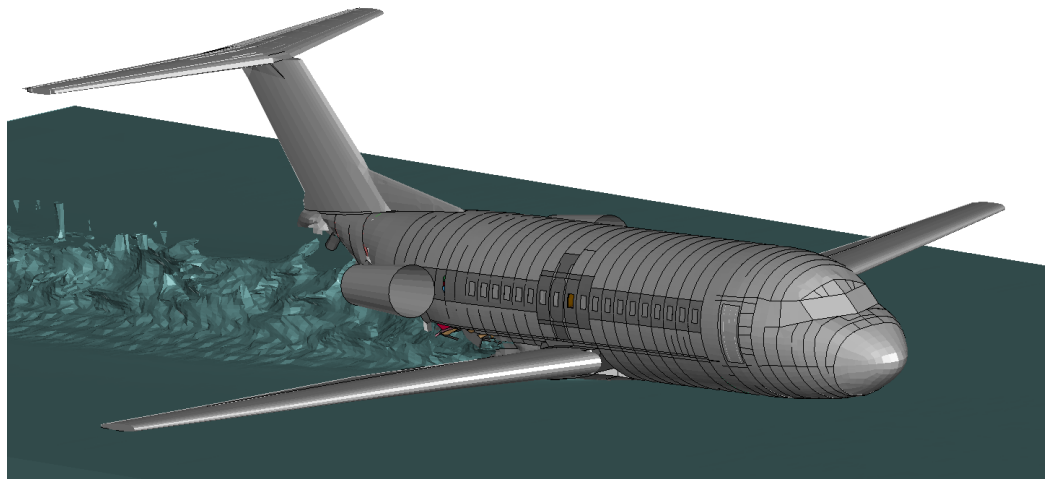




# Study of Aircraft Structural Response and Occupant Loading During a Ditching Event Utilizing LS-DYNA Simulation

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# Previous Land Based Vehicle Crashworthiness Evaluation

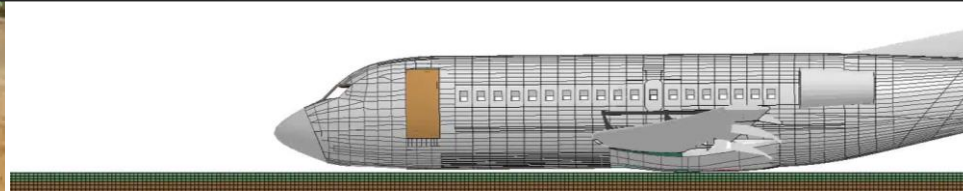


Vehicle Specs: Fokker F28 Aircraft

Test Conditions: 32 ft/s Vertical - 65 ft/s Horizontal Velocity



*Can an aircraft structural model, developed and validated utilizing land-based test data, be used to quantify aircraft crashworthiness during ditching?*



# What is Ditching?

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## Ditching

- Controlled emergency landing onto water for aircraft not designed for normal water landing
  - Low descent velocity
- “Severe but survivable”
  - Maintained volume for cabin egress
  - >1 surviving occupant
- Difficult to evaluate through traditional test methods

