Program for Warrior Injury Assessment Manikin (WIAMan)

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What is included the Plan?

- Accelerative loading
- Blunt impact
- Musculoskeletal injuries
- Direction of interest
  - Primarily vertical
  - Multi-directional because off-axis exposure occur
- Leveraging of maturation of emerging injury criteria and surrogates
  - i.e., FOCUS & MIL-Lx
- Human injury criteria research
- Biofidelity/Biodynamics response corridors
- IARV developments

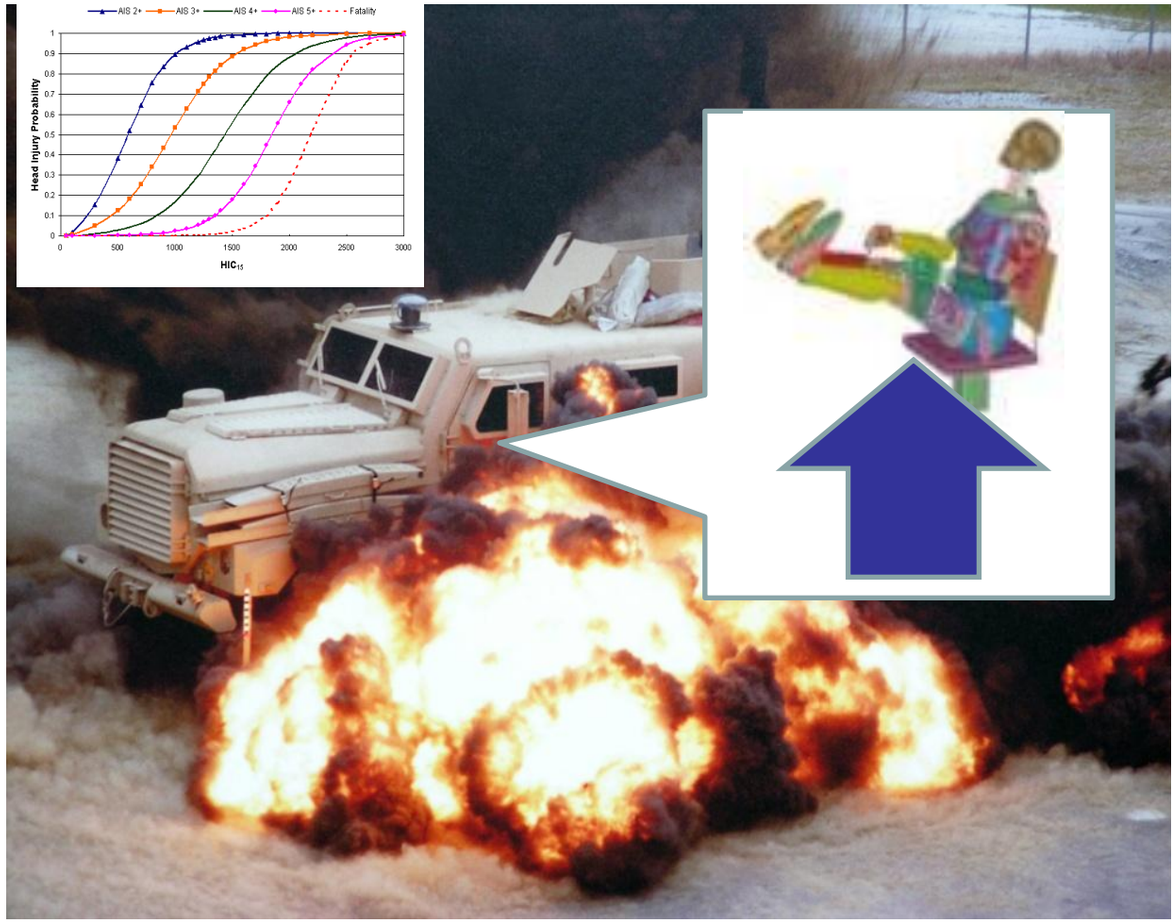
What is not included?

