Occupant Protection Project

Genie Bopp (JSC-Wyle)

Jeff Somers (JSC - Wyle)
Brad Granderson (JSC - Wyle)
Mike Gernhardt (JSC)
Nancy Currie (NESC)
Chuck Lawrence (GRC)

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Occupant Protection Overview

- The Occupant Protection Task 1 Project was formed in 2007 to study Orion crew loads and injury biomechanics analysis
  - *How to protect the crew during dynamic phases of flight?*
- Current NASA Standards
  - Dynamic Response Index (Brinkley) Model
    - Developed by the military for escape system safety
    - Simple mathematical model
    - Primary focus on Z axis with limited injury data in X and Y directions
  - Vehicle acceleration limits
- Project Proposes to Recommend New Standards
  - Current standards may not be sufficient to protect the crew
  - NASCAR data indicates that better seat and restraints can protect the driver (even beyond 100G)
  - The Brinkley model does not take these improvements into consideration
  - The Brinkley model has many assumptions that may not be met by current design and may not apply
  - In the X and Y axes, the Brinkley model is limited

Occupant Protection Collaboration

- NASA/Wyle is leveraging the experience of other institutions versed in the current state of the art in occupant protection to address spaceflight specific areas of concern (suit related injury, crew deconditioning)
- NASA is working with other Federal Agencies to understand how best to protect NASA crewmembers during spaceflight

- **NASA**
  - JSC
  - GRC
  - LaRC
- **Bioastronautics**
  - Wyle
- **USRA**
- **Lockheed-Martin**
- **ESCG**
- **Oceaneering**
- **SAIC**
- **Barrios**

- **US Military**
  - US Navy
  - US Air Force
  - US Army
- **Other Federal Agencies**
  - FAA
  - NHTSA
- **Racing Industry**
  - NASCAR
  - Indy Racing League

- **University Affiliations**
  - University of Cincinnati
  - Wayne State University
  - Wake Forest University
  - Virginia Tech
  - Ohio State University
- **Industry Experts**
  - Jim Brinkley
  - John Melvin
  - Bob Hubbard

Modeling Occupant Protection

- Dynamic Phases of Flight where occupant protection is applicable:
  - Launch
  - Launch Abort
  - Pad Abort
  - Landing
  - Any other flight phase were the crew are subjected to a dynamic environment

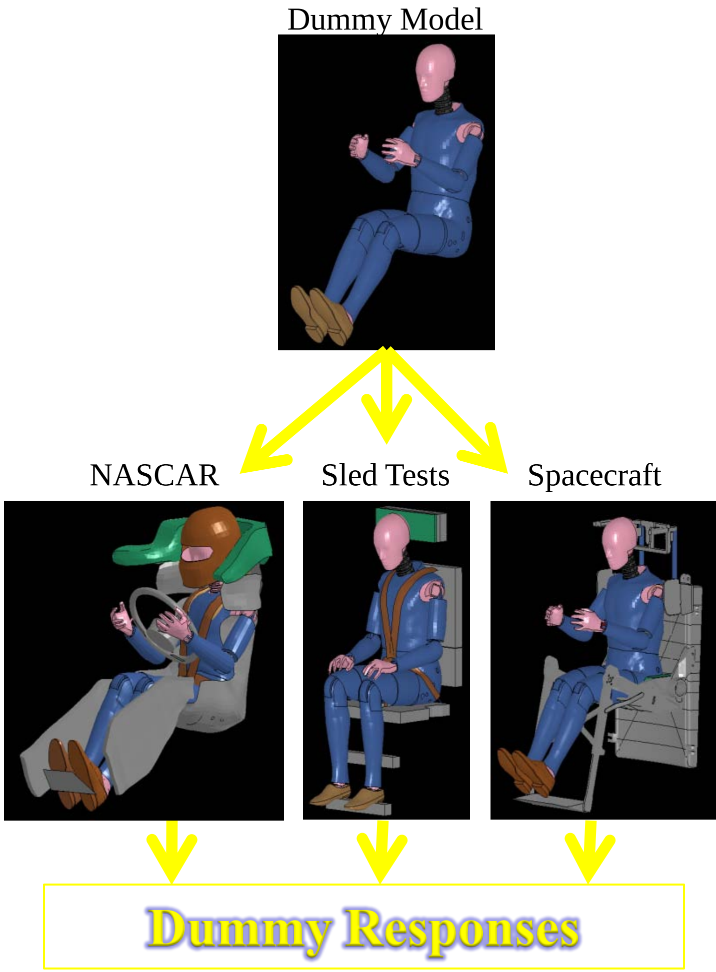
For Orion, a chute-out water landing will impart crew accelerations around 20 g's in the X&Z direction

