Gaps and Trends in Military Injury Biomechanics

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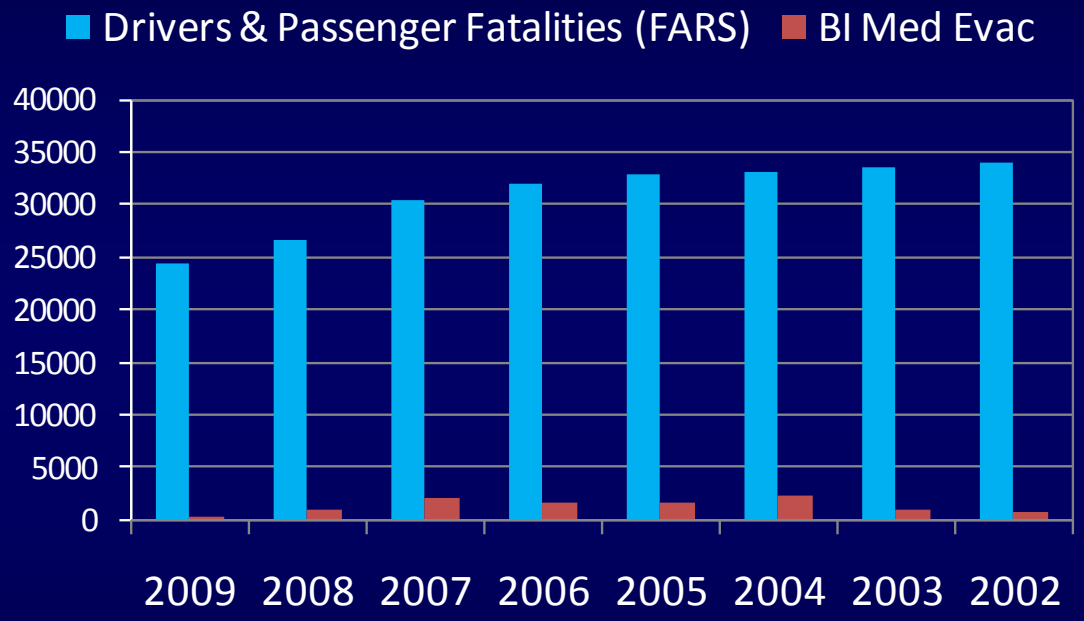
Injury Data:
A Challenge of Absolute Numbers

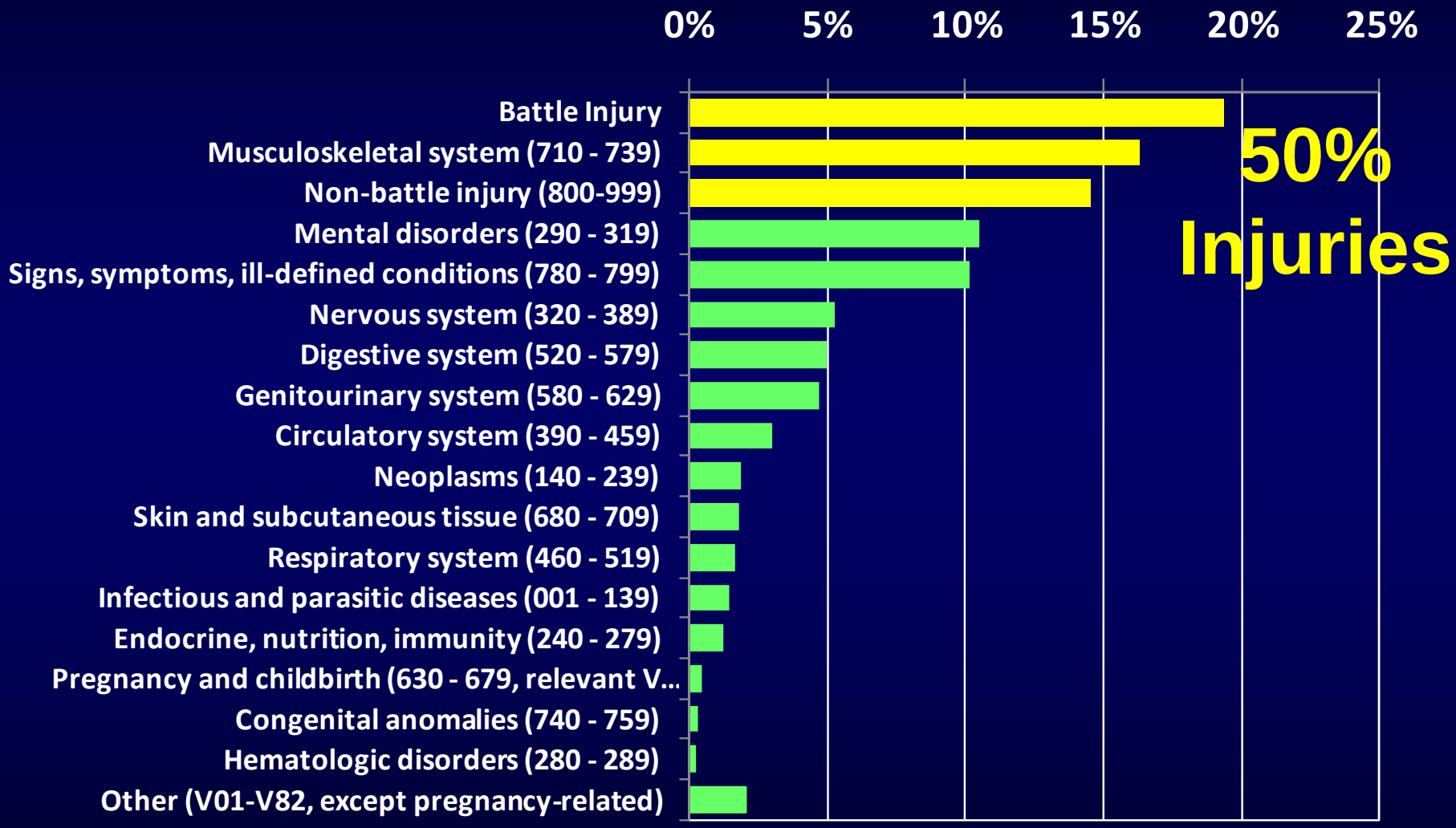
- Over 310 Million people in the U.S. with 2+ Million injured annually in MVAs



