The WIAMan Development Program: Objectives and Rationale

Michael Tegtmeyer
Warfighter Survivability Branch
Survivability/Lethality Analysis Directorate
Army Research Laboratory
michael.tegtmeyer@us.army.mil

Comments about our environment

We generally test for our primary injury mechanism

Primary blast effects in vehicles are of limited concern*

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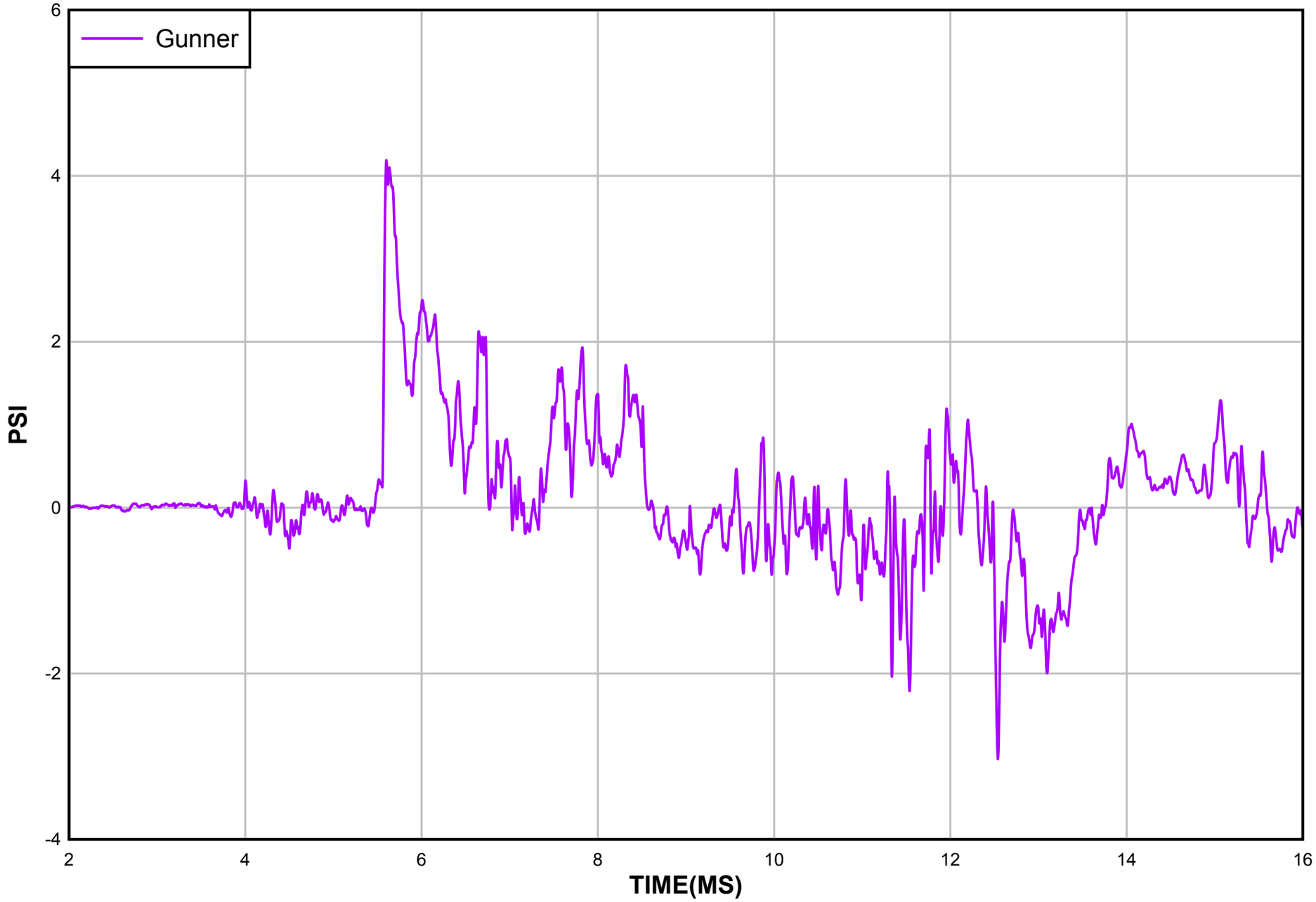

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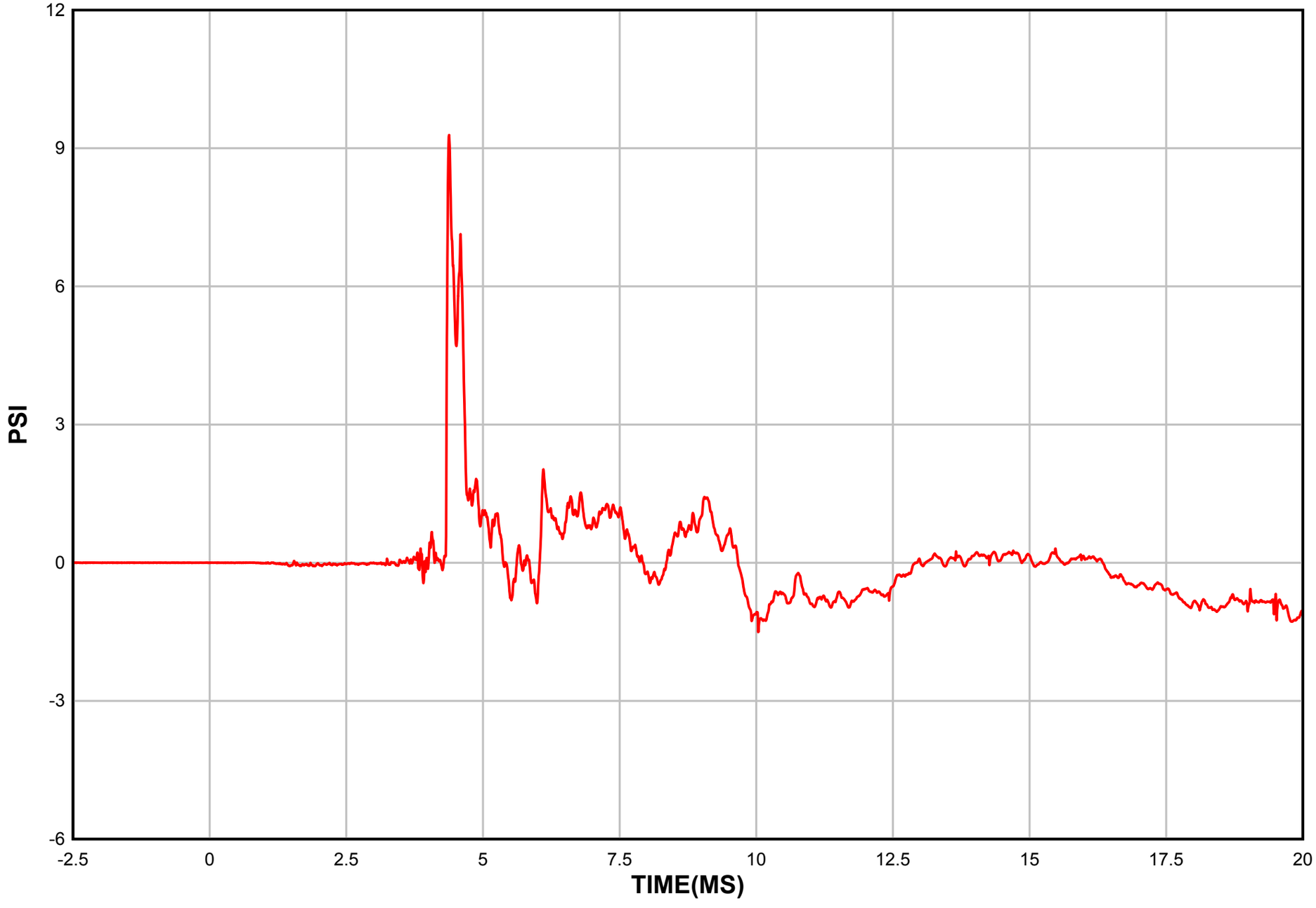

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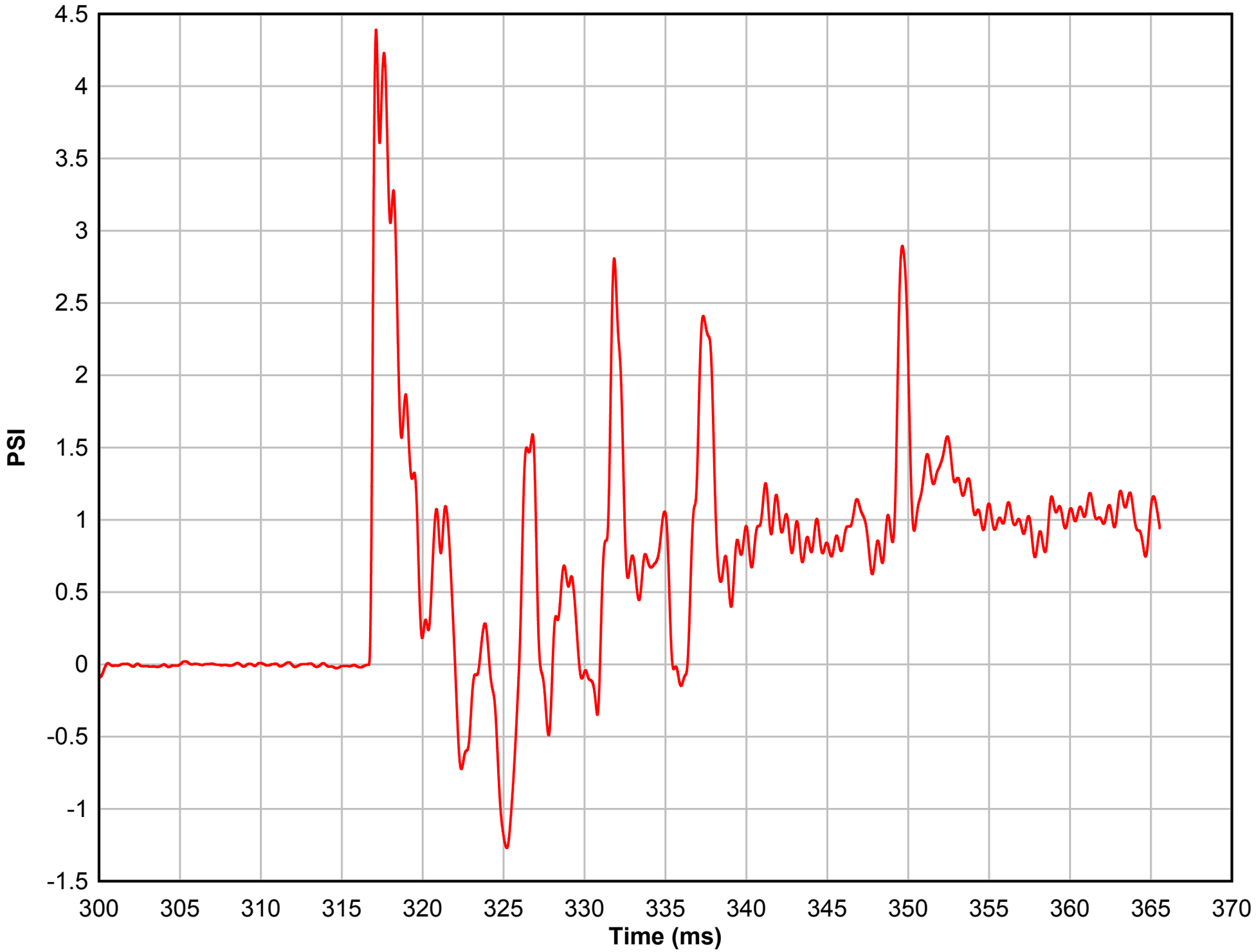
Joint Accelerative Injury Working Group

"Displacement of the body or part of body by the blast overpressure..."