Occupant Protection Considerations

- Anthropometrics
  - 1st to 99th percentiles (current HSIR requirement)
- Gender Differences
  - Address any areas where gender differences put one gender at greater risk
- Suit-related issues
  - Point loading, restraint interactions, blunt trauma from suit interaction, etc.
- Crew Deconditioning
  - Physiological effects of long duration spaceflight may lead to increased risk for certain types of injuries
- Flail
  - Determine how to quantify flail and how to verify protection is adequate
- Anatomical Localization & Severity of Injuries
  - Injury location and severity can effect occupant survivability or functionality after mishap
- Nominal, off-nominal and contingency landing conditions
  - Determine if alternate requirements are necessary for crew protection in off-nominal or contingency landing situations

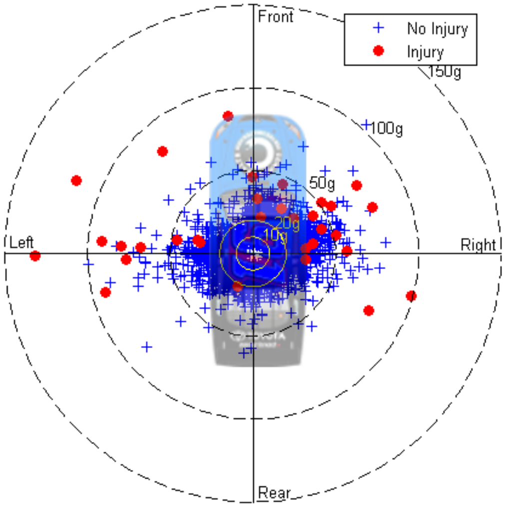
Project Approach

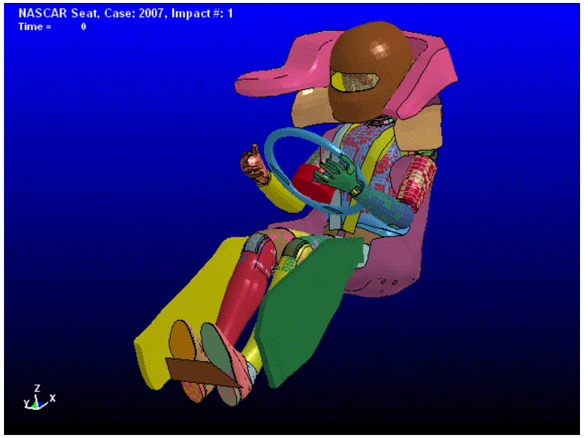
- Analysis Tools
  - Employ existing crash test dummy models in vehicle specific restraints
  - Use exposure (NASCAR) and volunteer data (Sled Tests) to “normalize” dummy responses to injury
  - Use model in spacecraft to assist in design and for verification
  - Supplement with Toyota THUMS human model to investigate suit-related injury (blunt trauma, point loading, restraint interactions)
- Injury Criteria
  - Develop list of critical injuries
  - Define dummy response limits related to those critical injuries
  - Use exposure and volunteer data to update limits
  - Use limits as input to vehicle design
- Testing Program Development
  - Use testing to support verification by analysis using dummy models

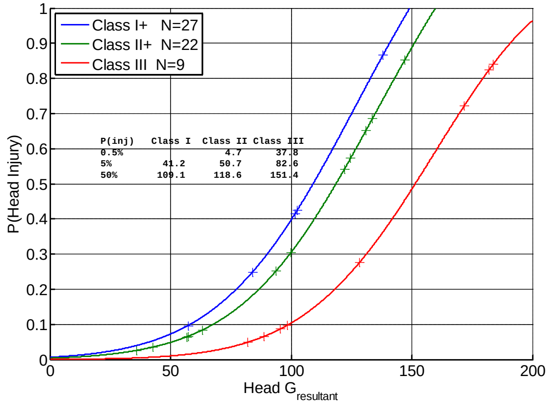


Injury Criteria Update Methodology

- Completed NASCAR injury biodynamics analysis
  - 4071 impacts analyzed, and 274 cases simulated
  - Use dummy responses along with actual injury data to develop probability of injury associated with each dummy response
  - Update requirements based on results
- Use similar methodology with other datasets
  - Indy Racing League (IRL)
  - Crash Injury Research Engineering Network (CIREN)
  - National Automotive Sampling System (NASS)
  - Human volunteer testing
  - Cadaveric testing
  - Soyuz landing Data

