Injury Potential and Regulatory Compliance for Passenger Seats with Install Angle Above 18 Degrees

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Objective

- *Premium "Herringbone" seats*
  - *Side Facing Seats (install angle > 18 deg.)*
  - *Impact Vector predominantly forward*
- *Compliance is Complex and Confusing*
- *Airbags used to help satisfy Injury Compliance*

OBJECTIVE: Share Experience (Lend some Historical Perspective)
Identify Considerations and Issues

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Background: Seatbelt Airbag

Introduced in 2001, Revised and Expanded in 2002

- First BAE J-41, then Airbus A340, and A330, A320, B777, CRJ
- Front Row Economy and special economy (life raft bustle, etc.)

  Solution for FAR 25.562 Head Injury Criteria (HIC)

- 2003: Premium Seats
- 2004: Introduced onto General Aviation
- Since 2005: Several Business / Premium Interiors and full economy class
- Over 50k Seat Placements and over 50 Commercial Airlines

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Side Facing Seat – Existing Guidance

Seat angle > 18 degree: Side Facing Seat
"Herringbone Interior"

- Issue Paper / Special Conditions

Support Wall: Full Body
Head, Chest, Pelvis

- *HIC < 1000*
- *Thoracic Trauma Index (TTI) < 85G*
  TTI = ½(RIBG+T12G)
- *Pelvic Acceleration < 135 G*
- *May require reporting of neck loads*

…and Airbag Special Conditions

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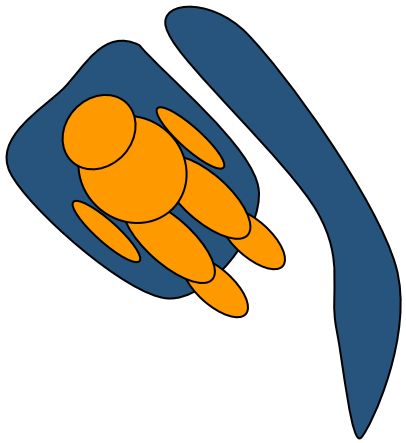
Side Facing Seat – Existing Guidance

Considerations

- Impact Vector toward monument
  - Monument part of seat structure or Interior
  - Row to Row vs Front Row and Seat TSO



Aircraft Longitudinal Axis / Impact Vector

- Side Facing Anthropomorphic Test Dummy (ATD) for TTI and Pelvic Acceleration Data
  - EuroSid II recommended by FAA CAMI,
- Hybrid II and/or FAA Hybrid III for HIC and Neck

- No recent programs with side wall…..evolution of SFS…… new questions?? (standardized process still applicable?)

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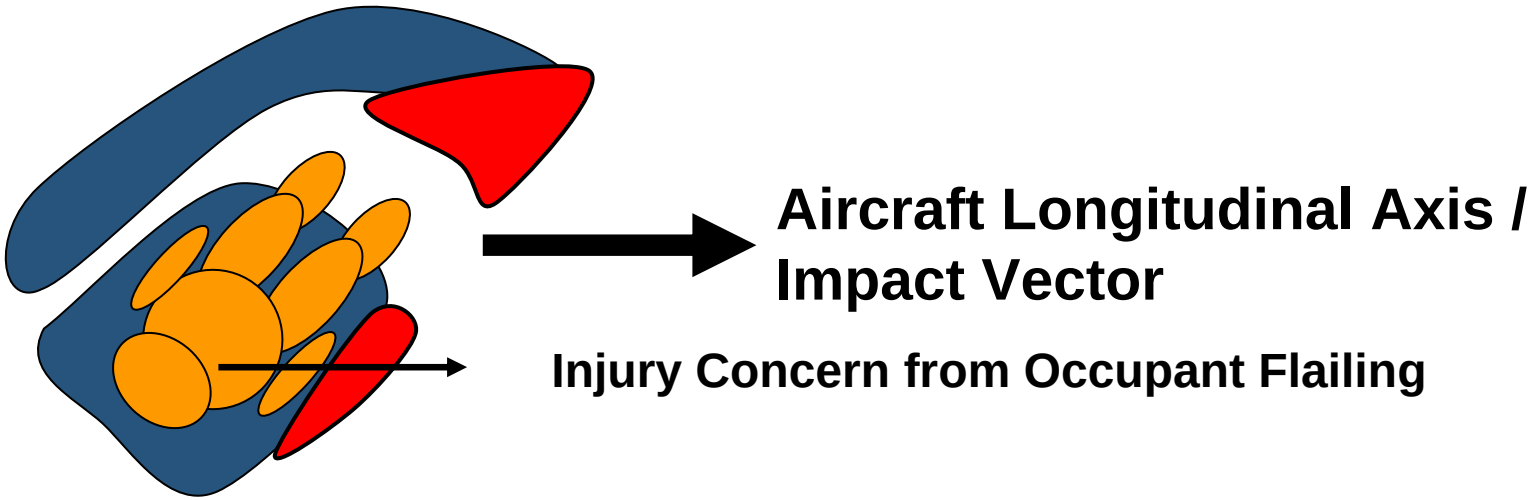
Side Facing Seat – No Support Wall

