TTCP PA LND Group Meeting

Integrated Ballistic and Blast Protection for the Individual Warfighter

Facial and Ocular Countermeasure Safety (FOCUS) Headform Development

Natick Soldier Research, Development, and Engineering Center

Natick, MA
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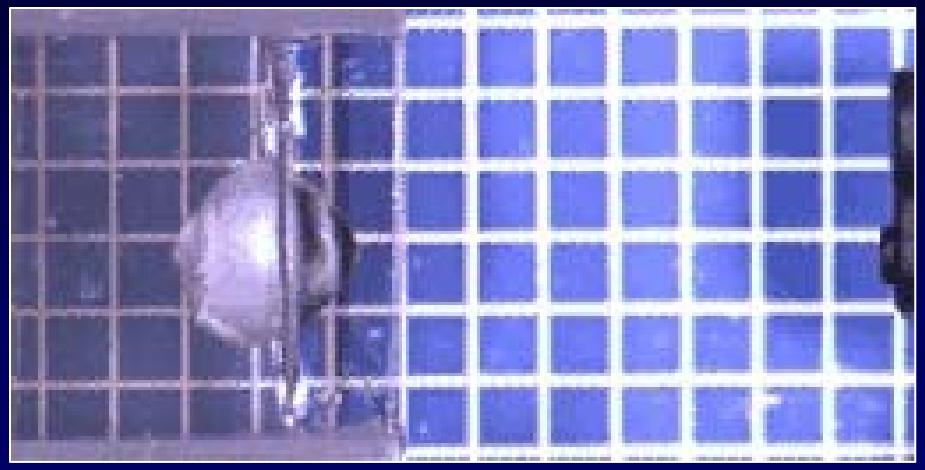
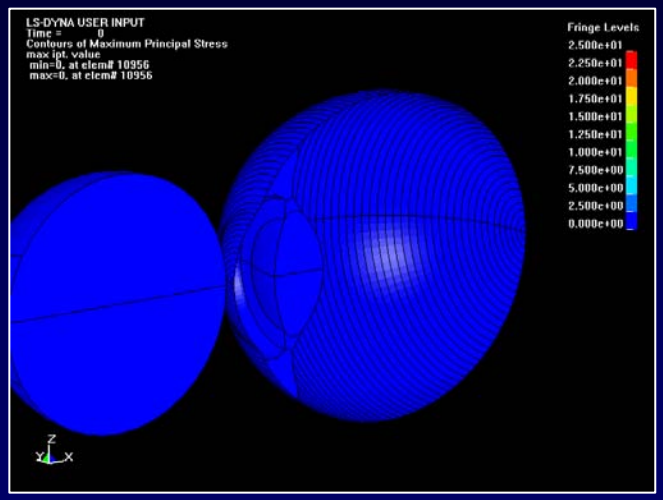
Eye Injuries

- 1.9 Million people suffer from eye injuries in the U.S. each year (McGwin, 2005)
- The rate of eye injuries has dramatically increased in warfare since the American Civil War (Heier, 1993)
- During recent conflicts the percentage of eye injuries is now 13% of ***ALL*** combat injuries (Heier, 1993)

Eye and Facial Injury Prediction Techniques



Experimental Impact Tests



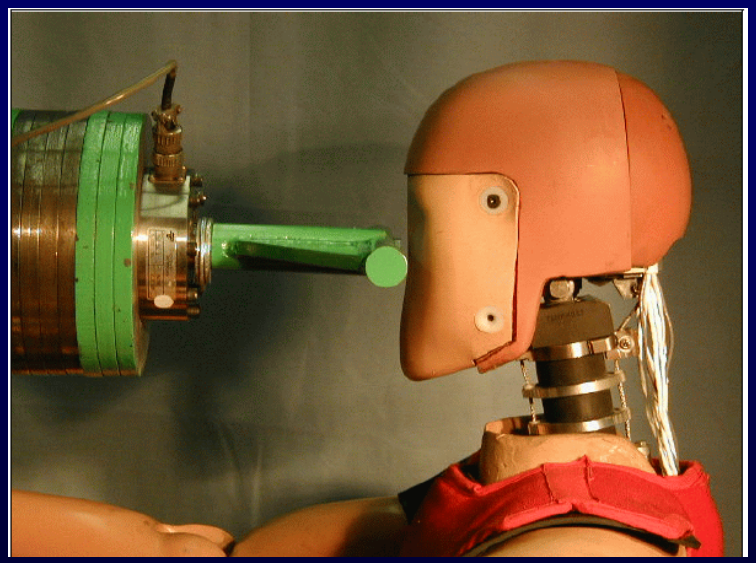
Computational Models

Crash Test Dummies

- Alderson (ANSI)
- Hybrid III
- NOCSAE
- THOR

Dummy Headforms

- Alderson (ANSI)
  - Detailed facial features
  - Uni-axial acceleration
  - No facial or eye instrumentation
- Hybrid III
  - Crude facial features
  - Linear and angular acceleration
  - No facial or eye instrumentation
- NOCSAE
  - Helmet certification
  - Gelatin filled skull
  - Acceleration measurement
  - No facial or eye instrumentation
- THOR
  - Facial load cells
  - Lack of detailed anatomical facial features



Warfighter Face and Eye Injury Protection

Purpose:

Provide materiel developers with fast, economical, and accurate ability to assess face/eye injury probability and severity

Product:

- ***Physical models of the face and eye (manikin) - reducing reliance on costly and inefficient cadaver based tests***
- ***Mathematical models predicting risk and severity of face/eye injury***

Payoff:

- ***Objective assessment of injury risk and severity***
- ***Reduce testing cost***

FOCUS Design and Packaging

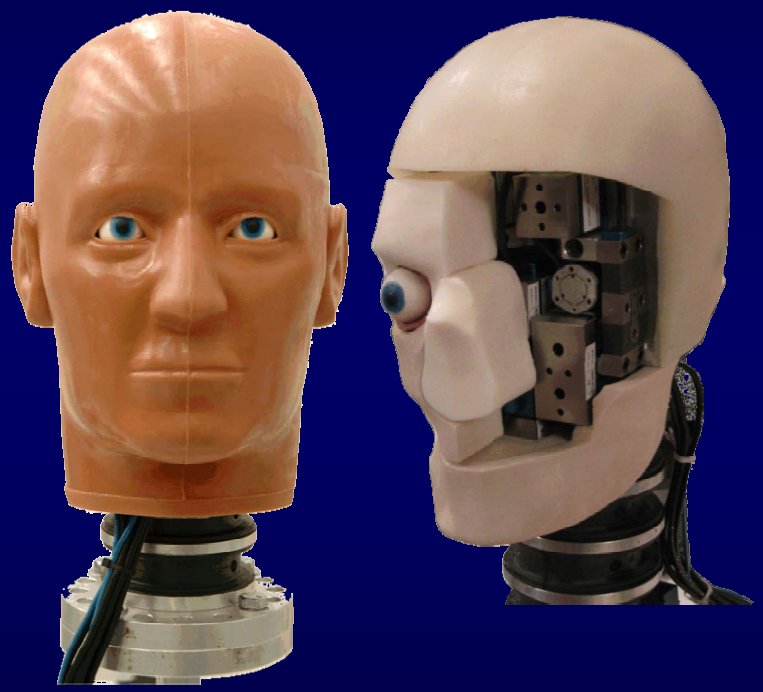
“Team Effort”

- USAARL
  - Conceptual framework
  - Definition user needs & design approval
- Center for Injury Biomechanics
  - Design requirements and specifications
  - Biofidelity definition
  - Materials selection
  - Validation testing
- Denton, Inc.
  - Design packaging and manufacturing
  - Load cell design and calibration
  - “Most challenging dummy design ever attempted or accomplished”

FOCUS Headform

Facial and Ocular CountermeasUre Safety Headform

- Fully Instrumented Headform for Assessing Eye and Facial Injury Risk from Impact Loading
  - Military, automotive and sports scenarios
  - Assess the risk of eye injury and the capability of protective equipment in reducing those injuries
- Design Considerations
  - ***Anthropometry***
  - ***Facial Segmentation & Instrumentation***
  - ***Eye Design & Instrumentation***
  - ***Biofidelity***
  - ***Injury Prediction/Sensitivity*** . . .



