Assessment of Injury Potential in Aircraft Side-Facing Seats Using the ES-2 Anthropomorphic Test Dummy

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Background

- **Occupant injury assessments found in dynamic seat testing requirements focus on forward and aft-facing seats.**
- **Current FAA policy on side-facing seats cites injury assessments based in part on Federal Motor Vehicle Safety Standards (FMVSS)**

Background

- **Advanced means of assessing injuries in side impacts have been developed for application to motor vehicles.**
  - Test dummies with improved biofidelity
  - More specific prediction of injury
- **Inflatable restraint systems now available to potentially mitigate injuries in side-facing impacts.**

Project Goals

- **Conduct a project to evaluate the injury risk presented by a typical side-facing seat configuration using the state-of-the-art methods.**
- **Assess the potential for injury mitigation provided by inflatable restraint systems.**

Project Tasks

- **Conducted dynamic tests with typical aircraft side-facing seat configurations using the ES-2 ATD.**
  - ES-2 ATD cited in proposed automotive requirements
  - 44 ft/s 16 G (Part 25) test condition (used to allow comparison with previous studies)
  - Rigid seat used for repeatablilty

Project Tasks

- **Conducted dynamic tests with typical aircraft side-facing seat configurations using the ES-2 ATD (continued).**
  - Seat and restraint configuration based on survey of leading seat manufacturers
    - Rigid seat configuration reflected the pertinent reported dimensions
    - Three point (body-centered) restraint system
  - Seating Scenarios
    - Next to a rigid wall (full body support)
    - Center occupant of a multiple-place couch
    - Next to an armrest

Project Tasks

- **Evaluated the potential for injury using current, proposed, and preliminary injury criteria.**
  - 14 CFR 25.562
    - Head Injury Criterion (HIC)
    - Shoulder Belt Tension
  - FMVSS-214
    - Thoracic Trauma Index (TTI)
    - Pelvis Acceleration
  - EU 96/27/EC
    - Viscous Criterion (V*C)

Project Tasks

- **Evaluated the potential for injury using current, proposed, and preliminary injury criteria (continued).**
  - Proposed FMVSS-214 (Notice of Proposed Rulemaking)
    - T-12 (chest) Acceleration
    - Rib Deflection
    - Abdominal Forces
    - Pubic Force

Project Tasks

- **Evaluated the potential for injury using current, proposed, and preliminary injury criteria (continued).**
  - FMVSS-208
    - Neck Forces and Moments
    - Preliminary Lateral Nij
  - Research Criteria
    - Neck Bending Angle
    - Femur Twisting Moment
    - Belt Impingement on Neck

Project Tasks

- **Evaluated the ES-2 ATD's functionality when used in the aviation environment**
  - Interaction with restraints
  - Durability
- **Investigated test methods unique to side-facing seats**
  - Seating methods for consistency

Project Tasks

- **Evaluated the ability of inflatable restraint systems to mitigate injuries in these seating configurations**
  - Inflatable Shoulder Belt
  - Self contained crash sensor / inflation system.
  - Prototype similar to current certified systems from AmSafe

Project Tasks

- **Test Matrix**

Configuration	Restraint Type	ATD Type	Test Number
Center	Conventional	ES-2	A05066
		ES-2	A05068
	Inflatable	ES-2	A05067
		ES-2	A05070
Close Wall	Conventional	ES-2	A05065
Far Wall	Conventional	ES-2	A05071
	Inflatable	ES-2	A05072
Armrest	Conventional	ES-2	A05075
		ES-2	A05076
	Inflatable	ES-2	A05073
		ES-2	A05074
	Conventional	FAA H-III	A06004

