Development of an Instrumentation Suite to Measure Helmet Windblast and Impact Loading

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John Plaga
Human Effectiveness Directorate
Air Force Research Laboratory
Doug Coppess
Glenn Thomas
Greg Thompson
General Dynamics

Background

- **Windblast forces during ejection impart potentially injurious head and neck loads**
- **Integrated Chin/Nape Straps (ICNS) have been recently installed on USAF helmets to increase stability**
- **Ejections have shown potential for head/headrest impacts**
- **Expanded crewmember range may result in lower tolerances to injuries**

Problem

- Traditional ejection test manikins have limited head sensors
  - Upper neck forces/moments
  - Triaxial accelerometer
  - Possibly angular (pitch) accelerometer
- Difficult to determine what exactly is contributing to the neck loading

Application

- Newton's Second Law
  - $F = ma$
  - $\Sigma F = ma$
  - $F_1 + F_2 + F_3 + F_n = ma$
- Forces include
  - Inertial
  - Aerodynamic
  - Reaction e.g. headrest force/impact
  - Neck reaction force

$$\sum \vec{F} = m\vec{a} \qquad \sum \vec{\Gamma} = I\vec{\alpha}$$

Objectives

- Determine loads acting from helmet into head
  - Helmet lift loads
  - Chin strap tension
  - Aft headrest impact
- Correlate a measurable force with neck tension as helmet is being lifted from head
- Determine if headrest impacts are injurious

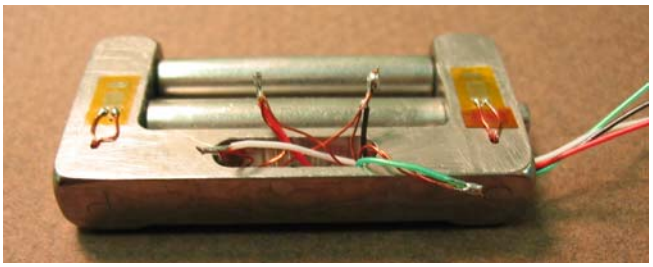
Approach

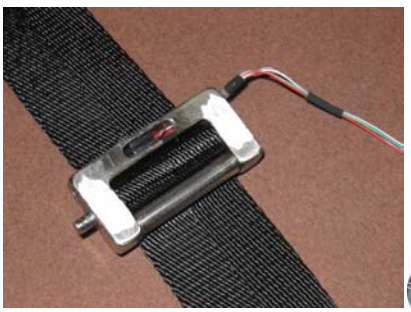
- Measure neck loads
  - Upper and lower neck forces and moments
- Measure head accelerations
  - CG, Earplugs, angular pitch
- Measure other loading
  - Aerodynamic
  - Helmet static pressure
  - Reaction (impact, e.g. headrest)
- Determine aerodynamic loading

Chin Strap Load Cell

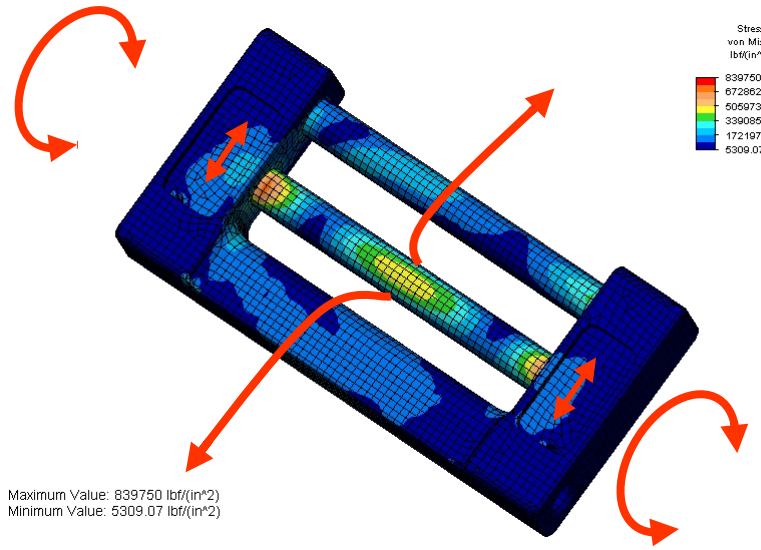
- Small and light weight
  - 15 grams
  - Minimize inducing loads
  - Titanium alloy
- Shaped for minimized friction
  - Filleted or cylindrical edges
  - Free rolling center shaft
- Two pairs of strain gages
  - Full bridge
  - Greater output
- Small, durable wiring
  - Channels/pockets