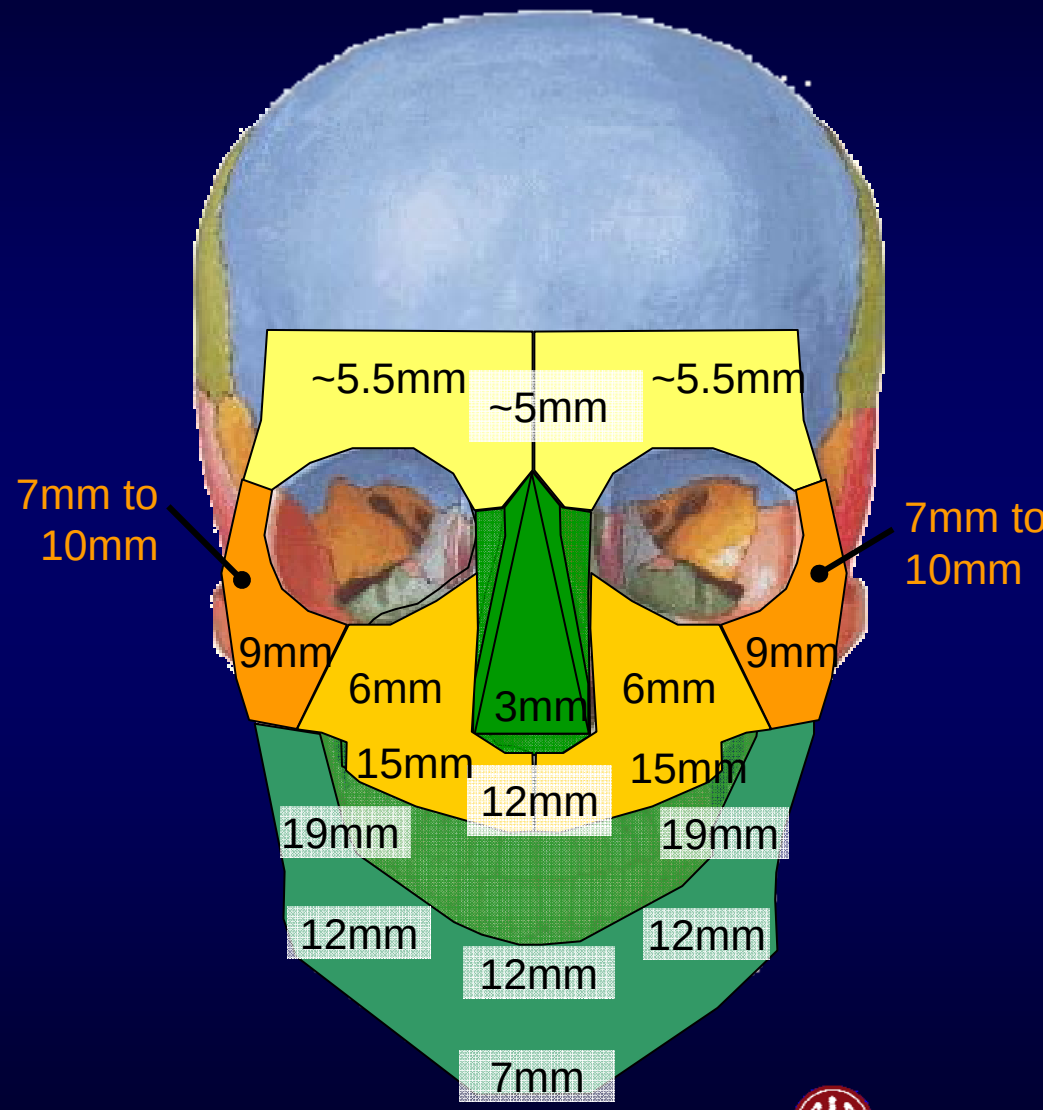
FOCUS Headform Anthropometry

- 50th percentile male US Soldier
- Dimensions: Tri-service anthropometry study (USAARL Tech Report 88-5)
- Weight & CG of Hybrid-II headform
  - 11.2 ± 0.1 lbs
  - Same inertia corridor as Hybrid-II

- Chin and nape for proper helmet fit
- Ears to facilitate spectacle placement

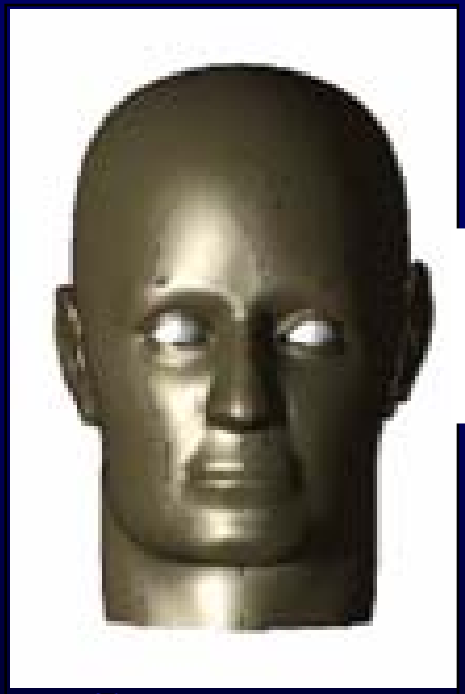
FOCUS Skin Thickness

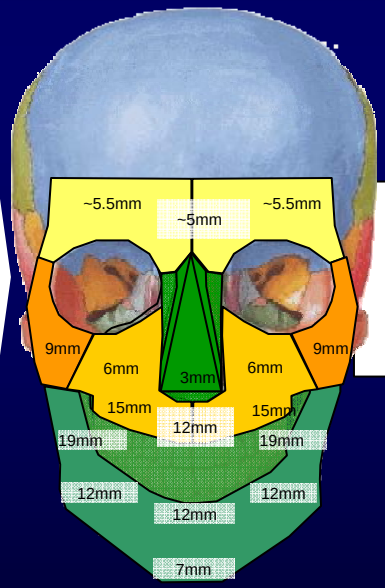
- Skin thickness selected to provide appropriate biofidelity
- Based on skin thickness measurements from forensics literature
- Material selection for skull and skin chosen from existing dummy designs