Wall Position
Conventional Restraint

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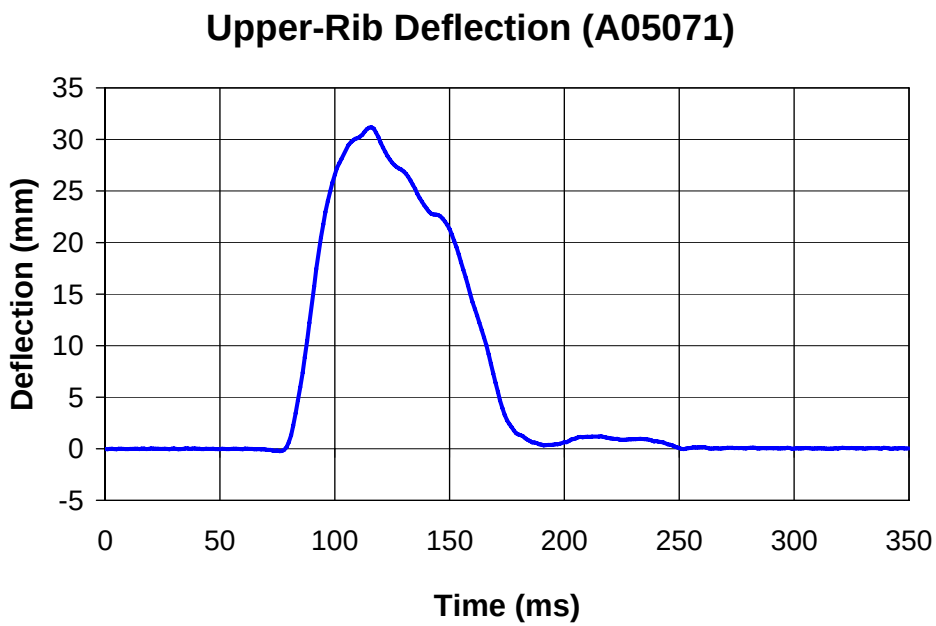
Wall Position
Conventional Restraint



Wall Position Inflatable Restraint

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Center Position Conventional Restraint

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Center Position Inflatable Restraint

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Armrest Position Conventional Restraint

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Armrest Position Conventional Restraint

