Potential Injury Criteria for Sideways Facing Aircraft Seats

TNO Automotive

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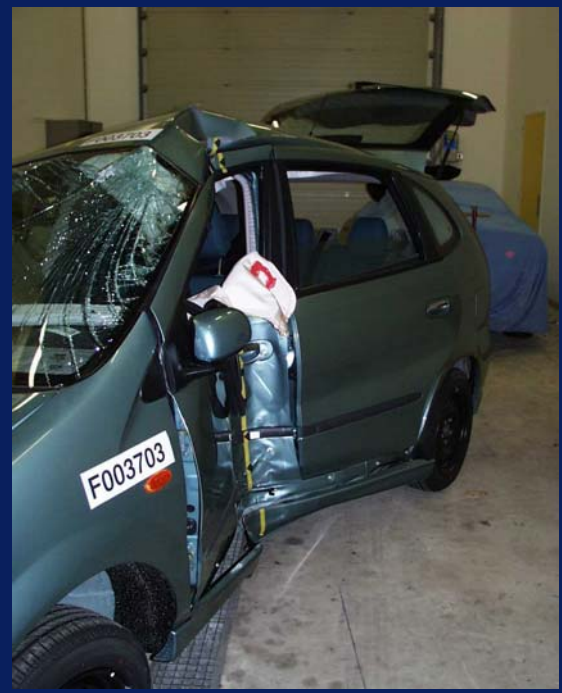
Problem Formulation

- Current aviation regulations only for forward facing seats (FARs 23.562, 25.562, 27.562, 29.562)
- Increasing use of sideways facing seats (business jets)
- Side impact loading
- Current regulations don't consider side impact loading

Need for injury criteria and tolerance levels for certification standards of sideways facing aircraft seats

Presentation Overview

- Automotive side impact
- Side impact regulations & tests
- Dummies
- Protective systems
- Injury criteria
- Required additional research
- Virtual testing
  - dummy models
  - human models
- Aviation simulations in MADYMO



Automotive vs. Aviation Side Impact

- Loading conditions
  - severity
  - duration
- Intrusion
- Contact with environment
- Restraints
- Protection

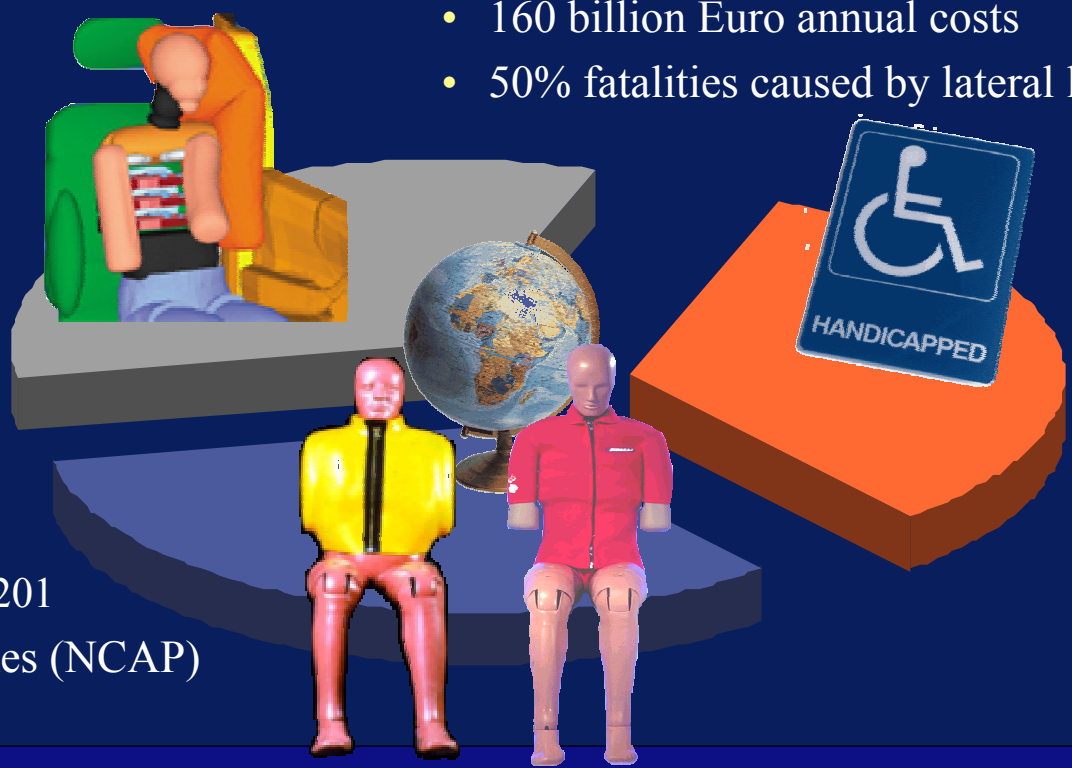
Automotive Side Impact

Technical

- complex
  - loading conditions
  - interactions
- occupant surrogates

Social

- EU annual road toll:
  - >40,000 fatalities
  - 1.6 million injured
- 160 billion Euro annual costs
- 50% fatalities caused by lateral loading

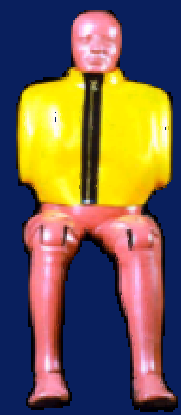


Regulations

- different standards
  - ECE 95
  - FMVSS 214 & 201
- consumer programmes (NCAP)
- globalisation

Automotive Side Impact Regulations
FMVSS 214

- US side impact barrier requirements introduced in the early 1990's.
- Metal honeycomb barrier positioned based on target vehicle wheelbase (56km/h)
- Front and Rear Seat US-SID Dummies
- Acceleration based injury criteria
- No head/neck criteria



Automotive Side Impact Regulations
ECE 95

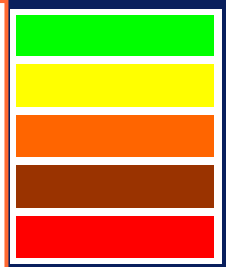
- European side impact barrier requirements introduced in the early 1990's.
- Metal honeycomb barrier positioned based on front occupant H-point
- Front Seat EuroSID-1 dummy
- Deflection, force, acceleration, and viscous based injury criteria.
- No neck criteria

