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IMPACTING ON SAFETY

THOR-50M Frontal Impact ATD

THOR-50M - Frontal Impact ATD

- Introduction to ATDs
- Development of Injury Risk Curves
- History of ATD Development
- THOR-50M Overview
- Hybrid III vs. THOR-50M
- Future of ATDs
- Summary

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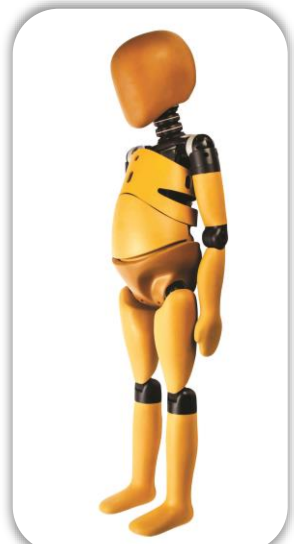

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Introduction to ATDs

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Development of Injury Risk Curves

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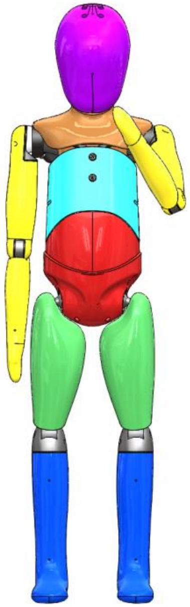
Identify Body Region

- 1. Head (Cranium and Brain)
- 2. Face
- 3. Neck
- 4. Thorax
- 5. Abdomen and Pelvis
- 6. Spine
- 7. Upper Extremity
- 8. Lower Extremity
- 9. External (Skin)



Abbreviated Injury Scale (AIS)

- Method of characterizing injuries
- 6-point ordinal scale.

AIS	Severity Code	Neck
0	No Injury	
1	Minor	Minor laceration/Contusion
2	Moderate	Spinous process fracture/Trachea contusion/Disc herniation.
3	Serious	Atlantoaxial dislocation/Dens fracture
4	Severe	Incomplete cord syndrome
5	Critical	Complete cord syndrome (C4 and below)
6	Maximal	Complete cord syndrome (C3 and above)

(Pellettiere, 2012)

Define Environment

- Define the circumstances under which the injury criteria would apply.
  - Impact Direction
  - Impact Location
  - Restraints
  - Occupant Orientation

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Development of Injury Risk Curves

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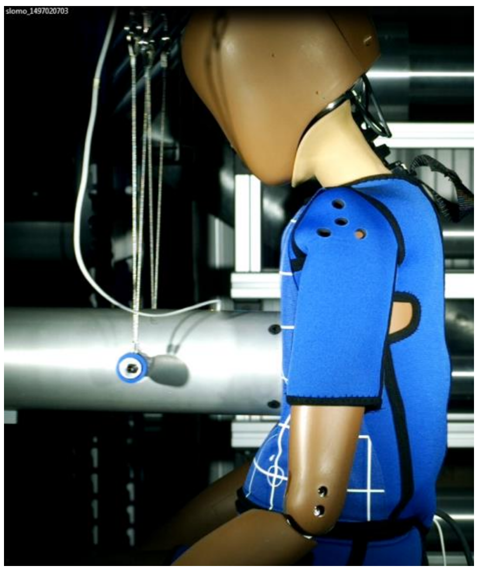
Energy Input

- Define the amount of energy input for the specific scenario.



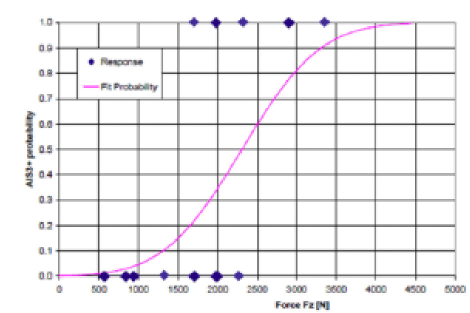
Injury Data Acquisition

- Low energy impact testing on live human subjects.
- High energy testing on PMHS.
- Subject could have some underlying pathology that would cause weakness.
- Also, the average age of the PMHS is usually high, effecting bone density.
- PMHS lacks muscle tone.