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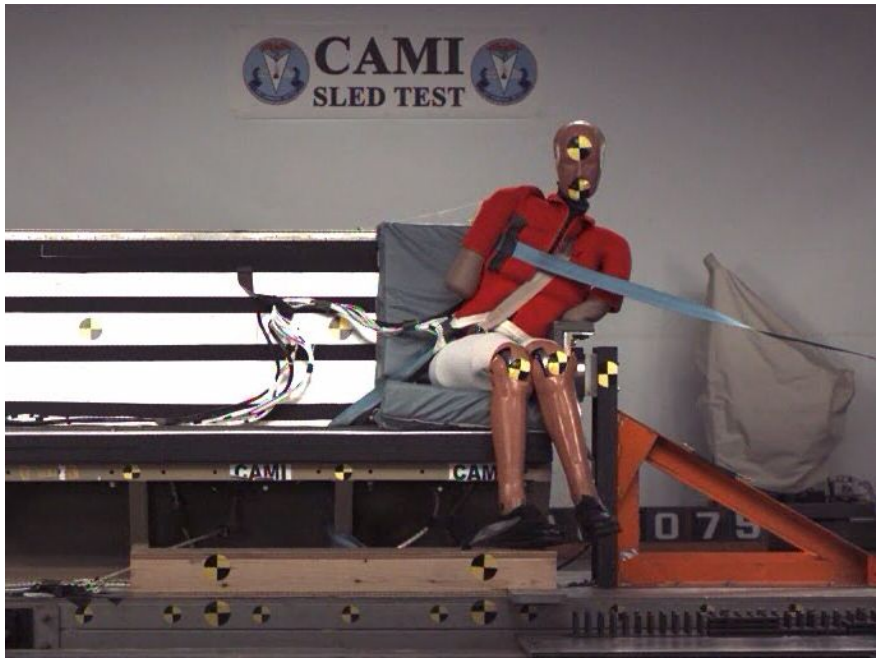
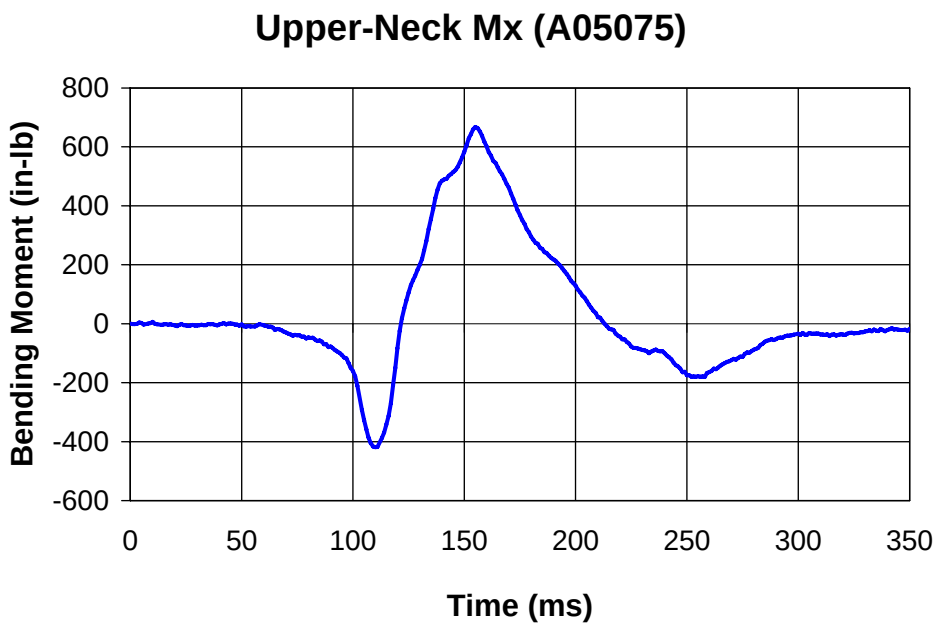
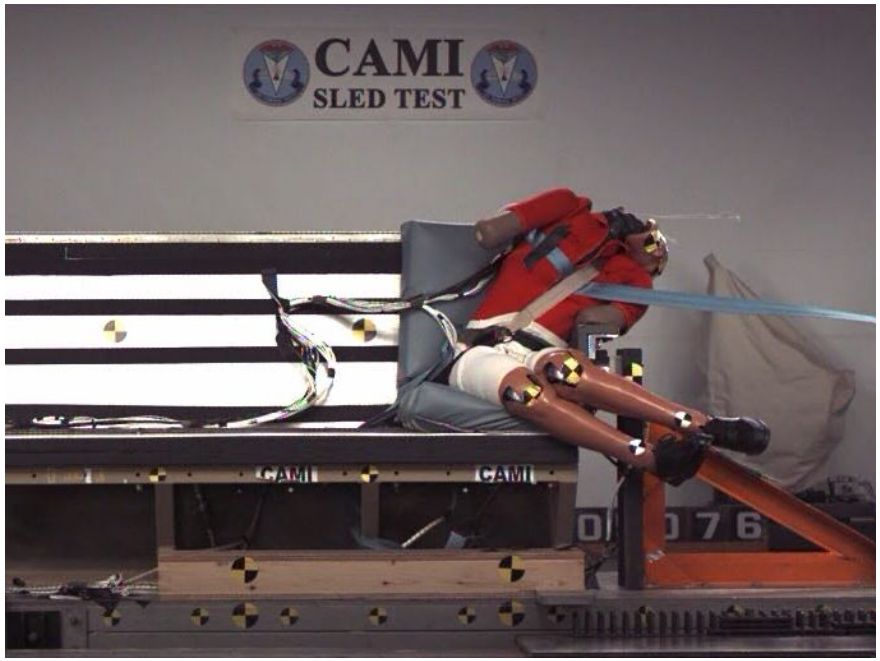
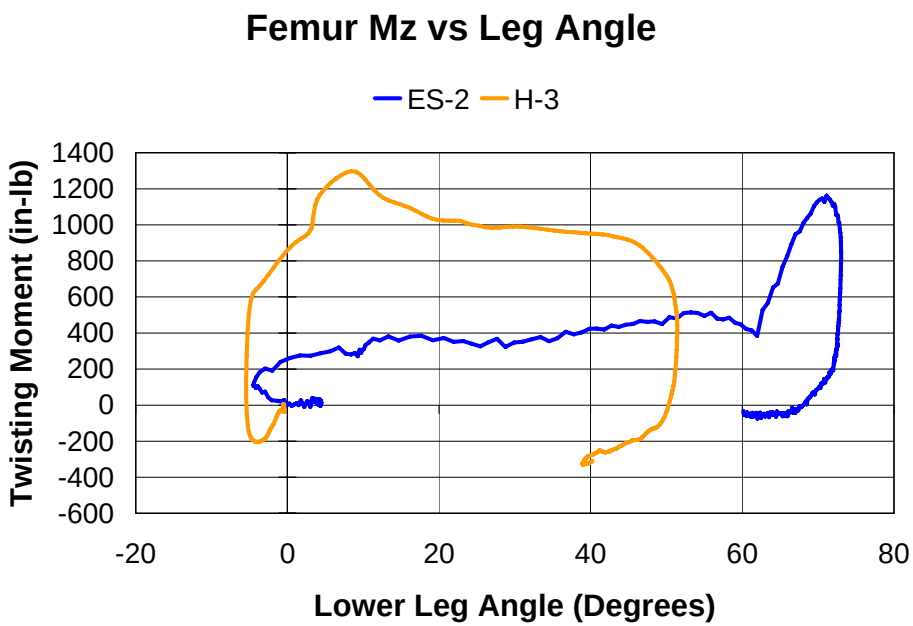
Armrest Position
Conventional Restraint