# Ditching Event Evaluated

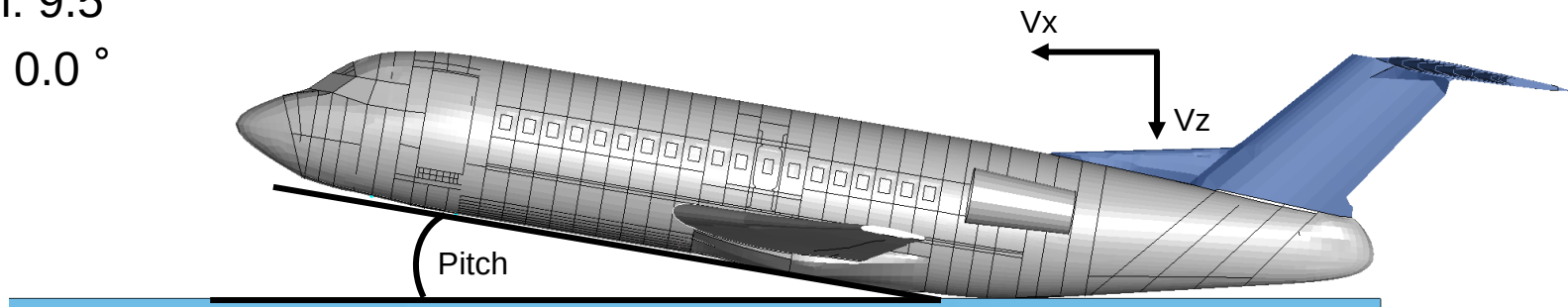


- US Airways Flight 1549 Ditch into the Hudson River
- Flight 1549 experienced a bird strike and subsequent engine failures, leading to the emergency landing into the Hudson River
- 150 passengers and 5 crew, all of whom safely egressed from the aircraft and were rescued
- National Transportation Safety Board (NTSB) recorded 5 injuries, conducted aircraft retrieval, performed a detail structural damage assessment



# Recorded Ditching Conditions

- Vehicle impact conditions determined by NTSB
- Low descent velocity
  - Horizontal velocity ( $V_x$ ): 211 ft/s
  - Vertical Velocity ( $V_z$ ): 12.5 ft/s
- Ideal impact angle
  - Yaw:  $0.0^\circ$
  - Pitch:  $9.5^\circ$
  - Roll:  $0.0^\circ$