- U.S. service members OIF and/or OEF during 2001 – 2009 (MSMR, Feb 2010)
  - Approximately two million in theater
  - Over 10,000 medically evacuated for Battle Injuries (Principle Diagnosis)

Medical Evacuations from OIF & OEF

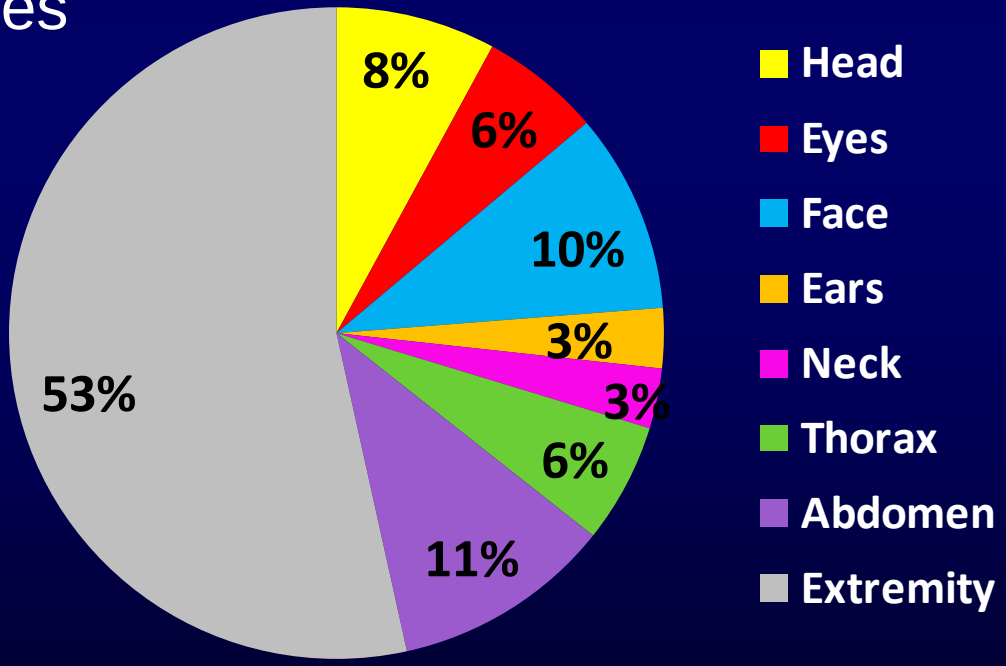
(Oct 2001 – Sept 2009)



(MSMR, Feb 2010)

JTTR Injury Sample (Oct 2001 – Jan 2005)
(Owens, et al. J Trauma. 2008;64:295–299)

- "A total of 1,566 combatants sustained 6,609 combat wounds."
  - 4.22 on average
- Over half of the injuries received were to the extremities



JTTR Injury Sample (Oct 2001 – Jan 2005)

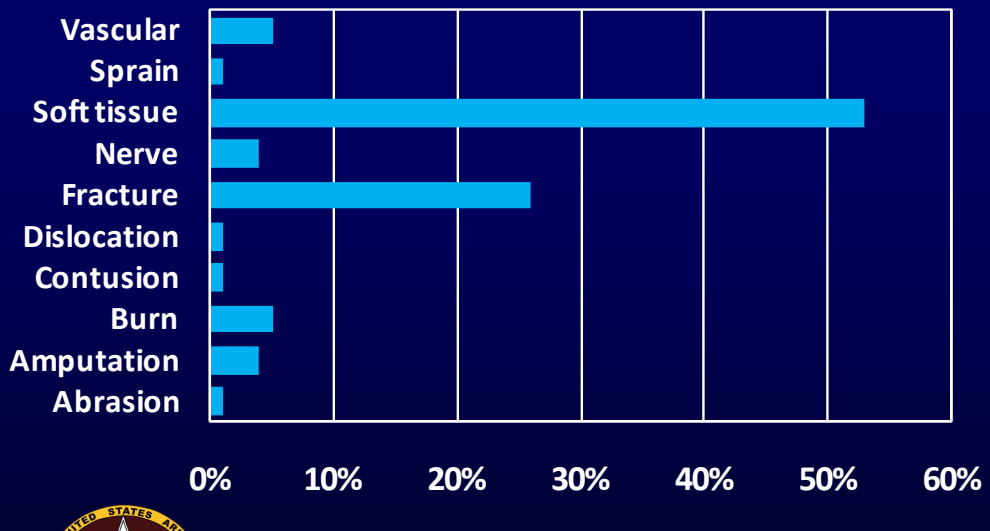
- 1566 individuals received 6609 combat wounds from October 2001 through January 2005 in OIF and OEF (Owens, et al. *J Trauma. 2008;64:295–299*)
  - 2 % are solely related motor vehicle accidents

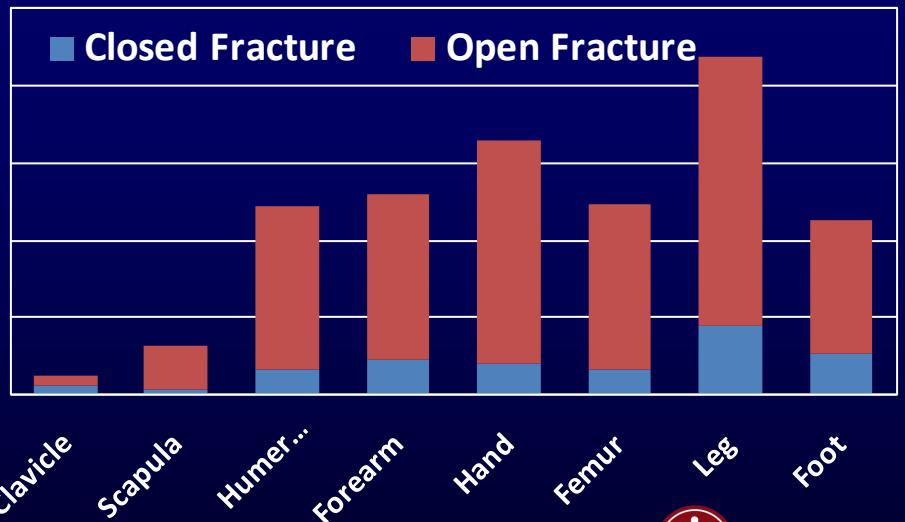
- 1281 Individuals sustained 3575 extremity combat injuries (Owens et al, J Orthop Trauma Volume 21, Number 4, April 2007)
  - 80%+ of all Individuals
  - 2.79 on average