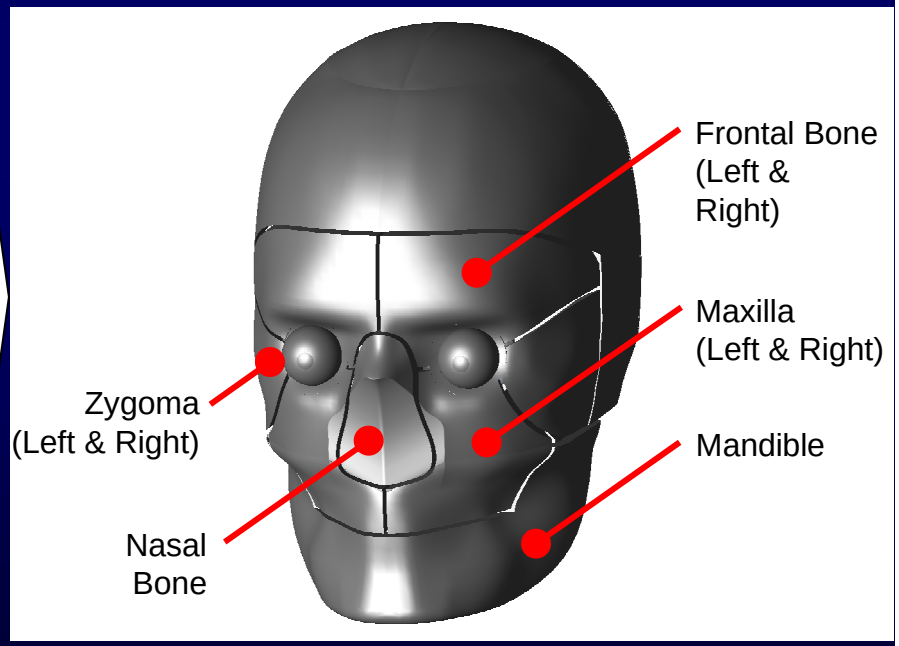


FOCUS Headform Skull

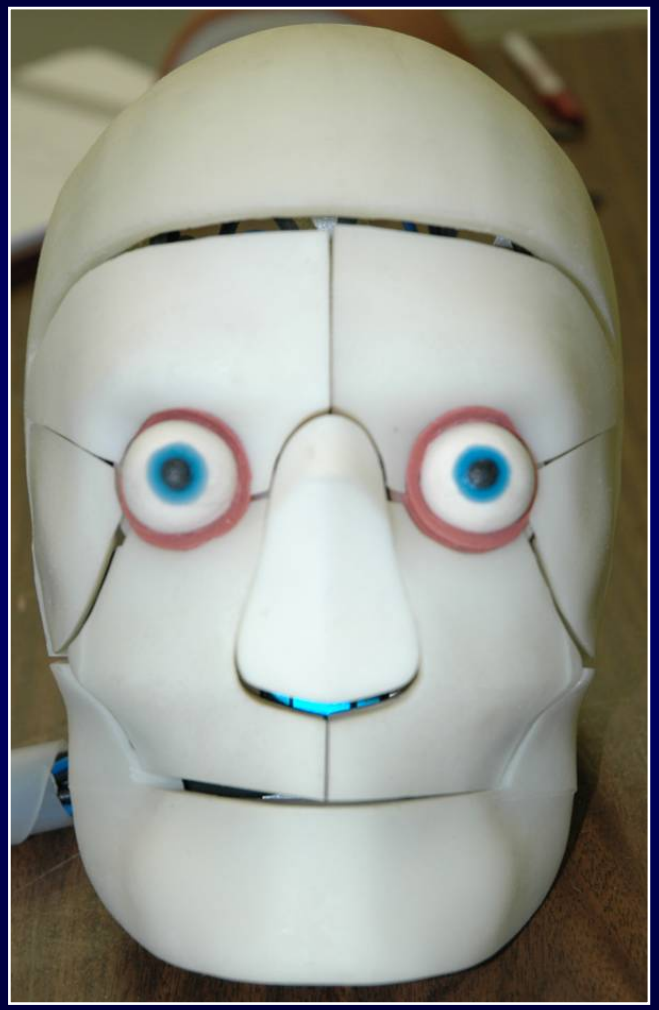
- Headform anthropometry and skin thickness used to define underlying “skull” shape
- Skull segmentation based on anthropometric relationships of human skull within packaging constraints
- Skull segmented into five facial regions (8 total segments)

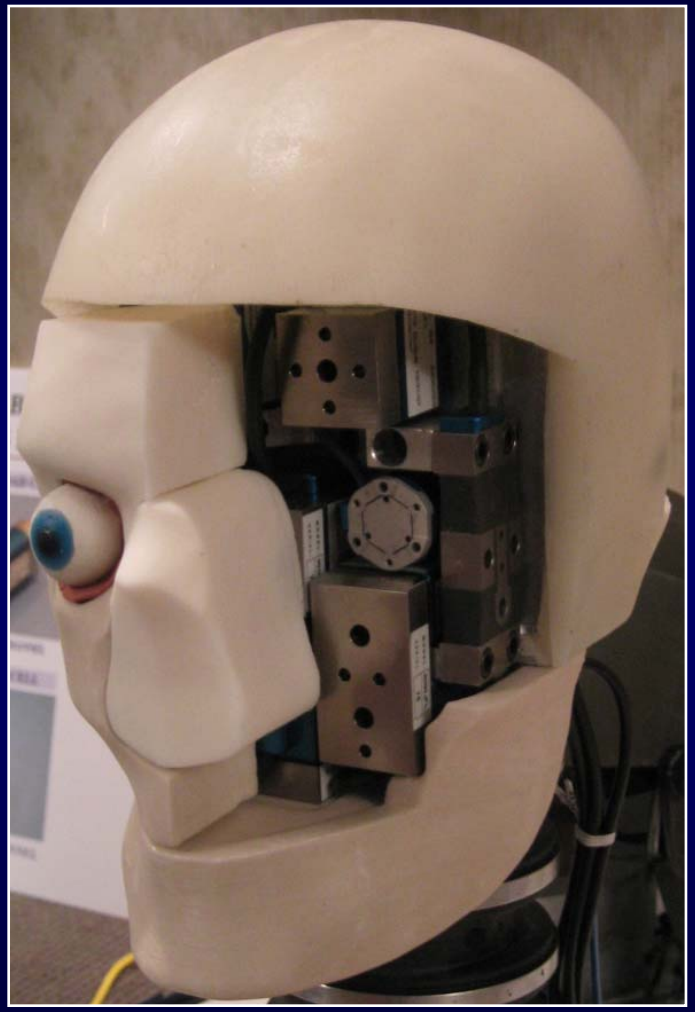






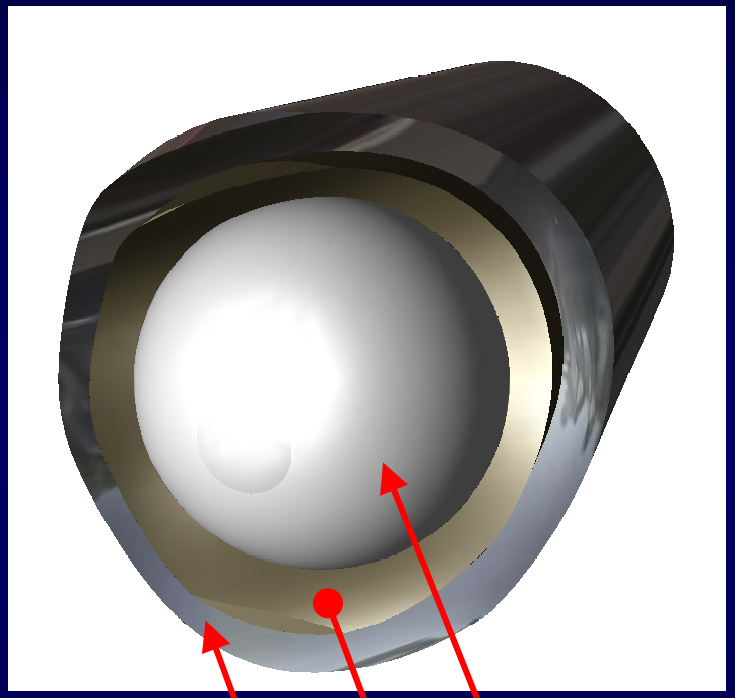
FOCUS Skull Assembly and Instrumentation