# Comparison of Aircraft



Ditching Conditions



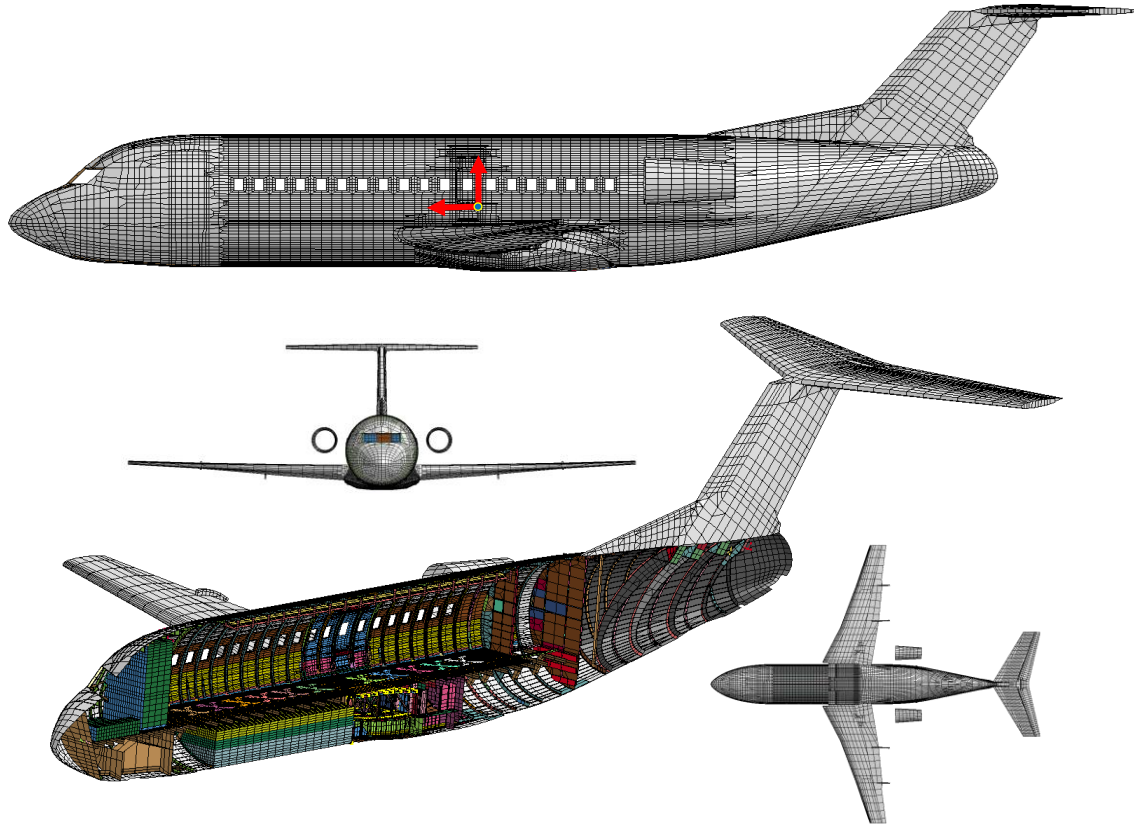
Simulated Aircraft



## Comparisons of the Fokker F28 and the Airbus A320 Aircraft

| Parameter                    | Fokker F28     | Airbus A320  |
|------------------------------|----------------|--------------|
| Classification               | Regional Jet   | Jet Airliner |
| Length, ft.                  | 89             | 123          |
| Wingspan, ft.                | 77             | 117          |
| Weight, lb.                  | 35,517 (empty) | 82,100       |
| Range, nmiles                | 920            | 3,300        |
| Seating Capacity, passengers | 65             | 150-186      |
| Number of Crew               | 5              | 6            |

# Aircraft Ditching Model - Fokker F28 Vehicle



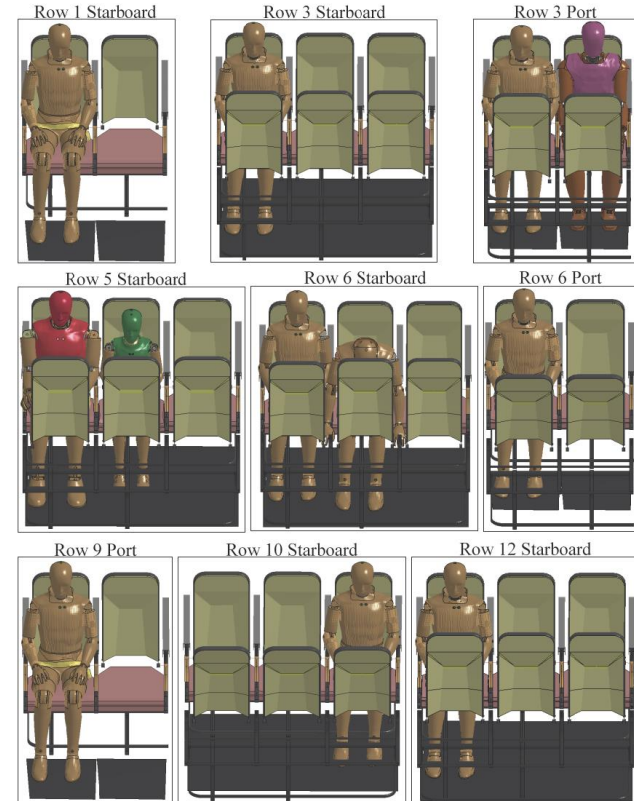
## Airframe Contains:

- 743 Parts
- 79 Material cards
- 106,395 Nodes
- 25,706 Beam elements
- 80,776 Shell elements
- 19,682 Solid elements
- 26 Conc. element masses
- 76 CNRBs
- 1 Initial velocity card (70-ft/s forward and 30-ft/s vertical)
- 4 Contact surfaces

# Aircraft Ditching Model - Occupants



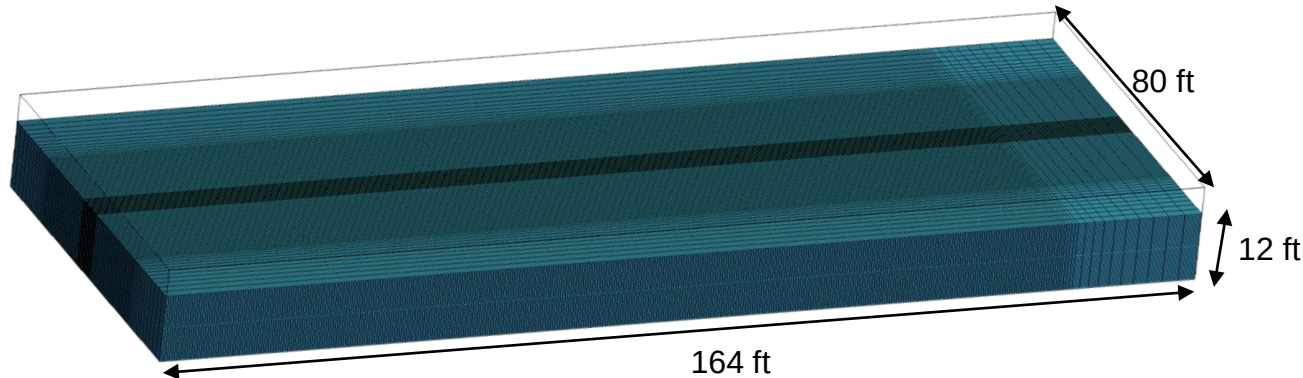
- 11 occupants were simulated throughout aircraft utilizing Anthropometric Test Device (ATD) models:
  - Hybrid III FAA 50<sup>th</sup> (Humanetics)
  - Hybrid III 5<sup>th</sup> (Humanetics)
  - Hybrid III 95<sup>th</sup> (LSTC)
  - THOR 50<sup>th</sup> (NHTSA)