(Wired, 2010)

Regression Analysis

- Combine the data on non-injuries and injuries.
- Define an input parameter such as load or displacement.
- Output:
  - **0 = No Injury**
  - **1 = Injury**
- Display the results in a Binomial plot and shows the transition between no injury and injury.



(Pelletiere, 2012)

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History of ATD Development

(Kenney, 2014)

Col. John Stapp

- Investigated effects of G force on human body.
- Initially concerned with injury upon pilots during manoeuvres and ejection.
- Due to high mortality rates in vehicles, Stapp turned his focus onto automotive safety.

Sierra Sam (1949)

- 91kg and 178 cm tall, constructed from Steel and Rubber including moveable joints.
- Used as a loading device. No measurement capability.
- However, the dummy didn't represent a correct driving position in the vehicle. Due to incorrect mass distribution the kinematics were not representative of a human body.

(National Highway Traffic Safety Administration)

Hybrid I, II & III (1970's)

- Development by General Motors, weighing 77kg and is 177cm tall.
- Can be instrumented to determine injury risk for various body regions.
- Comparative testing between Hybrid III and PMHS shows that the global kinematic behaviour of the dummy has a good correlation.
- The magnitude of the PMHS head-neck frontal flexion is greater. Comparisons also show that the dummy thorax is stiffer than the PMHS.

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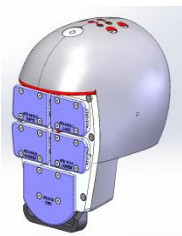
THOR-50M Overview

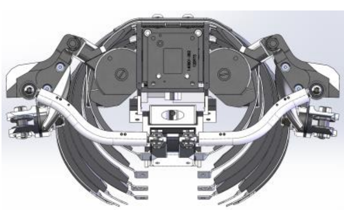
2001 — THOR-Alpha

2005 — THOR-NT

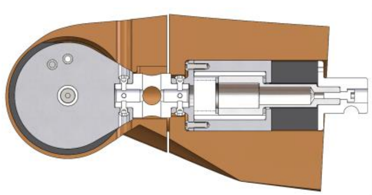
2013 — **THOR-50M**
- Increased Bio-fidelity
- Injury assessment
- Repeatability
- User friendliness



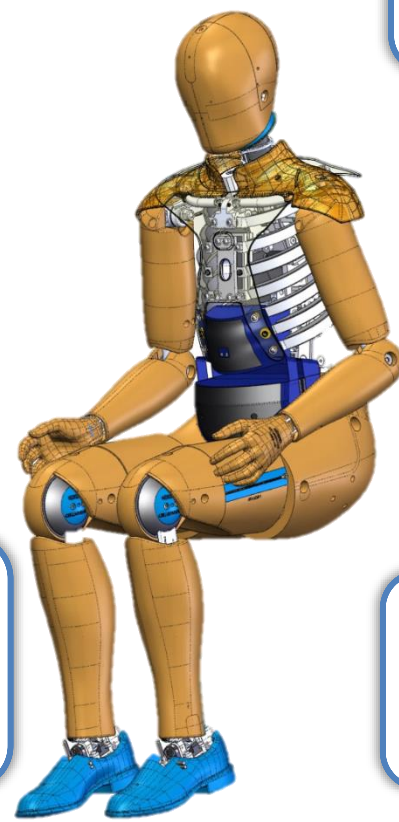
Head
- Load cells to assess facial fracture probability.

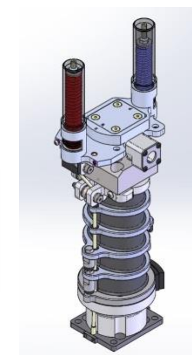


Thorax
- Elliptical ribs for better bio-fidelity
- Deflection sensors measure dynamic 3D compression at 4 points.

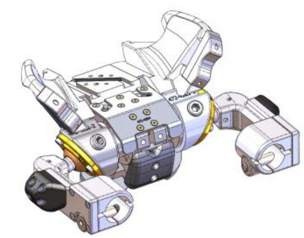


Upper Leg
- Compliant element in femur to provide correct force transmission for axial loading.

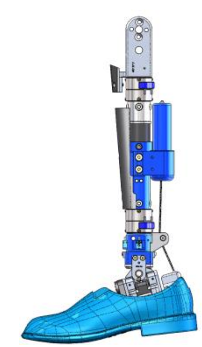




Neck
- Ligament representation
- Increased bio-fidelity



Pelvis
- 3 axis load cell at each hip joint.
- Belt load sensors on each iliac notch.



