paths



NASS CDS: 17%

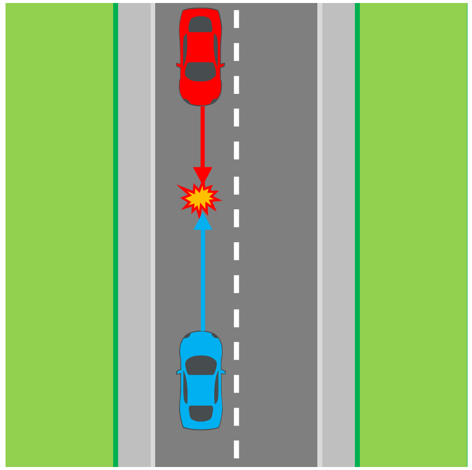
TIP

Turn Into Path



NASS CDS: 18%

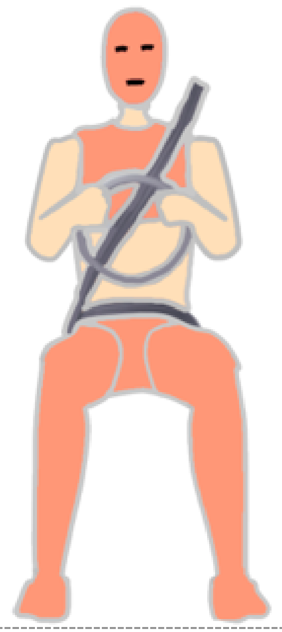
Head-on



NASS CDS: 12%

Östling M, Lubbe N, Jeppsson H, Puthan P. Passenger car safety beyond ADAS: Defining remaining accident configurations as future priorities.. ESV conference 2019

Future Cars
Most Common Injuries in Near-Side Impact - TAP

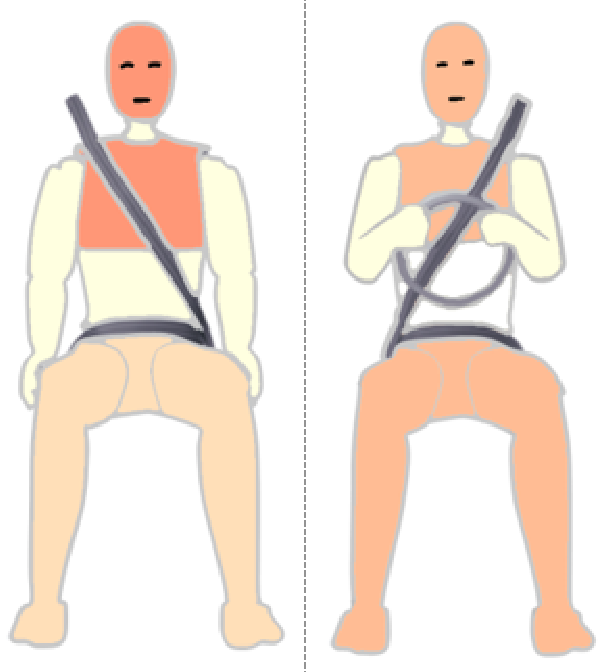


	Driver	%
Head	Concussion	53
	Subdural	27
	Cerebrum	13
Up. Ext	Shoulder	69
	Forearm	14
	Wrist, Hand	10
Thorax	Ribs	57
	Thorax cavity NFS	20
	Lung	18
Spine	Lumbar	54
	Cervical	37
	Thoracic	6
Abdom.	Spleen	51
	Liver	27
	Kidney	11
L. Ext.	Pelvis	88
	Lower leg NFS	5
	Ankle Joint	2

Pipkorn B, Iraeus J, Lindquist M, Puthan P, Bunketorp O. Occupant Injuries in Light Passenger Vehicles – A NASS Study to Enable Priorities for Development of Injury Prediction Capabilities of Human Body Models .. AAP under review

Future Cars
Most Common Injuries in Far-Side Impact - SCP

	Passenger	%
Head	Subdural	50
	Concussion	49
	Base	1
Up. Ext	Forearm	56
	Shoulder	33
	Wrist, Hand	11
Thorax	Ribs	98
	Diaphragma	1
	Major Vessels	1
Spine	Lumbar	79
	Cervical	14
	Thoracic	8
Abdom.	Spleen	83
	Kidney	15
	Liver	2
L. Ext.	Knee Joint	40
	Pelvis	25
	Femur Shaft	12