# Aircraft Ditching Model – Water Environment

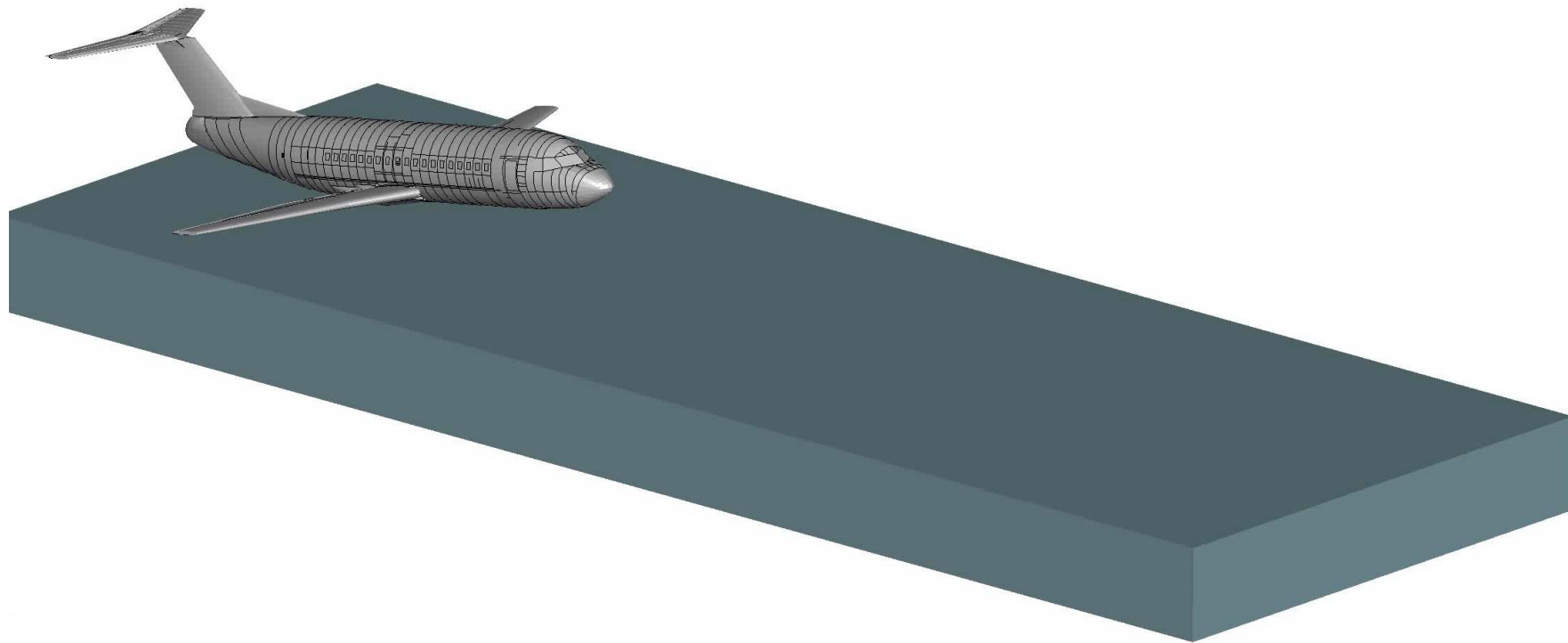


- Water environment simulated utilizing water model developed for NASA spacecraft landing simulation
  - Arbitrary Lagrangian-Eulerian (ALE) model
  - Developed, calibrated, and validated against extensive crew capsule water landing tests
  - Variable mesh density (32 in – 3 in)