Chin Strap Load Cell

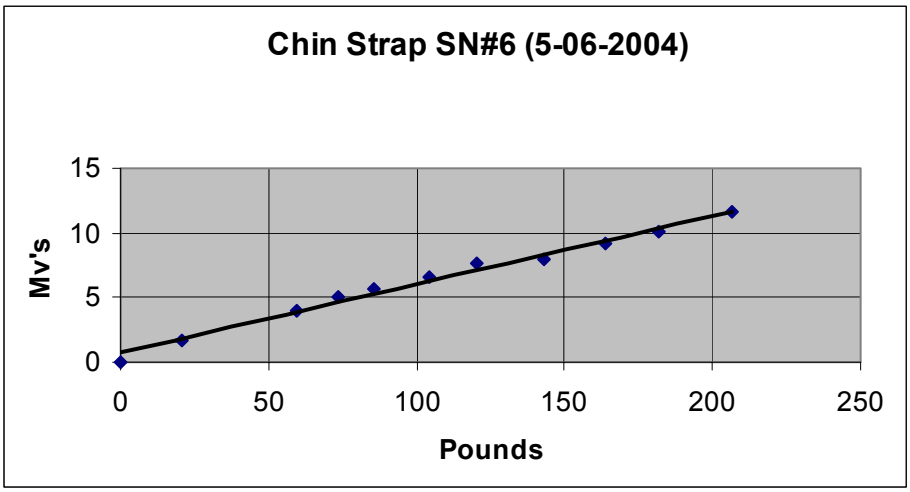




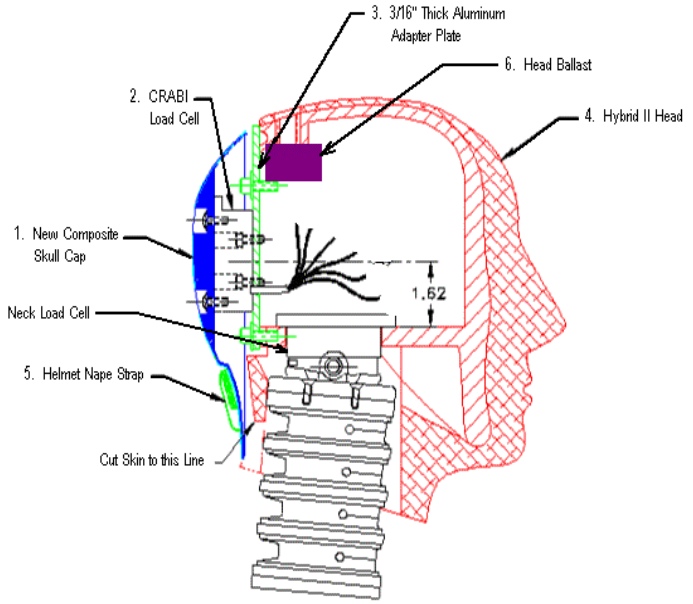
Chin Strap Load Cell Loading



Chin Strap Calibration



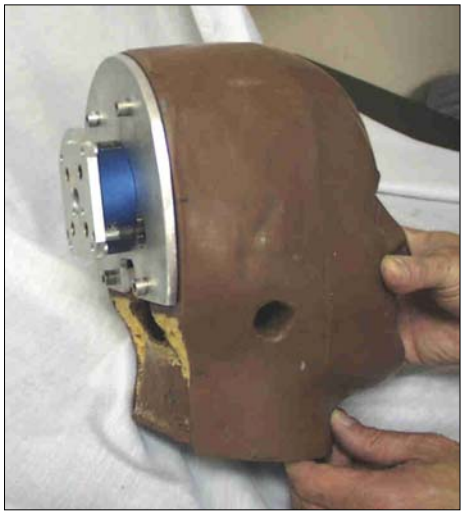
Skull Cap Load Cell



Skull Cap Load Cell

- **CRABI Load Cell, Denton 2254 (FTSS-IF-954)**
- **Rotated so that Fx load is lift load and Fz is horizontal compression load**
- **Capacity**
  - **Fx & Fy – 200 lbs**
  - **Fz – 500 lbs**
  - **Mx & My – 500 in-lb**
  - **Mz – 300 in-lb**

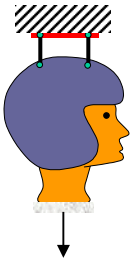
Skull Cap Load Cell

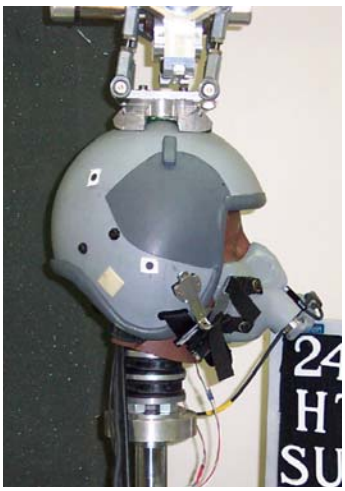


Modified Head