Lower Leg
- Increased injury sensing capabilities in the foot, ankle and lower leg.

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Hybrid III Vs. THOR-50M

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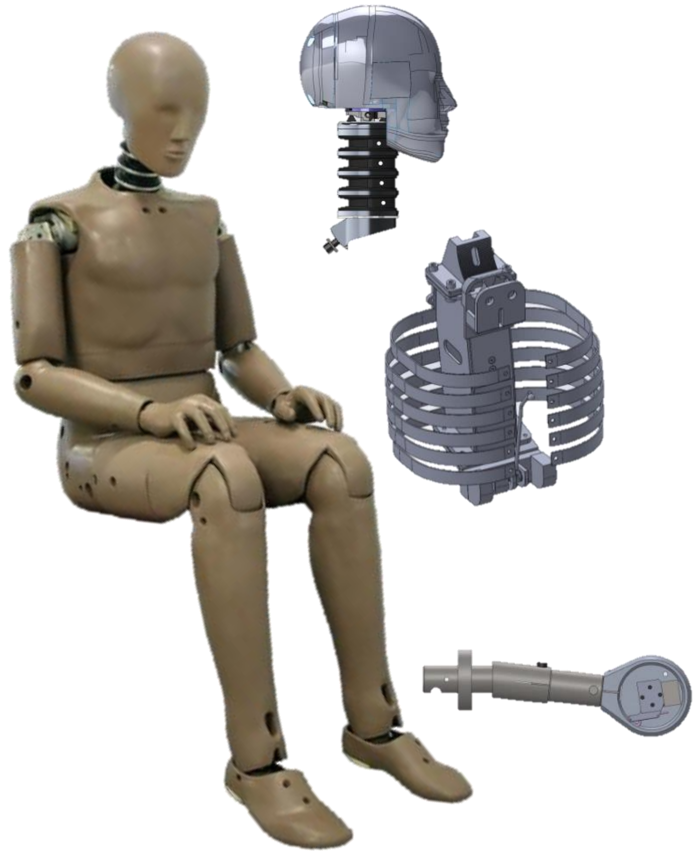
Hybrid III

- Max. 56 Output Channels.



Head/Neck

- THOR includes load cells in the face to assess facial fracture.
- Hybrid III has a single structure central neck assembly.
- THOR has a central neck column with muscle representation.

Thorax

- THOR includes thoracic structure with clavicle.
- Hybrid III Fixed Spine
- THOR has a articulating Spine.

Pelvis

- THOR pelvis has revised anthropometry, including injury assessment at the hips.

Upper Leg

- THOR includes a compliant element in the Femur.
- Hybrid III response does not correlate well to PMHS tests for Knee impacts.

THOR-50M

- Max. 156 Output Channels.

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(Stevenson, 2015)

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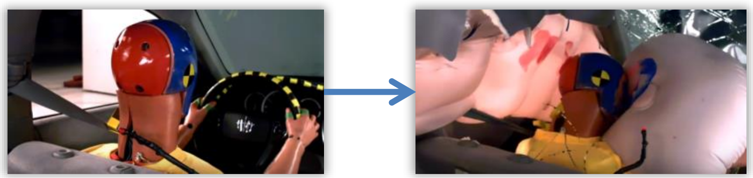
Future of ATD's

- Continuous development of the THOR or future dummy series. Improving bio fidelity and sensing capability.
- Further expansion in the Dummy range:
  - Increase in obesity in general population, driving the need for an obese dummy.
- Increasing the capability and sensitivity of the instrumentation to allow for better injury risk prediction.
- Frontal overlap tests generate a lateral and torsional loading of the dummy neck. Requires a frontal dummy with accurate lateral responses.



- Dummies with the alternative seating position capability for autonomous vehicles:
  - Current occupant dummies usually have a fixed pelvis flesh limiting their ability to recline in a seat.
  - Measurement systems need to be more sensitive to dummy position.
  - Capability of a single dummy to measure injury risk from multiple directions.

Human Body Modelling

- Development of finite element Human Models representing Flesh, muscle, bone, ligaments and internal organs.
- Brain injury risk can be determined using detailed brain models.
- Easier to scale and modify the subject to reflect different physical attributes.