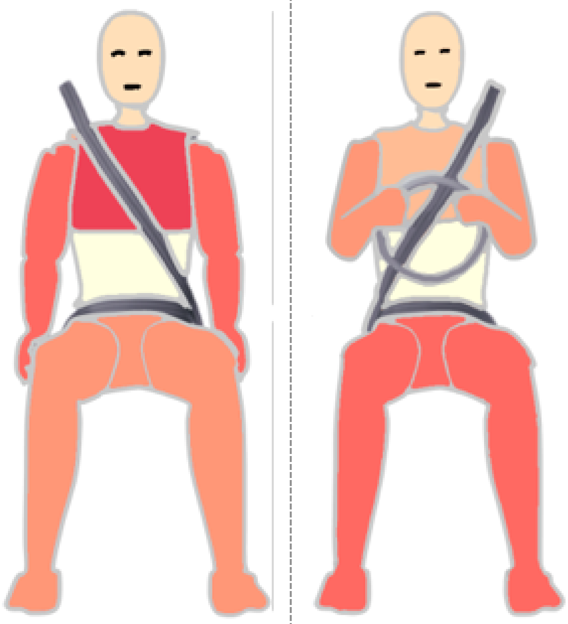


	Driver	%
Head	Concussion	84
	Subdural	9
	Cerebrum	6
Up. Ext	Wrist, Hand	47
	Shoulder	27
	Forearm	24
Thorax	Ribs	93
	Lung	5
	Thorax cavity NFS	2
Spine	Lumbar	97
	Thoracic	2
	Cervical	1
Abdom.	Spleen	48
	Liver	41
	Kidney	11
L. Ext.	Knee Joint	30
	Ankle Joint	22
	Lower leg NFS	14

Pipkorn B, Iraeus J, Lindquist M, Puthan P, Bunketorp O. Occupant Injuries in Light Passenger Vehicles – A NASS Study to Enable Priorities for Development of Injury Prediction Capabilities of Human Body Models .. AAP under review

Future Cars
Most Common Injuries in Frontal Impact – Head On

	Passenger	%
Head	Concussion	76
	Subdural	12
	Cerebrum	4
Up. Ext	Wrist, Hand	46
	Forearm	30
	Shoulder	16
Thorax	Sternum	54
	Ribs	34
	Thorax cavity NFS	8
Spine	Lumbar	54
	Cervical	29
	Thoracic	17
Abdom.	Spleen	73
	Mesentery	14
	Liver	6
L. Ext.	Ankle joint	31
	Knee joint	24
	Lower leg NFS	18



	Driver	%
Head	Concussion	75
	Subdural	16
	Cerebrum	4
Up. Ext	Forearm	44
	Wrist, Hand	34
	Shoulder	14
Thorax	Sternum	43
	Ribs	37
	Lung	12
Spine	Lumbar	60
	Cervical	30
	Thoracic	10
Abdom.	Liver	49
	Spleen	32
	Kidney	6
L. Ext.	Ankle Joint	26
	Knee Joint	20
	Foot	19

Pipkorn B, Iraeus J, Lindquist M, Puthan P, Bunketorp O. Occupant Injuries in Light Passenger Vehicles – A NASS Study to Enable Priorities for Development of Injury Prediction Capabilities of Human Body Models .. AAP under review

Future Cars
Novel occupant compartment designs and seating configurations
Identified problems and increased risks

Reclined and away from front airbags

- increased head accelerations and neck extensions (no frontal airbag)
- increase risk of submarining
- increased spine forces and pelvis acceleration (contact with seat pan and lap belt)