# Aircraft Ditching Simulation Results

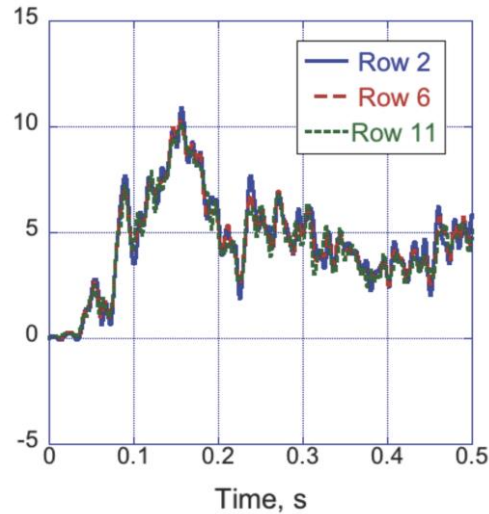
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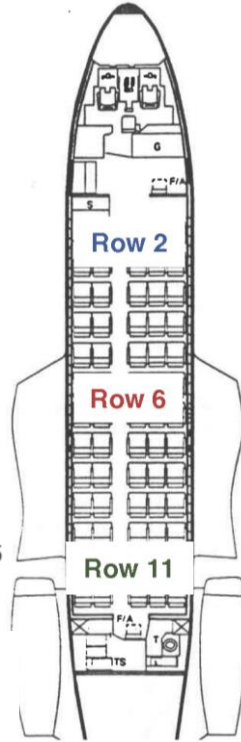
# Aircraft Ditching Simulation Results – Cabin Acceleration



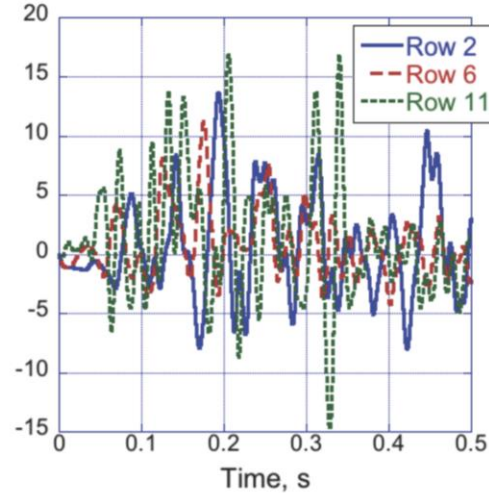
Forward Acceleration, g



Filtered using a Butterworth  
50-Hz low-pass filter

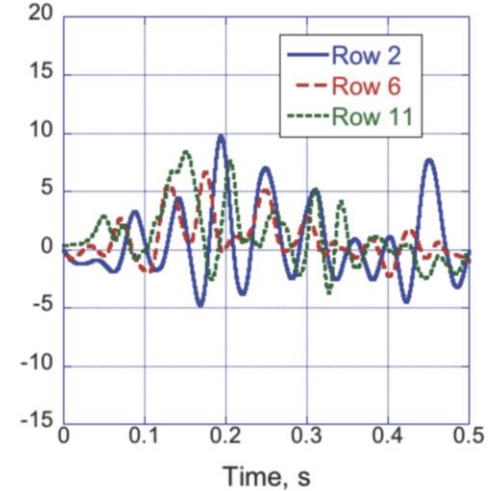


Vertical Acceleration, g



Filtered using a Butterworth  
50-Hz low-pass filter

Vertical Acceleration, g

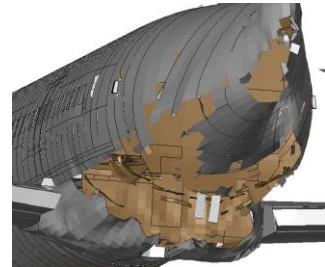
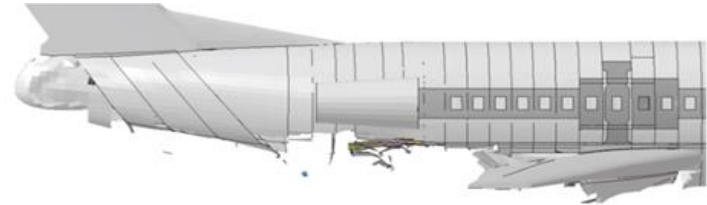