DoDD 6025.21E, E2.1.3. Tertiary Injuries caused by explosive devices

Joint Accelerative Injury Working Group



Thermal events inside the vehicle are generally too short (unless there are secondary fires)

Vehicle overmatches are not interesting

“Fragment catching” manikins

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Joint Accelerative Injury Working Group

Joint Accelerative Injury Working Group

“Laboratory environment” is relative

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Joint Accelerative Injury Working Group

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Cannot standardize into a pass/fail tests

We don't dynamically test vehicles (at least for now)

We care most about raw tissue damage - not injury scoring systems

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We need injury probability curves

2. GENERAL REQUIREMENTS....Continued

TABLE 1 - OCCUPANT CRASH PROTECTION INJURY CRITERIA

Injury Criteria	Dummies					
	50th male certified to S5.1.1(b)(1) 0-48 kmph belted, & S5.1.1(b)(2)0-56 kmph belted, & S5.1.2(a)(2), S5.1.2(b) 32-40 kmph (±30°) unbelted[5]	5th female barrier S16.1(a)(1) 0-48 kmph belted, S16.1(a)(2) 0-56 kmph belted, S16.1(b) 32-40 kmph unbelted, & S18.1 offset 0-40 kmph belted[5]	5th female low risk deployment S25.3[6]	12-month –old low risk deployment S20.4[7]	3-year-old low risk deployment S22.4[8]	6-year-old low risk deployment S24.4[8]
HIC 15	700 S6.2(b)(2)	700 S15.3.2(b)	700 S15.3.2(b)	390 S19.4.2(a)	570 S21.5.2(b)	700 S23.5.2(b)
Nij	1.0 (Critical Values 6806 N tens. 6160 N comp. 310 Nm flex. 135 Nm ext.) S6.6(a)	1.0 (Critical Values 4287 N tens. 3880 N comp. 155 Nm flex. 67 Nm ext.) S15.3.6(a)	1.0 (Critical Values 3880 N tens. 3880 N comp. 155 Nm flex. 61 Nm ext.) S25.4(a)	1.0 (Critical Values 1460 N tens. 1460 N comp. 43 Nm flex. 17 Nm ext.) S19.4.4(a)	1.0 (Critical Values 2120 N tens. 2120 N comp. 68 Nm flex. 27 Nm ext.) S21.5.5	1.0 (Critical Values 2800 N tens. 2800 N comp. 93 Nm flex. 37 Nm ext.) S23.5.5(a)
Neck Extension	N/A	N/A	N/A	N/A	N/A	N/A
Neck Flexion	N/A	N/A	N/A	N/A	N/A	N/A
Neck Tension	4170 N S6.6(b)	2620 N S15.3.6(b)	2070 S25.4(b)	780 N S19.4.4(b)	1130 N S21.5.5(b)	1490 N S23.5.5(b)
Neck Compress.	4000 N S6.6(c)	2520 N S15.3.6(c)	2520 S25.4(c)	960 N S19.4.4(c)	1380 N S21.5.5(c)	1820 N S23.5.5(c)
Neck Fore-Aft Shear	N/A	N/A	N/A	N/A	N/A	N/A
Chest g	60 g S6.3	60 g S15.3.3	60 g S15.3.3	50 g S19.4.3	55 g S21.5.3	60 g S23.5.3
Chest Compress.	63 mm S6.4(b)	52 mm S15.3.4	52 mm S15.3.4	N/A	34 mm S21.5.4	40 mm S23.5.4
Femur Load	2250 lbf. (10000 N) S6.5	6805 N S15.3.5	6805 N S15.3.5	N/A	N/A	N/A

[5] Calculated on data recorded for 300 ms after the vehicle strikes the barrier or from time zero in the sled test. (S4.11(a))
[6] Calculated on data recorded for 125 ms after the initiation of the final stage of air bag deployment designed to deploy in any full frontal rigid barrier crash up to 26 km/h. (S4.11(d))
[7] Calculated on data recorded for 125 ms after the initiation of the final stage of air bag deployment designed to deploy in any full frontal rigid barrier crash up to 64 km/h. (S4.11(c))
[8] Calculated on data recorded for 100 ms after the initial deployment of the air bag. (S4.11(b))

NHTSA

Area	Probability of Injury
Head	<10%
Neck	<10%
Chest	10%
Lumbar	42%
Pelvis	20%
Upper Leg	35%
Lower Leg	25%
Foot/Ankle	30%

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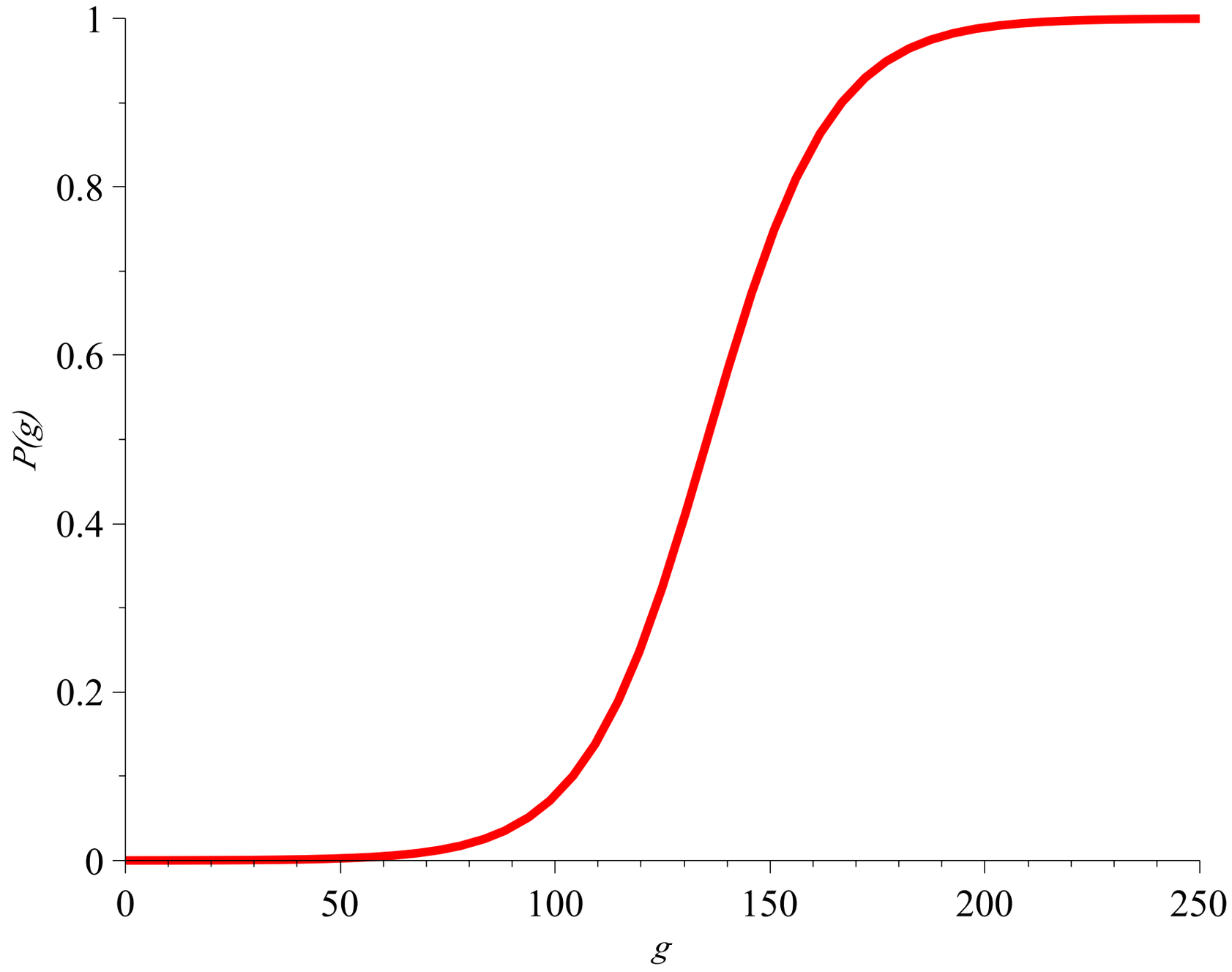
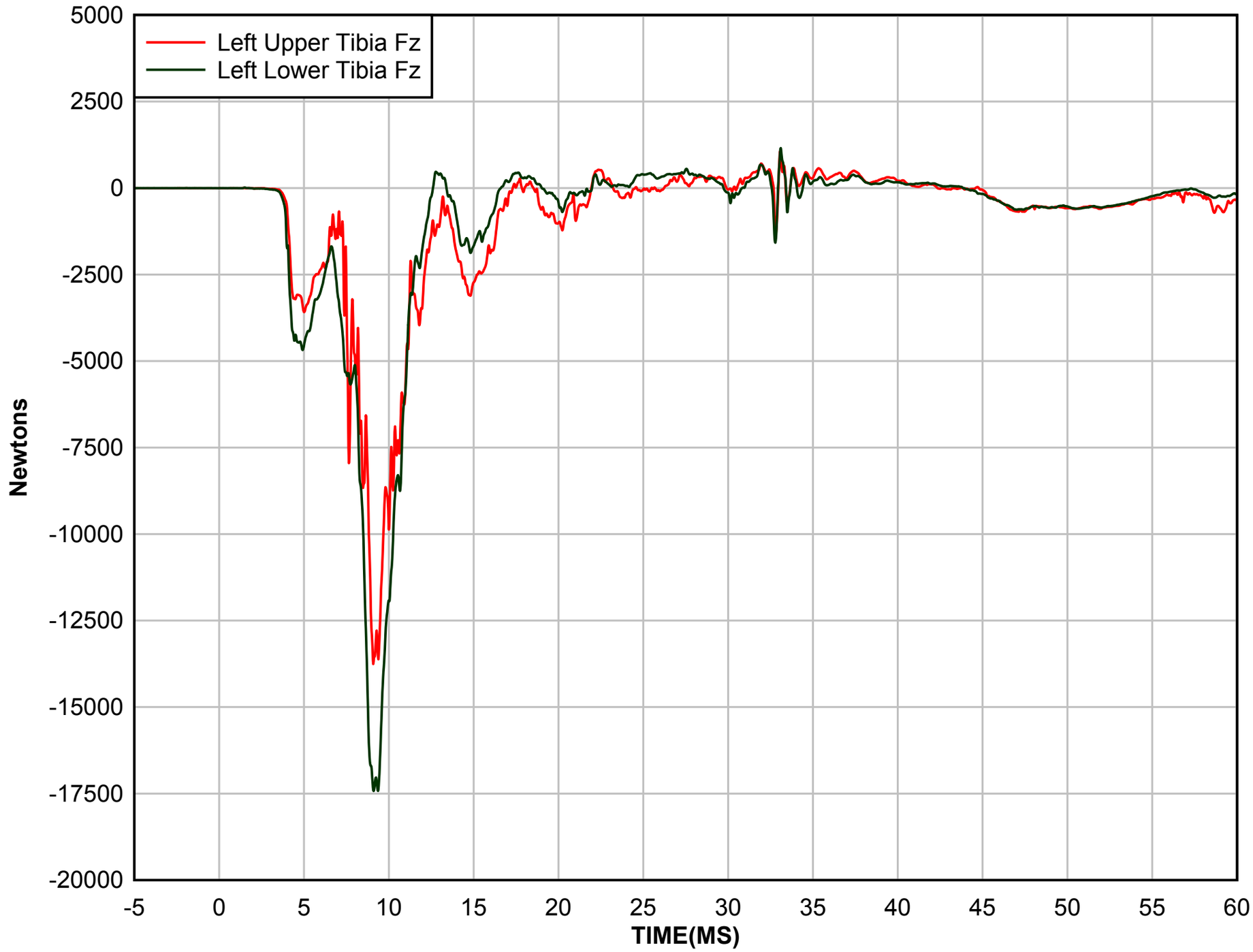
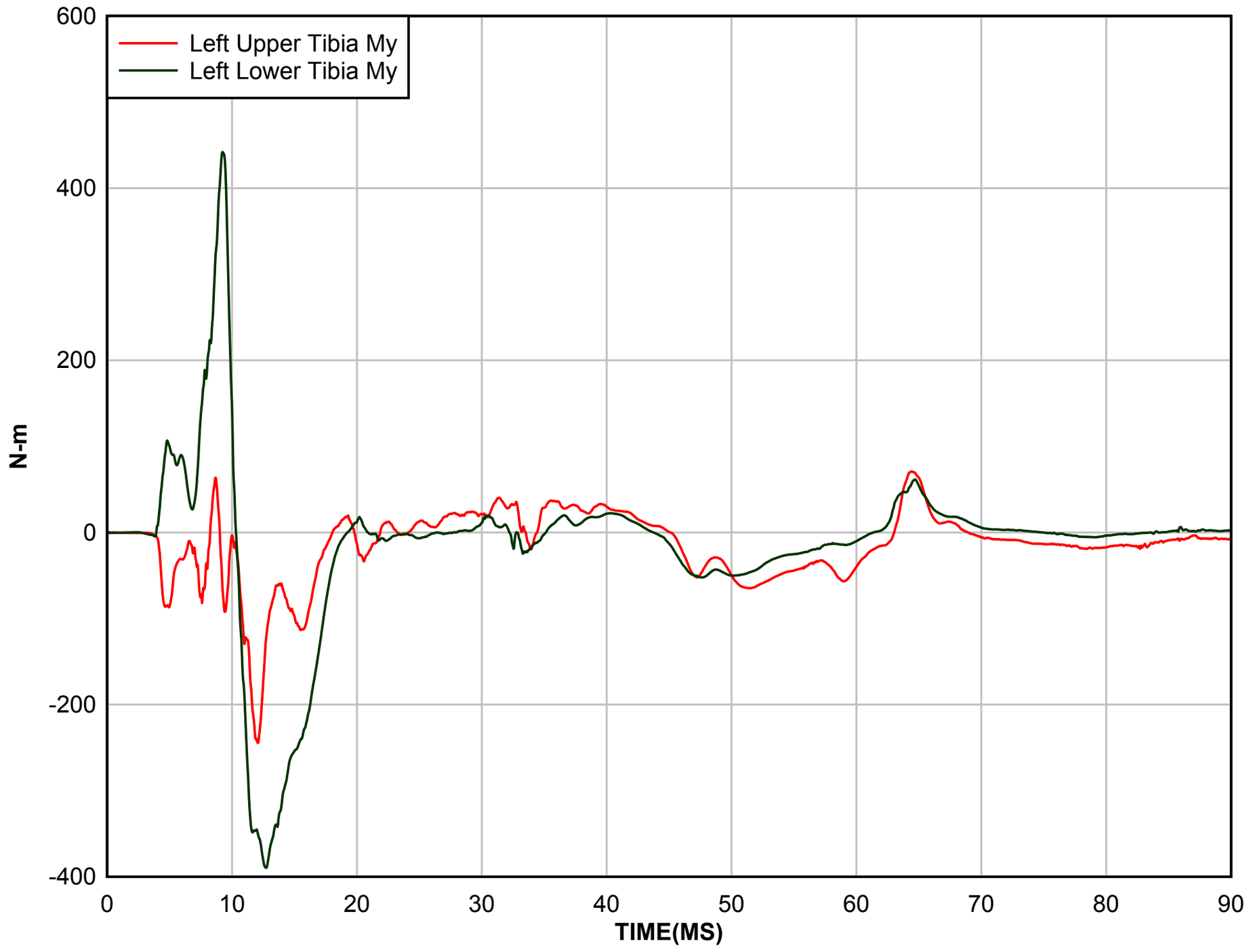
Joint Accelerative Injury Working Group