Automotive Side Impact Regulations
FMVSS 201

- 18 mph lateral pole test (254 mm diameter) with impact centered on head CG
- Front seat US SID/Hybrid III dummy
- HIC_{15} criterion only
- Test only performed if upper interior head protection is fitted (ITS/Curtain bags), allowing head impactor tests to be conducted at lower energy levels

Automotive Side Impact Consumer Tests EuroNCAP

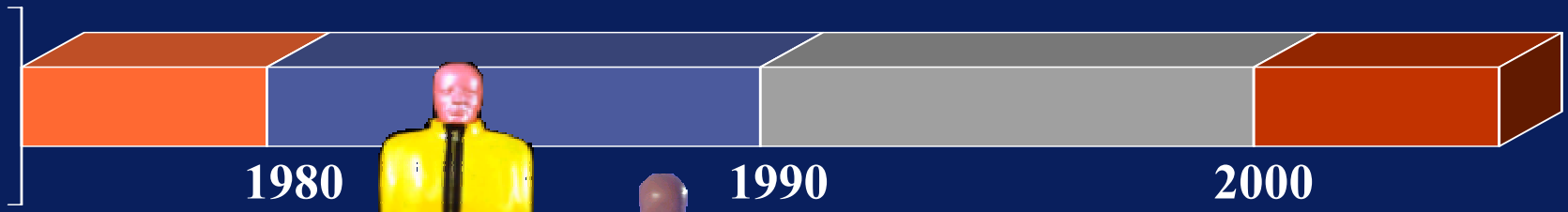
- Developed for legislation by European Enhanced Vehicle-safety Committee (EEVC)
- MDB tests @ 50 kph
- Includes assessment of child safety
- Test tools comply with regulations
  - ECE 95 for mobile barrier and EUROSID-1 dummy
  - ECE 44 for child dummies

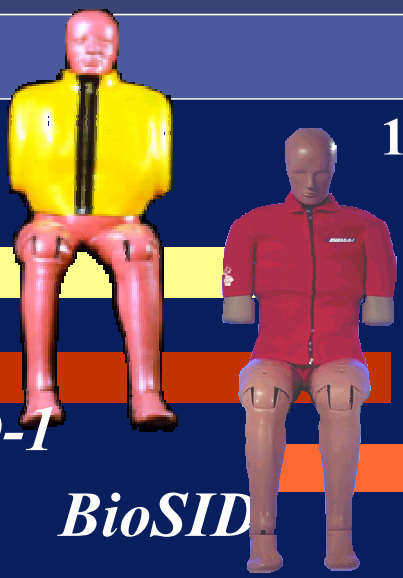


Additional Automotive Side Impact Tests
OOP Testing

- Performed in the past by NHTSA and IIHS to evaluate and rank the risk to occupants presented by side airbags
- Positions depend upon airbag configuration
  - Airbag Dependant
  - Occupant Dependent
  - Injury Dependent

Side Impact Dummies

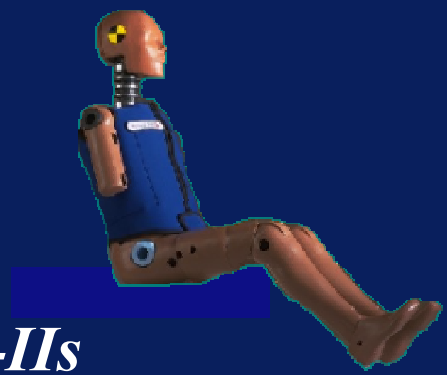




DoT.SID

EUROSID-1

BioSID



SID-IIs

EUROSID-2

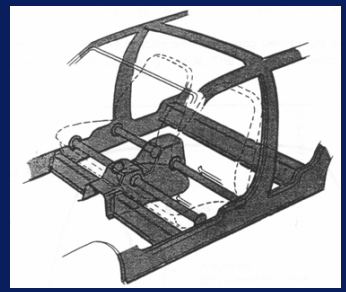
WorldSID

WorldSID Project

- Objective
  - development of new world-wide acceptable advanced side impact crash test dummy for improved injury risk assessment of car occupants in side impact
- Motivation
  - improved knowledge of human response in side impact results in improved dummy design and improved side impact protection
  - harmonisation will eliminate use of different dummies in different parts of the world and reduce costs

Protective Systems

- Vehicle structure



- Restraint systems

- Seat design

Side Impact Injury Criteria

- Proposed by IIHS for USNCAP

Injury Measure	ES-2 IARV	SID-IIs IARV
HIC15	700	779
Res. Head accel. (G)	80	
Neck lateral bending moment	68	
TTI	85	
Max. rib defl. (mm)	42	34
Max rib defl. Rate (m/s)	8.2	
Max V*C (m/s)	1	1
Spine lateral accel. (max G, 3 ms)	60	73
Max. abdominal defl. (mm)	39	32
Max. abdominal force (kN)	2.5	
Max. abdominal V*C (m/s)	1	1
Pubic force (kN)	10	4
Iliac force (kN)	10	4
Pelvis lateral accel. (G)	130	

OOP Injury Criteria

Body Region/Injury Measure	Dummy			
	Hybrid III 3-Year-Old Child	Hybrid III 6-Year-Old Child	Hybrid III Small Female	SID-IIs
Upper Neck				
Lateral moment (Nm)	30	42	67	67
Twist moment (Nm)	17	24	39	39
Lower Neck				
Flexion moment (Nm)	83	119	190	190
Extension moment (Nm)	34	48	77	77
Lateral moment (Nm)	60	84	134	134
Twist moment (Nm)	17	24	39	39
Tension (N)	1130	1490	2070	2070
Compression (N)	1380	1820	2520	2520
Thorax				
Spine acceleration (max g, 3 ms)	55	60	—	73
Abdomen				
Deflection (mm)	—	—	—	32
Deflection rate (m/s)	—	—	—	8.2
Pelvis				
Pubic symphysis load (N)	—	—	—	4000
Iliac load (N)	—	—	—	4000
Arm				
Resultant bending moment, ulna (Nm)	—	—	—	54
Resultant bending moment, humerus (Nm)	—	—	—	130

Whiplash Injury Criteria (1)