FOCUS Synthetic Eye Concept

- Eye
  - Solid urethane for repeatability and durability
  - Tooling and repeatability concerns for fluid-filled eye
  - Material selected for biofidelic force-deflection response
- Extraocular tissue
  - Material selected for biofidelic force-deflection response
- Modular orbit
  - Lightweight rigid urethane mounting cup
  - Modular orbit with removable/ replaceable eye

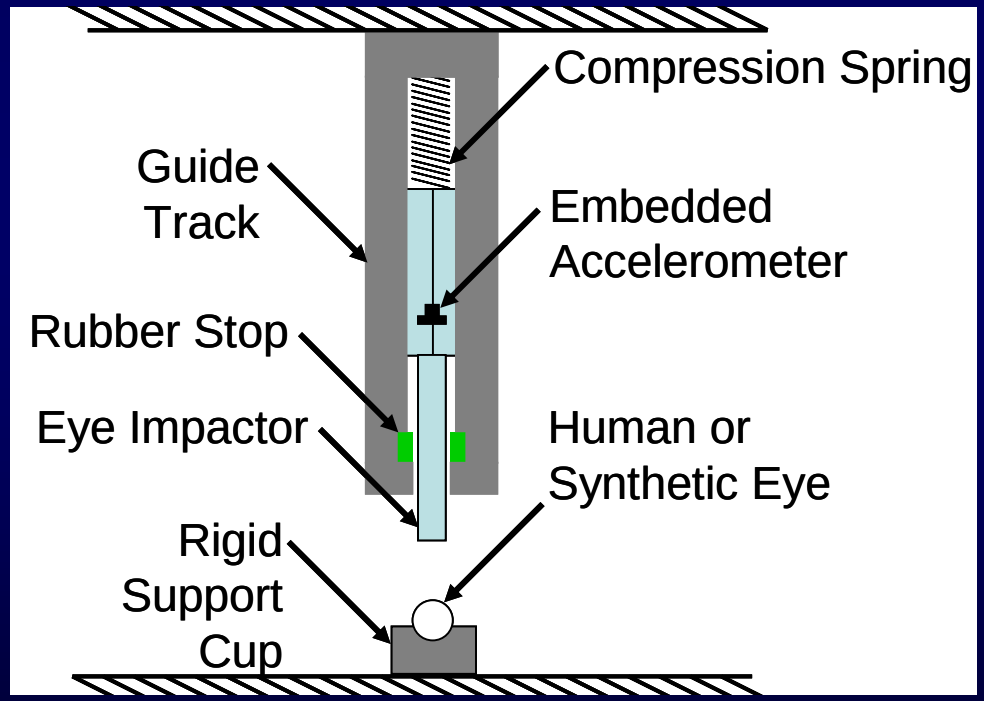


FOCUS Synthetic Eye: Biofidelity

- Step 1: Biofidelity of the Eye
  - Quantify the force-deflection response of the eye to blunt impact
  - Match the force-deflection response of a synthetic eye to the human eye response
- Step 2: Biofidelity of the Eye and Orbit
  - Quantify the force-deflection response of the in-situ human eye to blunt impact
  - Elucidate effects of extraocular muscles on the force-deflection and injury response of the eye to blunt trauma
  - Develop a biofidelic synthetic orbit assembly that matches the in-situ response for tested impact conditions

Biofidelity of the Eye

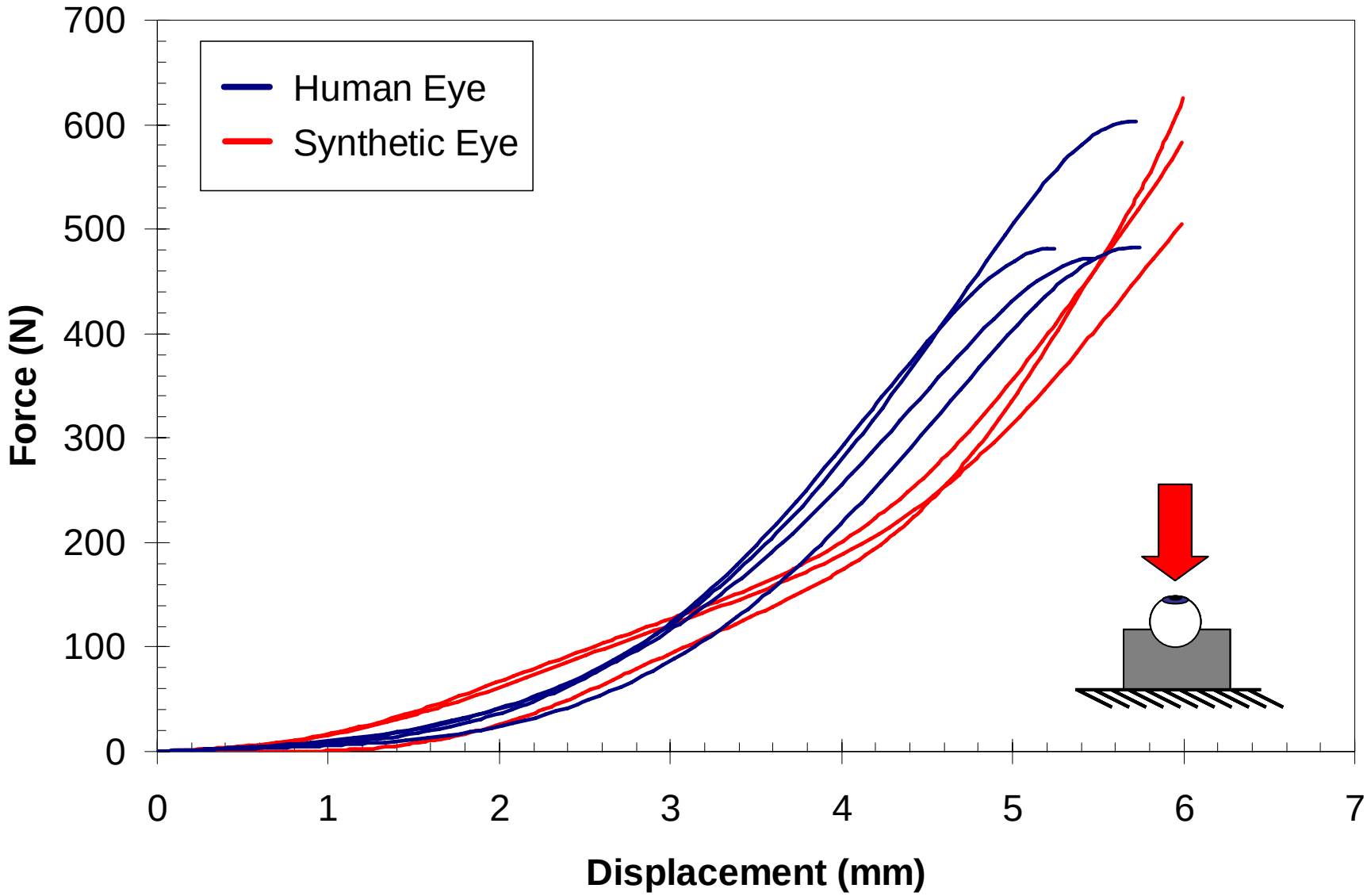
- Quantify the force-deflection response of the human eye to blunt impact
- Match the force-deflection response of a synthetic eye to the human eye response