Armrest Position
Conventional Restraint





Armrest Position Inflatable Restraint

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Armrest Position
H-III ATD, Conventional Restraint

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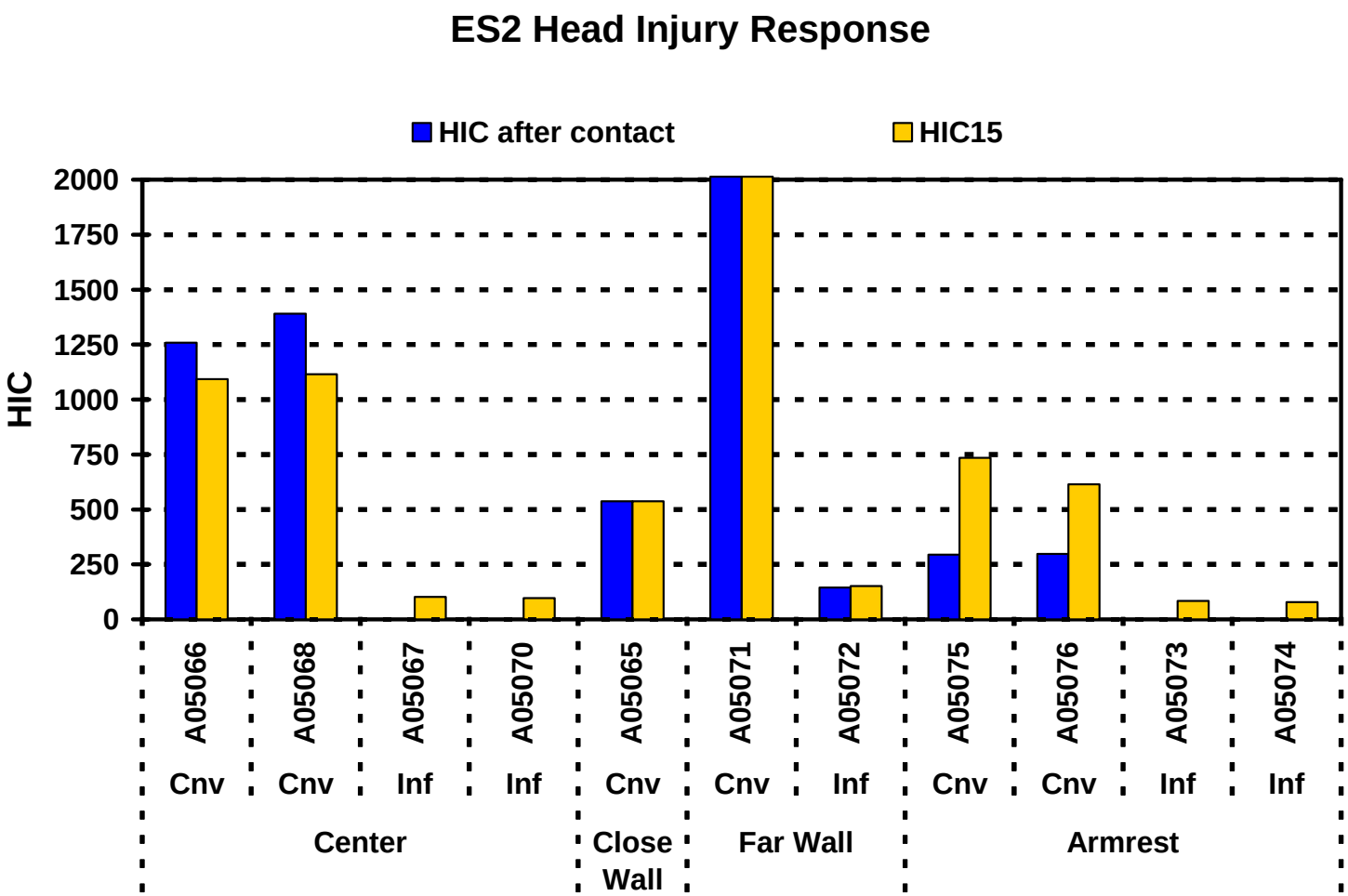
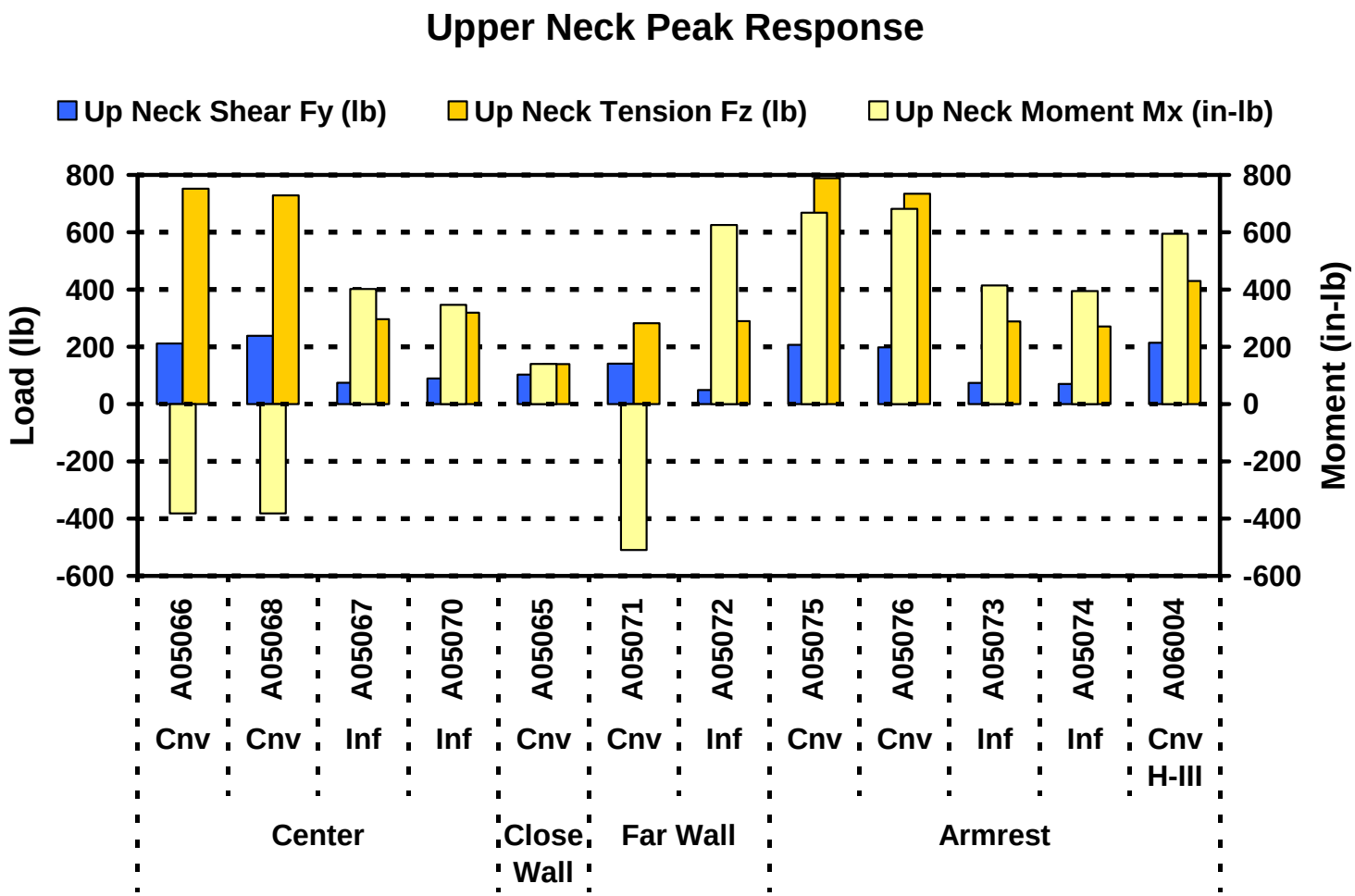
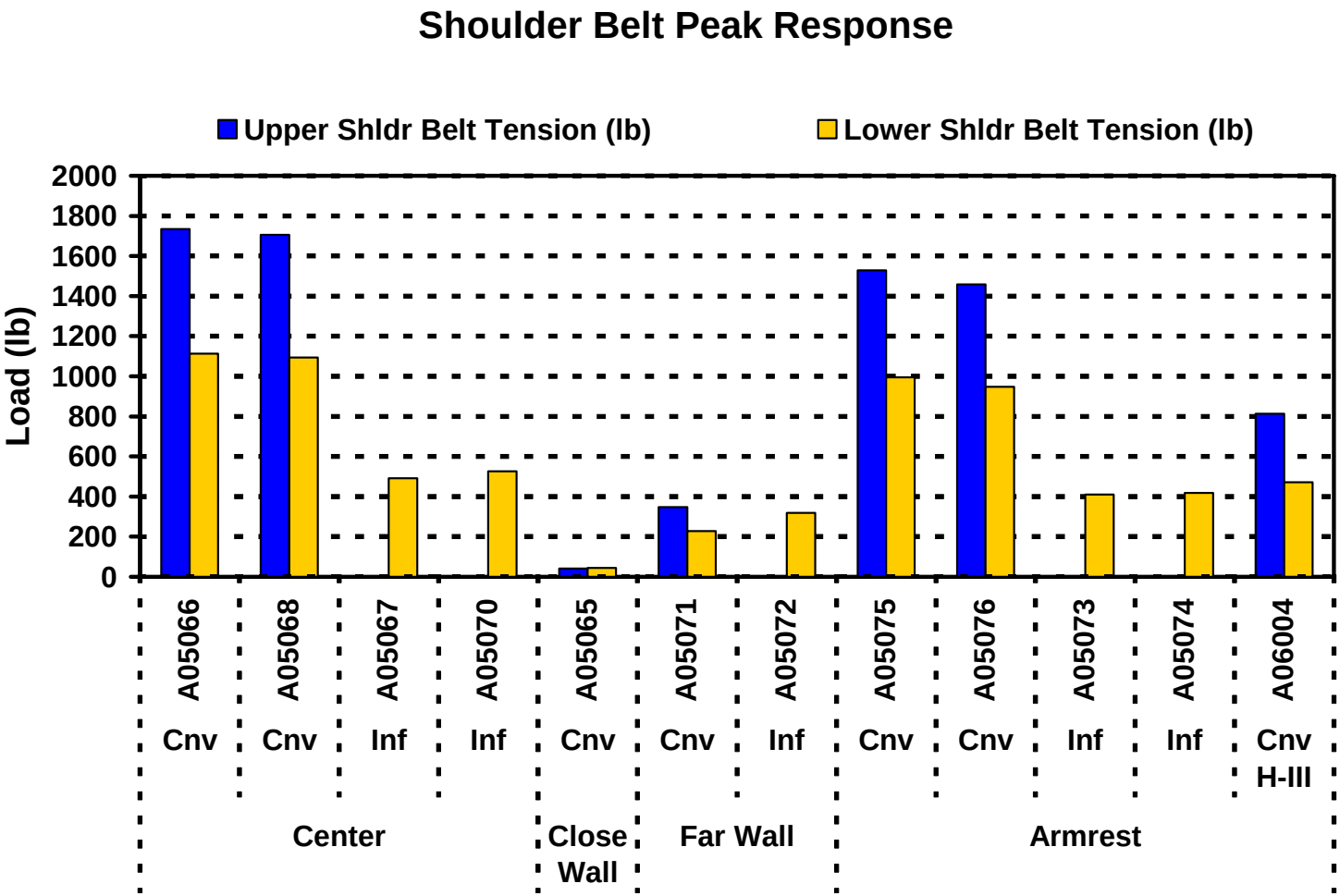
Head Injury Results