Filtered using a Butterworth  
20-Hz low-pass filter

# Aircraft Ditching Simulation Results – Damage



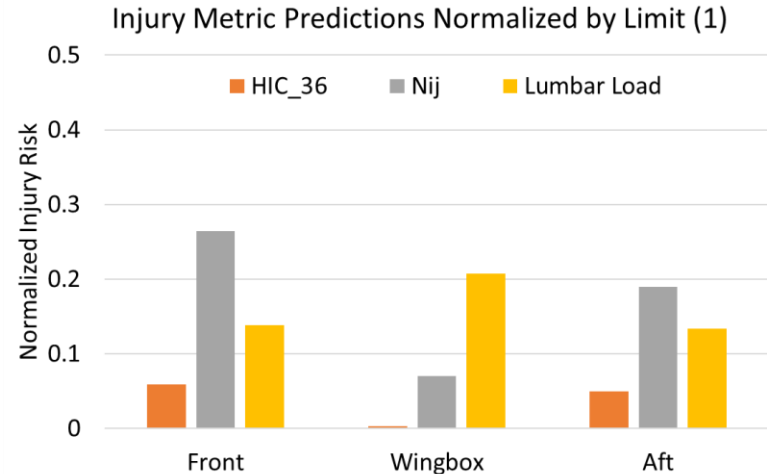
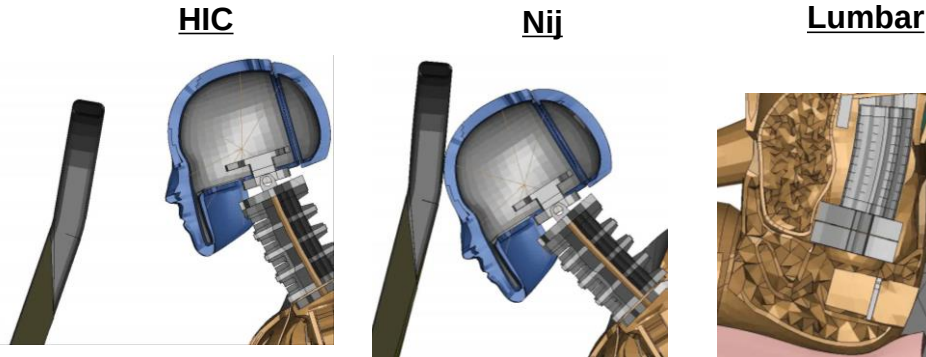
- Post impact damage photos taken of the flight 1549 aircraft by NTSB after recovery
- Damage occurred primarily in aft section of aircraft due to pitch up impact orientation
- Although different vehicles the developed F28 ditch model predicted similar damage severity and location



# Aircraft Ditching Simulation Occupant Results – Location



- Standard head, neck, and spine injury metrics evaluated
- Injury risk at these regions below certification limits
  - In line with lack of these injuries recorded in A320 event
- Dominant injury risk mechanism varied across seated location

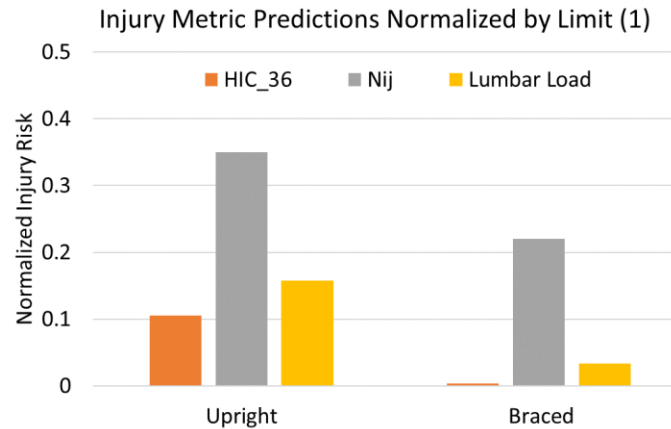
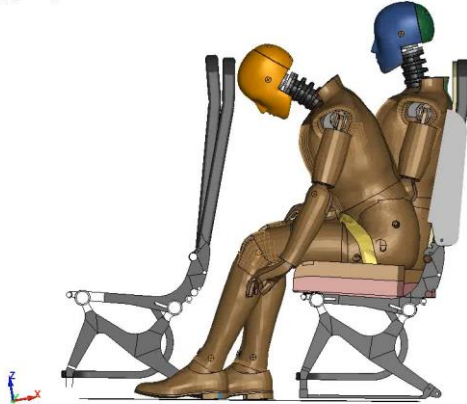