Test Conditions:

- 19 mm impactor
- 10 m/s impact speed
- 6 mm of free travel
- Human eyes pressurized to physiologic conditions
- Urethane synthetic eyes of various durometers

Biofidelity of the Eye



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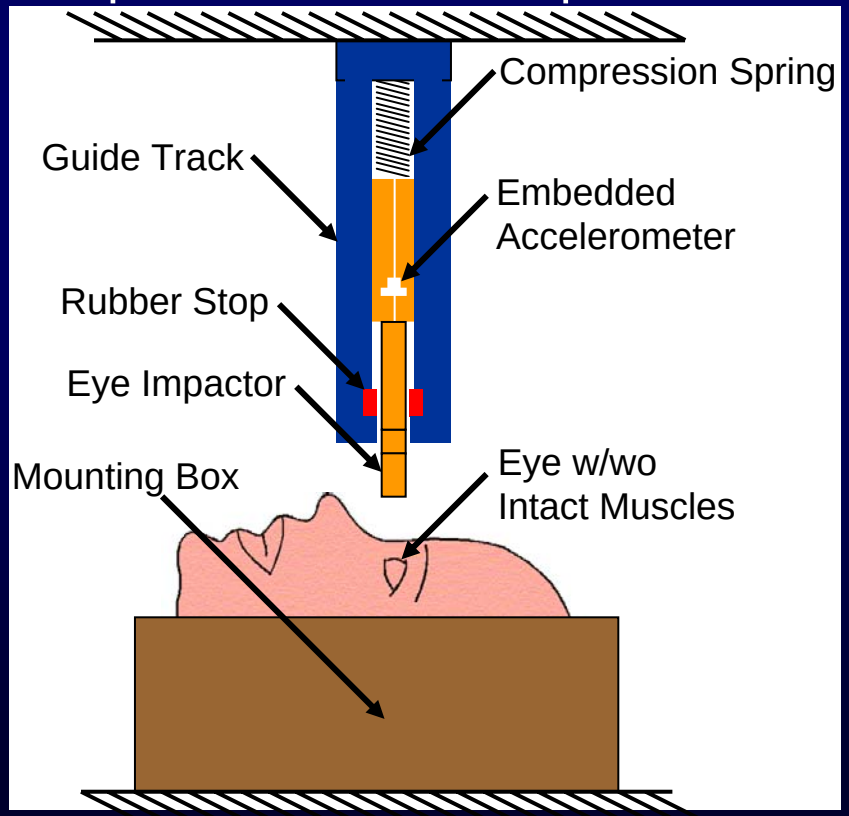
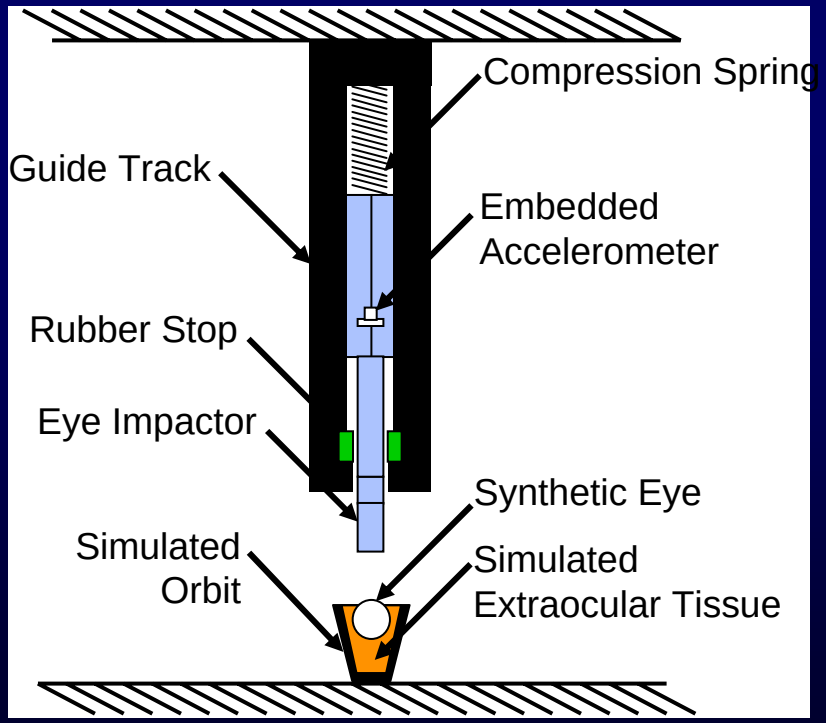
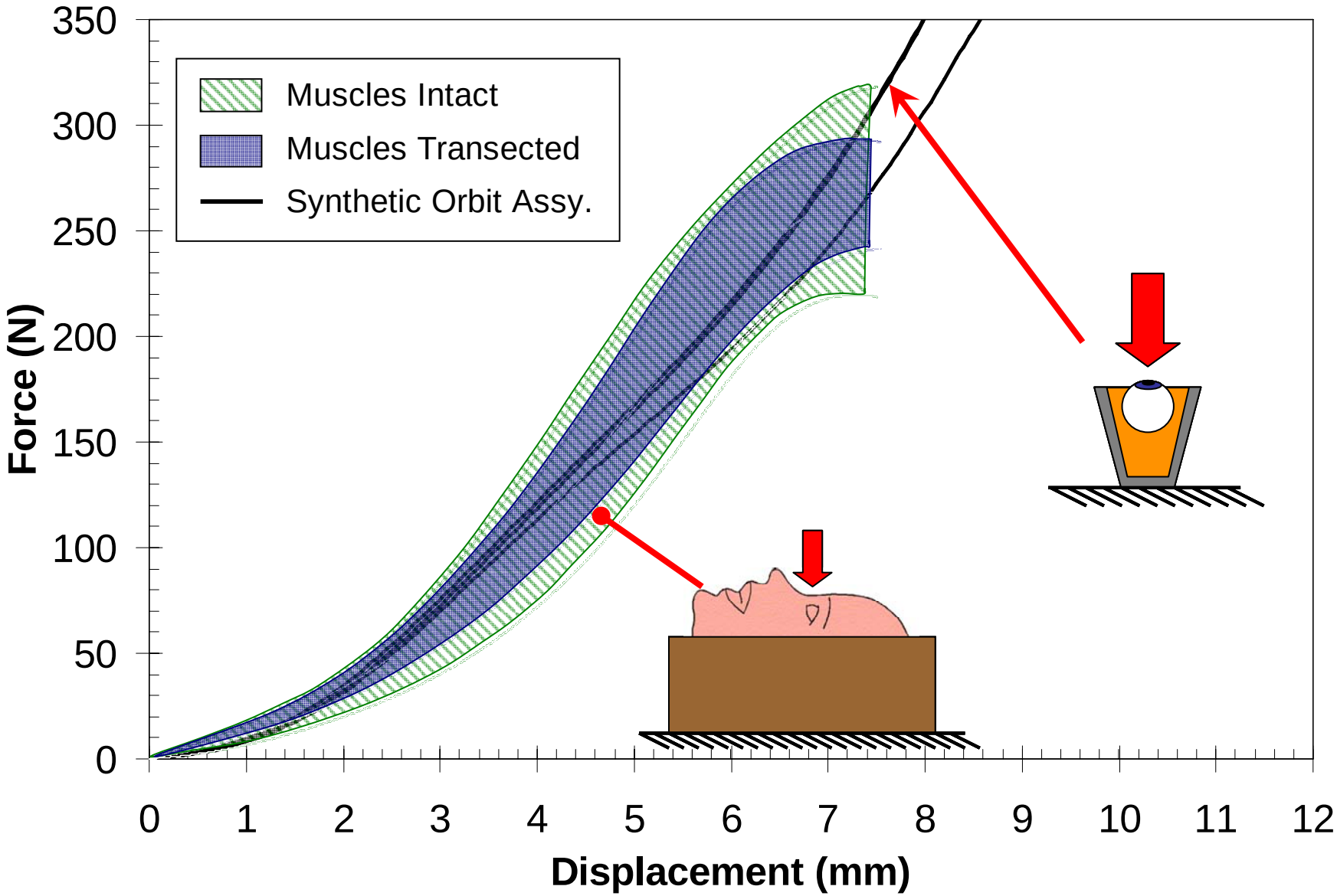