- Existing cap – 1.56 lbs
- Modified head
  - New Cap – 0.63 lbs
  - Load cell – 0.31 lbs
  - Adapter Plate – 0.50 lbs
- Head ballasted to match 95th percentile head weight and CG
  - 10.49 lbs (10.55” target)
  - CGx = 0.25” (met target)
  - CGx = 1.79” (1.77” target)

Testing Using Instrumentation





- **Loading rate of approximately 33,400 N/s (7,500 lb/s)**
- **Test ends when MTS load reaches 4500 N (1,000 lbs) or strap failure**

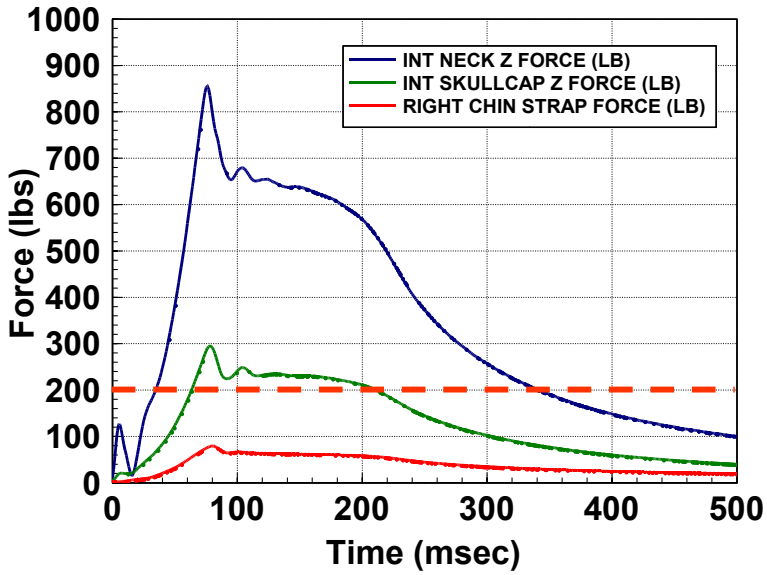
- Actuator is an MTS hydraulic system that pulls the head downward out of helmet
- Load cells in manikin neck (internal) and top of bracket (not shown)