# Aircraft Ditching Simulation Occupant Results – Position



- Bracing position predicted to reduce head, neck, spine injury risk compared to upright posture
- Two shoulder injuries reported during A320 ditching were associated with being in the braced position
  - Quantification of these injury risks are limited using traditional ATD evaluation

LS-DYNA keyword deck by LS-PrePost  
Time = 0



# Conclusion and Future Work

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- Aircraft structural model, developed utilizing land landing test data, provided reasonable prediction of vehicle response during ditching
  - Vehicle model stable within water impact environment
  - Prediction of aircraft kinematics and damage generally representative of recorded ditching outcomes
  - Water model previously validated for vehicle impact prediction
- Occupant models predicted low injury risk values for ditching event
  - Head, neck, spine risk below certification limits
  - ATD's limited in evaluating other injury mechanism (bracing induced injury)
- Future work: Human body modeling to evaluate total body injury risk within both land and water impact conditions



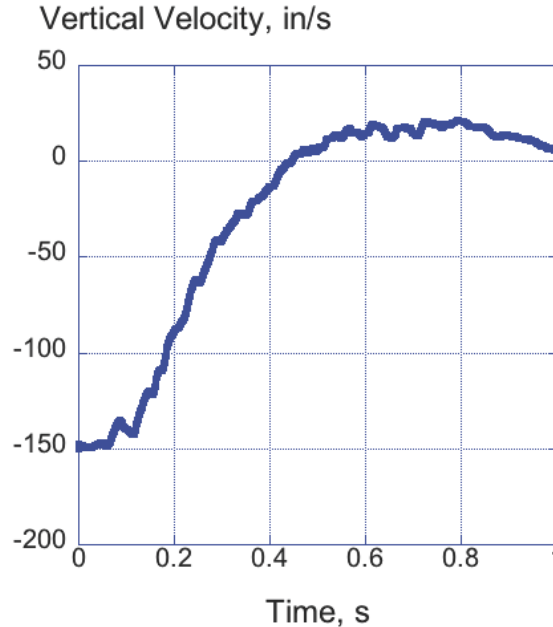
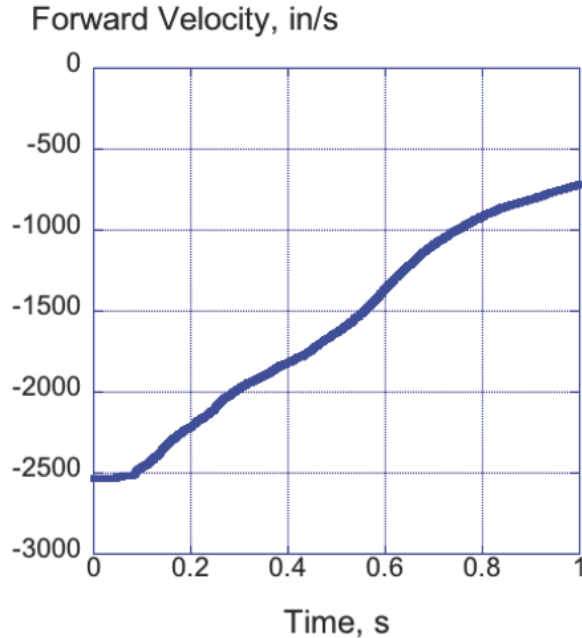
Questions?

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# Aircraft Ditching Simulation Results – Kinematics



Note: even after running for 1.0-s, the forward velocity has not crossed zero, and has 700-in/s of residual velocity

Vertical velocity crosses zero at 0.435-s, rebounds to 21-in/s

# Understanding Aircraft Structural Response During Ditching



- Aircraft structural response during water impact not easily evaluated through traditional testing methods
- Current ditching performance relies on similarity to traditional aircraft design
  - Last modern airplane physical model tested (1/17<sup>th</sup> scale) in 1970s  
(<http://www.tc.faa.gov/its/worldpac/techrpt/ar95-54.pdf>)
- How do we evaluate aircraft of the future?
  - New shapes, materials, flight paths cannot rely on flight history to demonstrate ditching performance
- FE modeling can be used to analyze ditching conditions but what level of accuracy maybe expected if not correlated to water impact tests?