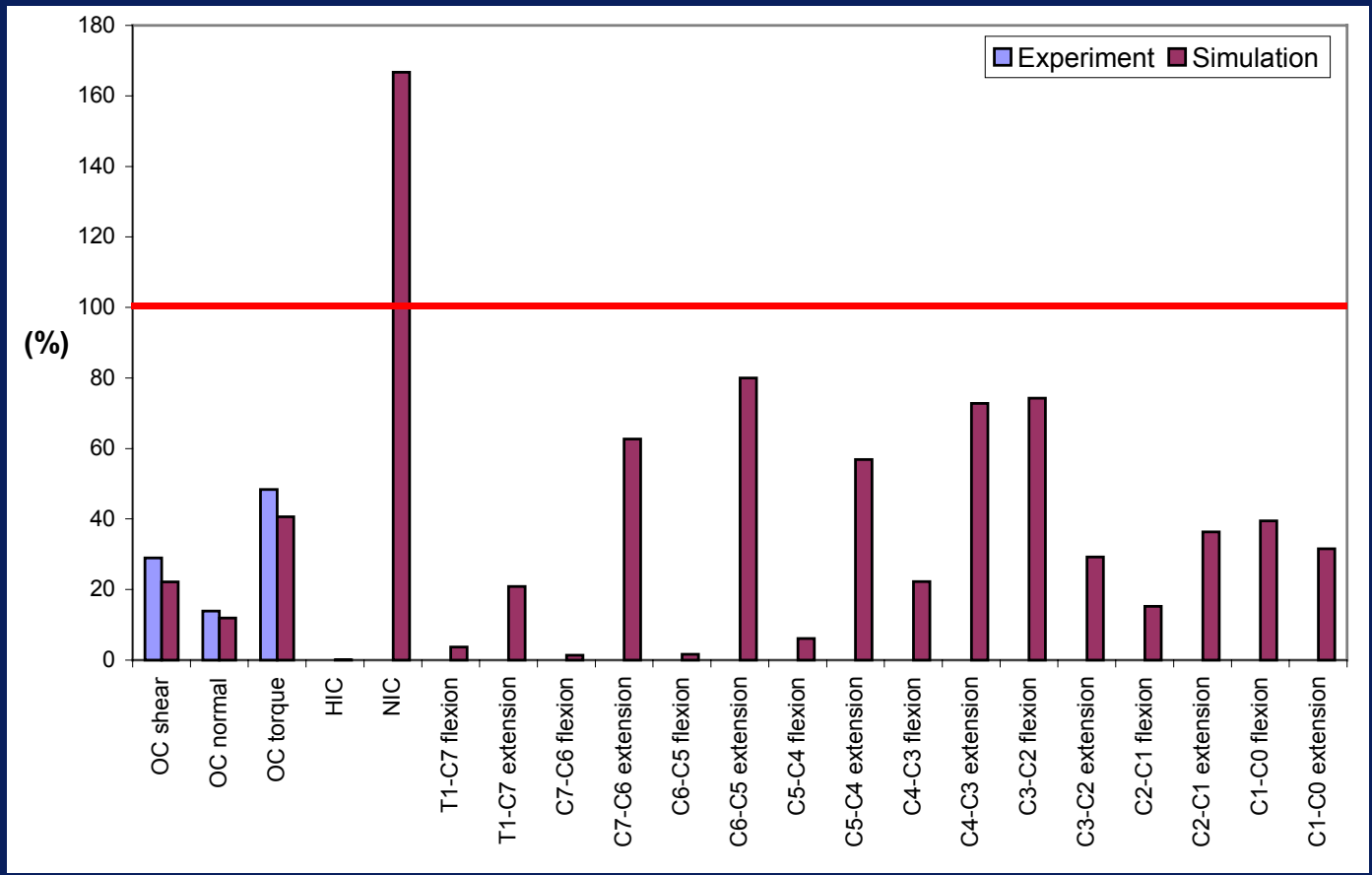
- FNIC (Mertz *et al*., 1971; Lowne, 1996)
  - Occipital condyle (OC) loading
  - normal & shear force, torque
- NIC (Boström *et al*., 1996)
  - relative motion between upper and lower neck

$$NIC = a_{rel}(t)L + v_{rel}^2(t)$$

- IV-NIC (Panjabi *et al*., 1998)
  - Rotation between vertebrae
  - not measurable in current dummies
- Nij
  - load transferred through occipital condyles
  - neck axial force Fz (tension / compression)
  - flexion/extension moment My

$$Nij = \frac{F_z}{F_{zc}} + \frac{M_y}{M_{yc}}$$

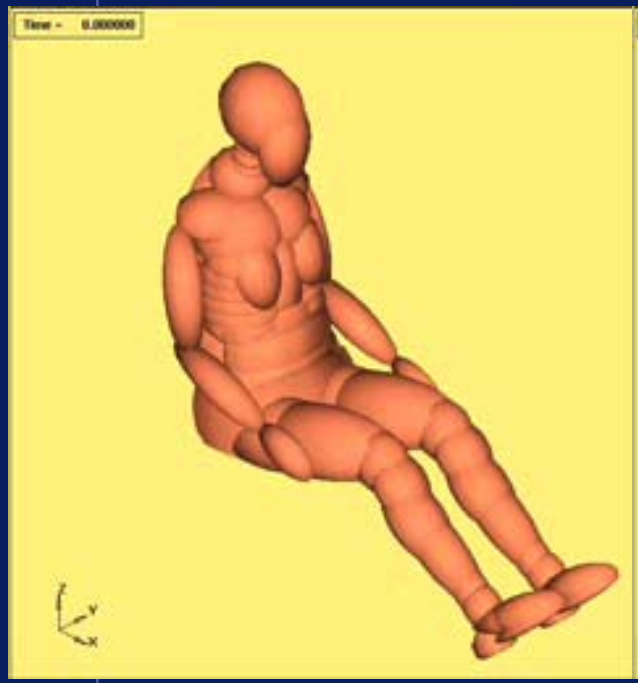
Whiplash Injury Criteria (2)



Required additional research

- Biomechanical testing
  - volunteers
  - PMHS
  - dummies
- Virtual testing
  - dummy models
  - human models