ICNS Dynamic Test

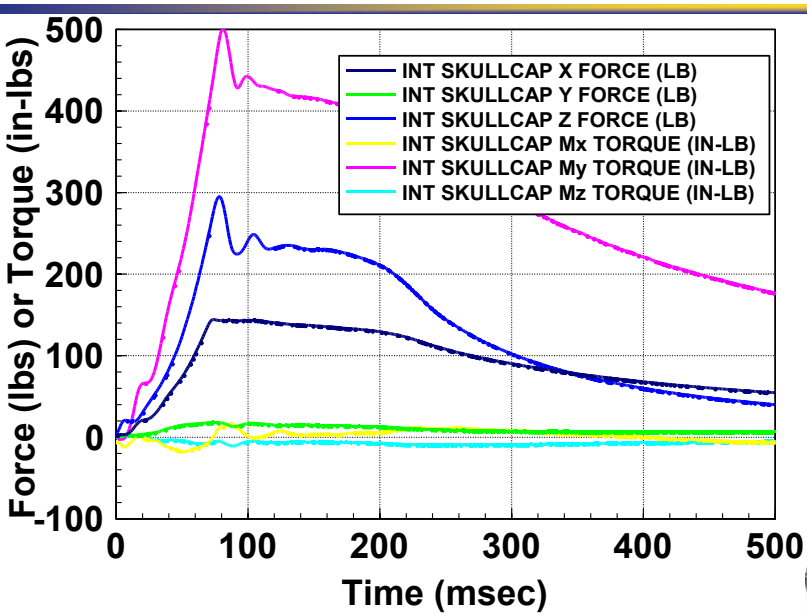
- **Test terminated @ 4500 N**
- **3 Test Configurations:**
  - **No Mask**
  - **MBU-12/P Mask**
  - **MBU-20/P Mask**