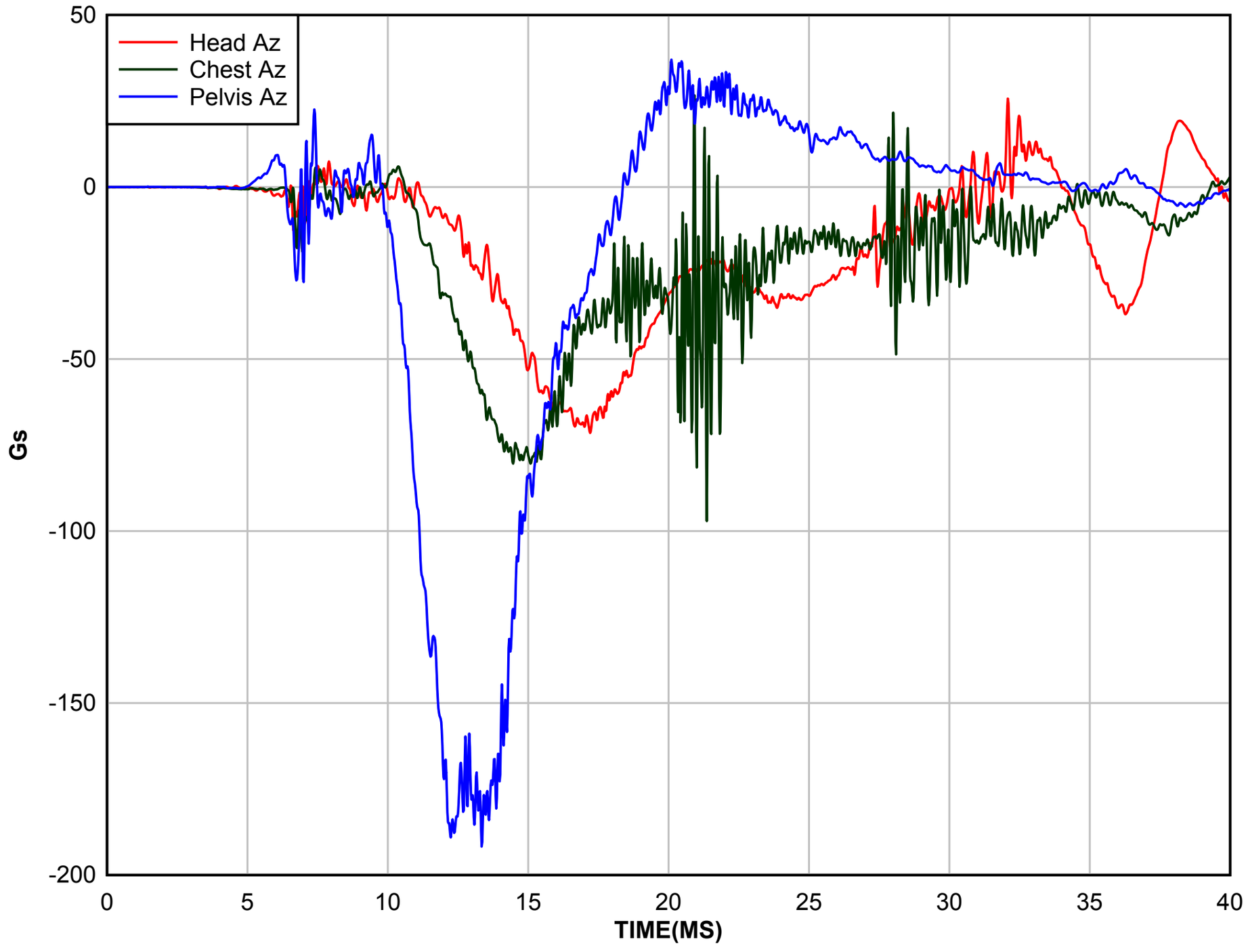
Joint Accelerative Injury Working Group



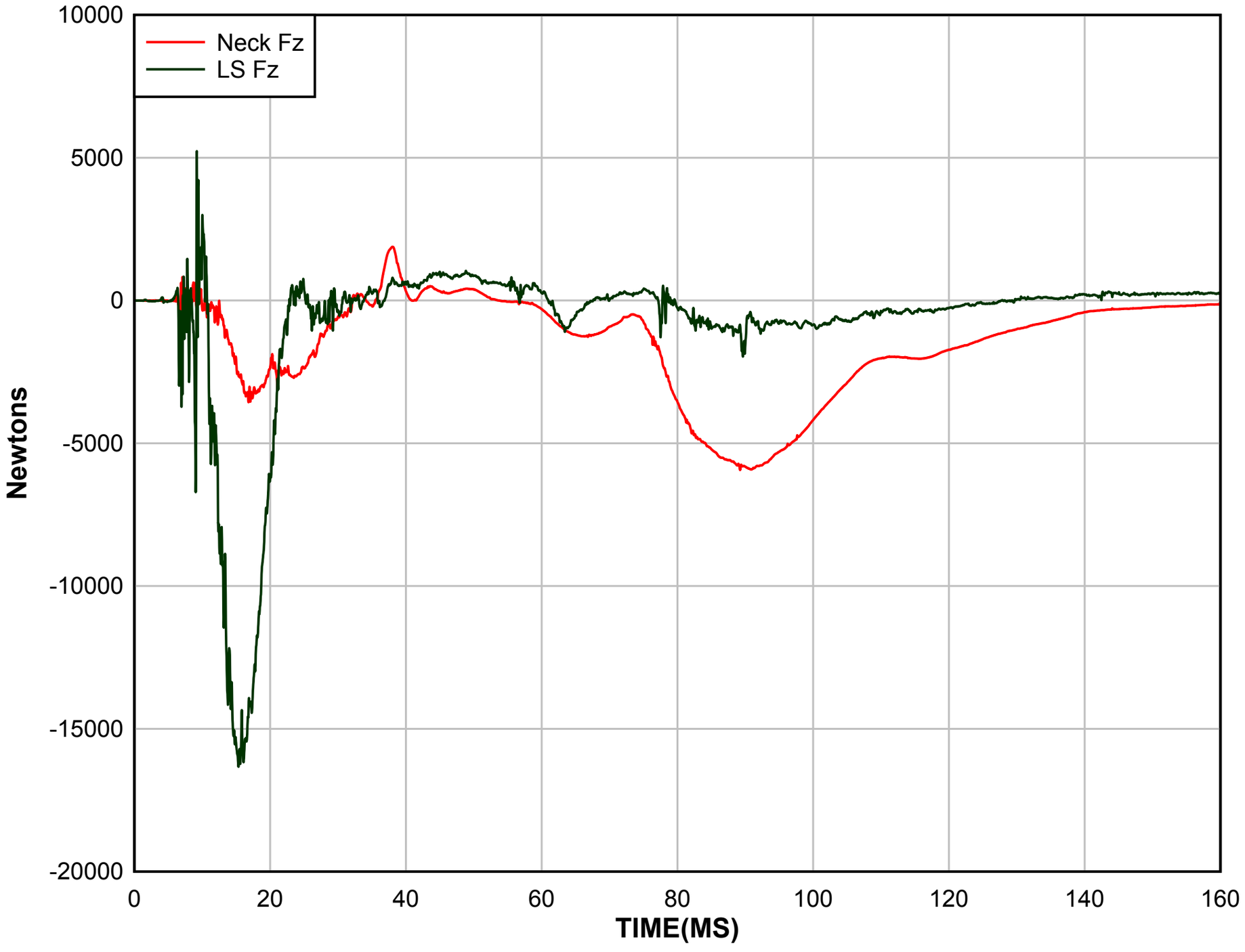
Joint Accelerative Injury Working Group



Joint Accelerative Injury Working Group



Joint Accelerative Injury Working Group



Program for Warrior Injury Assessment Manikin (WIAMan)

Carol Chancey, Ph.D.
Injury Biomechanics Branch
Warfighter Protection Division
Army Aeromedical Research Laboratory
Valeta.Carol.Chancey@us.army.mil

Joe McEntire
Injury Biomechanics Branch
Warfighter Protection Division
Army Aeromedical Research Laboratory
joe.mcentire@us.army.mil

Risa Scherer
Ground System Survivability
Tank Automotive Research, Development and Engineering Center
risa.scherer@us.army.mil

Patricia Frounfelker
Warfighter Survivability Branch
Survivability/Lethality Analysis Directorate
Army Research Lab
patricia.frounfelker@us.army.mil

Michael Tegtmeyer
Warfighter Survivability Branch
Survivability/Lethality Analysis Directorate
Army Research Lab
michael.tegtmeyer@us.army.mil

What is included the Plan?

- Types of Loading
  - Accelerative loading
  - Blunt impact
- Types of Injuries
  - Fractures
  - Dislocations
  - Amputations
  - Musculoskeletal injuries
- Direction(s) of interest
  - Primarily vertical
  - Multi-directional because off-axis exposures occur
- Leveraging of maturation of emerging injury criteria and surrogates
  - i.e., FOCUS & MIL-Lx
- Injury Research
  - Human tolerance & injury criteria research
  - Biofidelity/Biodynamics response/behavior research
  - IARV developments

What is not included?

- Types of loading
  - Primary blast
  - Ballistic penetration
  - Blunt impact due to ballistic events (behind armor effects)
- Types of Injuries
  - Research that would be based on cognitive measurements (TBI)
  - Internal organs
  - Acoustic trauma
  - Thermal/Inhalation
- Injury Research
  - Frangible/expendable surrogates/criteria
  - Stand-alone Modeling & Simulation efforts