(Toyota, 2018)

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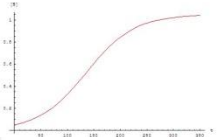
Summary

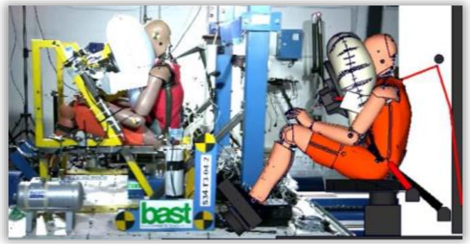
- Development of ATD's has progressed a long way:
  - Loading devices → Advanced measuring devices capable of assessing injury risk.
  - Dummies have become better at replicating human kinematics in a crash.
  - Allowed the development and testing of advanced restraint systems.

(Oagana, 2018)

(EURONCAP, 2017)



- Virtual crash testing helps to support the development of both the dummies and safety systems:
  - Allows variations in testing setup to be analysed quickly
  - Virtual dummies do not experience wear and don't require any maintenance.
  - Still require physical testing for validation.



(Seniors Project, 2018)

- The future of the Automotive industry suggests a shift towards autonomous driving:
  - Ability for dummies to be placed in vehicle in alternative seating positions.
  - Multi-directional sensing dummies capable of predicting injury from impacts in a range of orientations.

Thank you for listening

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Testing Methods

Region	Test		
Head	Head Impact - Fully assembled dummy - 23.4kg Impactor - Impact Velocity 2m/s - Peak Force = 4980N → 6090N	Head Drop - Head assembly - 376mm above impact plate - Peak Acc. = 225g → 275g	
Neck	Dynamic Pendulum Frontal - Head/Neck Assembly - O.C. Moment = 46.6Nm → 57.0Nm	Dynamic Pendulum Lateral - Head/Neck Assembly - O.C. Moment = -81.1Nm → -99.2Nm	Occipital Condyle Joint Rotation - Head/Neck Assembly - Peak Flexion Moment = 8.7Nm → 11.7Nm - Peak Extension Moment = -8.7Nm → -11.7Nm
Thorax	Upper Ribcage Central Impact - Fully assembled dummy - 23.4kg Impactor - 4.3m/s - Max Force = 2450N → 2950N - Max X-Displacement = 49mm → 59mm - 6.7m/s - Max Force = 5630N → 6870N - Max X-Displacement = 65mm → 79mm	Lower Ribcage Oblique Impact - Fully assembled dummy - 23.4kg Impactor - 4.3m/s - Max Force = 3390N → 4140N - Max X-Displacement = 41mm → 51mm	
Abdomen	Upper Abdomen Dynamic Impact - Fully assembled dummy - Steering wheel shaped impactor angled at 30° of 18kg - 8m/s - Max Force = 5220N → 6380N - Max X-Displacement = 41mm → 50mm	Lower Abdomen Dynamic Impact - Fully assembled dummy - 25mm diameter rigid bar impactor of 32kg - 6.1m/s - Max Force = 2200N → 2700N - Max X-Displacement = 49mm → 60mm	
Femur	Knee Impact - Fully assembled dummy - 76mm diameter impactor of mass 5kg - 2.6m/s - Max Force = 3510N → 4290N		
Face	Rigid Bar Impact - Fully assembled dummy - 25mm diameter bar impactor of mass 32kg - 3.6m/s - Max Force = 2750N → 3360N - Peak Time = 6.8ms → 8.8ms	Rigid Disk Impact - Fully assembled dummy - 152mm diameter impactor of mass 13kg - 6.7m/s - Max Force = 8390N → 9750N - Peak Time = 3.9ms → 5.1ms	
Lower Leg	Quasi-static Inversion and Eversion - Lower Leg Assembly - Rotate Ankle Joint - 6Nm = 17.5° → 21.3° - 23Nm = 29.3° → 35.9°	Dynamic Dorsiflexion - Lower Leg Assembly - Impact Vel. 5m/s - Max Tibia Compressive Force = 3058N → 3738N - Max Ankle Resistive Moment= 76.2Nm → 93.2Nm	Dynamic Heel Impact - Lower Leg Assembly - Impact Vel. 4m/s - Max Tibia Compressive Force = 2694N → 3292N