JTTR Injury Sample (Oct 2001 – Jan 2005)

(Owens et al, J Orthop Trauma Volume 21, Number 4, April 2007)

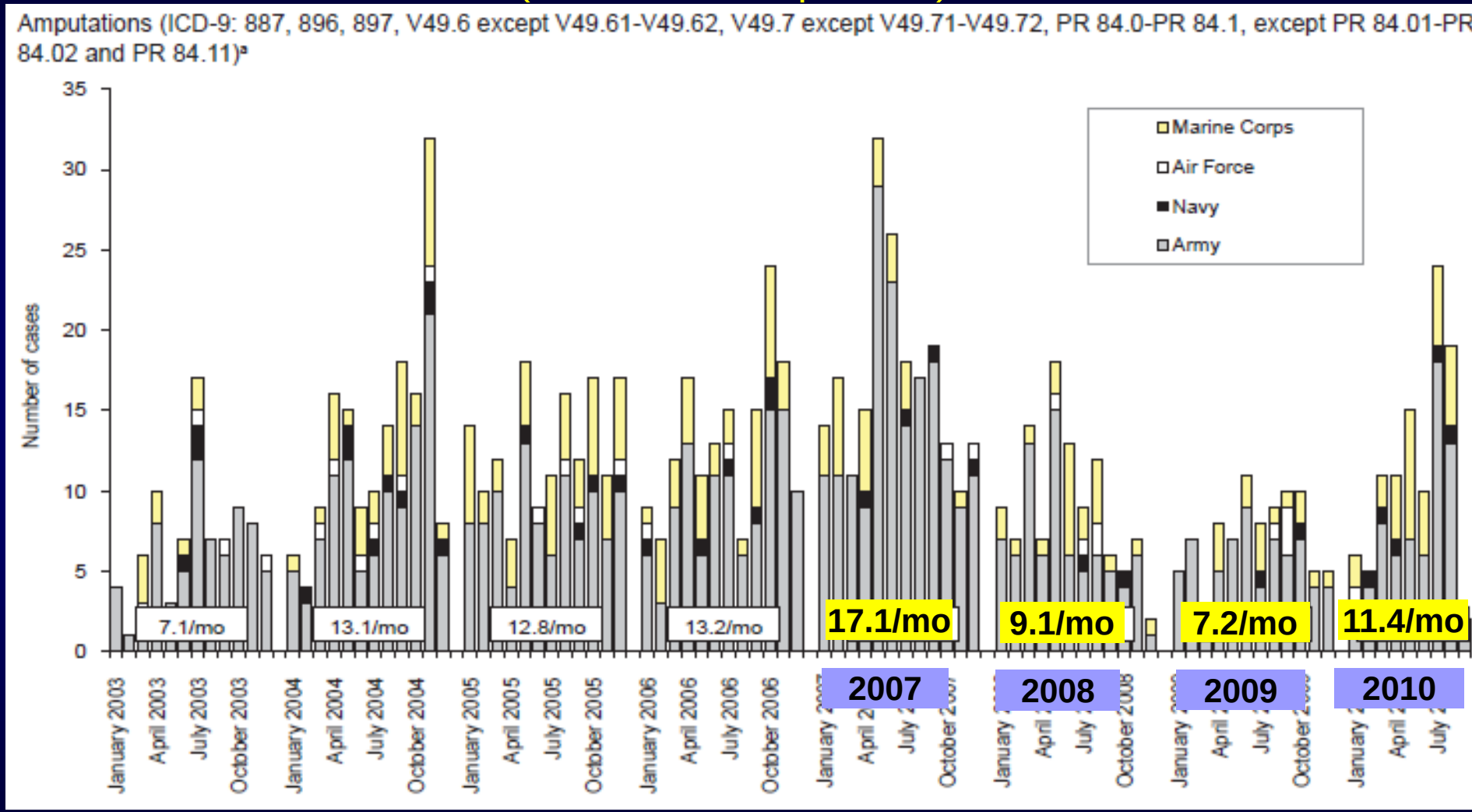
- "A total of 1281 soldiers sustained 3575 extremity combat wounds."
- "Fifty-three percent of these were penetrating soft-tissue wounds and 26% were fractures."
- Of the 915 fractures, 758 (82%) were open fractures
- Upper and lower extremity injuries
  - Approximately evenly distributed number of **injuries**
  - Most common fracture location in the upper extremity: **hand**
  - Most common fracture location in the lower extremity: **tibia and fibula**





Special Surveillance: Extremity Amputation

(Jan 2003 – Sept 2010)