MADYMO Dummy Models



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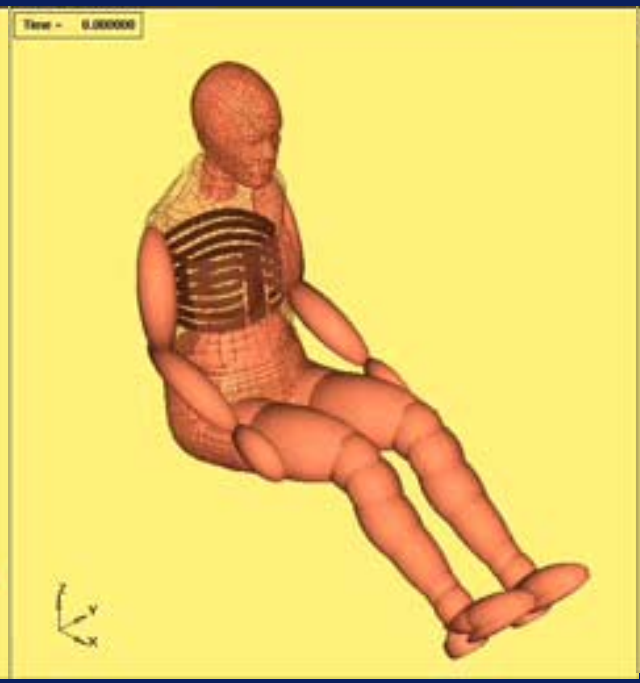

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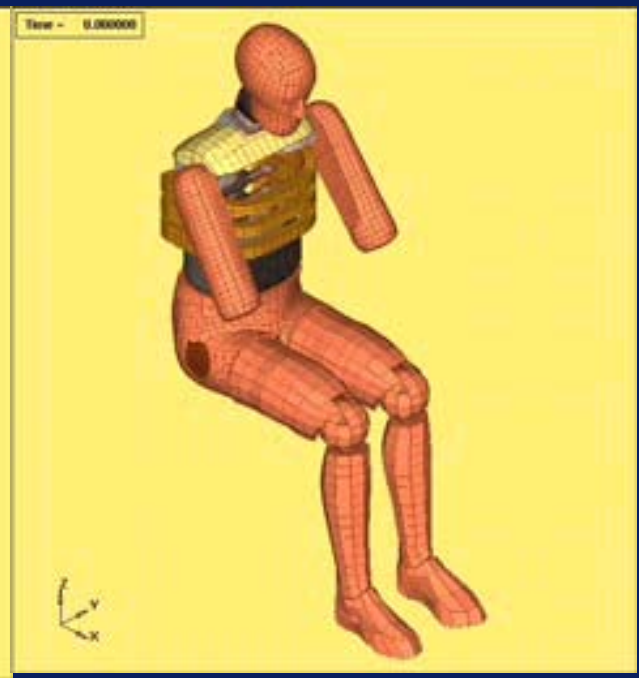

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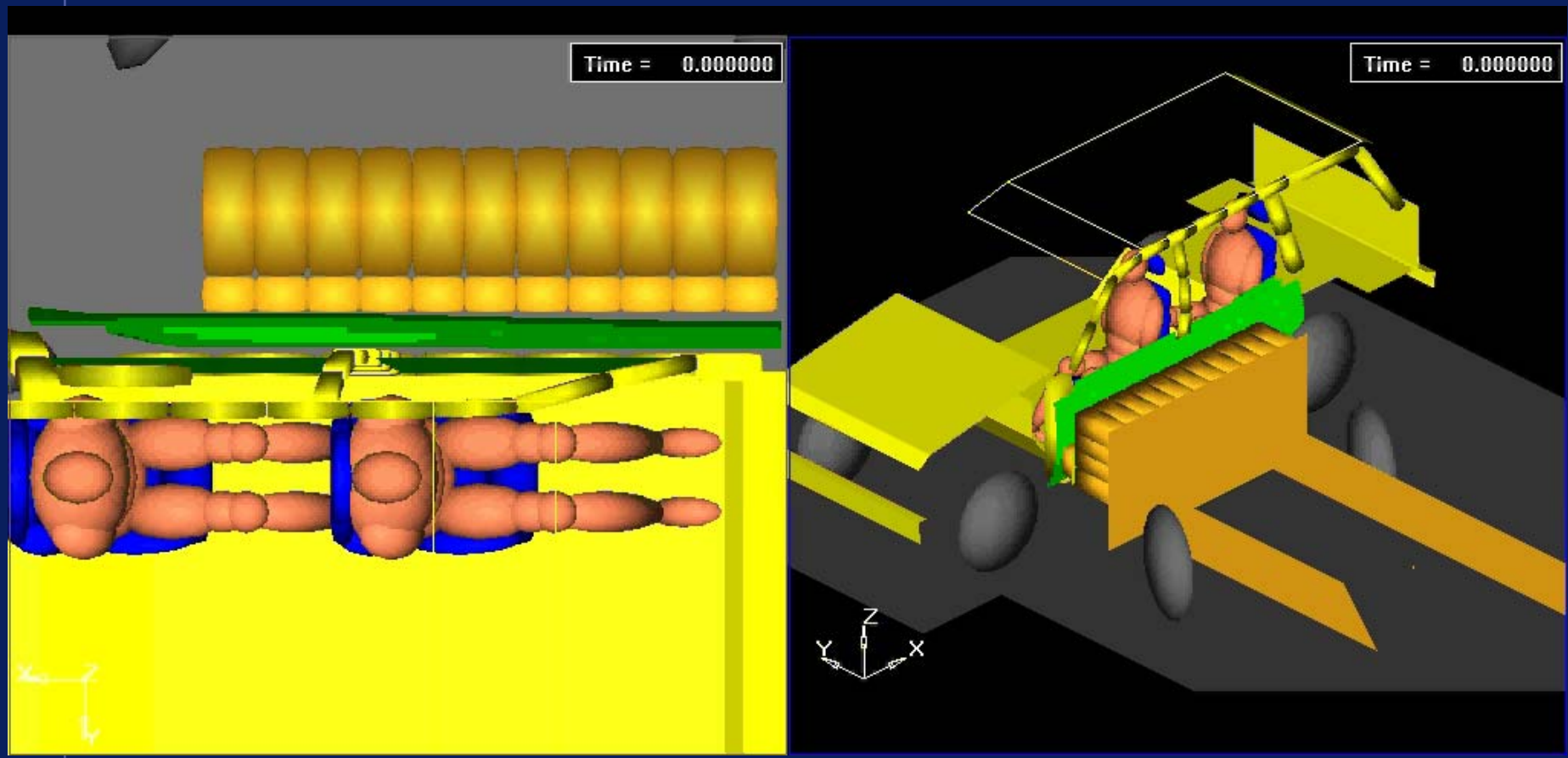
MADYMO Dummy Models in Side Impact