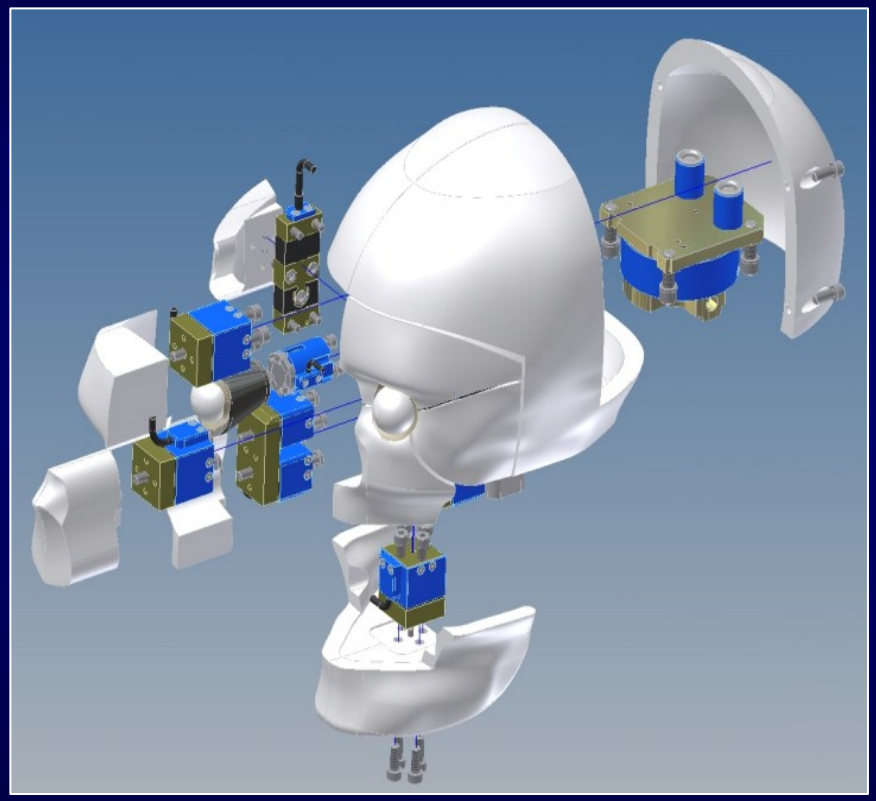


Force-Deflection of Synthetic Orbit Assembly



FOCUS Instrumentation

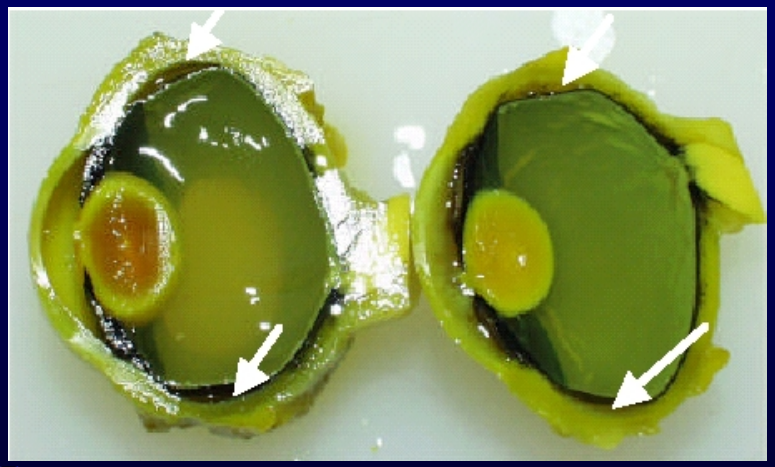
- Skull segments
  - 3-axis load cells
  - 1000-lbf max load
- Synthetic eyes
  - Single-axis load cells
  - 225-lbf max load
- Additional instrumentation
  - 6-axis upper neck load cell
  - Headform CG
    - 3-axis linear acceleration
    - 3-axis angular velocity



Injury Criteria

Relate loads measured by FOCUS headform to injury risk

- Eye injuries
  - Globe rupture
  - Retinal detachment
  - Lens dislocation
  - Hyphema



- Facial fracture thresholds
  - Frontal bone
  - Zygoma
  - Nasal bone
  - Maxilla
  - Mandible

Injury Criteria

Relate loads measured by FOCUS headform to injury risk

- Eye injuries
  - ✓ Globe rupture
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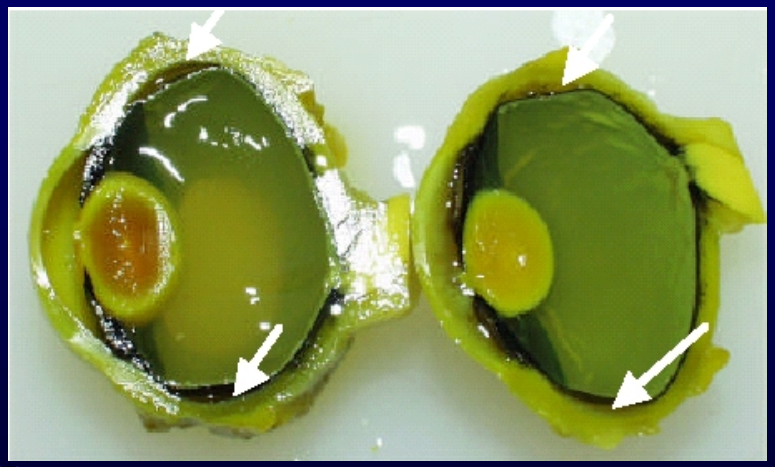