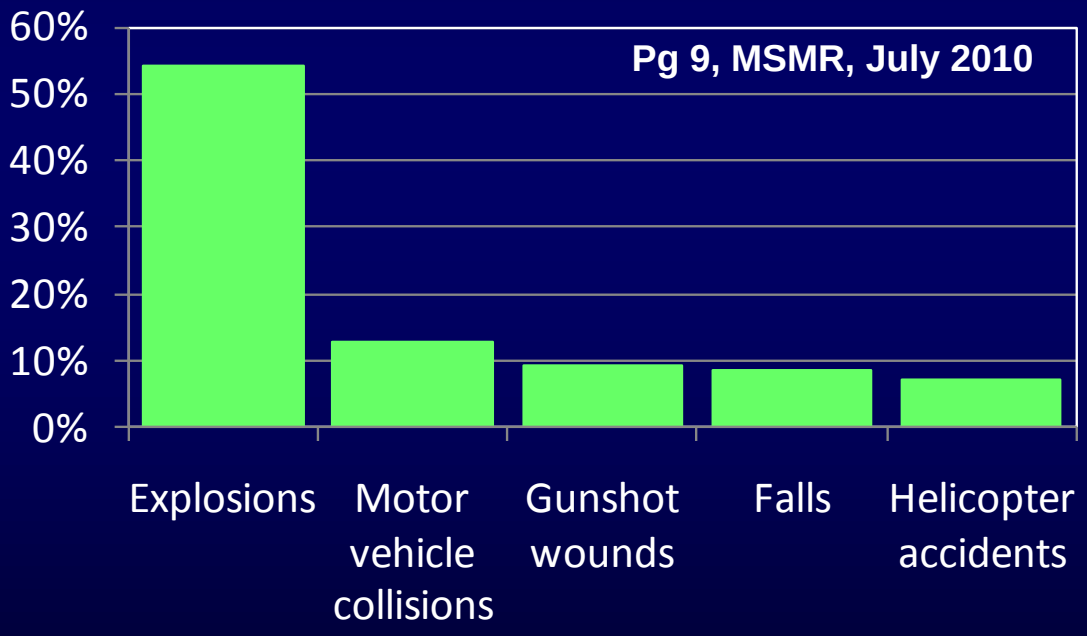


MSMR, October 2010

Injury Data Sample from OIF & OEF:

Spinal Injury and Relative Exposures

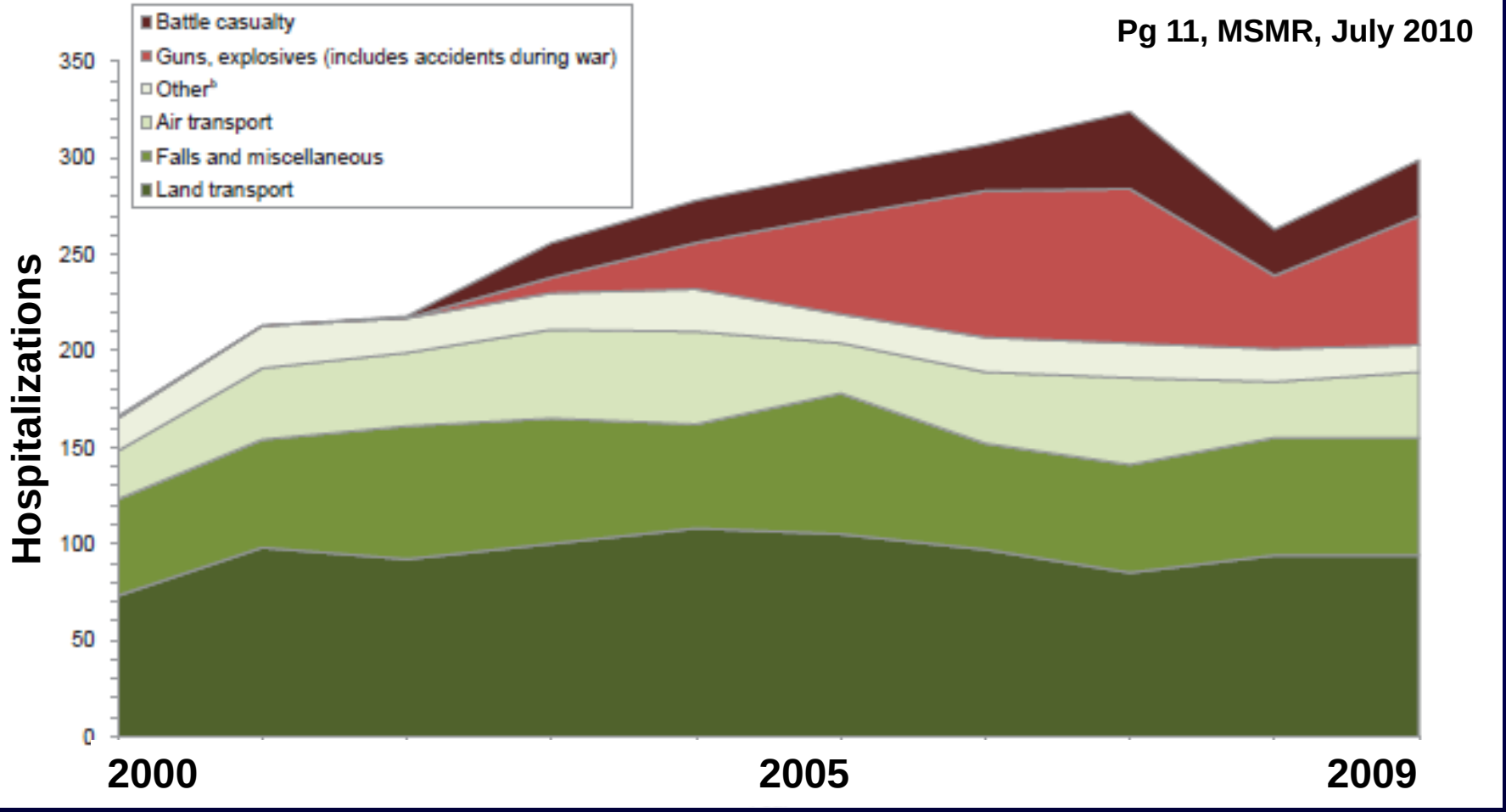
- 703 medical evacuations of military members with thoracolumbar spine fractures (2000-2009)
- Significant damage to the spinal cord is often life threatening, therefore, individuals with SCI may not survive to be hospitalized