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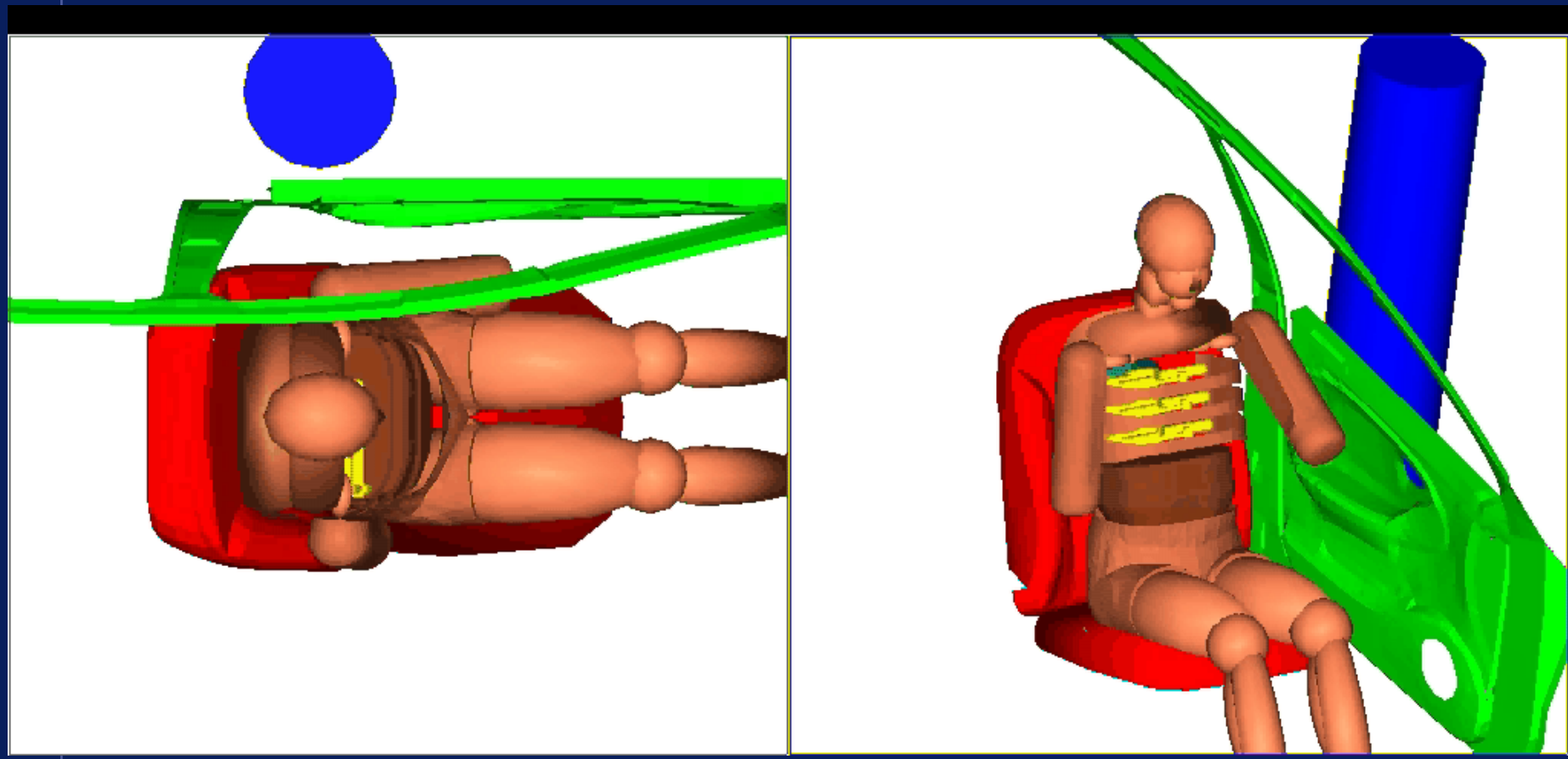

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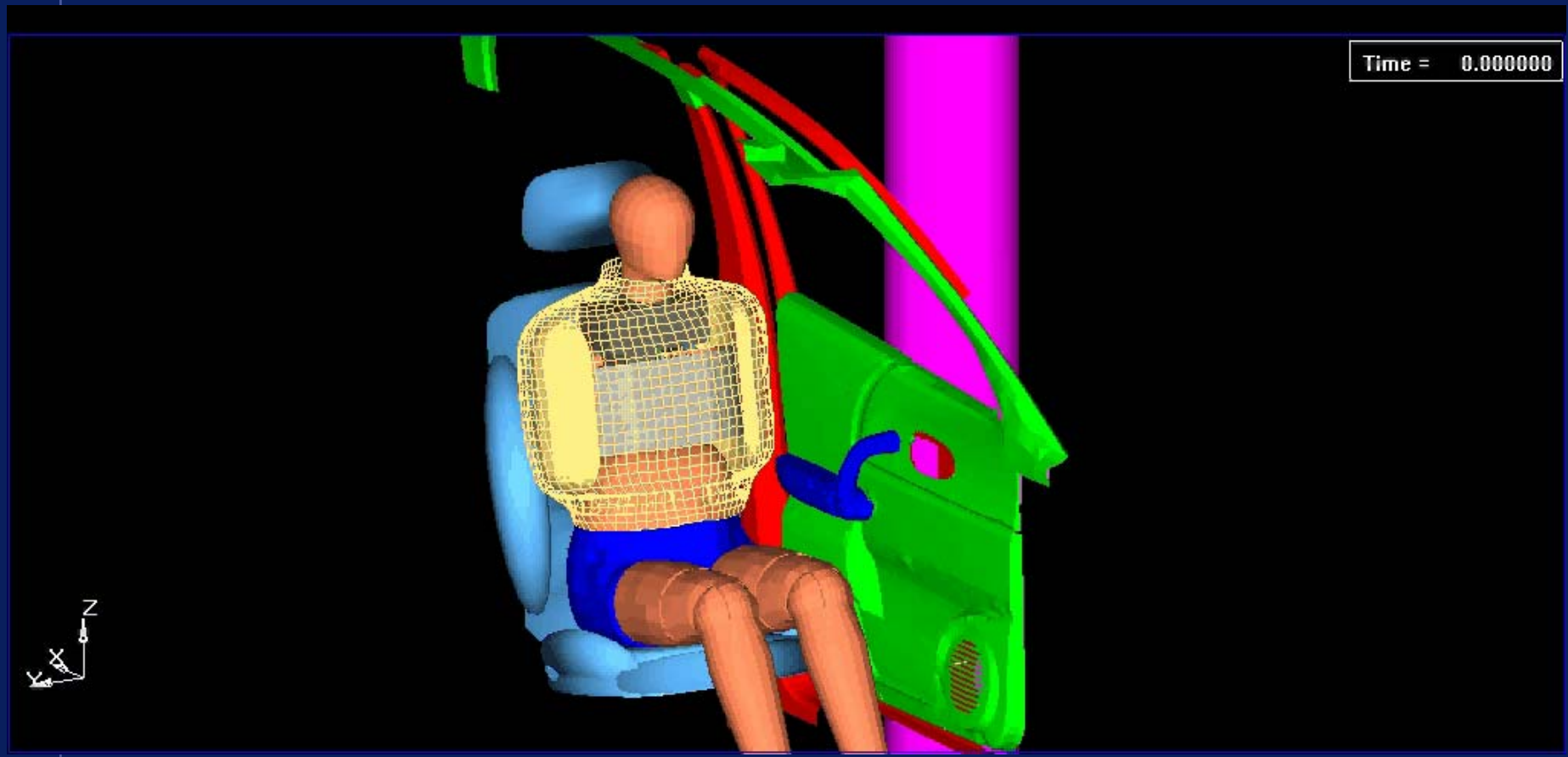