Considerations

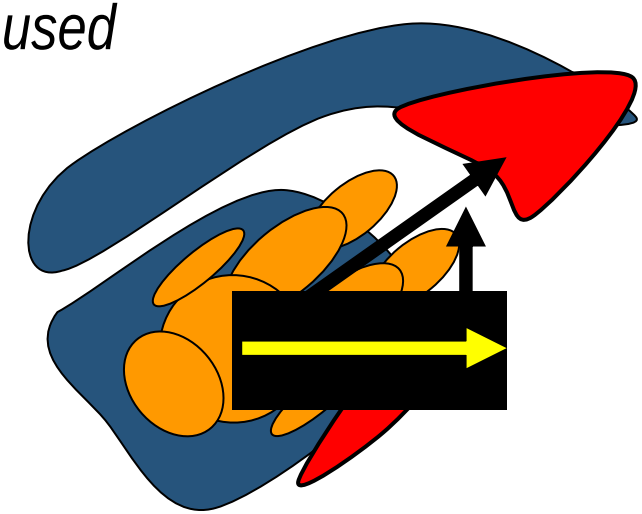
- Impact Vector away from monument into free space
  - No flailing over armrest
  - Footwell affect flailing?



- TTI, Pelvic Acceleration Data Don't Apply if not striking wall
- ATD: Hybrid II and/or FAA Hybrid III for HIC and Neck

Scope of Compliance Discussion

- *Process confusing and will have variations depending…*
  - *if FAA or EASA originated program (Boeing / Airbus)*
  - *Airline, Applicant, and Seat Supplier*
- *Compliance Approach is Variable*
  - *ELOS (Equivalent Level of Safety) is used*
  - *Injury compliance is Key*



- *Injury Compliance*
  - *No universally accepted ATD's for **predominantly forward** SFS*
  - *No universally accepted injury <u>measures</u> or <u>criteria</u> for open flailing*

  ….IS Therefore SUBJECTIVE

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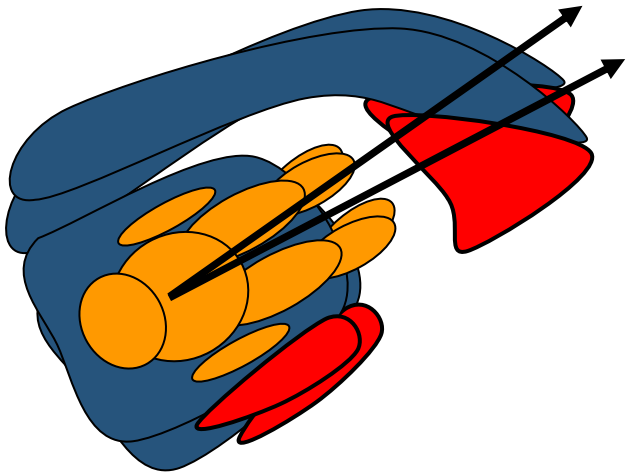
Comparison Point (example 25 ° install angle)

- *SFS, no support wall, Equivalent Level of Safety (ELOS)*

  Option A (Past): max seat angle per FAR 25.785 = 18°

A: 18°vs 25° (+10° yaw)



Demonstrate Similarity to a certifiable interior

Limit: - Existing Certifiable Forward Facing Seat Configurations
(some angle would be too large, 35°?, 40°?)