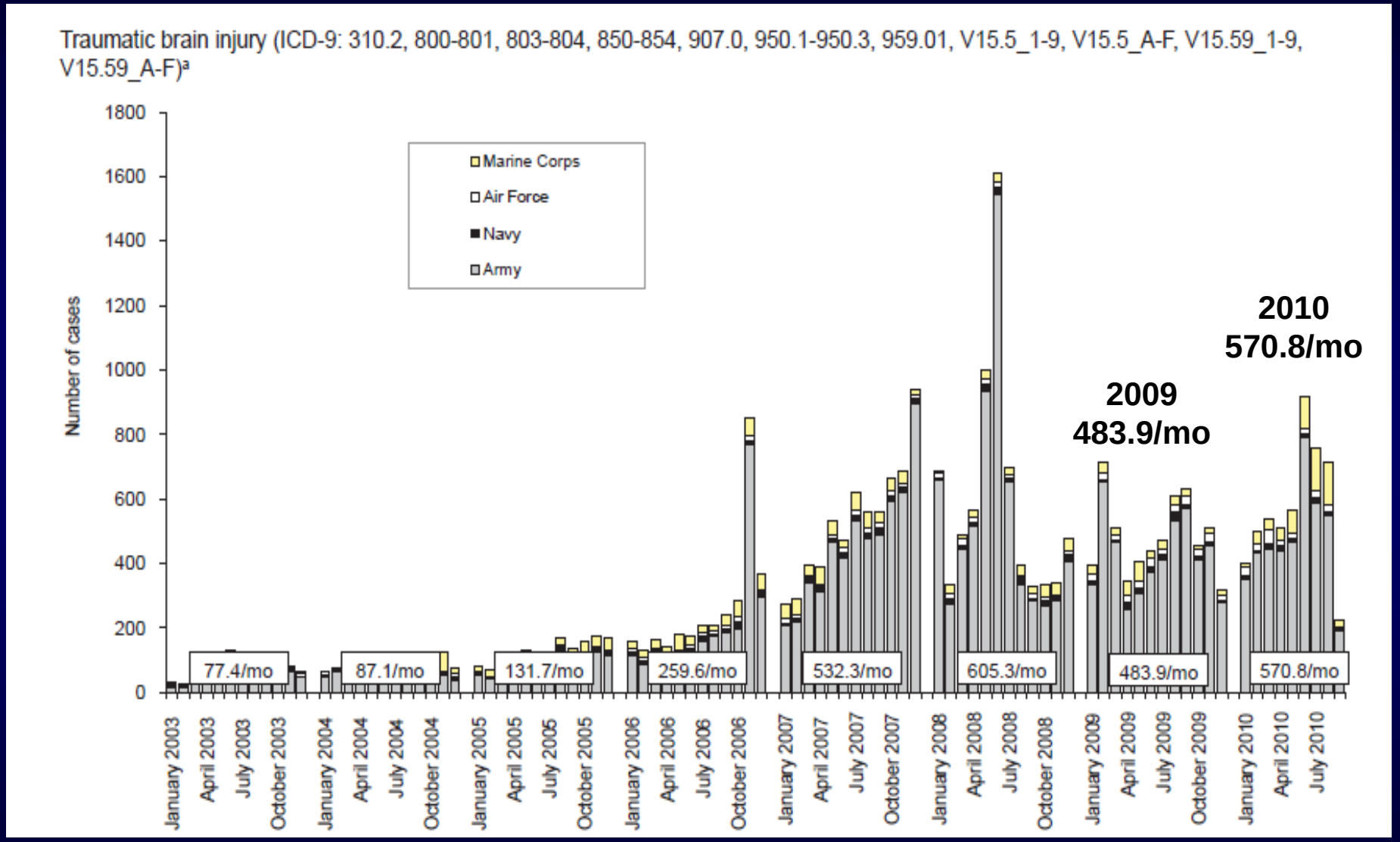
Fracture of vertebral column without mention of spinal cord Injury
805.2 Dorsal [thoracic], closed
805.3 Dorsal [thoracic], open
805.4 Lumbar, closed
805.5 Lumbar, open
805.8 Unspecified, closed
805.9 Unspecified, open
Fracture of vertebral column with spinal cord injury
806.2(x) Dorsal [thoracic], closed
806.3(x) Dorsal [thoracic], open
806.4 Lumbar, closed
806.5 Lumbar, open
806.8 Unspecified, closed
806.9 Unspecified, open

Injury Data Sample from OIF & OEF:

Spinal Injury and Relative Exposures



Special Surveillance: TBI (Jan 2003 – Sept 2010)



Overall Status of Operational Data

- Other databases
- Overall status of injury data
  - Most collected during treatment process
  - Not designed for injury biomechanics research
  - Classification (FOUO at a minimum)
  - Incomplete data sets as no one database contains all data
    - Databases need to be cross-referenced
    - New fields can make historical comparisons challenging
  - Absence of operational context
    - Challenge of classification/distribution
    - Unknown use of PPE and restraints
    - Unknown occupant location in vehicle
    - Challenge of specific equipment (seats, non-stowed equipment, mission gear) in vehicle/variants
    - Overall exposure is unknown

Operational Context

- Exposure and operational context data
  - Can not interfere with mission
  - Can not make Warrior or data collection team vulnerable
  - Challenge to determine what the measure and how to measure
- Influence of PPE on Occupant Kinematics, Loading, & Injuries
  - Preloading (40+ lbs) the Occupant and Occupant Surrogate
  - Pre-position of the Occupant and the Occupant Surrogate

Operational Context

Operational Context

- Mounting Variations with Seating
  - Stroking
  - Floor
  - Wall
  - Ceiling
- Occupant Operational Position
  - Seating facing Anterior or Posterior
  - Seating facing Laterally towards vehicle center
  - Standing gunner
  - Supine and seated patients
- Location of Blast Relative to Occupant
  - Creates numerous loading vectors

Gaps for Injury Assessments

- ***INADEQUATE BIOMECHANICAL SURROGATES*** - Current biomechanical surrogates (Anthropomorphic Test Devices, or ATDs) used for operationally relevant materiel and product test and evaluation, especially in the live fire setting (LFT&E), were exclusively designed for the civilian automotive industry and as such are not suitable to the combat environment
  - Hybrid III
  - ATD Instrumentation and DAQ were not designed for blast events
    - Unknown EMI response
    - Unknown ATD and instrumentation rate response (including resonance)
    - Loading magnitude that exceed instrumentation design/rating
  - ATDs were not designed to wear PPE