MADYMO Human Models

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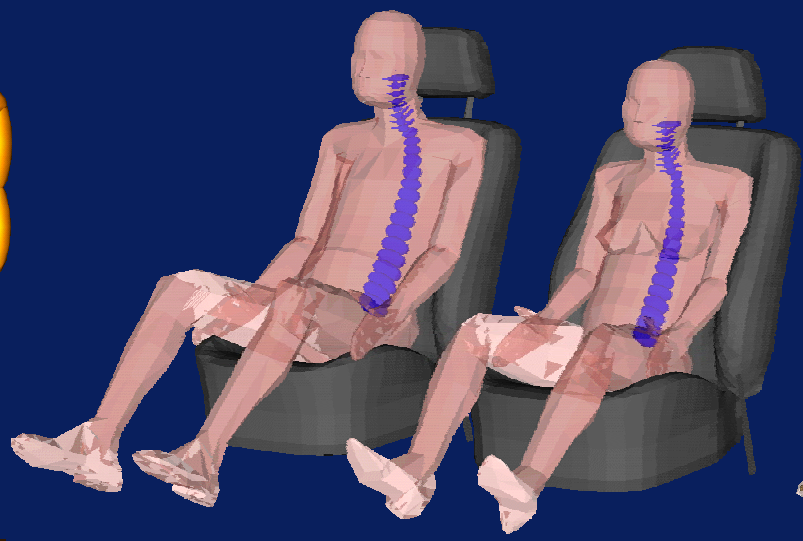

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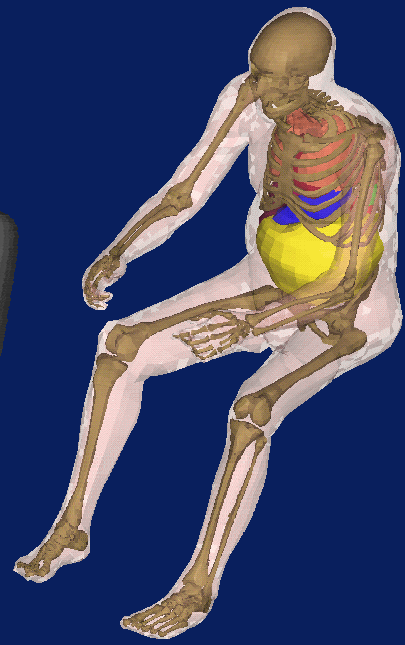