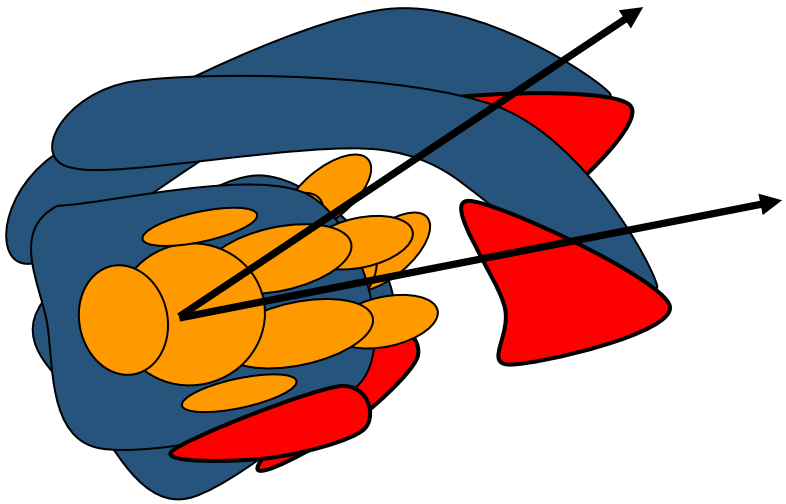
Concern: May not capture all potential injury
(allowable 18° seats may have injury mechanisms not taken into account)

Comparison Point (example 25 ° install angle)

- *SFS, no support wall, Equivalent Level of Safety (ELOS)*

  Option B (Current): most common forward facing seat = 0°

B: 0°vs 25° (+10° yaw)



Demonstrate no potential injury

Limits: None

Concerns:

- two very different angles (injury mechanisms may differ)
- Undefined injury measures and criteria
- Non 25.562 Furnishings don't apply

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Historical Note

- *Paper Abstract for this conference was submitted based on data evaluating injury comparisons using Option A. Compliance has evolved since that time. The paper was modified to reflect current status.*

Current Status: (Option B) – Comparison is ***0° standard seat***

- *Satisfy HIC for real interior using typical guidance*
- *Account for undefined / **subjective injury***
- *Allowances*
  - *TTI and Pelvic Accel. Not Mandatory (unless needed)*
  - *Side Facing ATD Not Mandatory (unless needed)*
  - *Flail Comparison can be done with Structural Tests*

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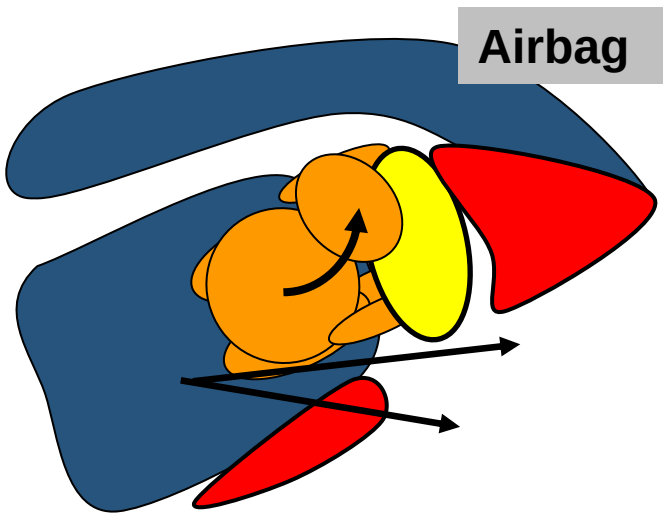
HIC Considerations

- *All Interior Combinations at + or - 10° yaw*
- *Representative Monuments allowed (at least as stiff as real)*
- *Airbag typically used to mitigate HIC*
  - *If monument is just within strike zone…*

  Bag may only interact with head…

  Can raise concern for Neck or other injury mechanisms

  (that would not be considered for a normal forward facing seat)



Head can twist if airbag contacts mostly head.