Rearwards

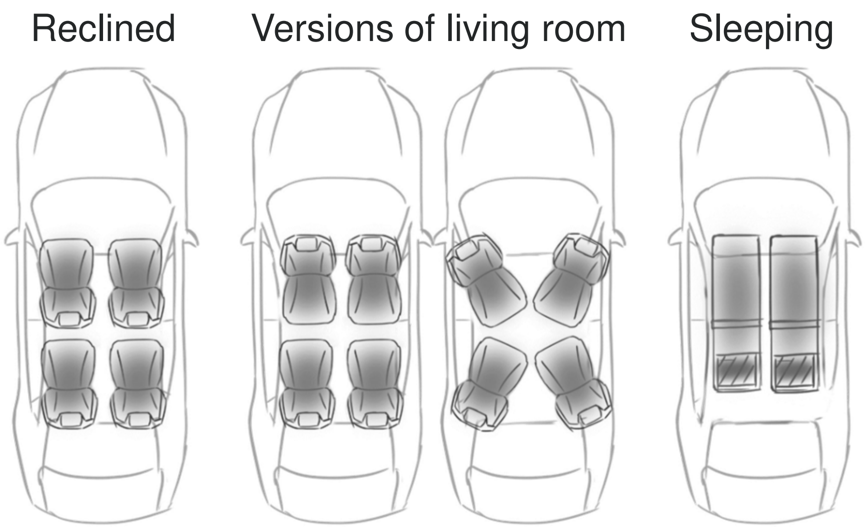
- increased spine tensions/compression
- lower leg impact to seat pan

Rotated

- occupant might tend to rotate out of the belt restraint depending on which side the seat belt is fixed
- increased head accelerations, rotational velocities, as well as uncontrolled leg kinematics

Sleeping

- uncontrolled kinematics, no body structure to load



EuroNCAP and Human Body Modelling

EURO NCAP
FOR SAFER CARS
www.euroncap.com
EUROPEAN NEW CAR ASSESSMENT PROGRAMME

Technical Bulletin

Pedestrian Human Model Certification

Version 1.01

December 2017
TB 024

A combination of physical testing and numerical **Human Body Model (HBM) simulations** is required to demonstrate the suitability of the sensing system for the range of pedestrian sizes; the timing of system deployment; and the bonnet deflection due to body loading.

Euro NCAP is continuing the process to include virtual testing in rating.

Pilot load case for human body evaluation will be selected by October 2019

Human body model simulations will be included in the 2022 upgrade

NHTSA’s Federal Automated Vehicles Policy

Table 1: Applicability of Guidance Areas to SAE Level 2-5 Automated Vehicle Systems

Levels of Automation	SAE Levels 3, 4, 5 (HAVs)	SAE Level 2
Safety Assessment Letter to NHTSA	***Yes***	***Yes***
C. Cross-Cutting Areas	***Fully***	***Partially***
C.1 Data Recording and Sharing	Yes	Yes
C.2 Privacy	Yes	Yes
C.3 System Safety	Yes	Yes
C.4 Vehicle Cybersecurity	Yes	Yes
C.5 Human Machine Interface	Yes	Yes
C.6 Crashworthiness	Yes	Yes
C.7 Consumer Education and Training	Yes	Yes
C.8 Registration and Certification	Yes	Yes
C.9 Post-Crash System Behavior	Yes	Yes
C.10 Federal, State and Local Laws	Yes	Clarify to driver
C.11 Ethical Considerations	Yes	Yes
F. Automation Function[47]	***Fully***	***Partially***
F.1 Operational Design Domain	Yes	No
F.2 Object and Event Detection and Response	Yes	No
F.3 Fall Back (Minimal Risk Condition)	Yes	No
F.4 Validation Methods	Yes	Yes
G. Guidance for Lower Levels of Automated Vehicle Systems	***No***	***Yes***

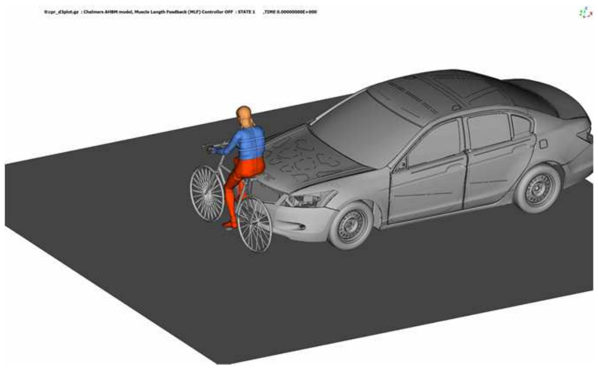
- OEMs “…should **exercise and demonstrate due care** to provide countermeasures that will fully protect all occupants given any planned seating or interior configurations. …
- …The tools to demonstrate such due care need not be limited to physical testing but also could **include virtual tests with vehicle and human body models**.”