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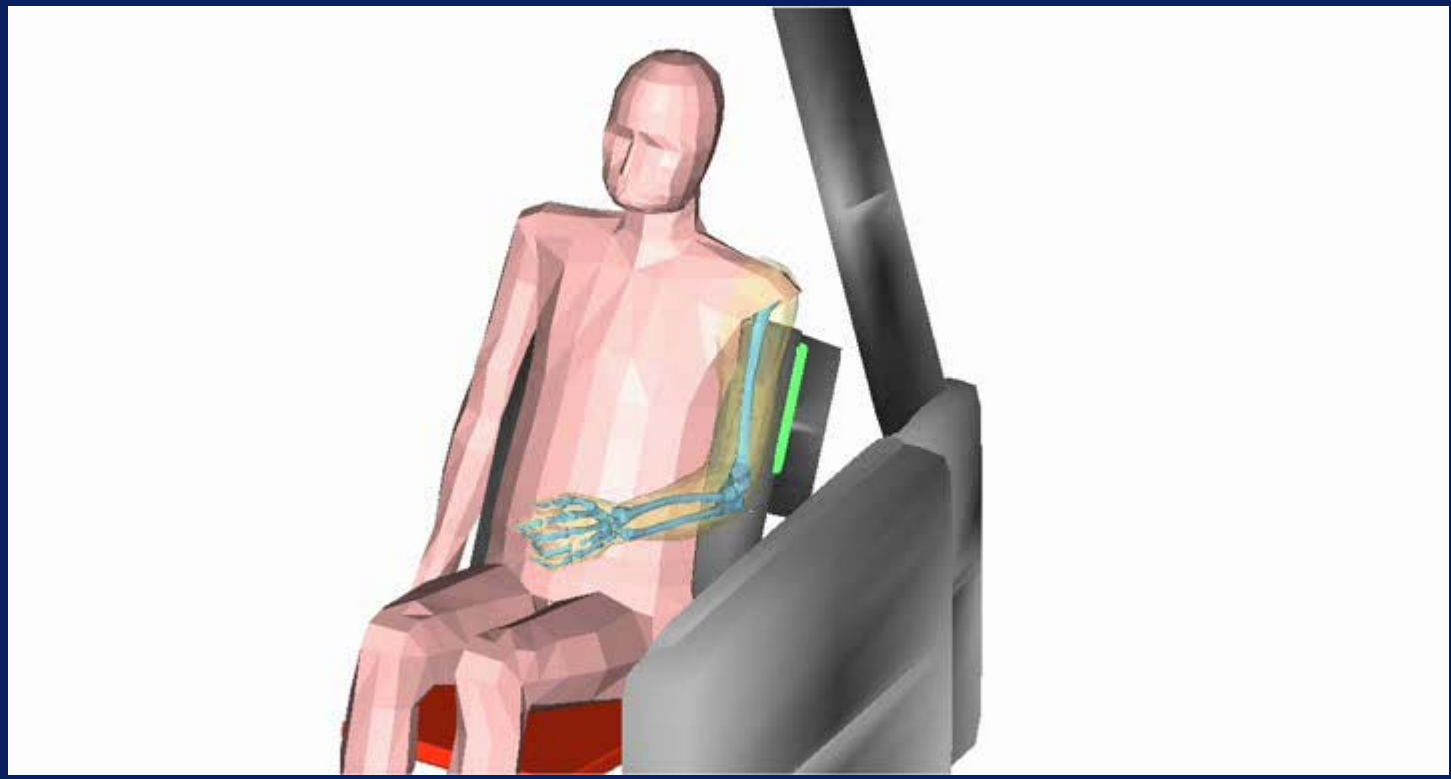
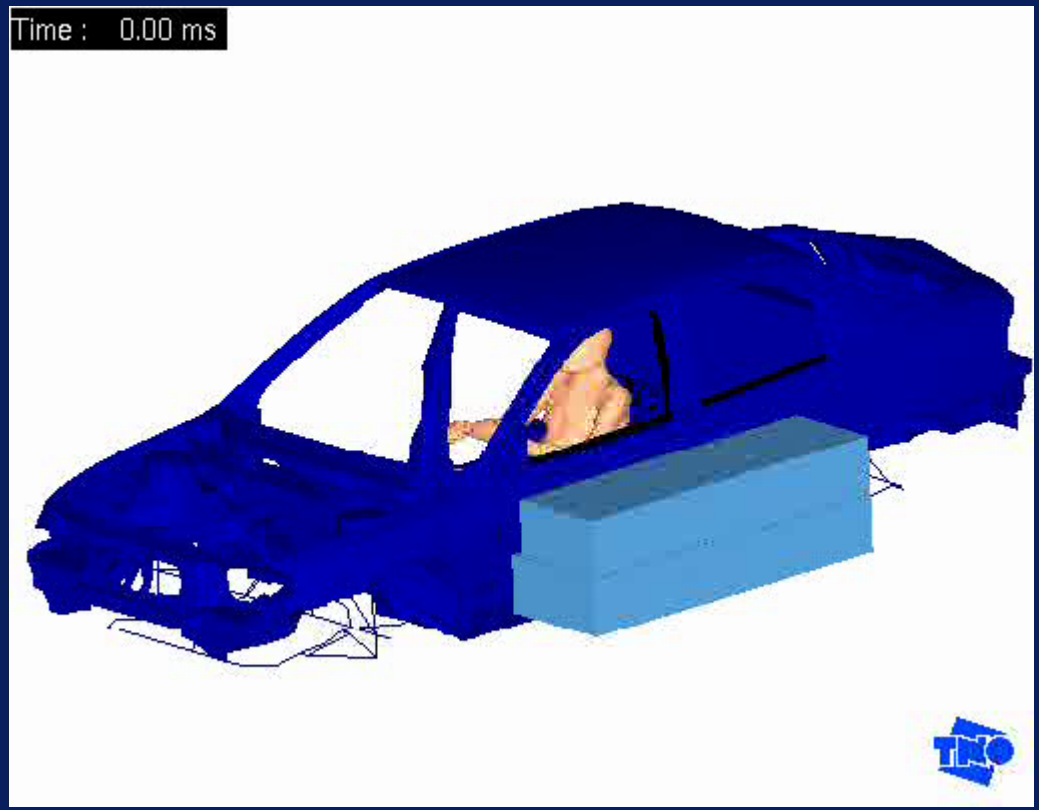
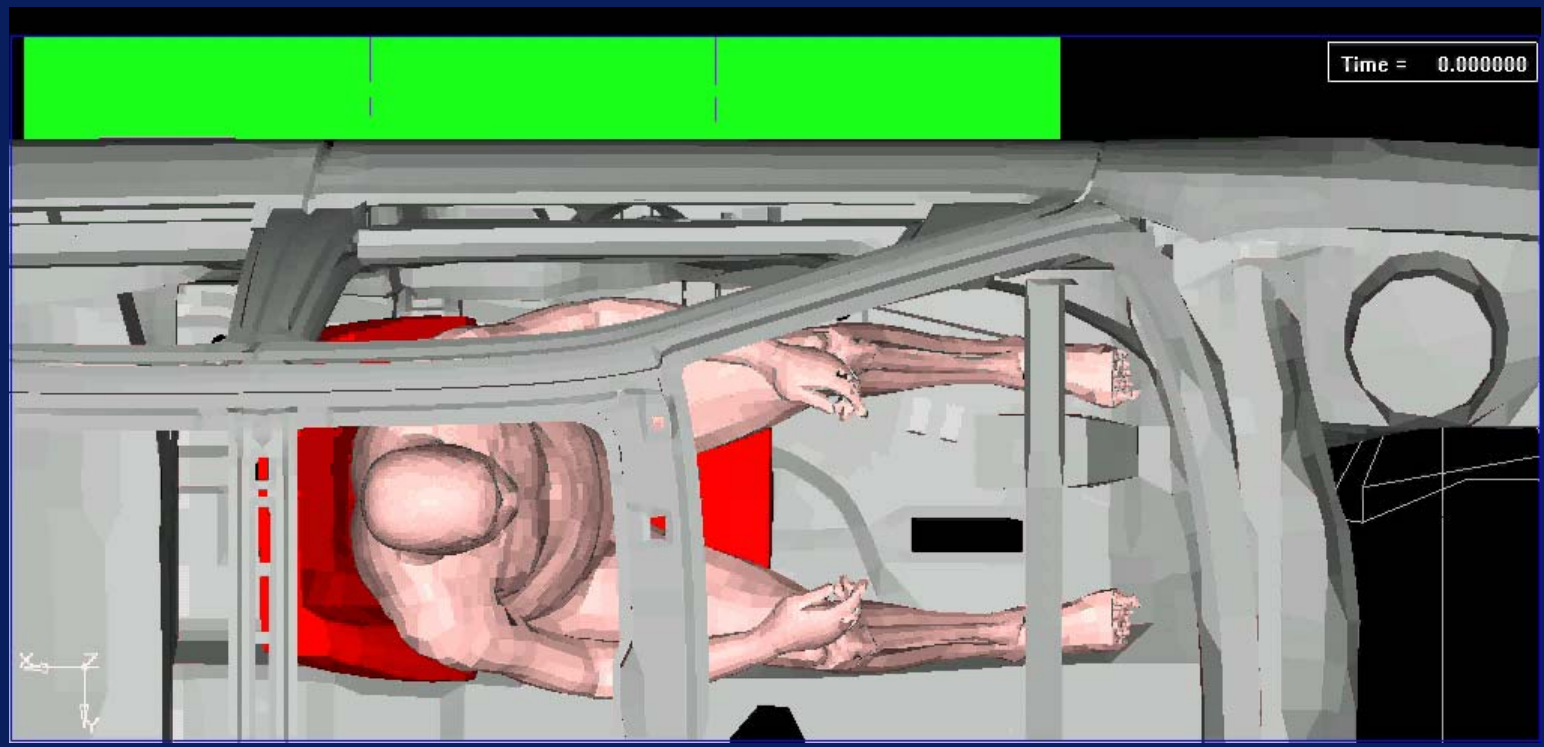
MADYMO Human Models in Side Impact