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Gaps for Injury Assessments

- ***APPLICABILITY OF SAE J211 (and associated references)***
  - For short duration events, filtering requirements result in a significant reduction in signal magnitude
  - Time-duration criteria have limited use for short blast-accelerative duration events

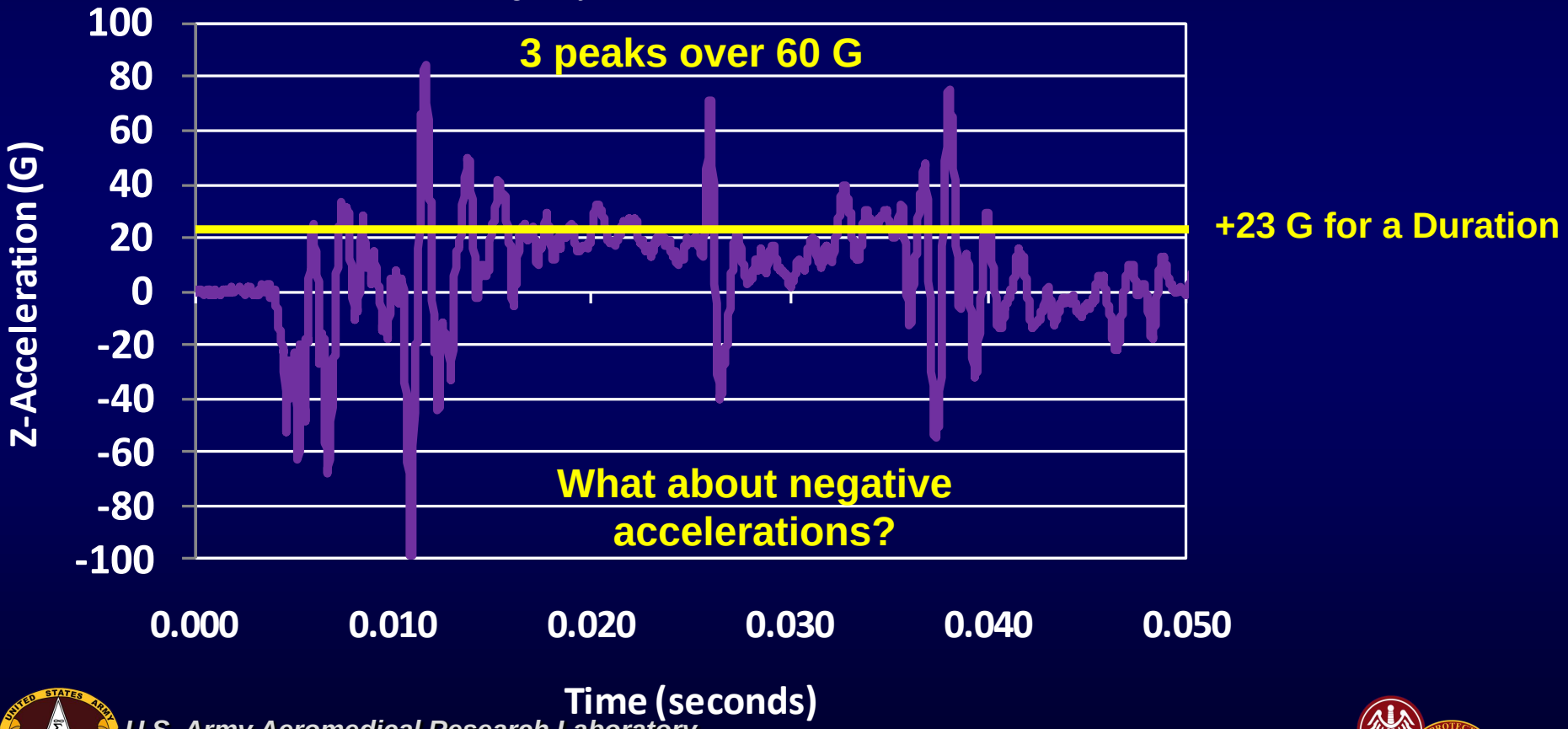
- ***INADEQUATE OCCUPANT & VEHICLE KINEMATIC CHARACTERIZATION***
  - Difficulty lighting inside a vehicle
  - Space constraints
  - Difficulty seeing through participating media
  - Challenge understanding force and acceleration data with possible kinematics (Little is as expected)