More torso support is needed.

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Subjective Injury Considerations

- *Best Tool Today: Occupant Kinematics from High Speed Video*
- *Six Axis Spine Load Cell used in past, but meaning poorly understood*
- *Neck Load criteria beginning to take shape, but lateral vs forward impact vectors add complexity*
- *Current Subjective Injury Status*
  - *Seat must allow **Free Flailing** (like a no-strike forward seat)*
- *Free Flailing: (no armrest or other structure in the way)*
  - *No obstructions impinging body*
  - *ATD should adopt "forward" vector*

  (recognizing that belt anchor points will not allow perfectly forward alignment)

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Spine

FAA CAMI Research and other sources establish that misalignment of spine drastically reduces injury threshold.

- *Severe flailing with complex (combined) motion can cause misalignment*
- *Objective:*
  - *Neck: Avoid bending with tension*

  (others will be researched in future)
  - *Spine: Avoid bending with rotation or tension or shear*
  - *Avoid intrusion into soft tissue*

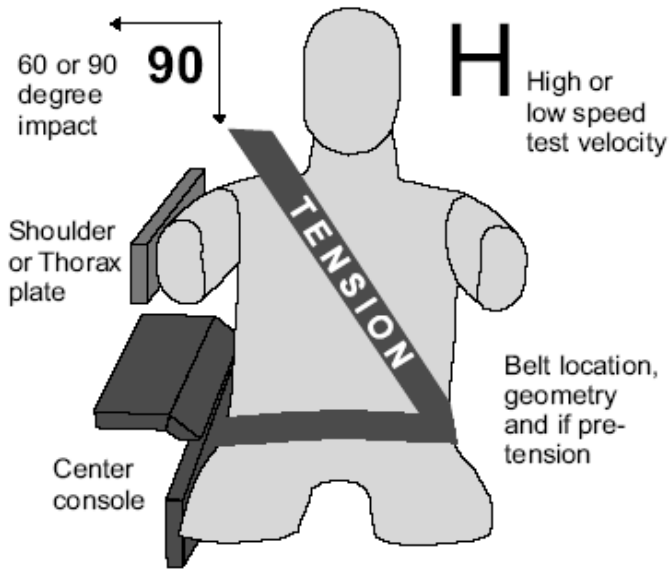
Flailing Over Structure (Armrest)

Automotive Research analogous to Angled Side Facing Seats
Far Side Impacts

- *Center Console is a significant source of trauma from far side impacts.*
- *Head flailing, chest and organ injuries are all of concern.*
- *Inboard restraints and shoulder and thorax plates helped in some ways, but not others. The specific design must be evaluated.*

Bottom Line Objective:
Must mitigate head flail and
Local chest deflections.

Injury Measures:
- *THOR-NT better for restraint evaluations*
- *WorldSID better for shoulder/chest support evaluations.*



Pintar F.A. et All, Comparison of PMHS, WorldSID, and THOR-NT Responses in Simulated Far Side Impact, Stapp Car Crash Journal, Vol 51, pp313-360, SAE 2007-22-0014.

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Conclusions

How to Certify Interior efficiently (no support wall)

1. *Mitigate HIC*
   - *Associated benefit for head flailing and neck loads*

   (limited head accel. mitigates injury, even if undefined)
2. *Move lateral obstructions out of the way*
   - *Mitigates local chest trauma in a practical manner*
3. *Compare Flailing to "Normal" Forward (0 degree install angle)*
4. *Save Some Effort: Avoid Side Facing ATD Tests*
5. *But Extra Effort is Needed to evaluate Subjective Injury:*
   Structure program to evaluate realistic flailing early
   Coordinate Occupant Kinematics Response with authorities

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Thank You For Your Time!

Questions?

Comments?

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