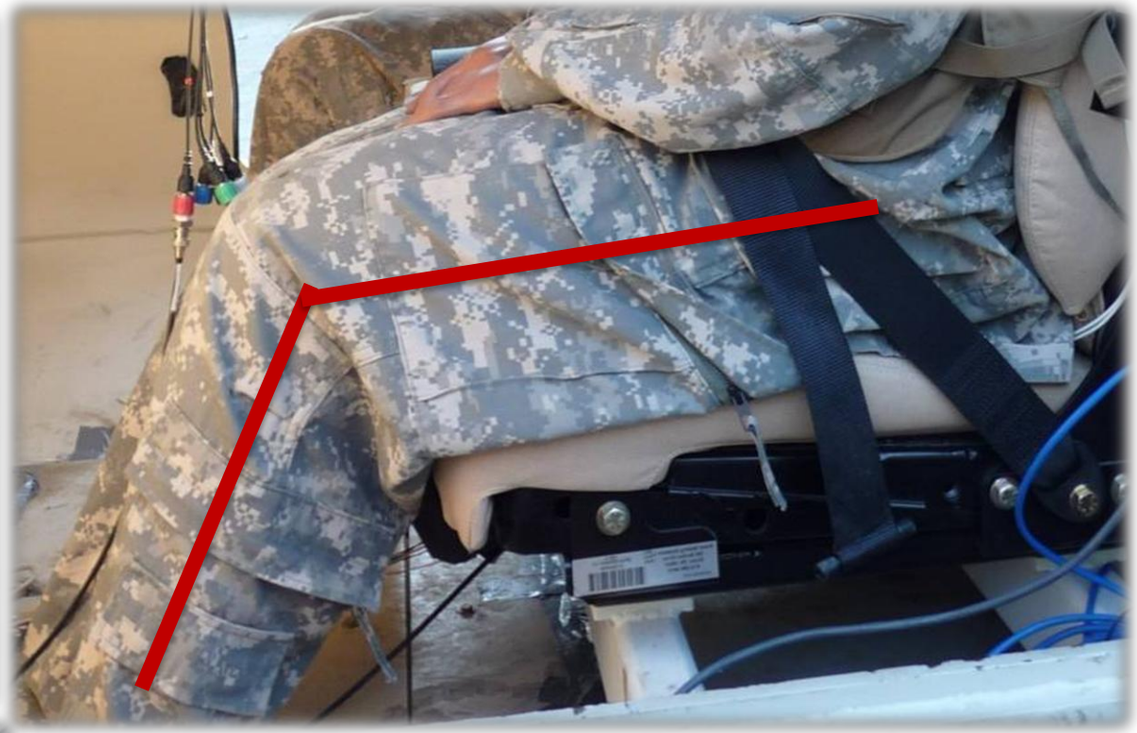
Occupant Loading Considerations

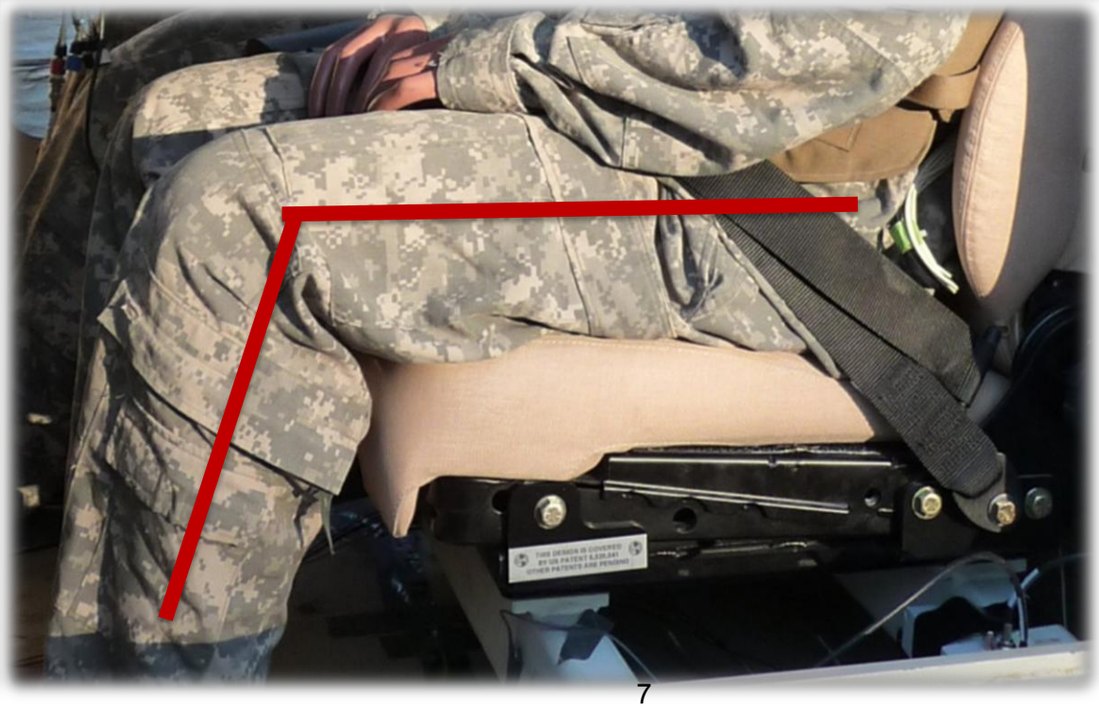
- Seat Mounting Variations
  - Stroking (Energy mitigating)
  - Floor
  - Wall
  - Ceiling

- Structural Variations
  - Energy mitigating flooring
  - Elevated foot rests (foot-pan, stirrups, etc)

- Occupant Operational Position
  - Drivers and Crew
  - Seating facing Anterior or Posterior
  - Seating facing Laterally towards vehicle center
  - Standing gunner
  - Variations in hip, knee, ankle angles
  - Operational preload

- Location of Blast Relative to Occupant
  - Creates numerous loading vectors





Technical Plan for Injury Assessment Research

Medical Research

For each body region:

Title: Biomedically valid injury risk curve development

What:
- Biodynamic Response Corridors
- Human Injury Probability Curves
- High Loading Rate Tissue Properties
- Injury Assessment Reference Curves

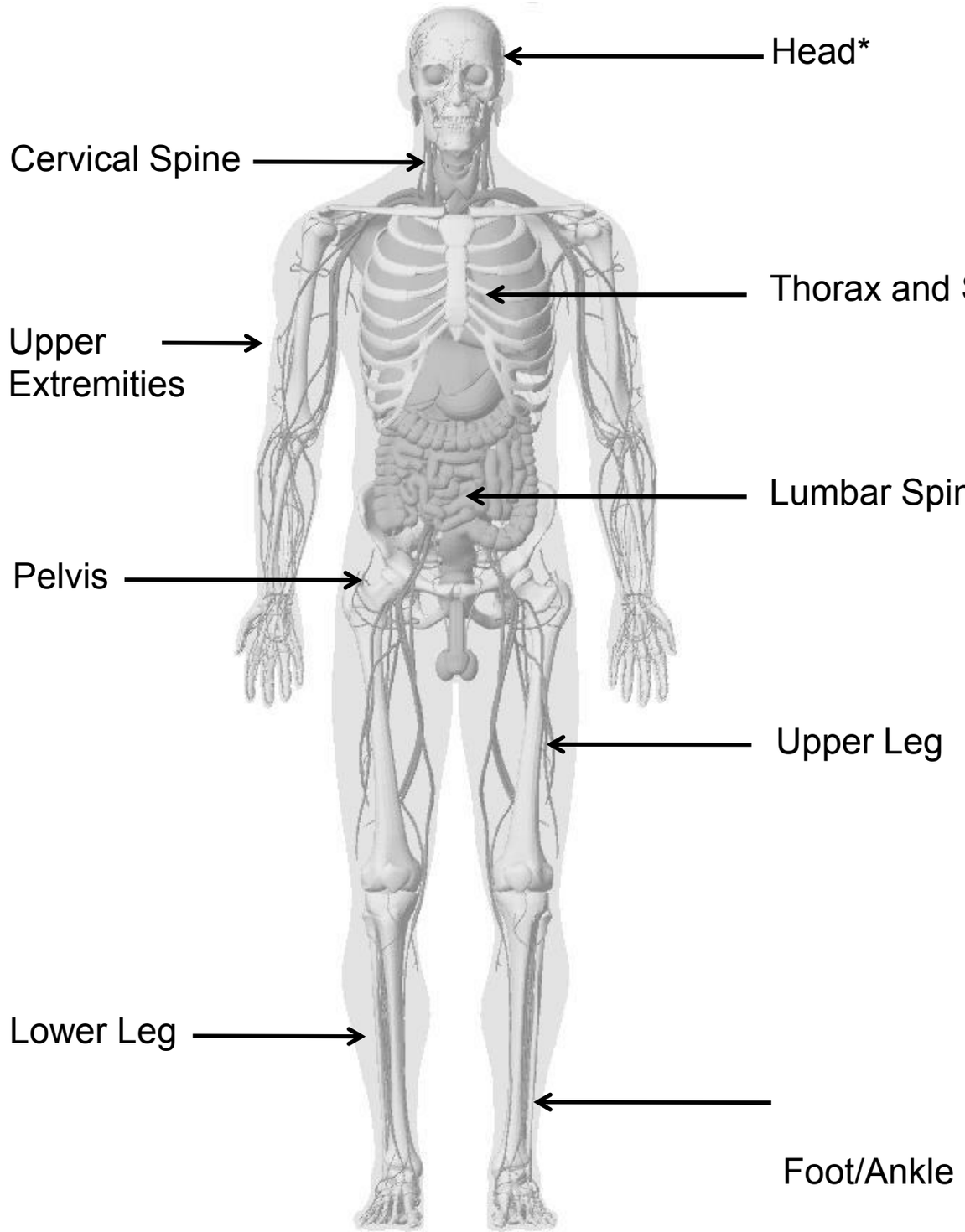
Why: Require biomechanical response corridors for surrogate development

Who: Laboratories with established cadaveric research programs with substantial government involvement (JAIWG)

When: Q3FY12 to Q2FY16

Where: Performing entity's laboratory

JAIWG PLAN (FALL 2010) FOCUSES ON 9 CORE BODY REGIONS WHILE ALLOWING FOR FLEXIBILITY OF EMERGING INJURY TRENDS



*Does not include mild traumatic brain injury

Program Execution Plan

Preliminary information necessary to conduct cadaveric testing by FY12

- Cataloging of operationally relevant injuries (JTAPIC)
- Existing LFT&E data mined to determine characteristic loading rate and direction range
- Analysis of occupant interaction with structure, seats, restraints, and PPE
- Analysis of probable occupant impact locations with free-flight equipment
- Determination of operational posture and what it means to occupant dynamics
- Anthropometry information be supplied by existing and ongoing soldier anthropometric studies

Incremental information made available to vehicle development programs throughout program

- New Injury Curves applied to existing Hybrid III in LFT&E if applicable
- Nominal occupant posture information
- Effect of anthropometry, occupant kinematics, and PPE

Peer-review by existing Injury Biomechanics and testing community

- Publication of non-sensitive results in open literature
- Technical Advisory Committee contains considerable Injury Biomechanics and LFT&E experience
- Documentation of results and findings available for government stakeholder review

Program Execution Plan

Based on validation of existing criteria for currently measured body regions

- Extensive historical data regarding measured loads in LFT&E
- Known areas of human tolerance information and anatomical familiarity by existing injury biomechanics community
- Current anatomical locations and injuries form strong basis for development of under-body blast specific methodology
- Mature and accepted test methodologies
- Low-risk development process

Cadaveric material property testing conducted by entities with extensive prior experience

- Existing Centers of Excellence in Injury Biomechanics limited almost exclusively to university labs
- Offers best collaborative possibilities with civilian world

Component and whole-body biofidelic verification completed primarily by government labs

- ATD development needs to be conducted in energetic environments to be successful
- Biofidelic testing requires a large number of tests; utilization of existing government assets reduces anticipated cost
- Provides easy transition to government test centers (ATC, RTC, etc.)

Program Execution Plan

Provides only ATD geometry and *initial* FEM to feed larger modeling and simulation efforts

- Injury prediction models *are not a prerequisite* of a validated ATD meeting all requirements of LFT&E
- A validated ATD *feeds* the development of future injury prediction model development

Timeline driven by cadaveric testing requirements

- Results sufficient to *begin* ATD material requirement development completed one year after cadaveric testing begins
- *Primary* loading path injury curves available to vehicle developers and LFT&E 18 months after cadaveric testing begins
- Duration of testing depends on the number of test parameters and the complexity of body region

Aggressive contractual requirements

What the government will provide

1a: Define the loading environment (displacement, acceleration, direction, etc.) which produces the injuries to be investigated

1b: Define the injury the ATD is intended to measure and the anticipated exposure loading conditions

2: Design and **test** - measure the applied loads and resultant injuries to produce **human injury tolerance curves** and **human response corridors** (*cadaver*)

3: Design and test - repeat exposures to **develop injury probability curves** (*cadaver*)

4: Develop mechanical surrogate to withstand anticipated loading conditions, measure the desired metric, and perform consistently and accurately (*ATD*)

5: Matched-Pair Testing: Expose cadaver and ATD surrogate to *identical* loading conditions to correlate ATD response to human response
6: Establish IARVs (Injury Assessment Reference Values) and validate injury tolerance curves.