Neck Injury Results



Shoulder Belt Tension Results



Conclusions

- **Injury Assessment**

Body Region	Tested Seat Configurations (Conventional Restraint)			
	Center	Close Wall	Far Wall	Armrest
Head	HIC		HIC	HIC15
Neck	Nij Prelim		Nij Prelim	Nij Prelim
Thorax	Belt Tension		Rib Def	Belt Tension
Abdomen				
Pelvis				
Leg				Femur Mz

Conclusions

- **Test Method Evaluation**
  - Consistent initial position achieved by preloading the lower torso during installation.
- **ATD evaluation**
  - Good overall functionality
  - Shoulder area not biofidelic
  - Neck not durable
- **Inflatable restraint evaluation**
  - Mitigated most injury risks

Conclusions

- **Proposed injury criteria can be met using proper seat design features and advanced restraint systems.**

Recommendations

- **Use of the ES-2 and its associated injury criteria for aircraft seat tests would allow a better assessment of the potential for injury than the current test methods.**
- **Neck injury criteria are needed to interpret the high neck loads measured.**
- **Improvements in the ES-2 shoulder's biofidelity would allow better assessment of the potential for injury caused by belt contact forces.**

Acknowledgments

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  - BE Aerospace
  - DeCrane Aircraft
- **Test articles:**
  - Restraint systems: AmSafe
  - Seat Cushions: BE Aerospace

References

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