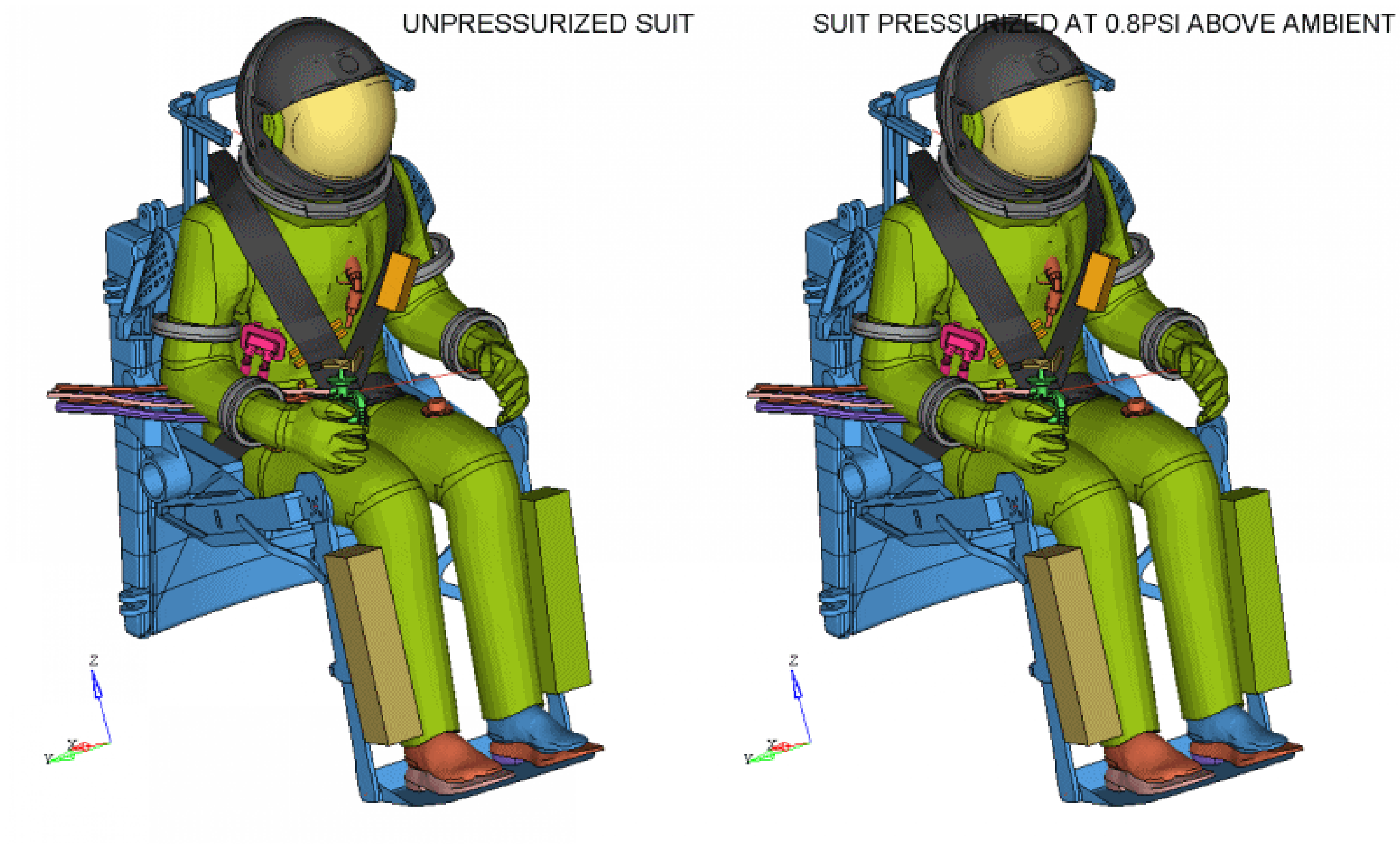






Unique Effects of Pressure Suits and Other Factors

- Pressure suits present unique challenges to design
  - Blunt trauma, point loading, poor restraint fit, helmet mass effects , etc.



Summary

- The Occupant Protection Project is working to improve NASA standards by:
  - Leveraging all current knowledge of occupant protection principles as demonstrated in NASCAR and other vehicles
  - Developing analytical tools and methodology
    - Design Iteration
    - Verification testing (test supported by analysis)
    - Injury Criteria Development
  - Defining better injury criteria and human tolerance limits consistent with spaceflight
    - Use modern modeling and technology to better assess injury potential during spaceflight
    - Analyze human injury databases to develop better human tolerance limits applicable to spaceflight
    - Conduct human impact testing in environments and with hardware similar to what is expected for future vehicles
  - Define and Develop Testing Methodology

Team Member Affiliations