MADYMO Human Models in Side Impact



MADYMO Human Models in Side Impact

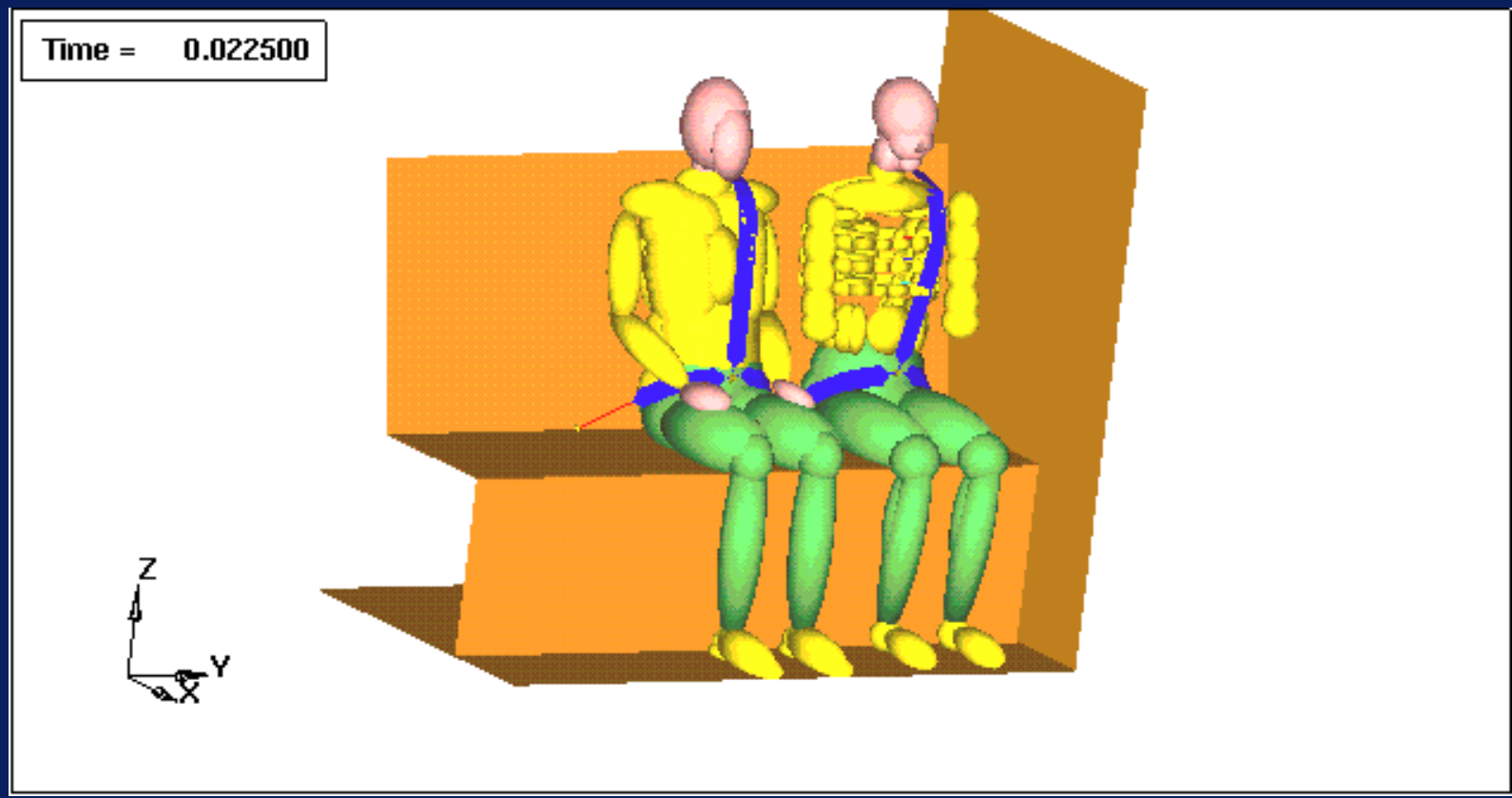


Aviation Simulations in MADYMO

- Plane crash

Aviation Simulations in MADYMO

- Sideways facing seats



Side Impact Neck Injury Criteria and Tolerances for US FAR

- TNO MADYMO North America & Wayne State University
- Inventory and definition
- PMHS experiments
- Injury criteria and tolerance levels
- Standard side impact test procedure