Future Development Needs

Today's vehicles occupants:

- Injuries for elderly and females
- Concussion
- Lumbar spine injuries
- Upper extremity injuries
- Pelvis injuries

Kinematics and injuries for vulnerable road users



Future vehicles occupant kinematics:

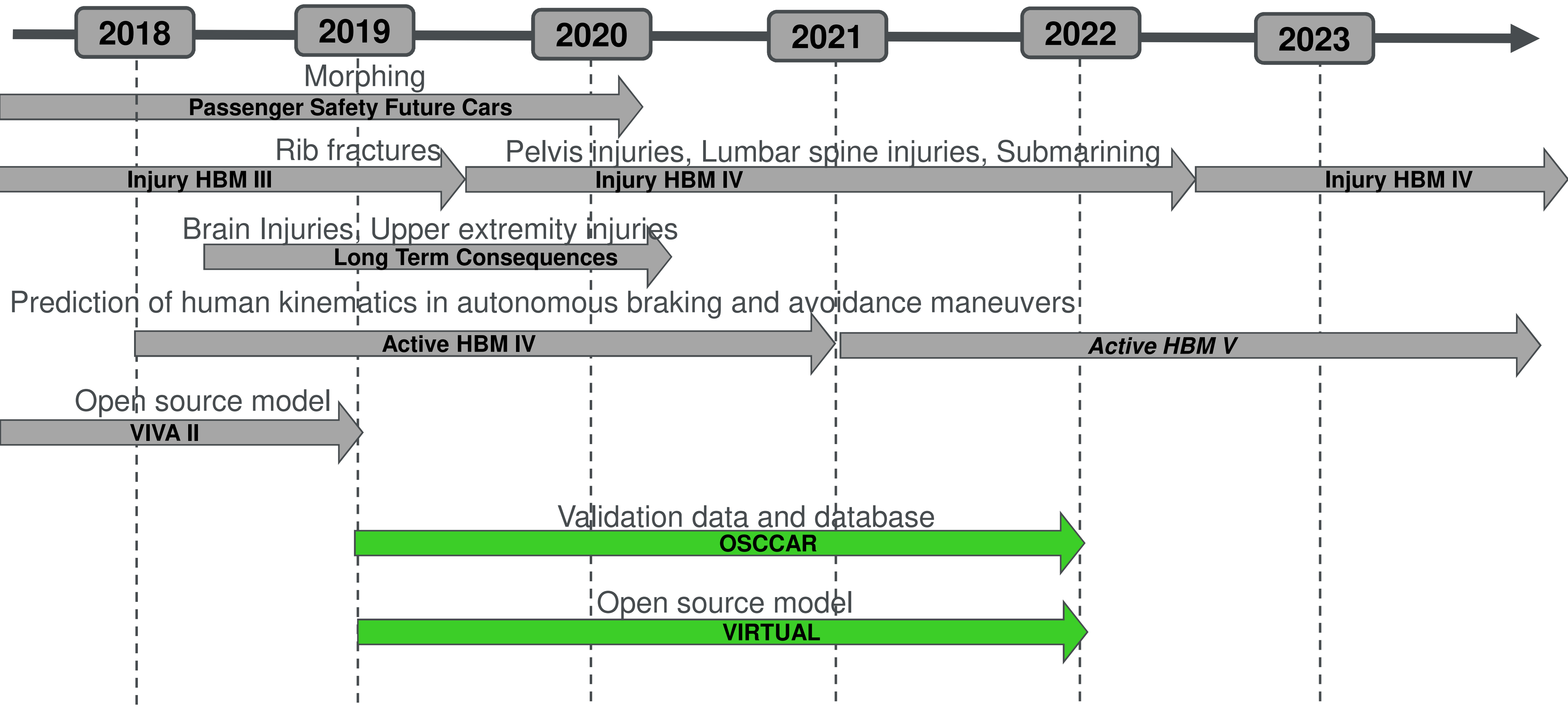
- Kinematics for reclined occupants
- Kinematics for rearwards facing occupants
- Kinematics for rotated occupants
- Kinematics for supine (sleeping) occupants

Future vehicles occupant injuries:

- Concussion and subdural hematoma
- Rib and sternum fractures
- Lumbar spine injuries
- Pelvis injuries
- Knee, Ankle & Wrist

Ongoing projects – HBM Development

*OSCCAR - Future Occupant Safety for Crashes in Cars

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