Gaps for Injury Assessments

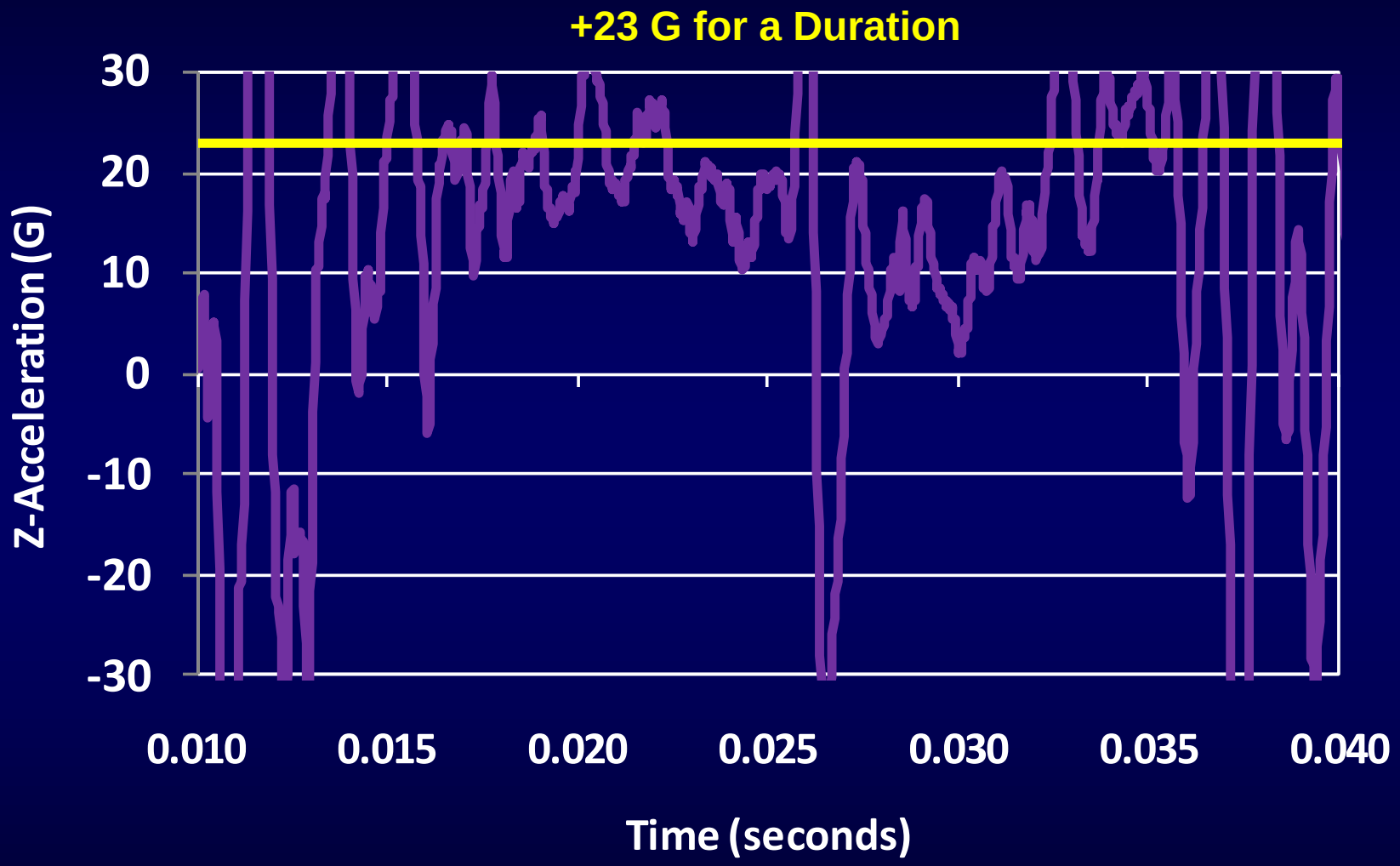
- ***MILITARY SPECIFIC HUMAN INJURY TOLERANCE AND CRITERIA NEEDED*** - Existing human injury tolerance and criteria are not validated for high-rate, high-magnitude, dynamic vertical and/or multi-directional (e.g., inertial and flail injury) loading conditions occurring during blast events
  - Current injury criteria do not correlate well to observed combat injuries
  - Non-existent criteria for body regions and ATD loadings being observed in LFT&E
  - Not all injury criteria have IARVs
- ***MILITARY SPECIFIC INJURY RESOLUTION NEEDED***
  - Existing injury criteria are based on specific civilian injuries
  - Previously research injuries may be of different AIS severities
  - Injury criteria may have a pre-determined discrete injury risk that creates an artificial level of importance for a specific injury when assessing a whole body event
  - Lack of ability to extrapolate civilian-based injury criteria to higher magnitude military-based response
  - Prevents relative comparisons between body regions and protection technologies

An Example of Pelvis Acceleration

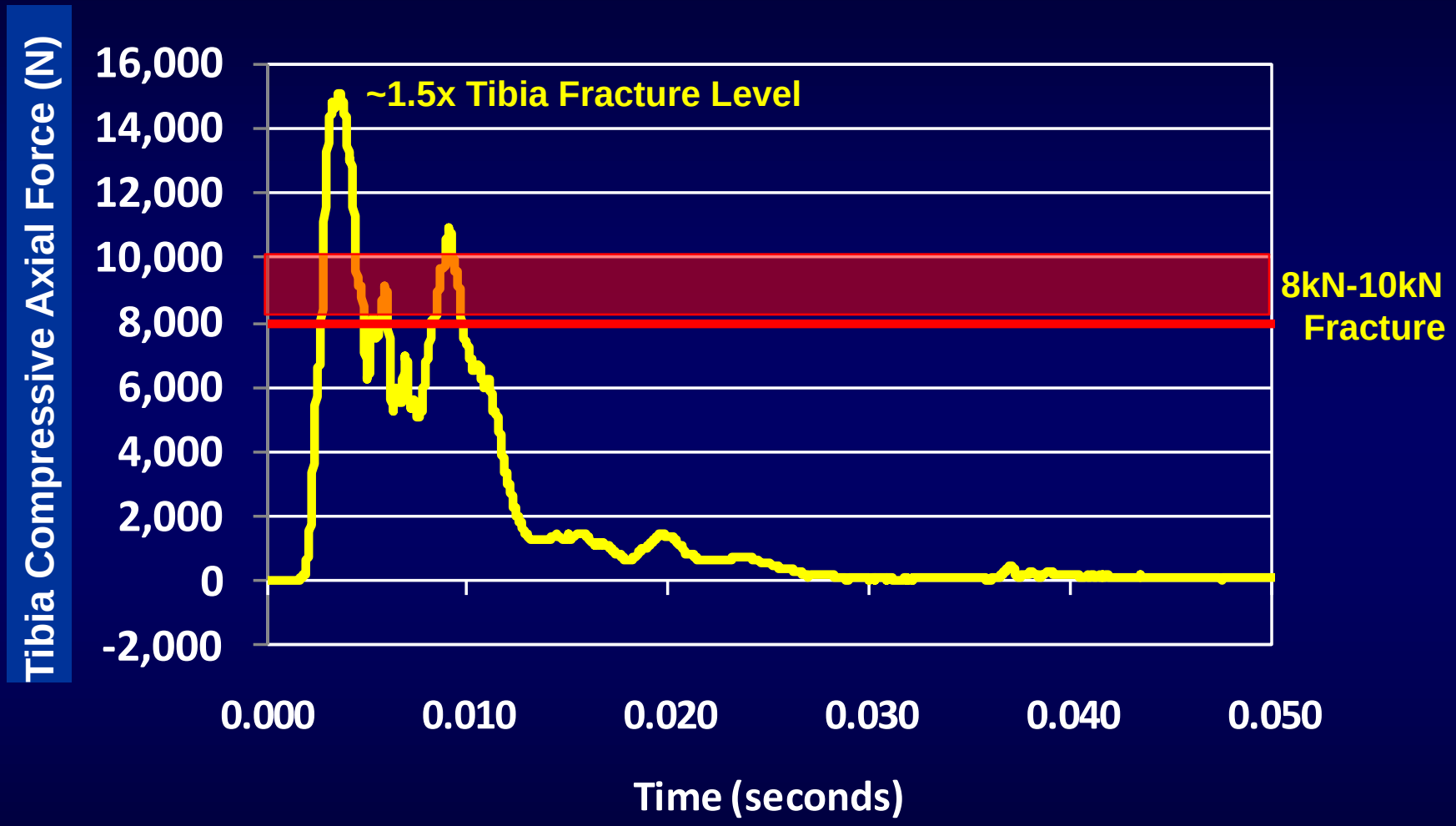
- Injury Criteria of a Magnitude with "duration" are challenging in blast accelerative loading
  - Entire event may be less than "duration" of criteria
  - Additive processes used in automotive differs from aviation
  - Magnitude of duration-related criteria is a fraction of the response magnitude
  - Direction of loading may be different