MTS29

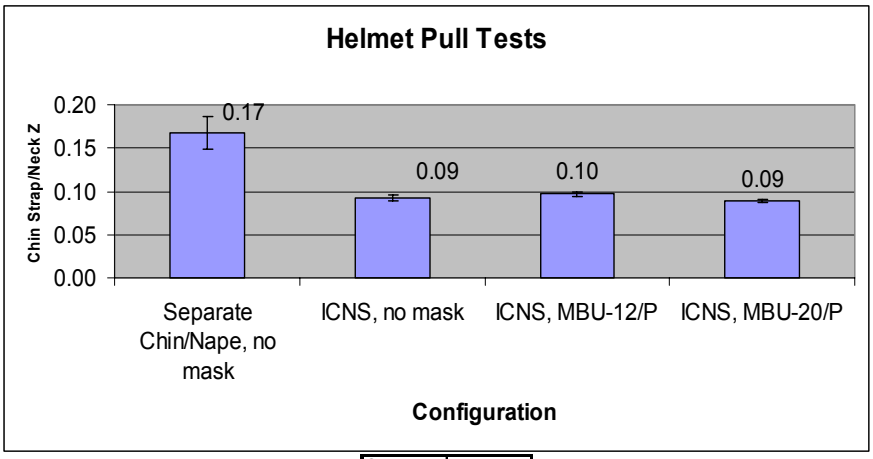
MTS Test Data



MTS Test Data



Results

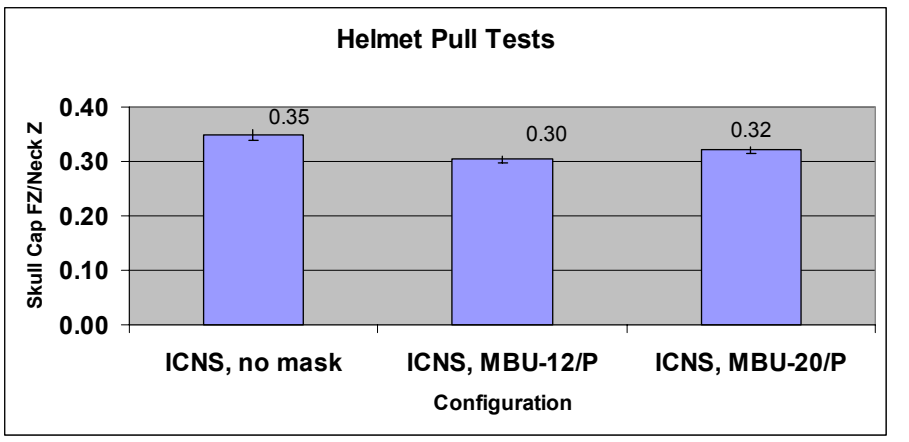


Average peak neck tensile load

	Chin	Fz
	Lbs	Lbs
SCNS, no mask	99	602
ICNS, no mask	76	817
ICNS, MBU-12/P	72	743
ICNS, MBU-20/P	74	832

Linear relationship between neck load and chin strap load

Results

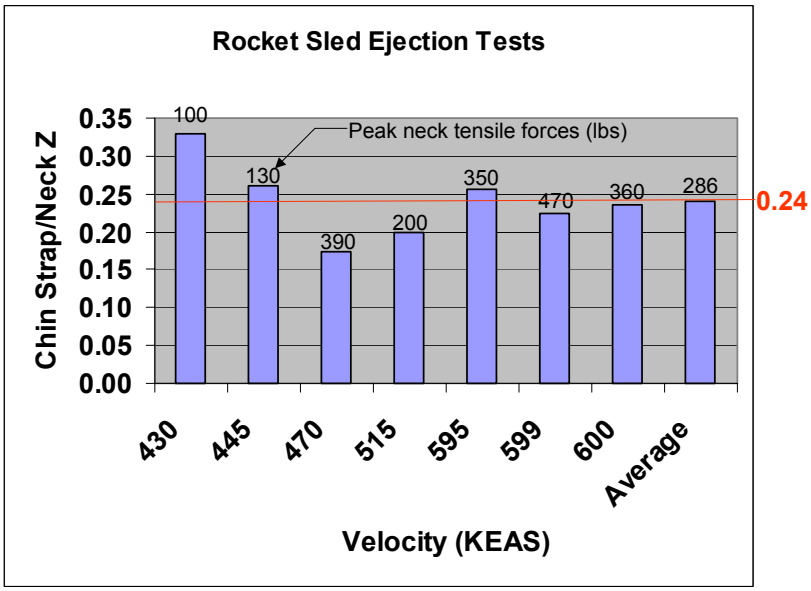


Average peak neck tensile load

	Neck Fz	Skull Fz
	Lbs	Lbs
ICNS, no mask	817	285
ICNS, MBU-12/P	743	226
ICNS, MBU-20/P	832	267

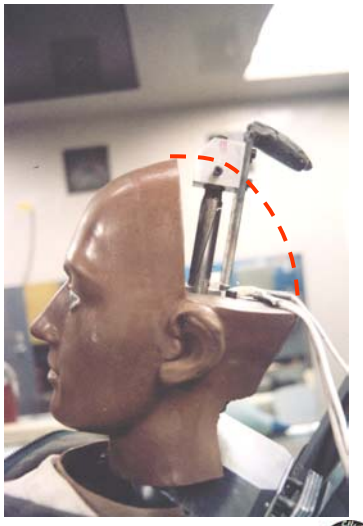
Linear relationship between neck load and chin strap load

Comparison with Rocket Sled Ejection Test Data (ICNS)