What the government will provide

1a: Define the loading environment
(displacement, acceleration, direction, etc.)
which produces the injuries to be investigated

- Series of Generic Hull Tests
  - ATDs
  - PMHS
- Analysis of LFT&E Data
- Analysis of emerging data from theater and developmental testing

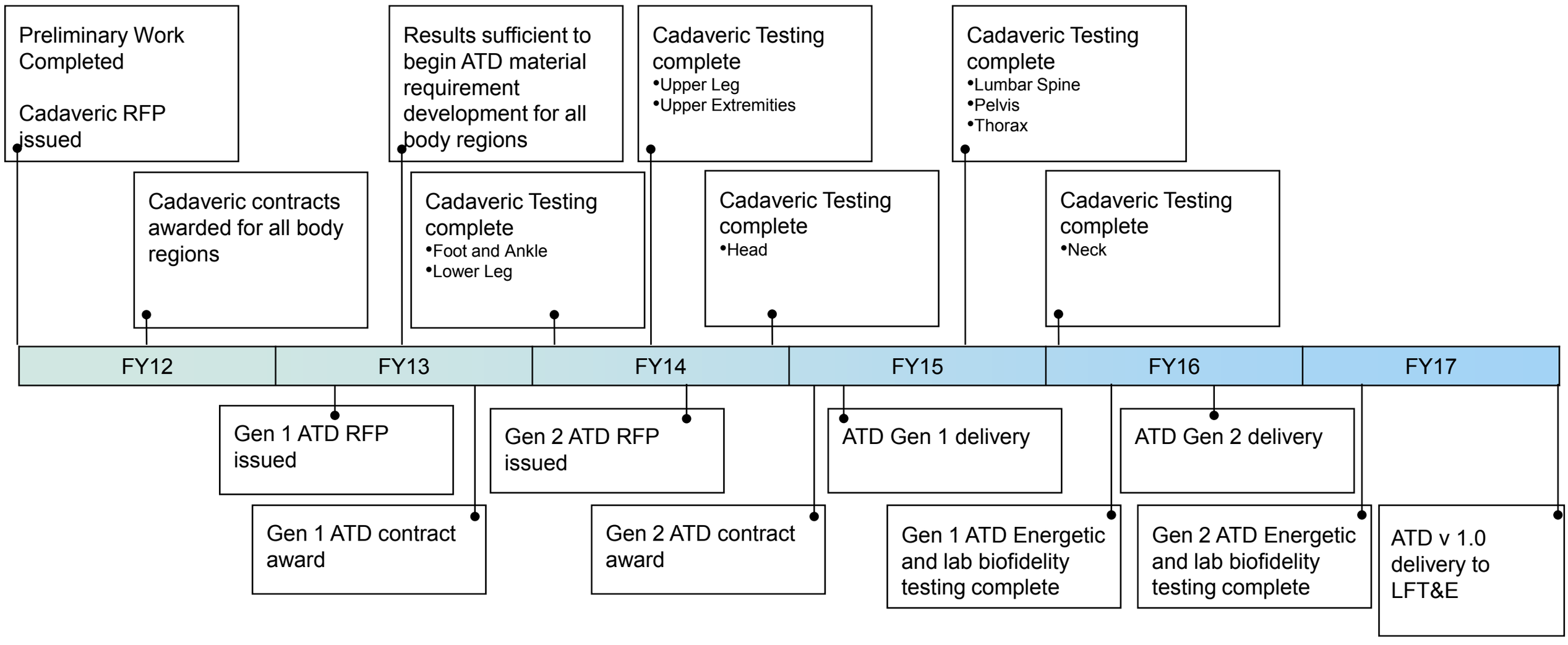
What the government will provide

1b: Define the injury the ATD is intended to measure and the anticipated exposure loading conditions

- Review of collected injury data
  - AIS
  - ICD-9
  - Medical Imaging
- Prioritize injuries to investigate with each body region

ATD Execution Plan

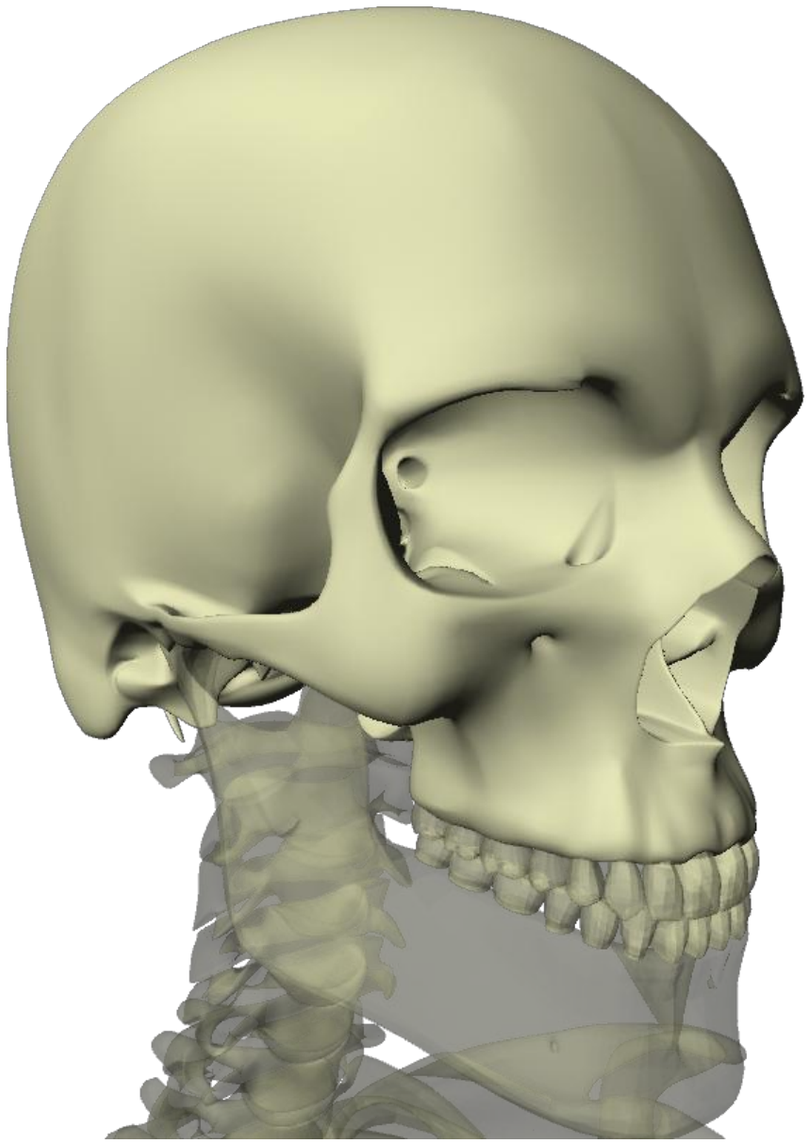
Medical and ATD Milestone Overview



Timeline driven by cadaveric testing requirements

ATD Development Plan

Head



Anticipated Enhancement:

- *Skull fracture* probability curves for (5) locations around crown for skull-helmet interaction for (3) loading rates
- *Skull fracture* probability curves for (3) lateral impact directions for skull-object interaction for (3) loading rates
- Maturation of FOCUS headform for injury curve development for blast-centric contact loading for facial fractures
- Investigative work for effects of angular rotation and linear acceleration effects on skeletal injuries

Target Initial Performance Period: 24 months

ATD Development Plan

Cervical Spine

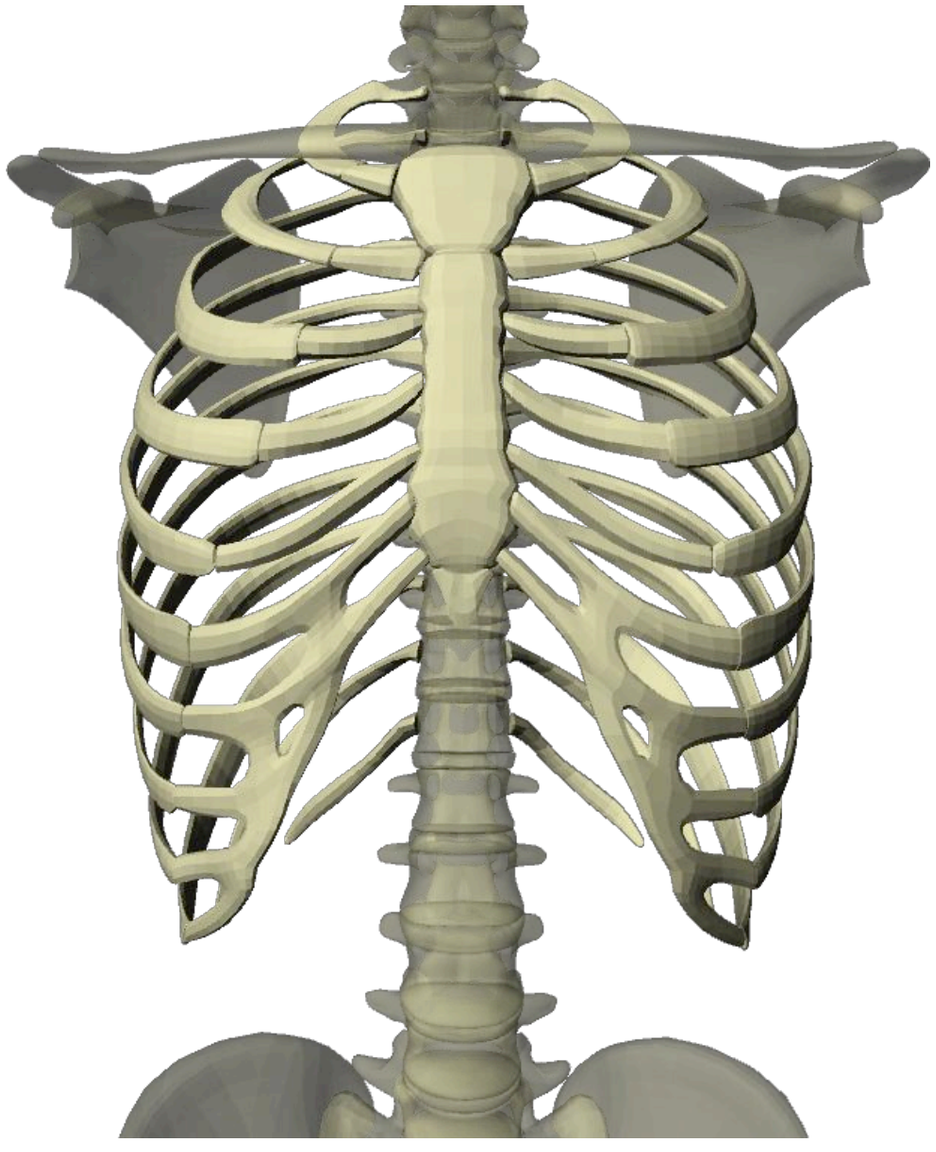
Anticipated Enhancement:

- Probability curves focused on *vertebral fracture, disc,* and *vertebral ligament damage* due to compression, tension, shear, flexion, extension, bending and *torsion.*
- Probability curves focused on acute spinal cord trauma
- Investigate effect of preloading due to head-supported mass

Target Initial Performance Period: 36 months

ATD Development Plan

Thorax and Shoulder



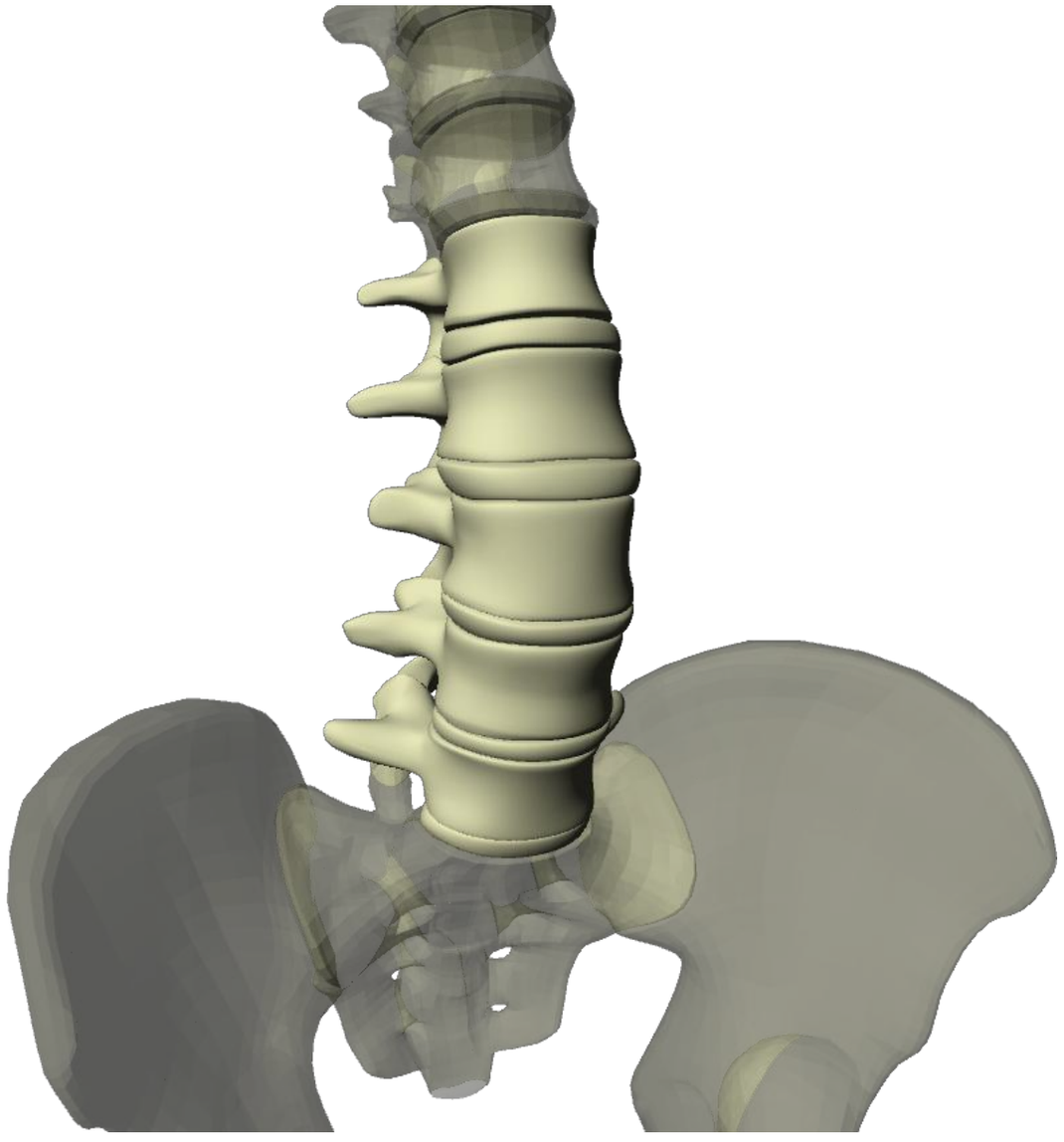
Anticipated Enhancement:

- Probability curves focused on *vertebral fracture, disc,* and *vertebral ligament damage.*
- Probability curves focused on *frame fracture* including rib fracture
- Probability curves focused on acute spinal cord trauma
- Investigate effect of preloading due to thoracic-supported mass
- Investigate thoracic response to 5 point restraint systems
- Volunteer study for shoulder rate-sensitive range-of-motion effects
- (All DoF) Primary and AP loading including 7, 9, and 11 o-clock oblique loading whole PMHS trunk testing

Target Initial Performance Period: 36 months

ATD Development Plan

Lumbar Spine



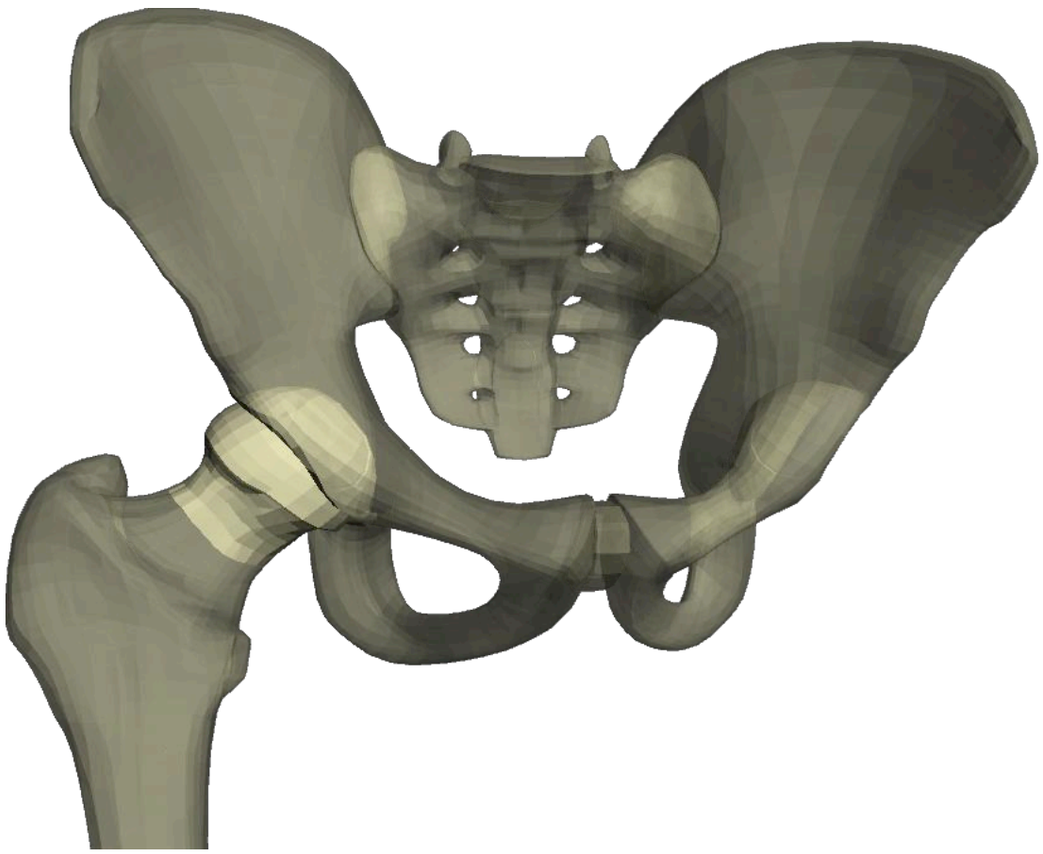
Anticipated Enhancement:

- Probability curves focused on *vertebral fracture, disc,* and *vertebral ligament damage* due to compression, tension, shear, flexion, extension, bending, and *torsion.*
- Probability curves for *combat burst fracture*
- Probability curves focused on acute spinal cord trauma
- Investigate effect of preloading (pre-compression and change in posture/orientation and torso stiffness) due to thoracic-supported mass

Target Initial Performance Period: 36 months

ATD Development Plan

Pelvis and Pelvis/Femur Interface



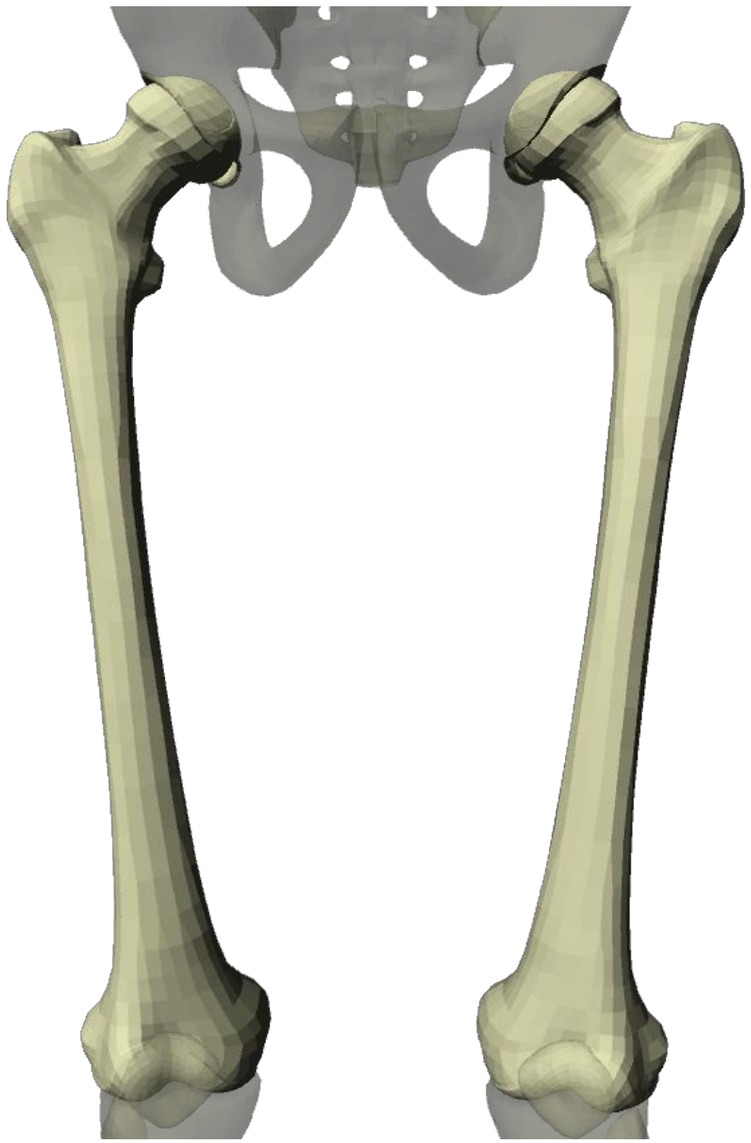
Anticipated Enhancement:

- Probability curves focused on *pelvic girdle fracture*
- Probability curves focused on *acetabular* injury
- Investigate effects of preloading due to thoracic-supported mass
- Investigate effects of PPE-thigh interaction on *acetabulum*
- (All DoF) Primary loading including effects of *hip orientation*

Target Initial Performance Period: 36 months

ATD Development Plan

Upper Leg



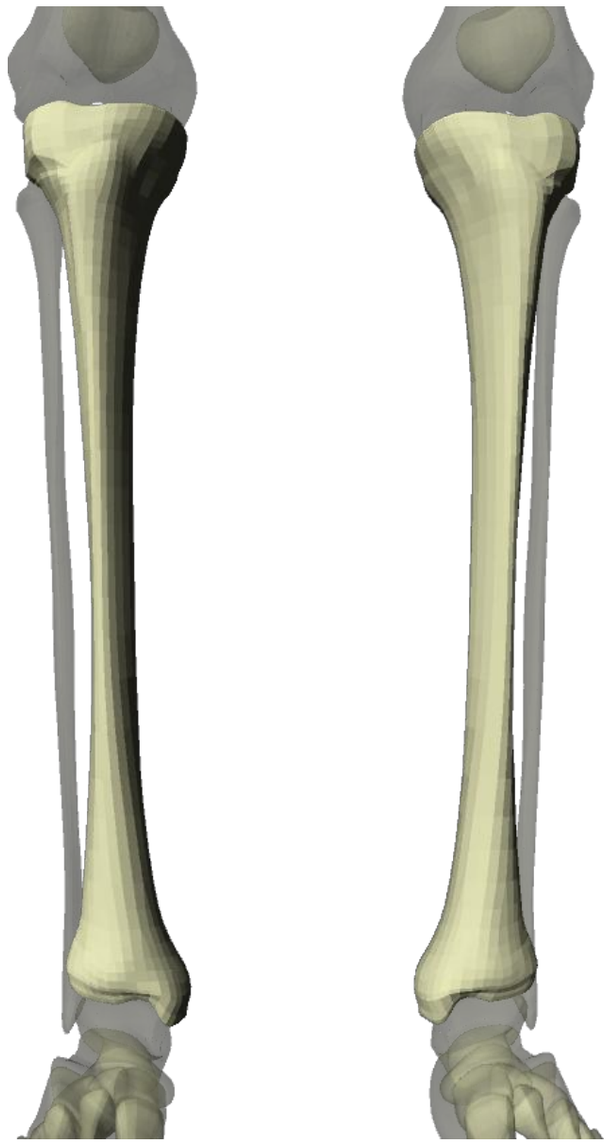
Anticipated Enhancement:

- Probability curves focused on high-rate *femoral shaft fracture* including tension
- Probability curves focused on high-rate *femoral head* fracture
- Combination metrics to include effect of combined bending and compression at high rate
- Investigate effects of PPE-thigh interaction on femoral shaft
- Investigate effects of knee angle (90 +/- 25 degrees) on loading
- Investigate effects of non-contact bending and shear through hip orientation (90 +/- 25 degrees)

Target Initial Performance Period: 24 months

ATD Development Plan

Lower Leg and Knee



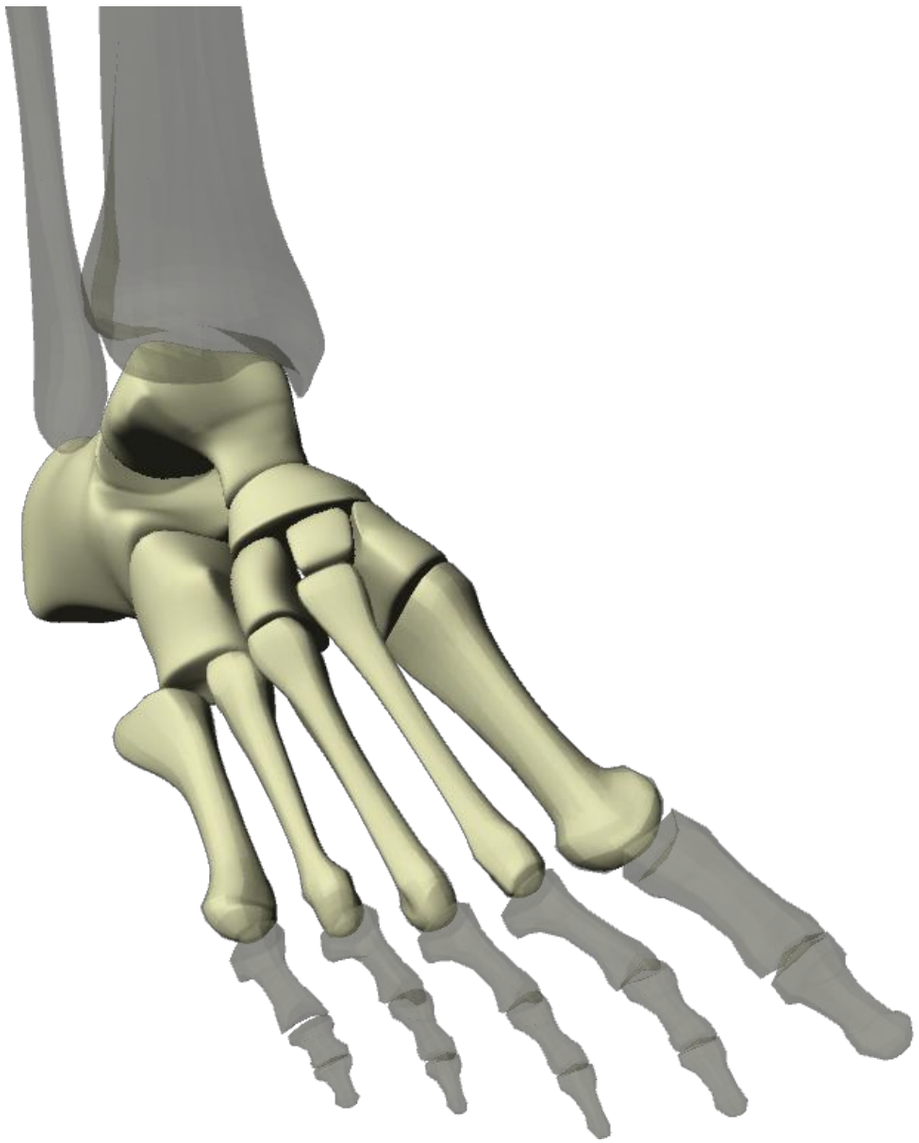
Anticipated Enhancement:

- Probability curves focused on high-rate *tibia shaft fracture*
- Probability curves focused on high-rate *condyle* and *patella* injury
- Probability curves for bending, shear, and torque at high rate
- Combination metrics to include effect of combined bending and compression at high rate
- Investigate effects of knee angle (90 +/- 25 degrees) on loading
- Maturation of existing MIL-LX leg development

Target Initial Performance Period: 18 months

ATD Development Plan

Foot and Ankle



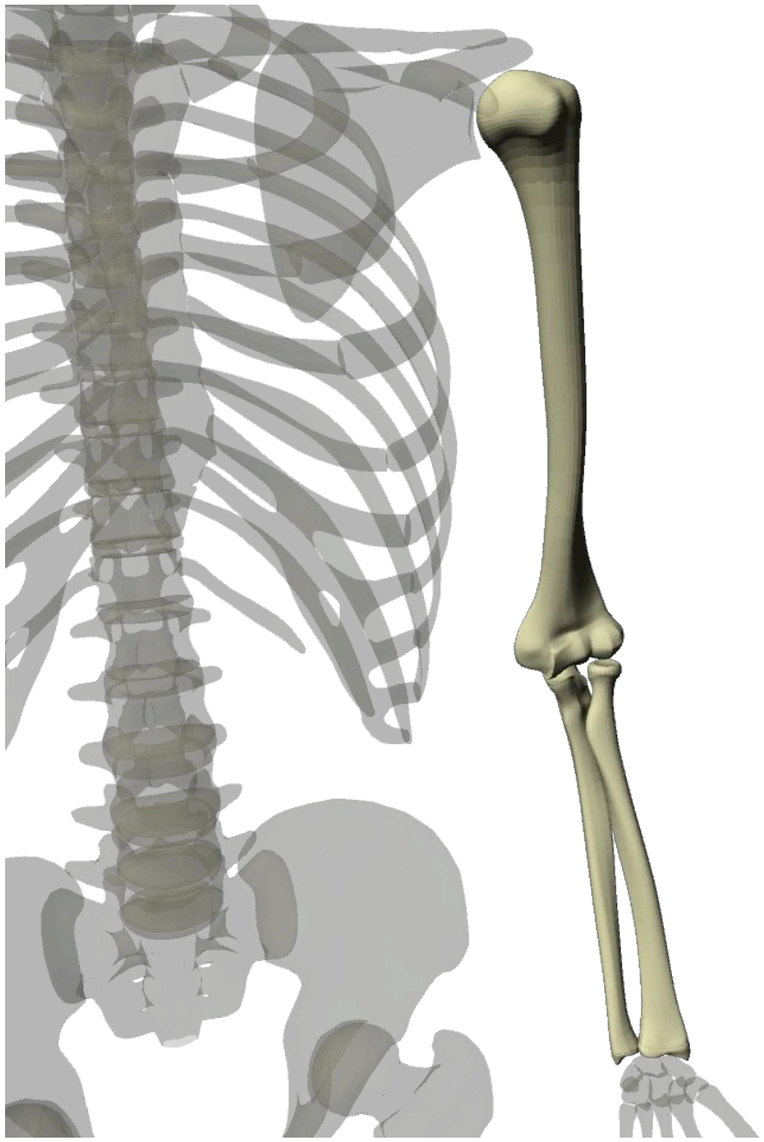
Anticipated Enhancement:

- Probability curves focused on high-rate *malleolus*, *talus*, and *calcaneus* fracture
- Probability curves for injury due to shear, and torque at high rate
- Investigate effects of ankle angle (90 +/- 25 degrees) on loading
- Maturation of existing MIL-LX leg development

Target Initial Performance Period: 18 months

ATD Development Plan

Upper Extremities



Anticipated Enhancement:

- Probability curves focused on *humerus, radius,* and *ulna* fracture due to *flail*
- Investigate effects of shoulder rotation on loading
- Investigate effects of elbow angle (90 +/- 25 degrees) on loading
- Investigate effects of PPE-thigh interaction on shoulder

Target Initial Performance Period: 18 months

Questions to Academia/Industry

- Will classification implications restrict your ability to execute?
- How can we best educate you on MRMC's PMHS and research policies?
- How open are you to multi-institutional collaboration?
- What else in addition to the data that we have discussed providing, would you need to perform research within this project?

Brief Injury Overview for Warrior Injury Assessment Manikin (WIAMan)

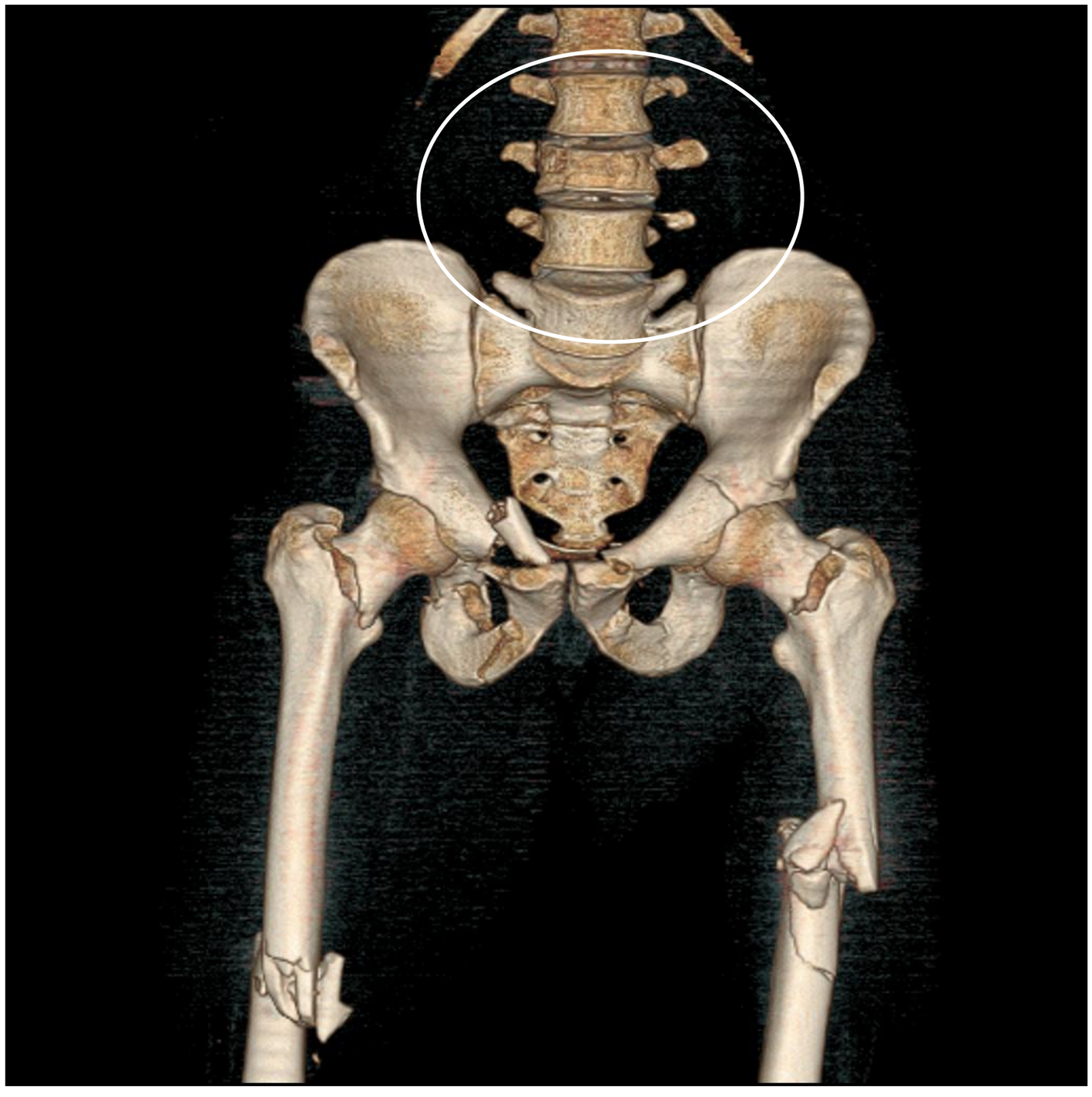
Example Cases from KIA

Stephen A. Bernstein, MD, MPH
COL, MC, MFS
USAARL

Sean Swiatkowski, DO
LCDR, MC
AFME

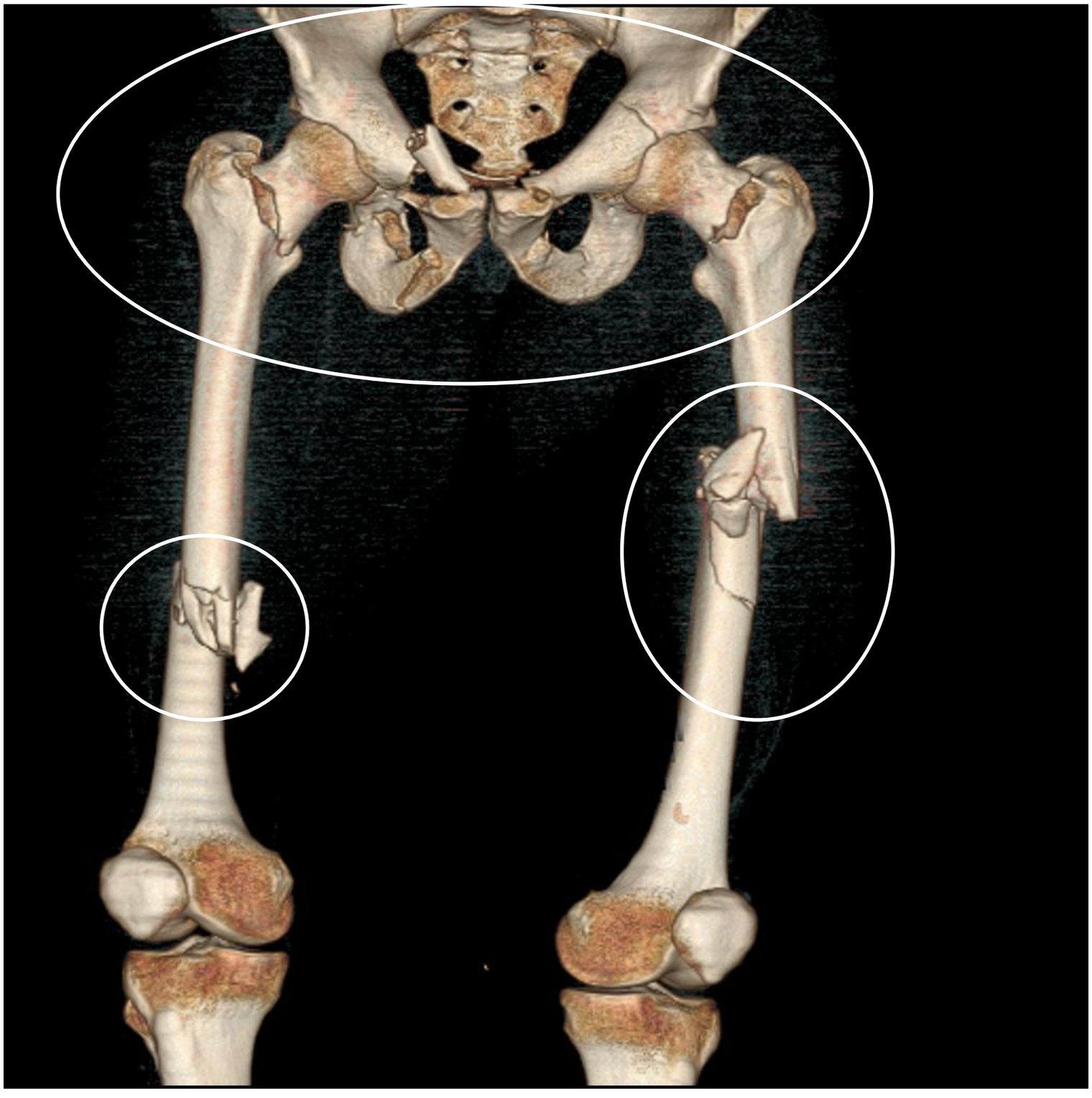
- Examples of cases with lower extremity
- Not all encompassing
- CT reconstruction process
- 2 cases with different postures
- Accelerative loading from UBB w/o hull breach