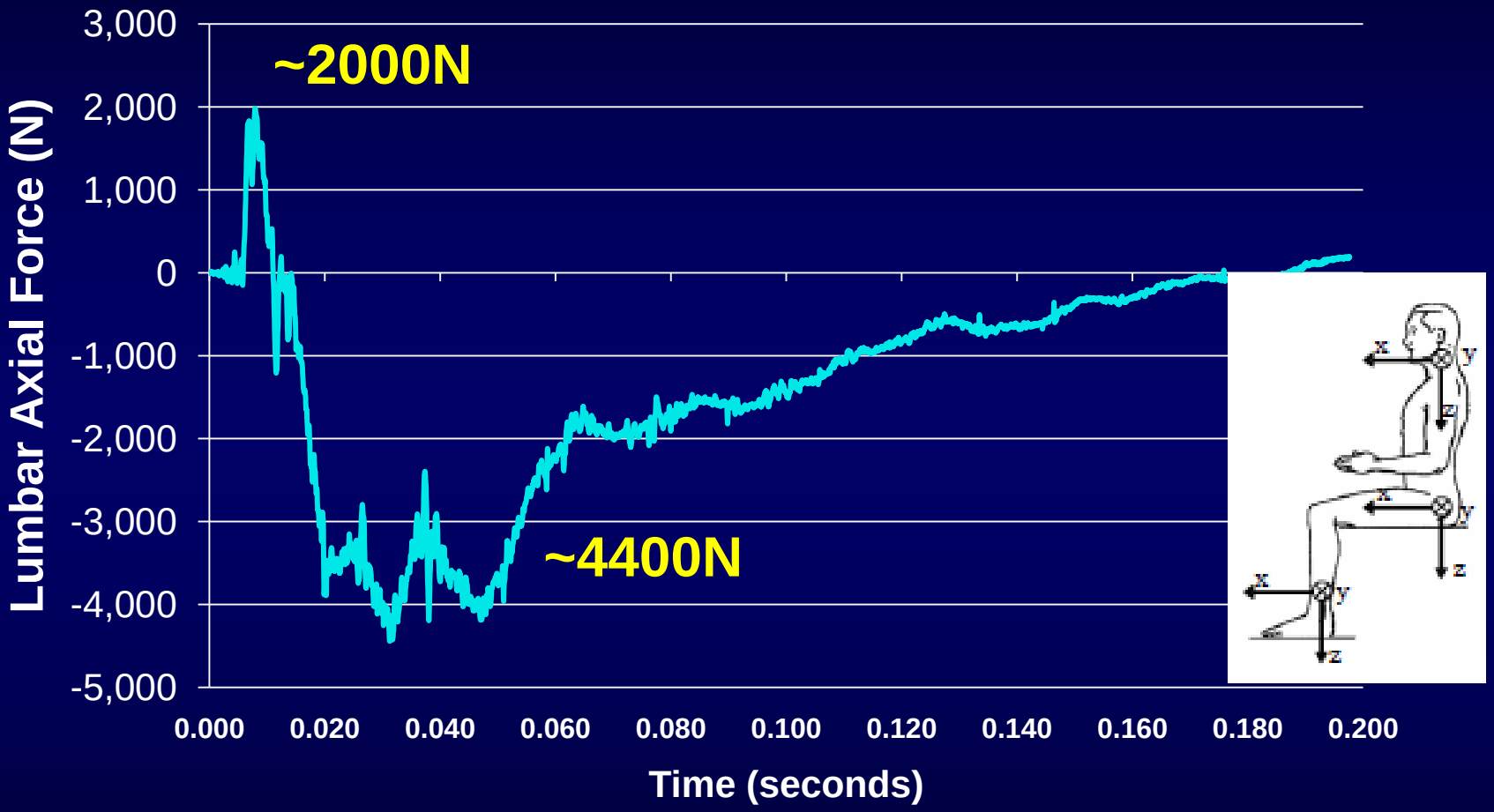
An Example of Pelvis Acceleration



An Example of Tibia Axial Force



An Example of Unfiltered Lumbar Force



Summary

- Common “mounted” injuries in theater are accelerative-related mechanisms . . . not primary blast (overpressure)
  - Different body regions
    - Anthropometry has changed (new effort ongoing: NATICK Soldier Systems Center)
  - More severe injuries than seen or previously investigated
    - *Higher-rate* and *higher-magnitude* loading
- New research into accelerative-related combat injuries needed
  - Verify existing injury criteria (IARVs)
  - Develop new, “cross over” ATDs that include civilian and military ranges of exposures
  - Determine new severity levels and new injury criteria and/or IARVs

Acknowledgements

Parrish Balcena, Kimberly Vasquez, Bethany Shivers,
Frederick Brozoski, Katie Logsdon, Joe McEntire,
LTC Shean Phelps
USAARL

Mike Tegtmeyer, Patricia Frounfelker, Sarah Coard
ARL/SLAD

Risa Scherer
TARDEC

Barbara E. Wojcik, Stephen H. Kleiman, Jason Orosco
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