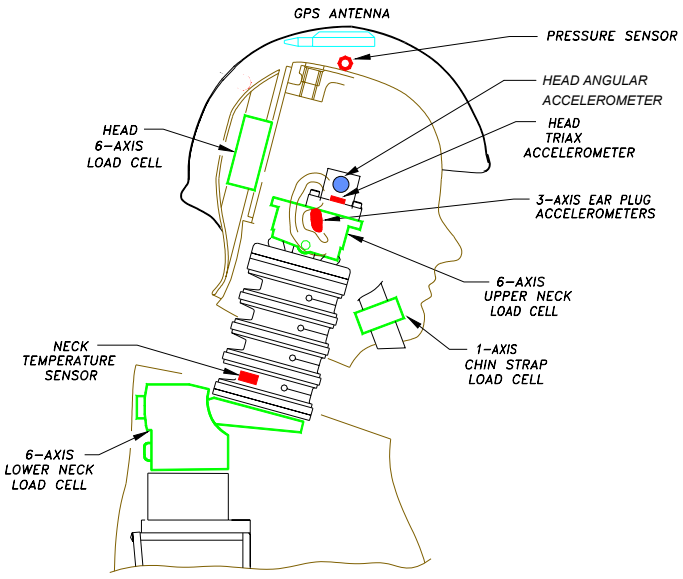


Ejection Test Differences

- Chin strap/neck tensile force
  - MTS: 0.10
  - Ejection: 0.24
- Not pure axial loading
- Aerodynamics
  - Stagnation pressure
  - Force on strap/load cell

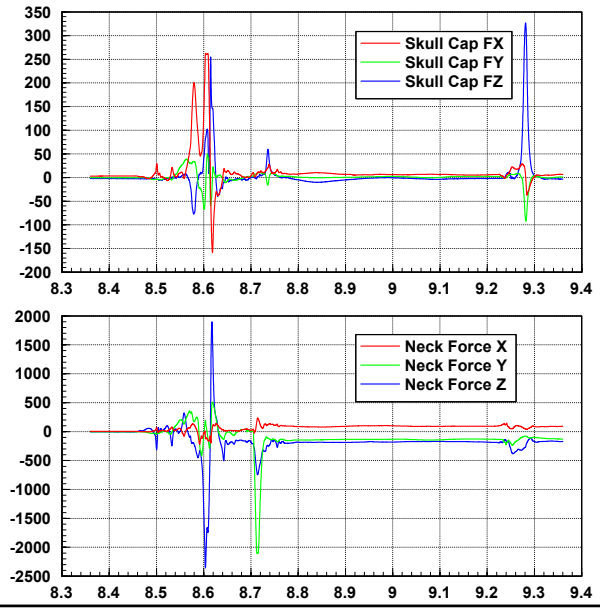


Head/Neck Sensors for Follow-up Rocket Sled Testing



0/0 Ejection Seat Test

0/0 Ejection Seat Test



Other Uses – Skull Cap

- Measure impacts to the back of the head
- Commercial and industrial helmet systems
  - Motorsports
  - Motorcycle
  - Bicycle
  - Hardhats
- Evaluation of the crashworthiness of vehicles
  - Rearward impacts
  - Rollover
- Falls from objects such as ladders
- The data can be used to assess the probability of injury

Results - Skull Cap Load Cell

- Testing "altered" the sensor
  - Five of the six channels were out of zero spec.
  - The metal wasn't located in the same geometry it was located when the gauges were initially applied
  - Recommend at least a three-fold increase in range

Results – Chin Strap Load Cell

- Effective in helmet pull and ejection seat tests
- Intermittent dropouts during windblast tests
  - Enamelized wires likely contacting conductive surface
    - Newest sensors use Teflon® insulation
- Use of “pockets” around stain gages
  - Better protection of strain gages
  - Possibly better concentrate strain

Conclusions

- Both the skull cap load cell and chin strap load cell have been used in several test programs
- A few problems occurred that can be corrected in the future
  - Higher range skull cap load cell
  - Teflon® insulated wires on chin strap load cell
  - "Pockets" cut in chin strap load cell
- Use of this instrumentation suite can yield valuable data in the area of reducing neck injuries during ejection
  - Can also be useful for other commercial applications