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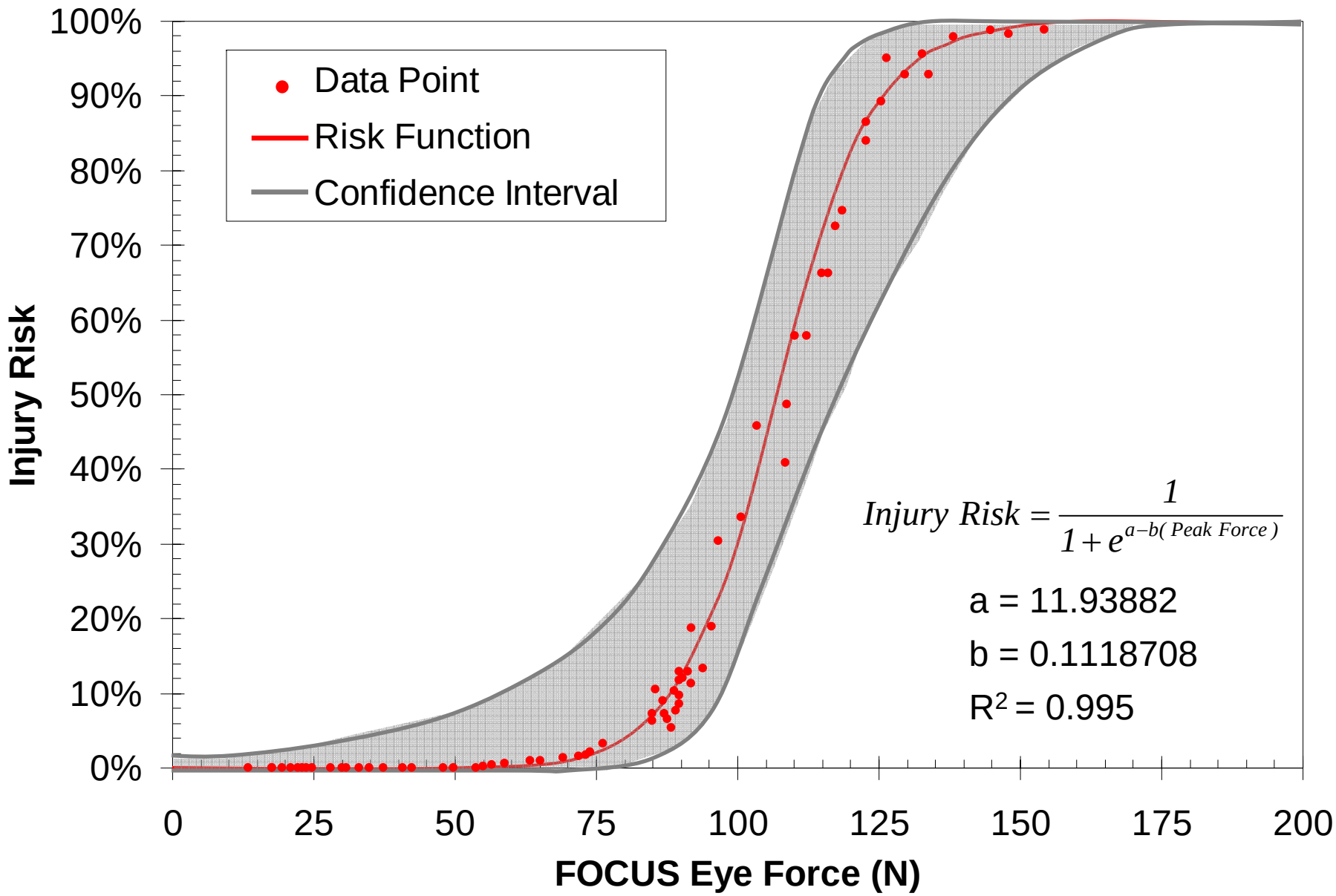
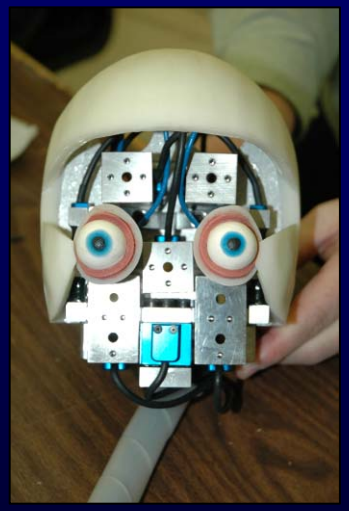
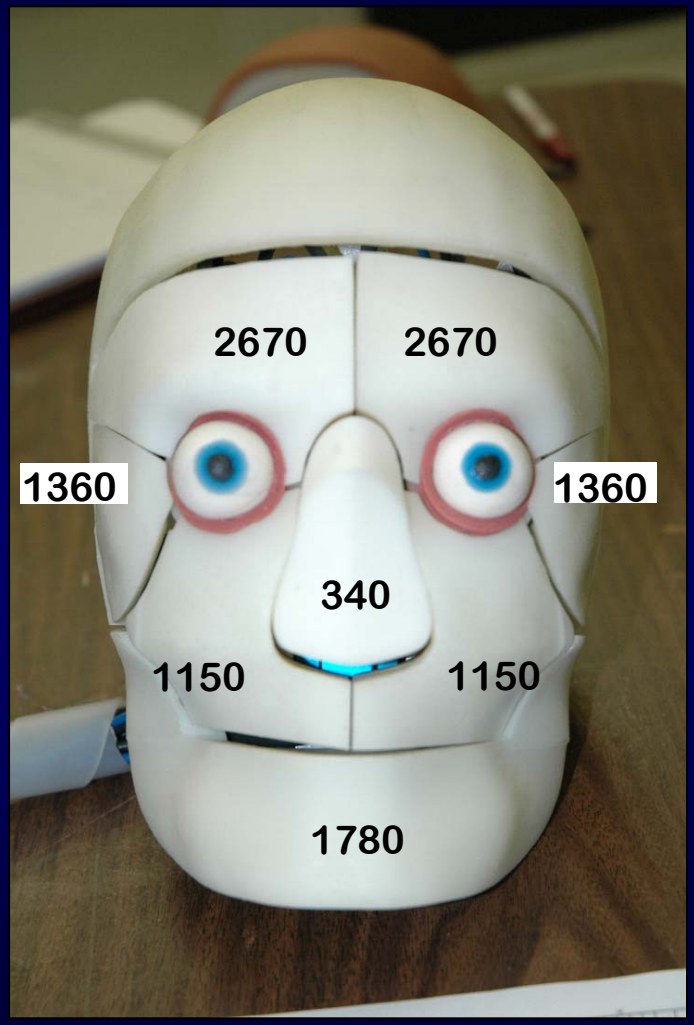
Globe Rupture Injury Risk Function



Facial Bone Fracture Thresholds

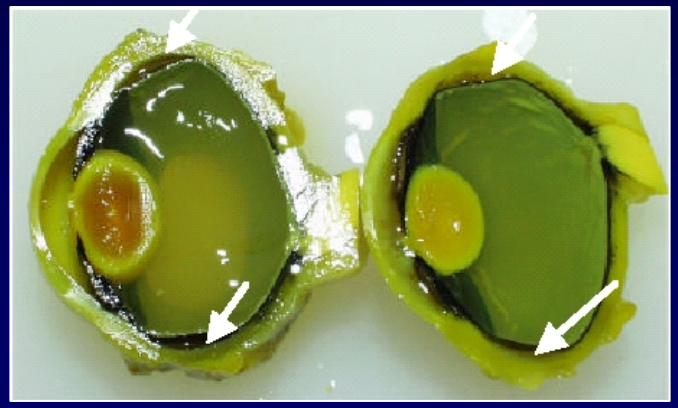
- Fracture thresholds
  - Frontal Bone: 2670 N
  - Nasal Bone: 340 N
  - Maxilla: 1150 N
  - Mandible: 1780 N
  - Zygoma: 1360 N





Continued Injury Criteria Development

- Lower level eye injuries
  - Retinal damage, lens dislocation, and hyphema
  - Addition data needed to develop injury risk curves
  - Collaborative agreement in place
  - Criteria expected May 2009



- Facial fracture
  - Addition facial bone impact tests needed
  - Injury risk curves expected late 2009