CASE 1



CASE 2

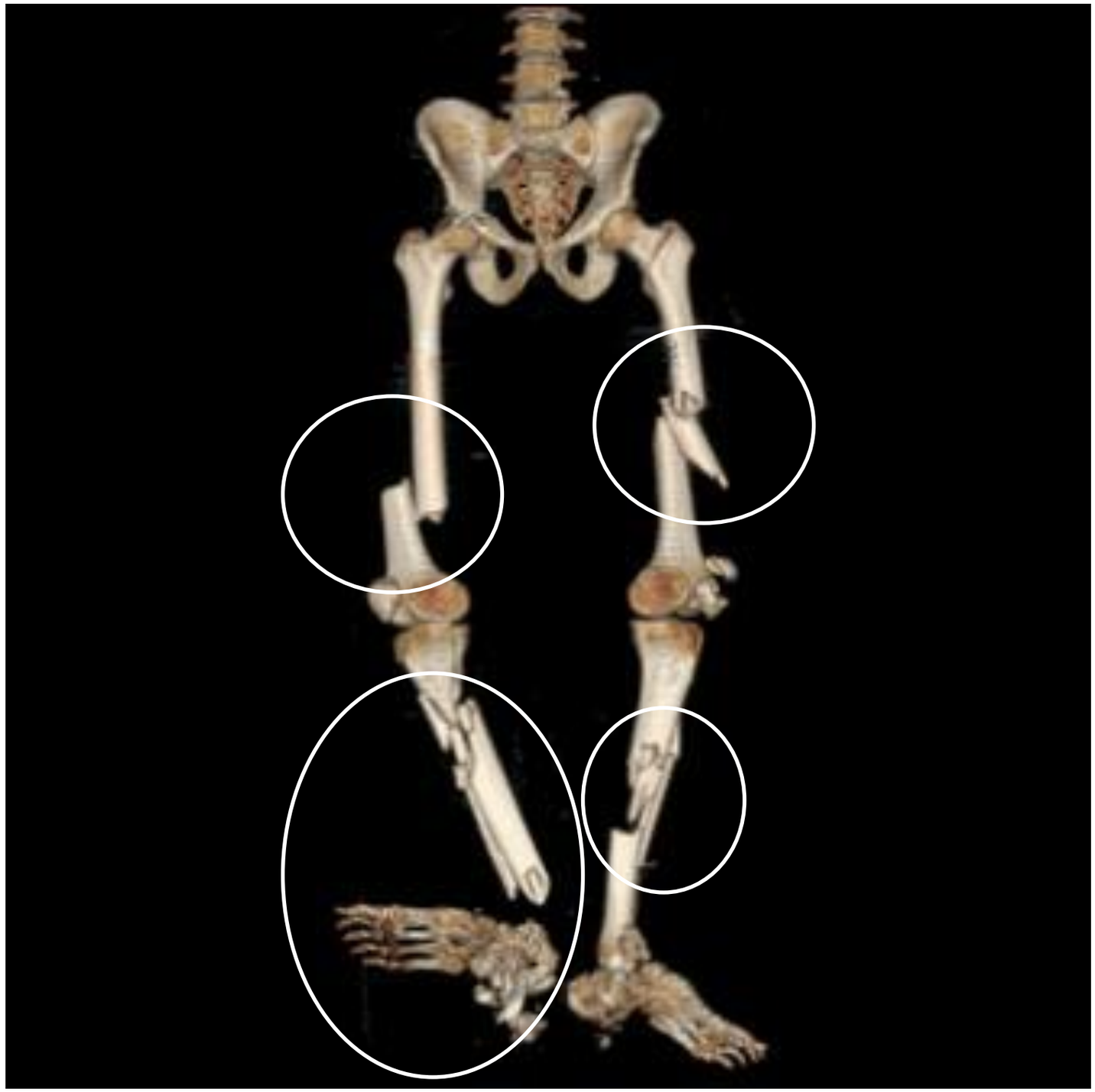
CASE 1



CASE 2

CASE 2

CASE 2



CASE 1

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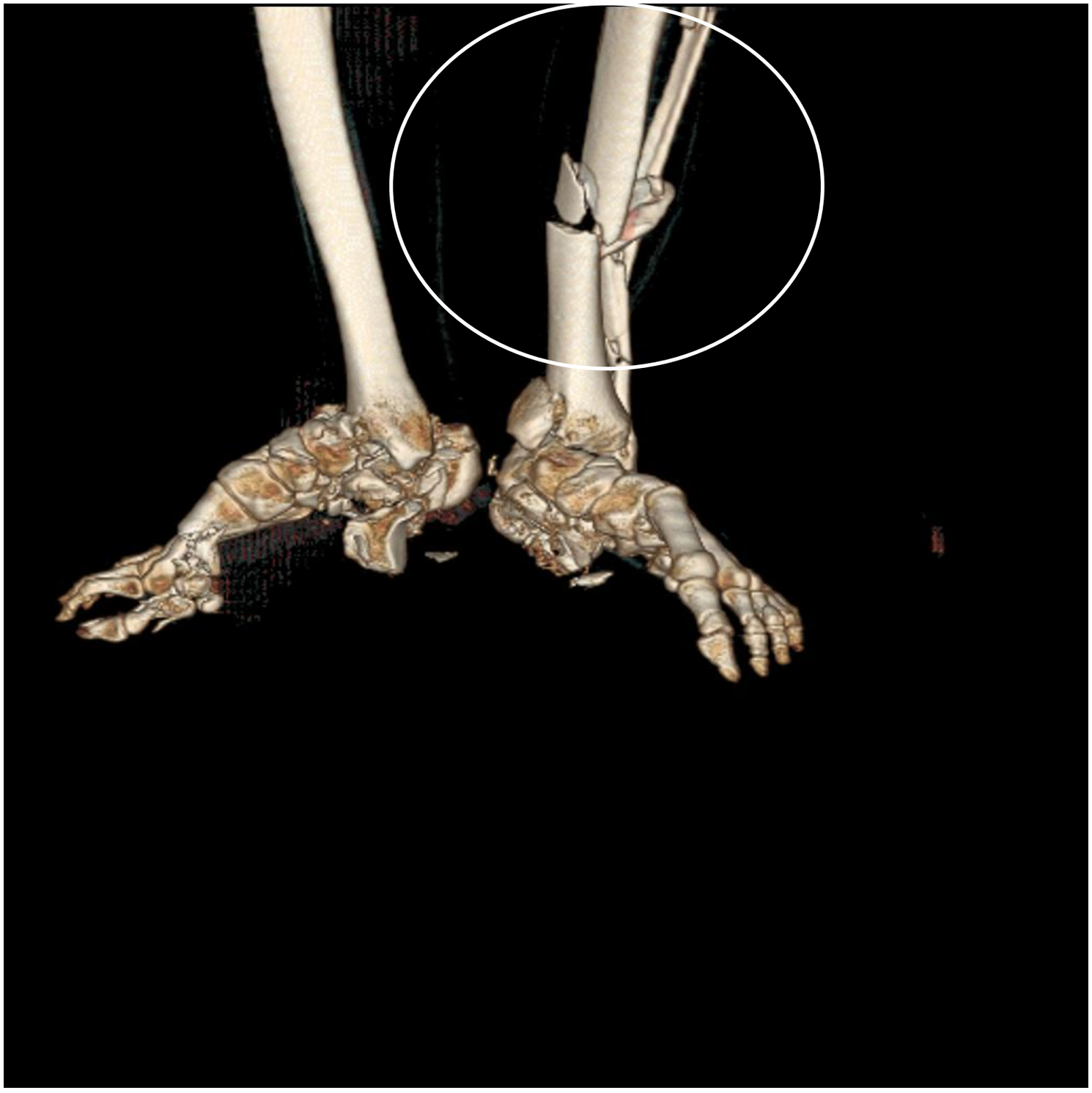
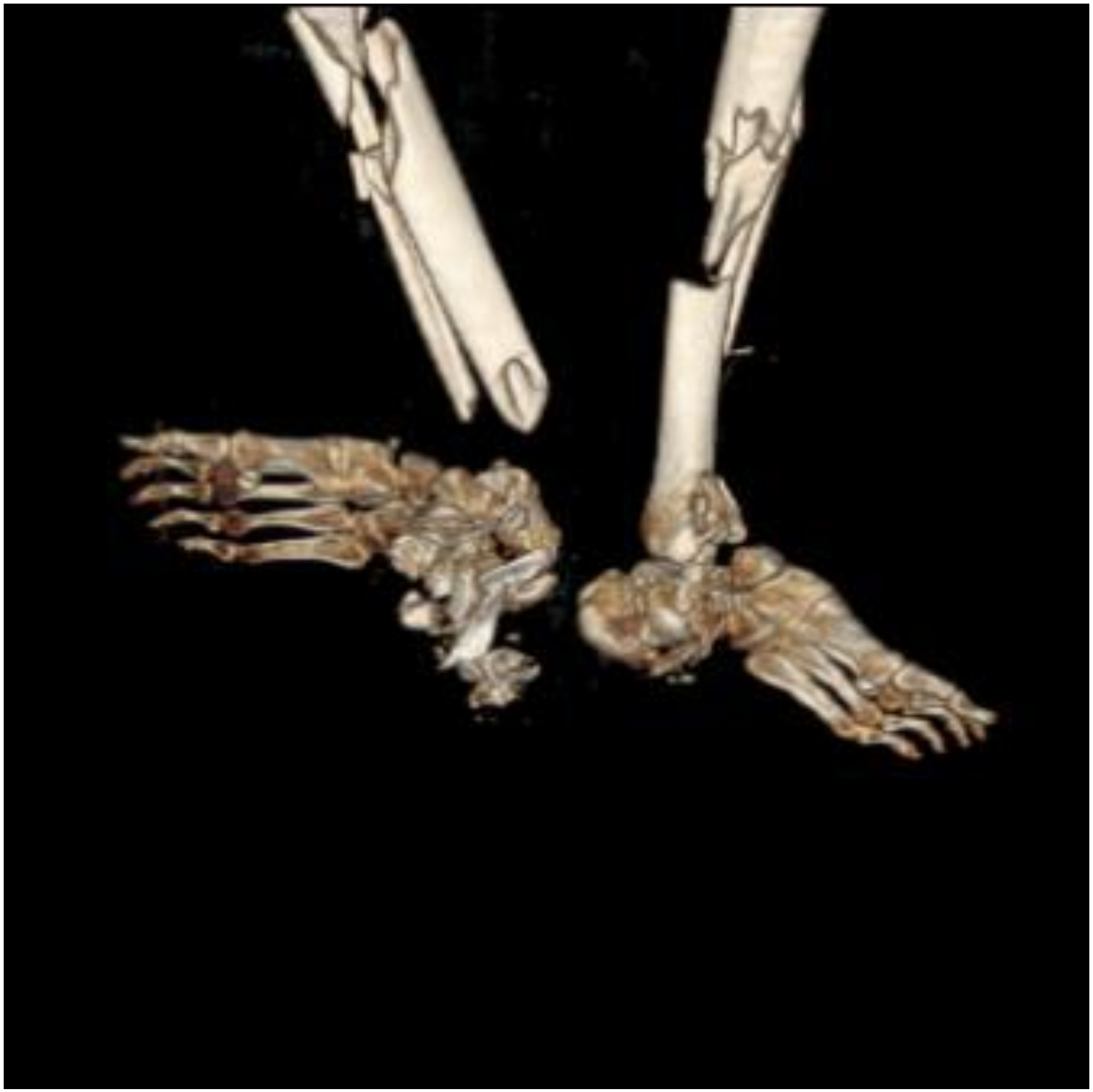


CASE 2



- Differences in pelvic and lumbar spine seen
- Compound LE fractures
- Please remember these images are from Soldiers who have been Killed In Action (KIA) in our defense. Please treat their information that is being shared with us, with the utmost dignity.
- Goal: Differentiation of injury severity
  - WIA vs KIA injury patterns
  - Shifting the threshold