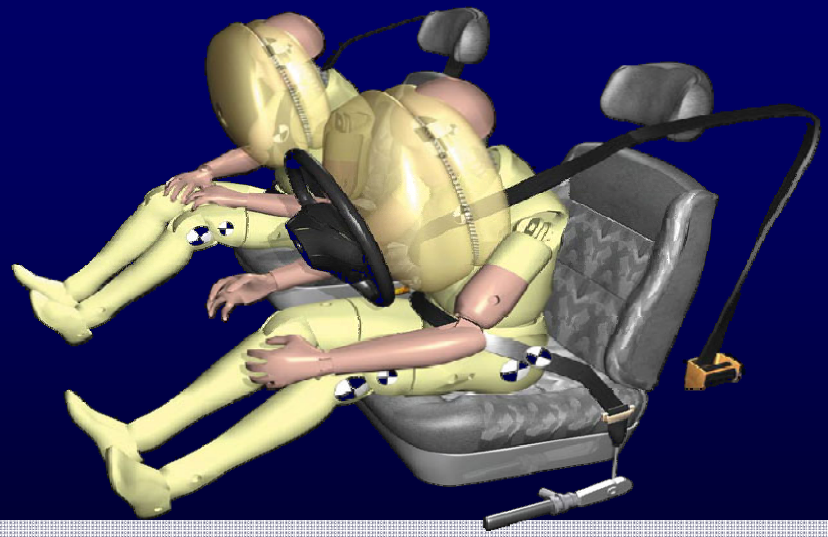
FOCUS Headform Limitations

- Developed for blunt injury
- Not intended for direct ballistic impacts

FOCUS Applications

Military: Troop Protection

Sports: Injury Prevention



Automotive Impact Scenarios

FOCUS Blast Testing

- Investigate feasibility of using FOCUS during blast testing
  - Sensitivity
  - Repeatbility
  - Fidelity

FOCUS Blast Testing

Test Setup

- NSRDEC test series at Blossom Point
- 30 blast events
- C4 and SYS2 charges
  - C4 – 1.5 & 2.0 lbs charge weights
  - SYS2 – 1.45, 2.0 & 2.75 lbs

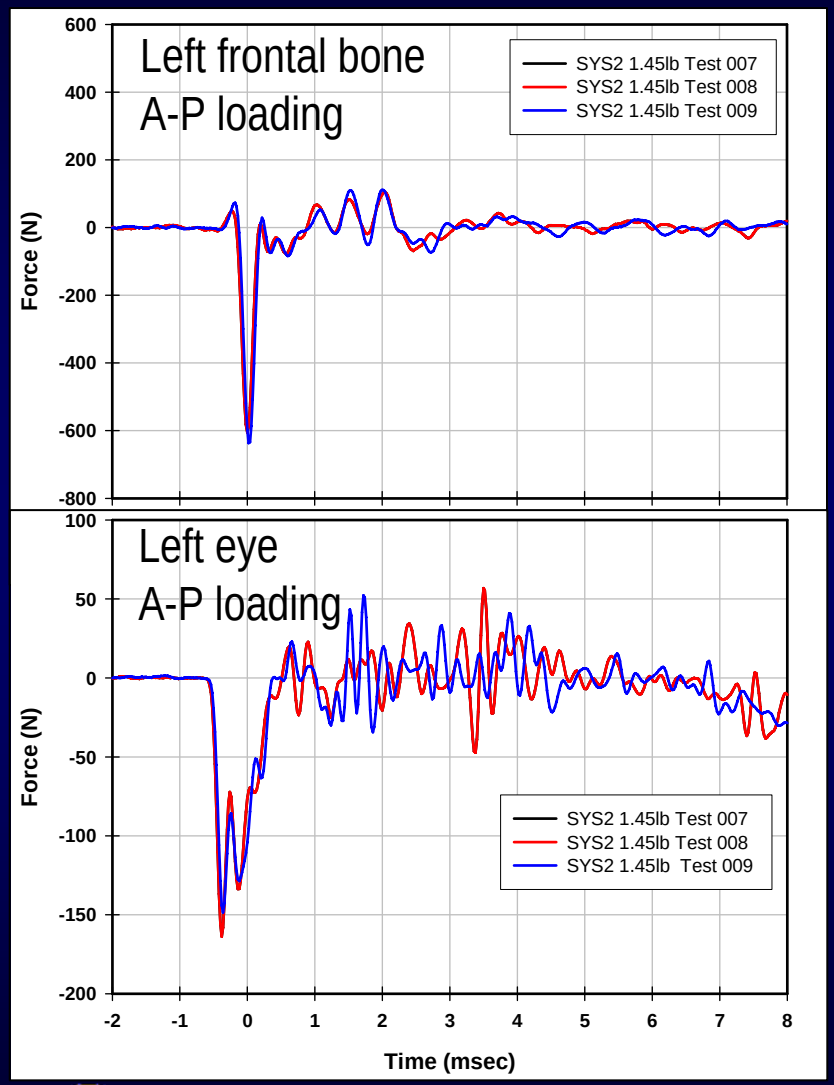
FOCUS Blast Testing

Test Setup

- Mid-size male Hybrid III with FOCUS headform
- Headform facing blast
- 92 inches from center of blast to FOCUS nose
- 26 data channels
- 50,000 Hz sample rate

FOCUS Blast Testing

Results: Sensitivity and Repeatability



- SYS2 test series
  - 1.45-lb charge weight
  - No protective eyewear
- Anterior-posterior load direction
- Left frontal bone and left eye

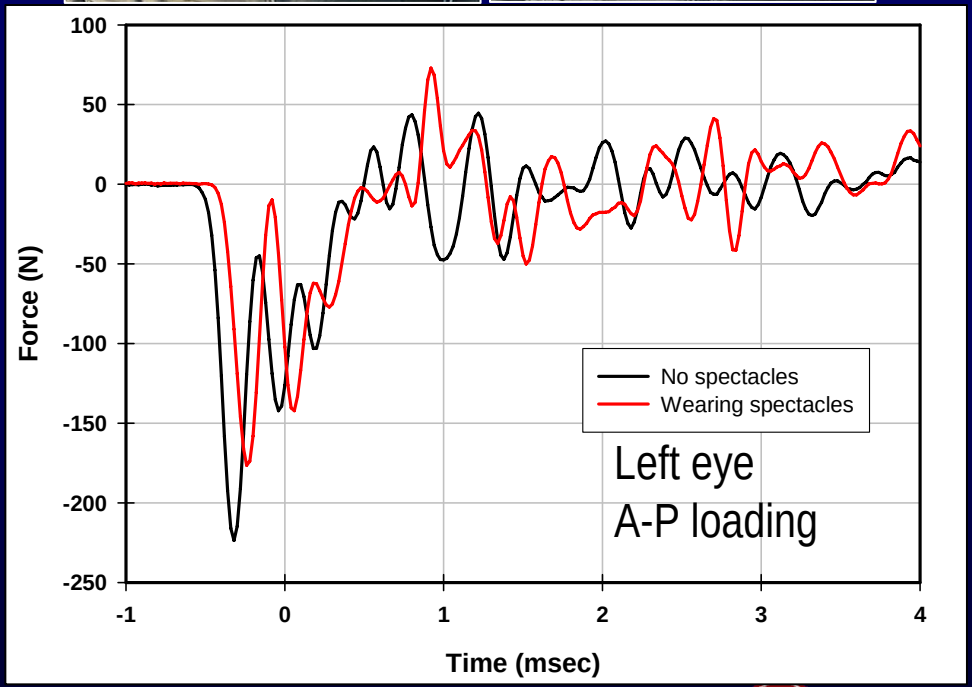
- FOCUS is capable of measuring face and eye loads resulting from blast events
- Results are repeatable

FOCUS Blast Testing

Results: Fidelity

- SYS2 tests
  - 2.0-lb charge weight
  - No helmet
  - With and without protective eyewear

- Left eye, A-P loading
- Reduction in peak force with protective eyewear



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