- TBI research that would be based on cognitive measurements (i.e., mTBI)
- Internal organs will not be a major focus
  - Internal organs will only be considered if skeletal injuries or surrogate mechanical measures can be correlated to internal organ injuries to the extent that existing/prior research can be leveraged
  - Injuries resulting from
    - Primary blast
    - Ballistic penetration
    - Blunt impact due to ballistic events (behind armor effects)
  - Frangible/expendable surrogates/criteria
  - Modeling & Simulation (beyond FEM of Manikin)

Considerations

- Variability in military seat systems
  - Attachments (dictate how energy enters the occupant or how the occupant is loaded)
    - Floor
    - Ceiling
    - Wall
    - Energy mitigating
    - Stroking
- Feet +/-90, mitigating floor, foot-pan, stirrups
- Postural position(s)
- Operational preload

Warrior Injury Assessment Manikin & Framework



Purpose:

Create a Warrior-representative test dummy and associated biomedically-validated injury assessment tools for use in live-fire test & evaluation and vehicle development efforts

Results:

- A test dummy to provide an operationally relevant state of the art soldier surrogate
- Human response for individual body regions that inform the concurrent design of the test dummy
- A robust set of baseline data for blast events and resultant injuries
- Realistic accelerative injury response curves and analytical methods based on realistic vehicle environment in Under Body Blast testing
- Input to vehicle/weapon system designs to improve survivability

Schedule

MILESTONES	FY12	FY13	FY14	FY15	FY16	FY17
Define Warrior Environment						
Cadaveric Testing						
Injury Assessment Dev.						
Guidance to Stakeholders						
WIAMan Gen 1 Fab, & Test						
WIAMan Gen 2 Fab, & Test						

Milestone Indicators: TRL or SRL: ◆ Milestone Timeline: ▬

Payoff:

- Ability to accurately measure accelerative loads caused by Under Body Blast testing
- Increased knowledge of Warrior vulnerability in Under Body Blast testing
- State of the art criteria, methodologies & metrics used to assess injuries from accelerative loading sustained during Under Body Blast testing
- Potential for enhanced vehicle and soldier survivability

Current and Historical fielded AnthropomorphicTest Devices (ATD's)

The development of a domain-specific ATD and components by the DoD is not new

Frontal Impact

- Hybrid III (50%, 95% male, 5% female)
- Hybrid II (50% male)
- TNO-10 (50% male) - safety belt
- Body Block - steering system
- MAMA2B (5% female kit) - pregnancy abdomen
- THOR

Aerospace & Military

- HURD (116 lbs - 245 lbs)
- MIL-LX Legs (Developed in conjunction with TARDEC)
- MIL-SID (Ongoing development with TSWG)
- Hybrid II (5%, 50%, 95% male, 5% female)
- FAA Hybrid III (50% male)
- ADPATS
- JPATS (USN, USAF Joint Primary Aircraft Training System)
- ADAM (large & small)
- MIDAS (Developed at USAARL)
- CG (3%, 5%, 50%, 95%, world and Japanese male) - ejection
- Helisafe (50%, 95% male) - helicopter
- FOCUS (50% male headform) - (Developed at USAARL)

Side Impact

- SID-II
- EuroSID-1, ES-2, ES-2re (50% male)
- WorldSID (50% male, 5% female)
- BioSID (50% male)
- US DOT SID (50% male)
- SID-H3 (50% male)

Child

- Hybrid III (3, 6, 10 Year Old)
- VIP (3 Year Old)
- Hybrid II (6 Year Old)
- P-Series (P1, P3/4)
- Q-Series (Q3, Q10)
- CRABI (6, 12, 18 Month Old)

Pedestrian

- Hybrid III (50%, 95% male, 5% female)
- Flex-PLI-GTR Legform (50% male) - leg and knee impact

Rear Impact

- BioRID-II (50% male)
- RID3D (50% male)

ATD Development Standard Practice

Preliminaries

- ATDs measure *mechanical loads* via accelerometers, load cells, displacement gauges, etc.
- ATDs must be *durable, repeatable, reproducible*, and should be *robust*
- Mechanical loads are measured via the ATD *skeletal structure*
- *Injury Probability Curves (Criteria)* are a material failure probability curve for a given load
- *Biofidelity* is a measure of the ATD's ability to mimic human response to specific loading conditions
- ATDs represent a certain human population. Those parameters represent ATD *Anthropometry*
- *Human Response Corridor* is the ATD kinematic response compared to known input and forms the basis for biofidelity
- *Human Tolerance Threshold* is the accepted level at which *a predetermined* probability of injury occurs
- The correlation between a specific ATD design and a Human Tolerance Threshold for a known load is *Injury Assessment Reference Values (IARVs)*
- Exposing multiple items to the same controlled conditions to establish correlation between them is done by *Matched-Pair Testing*. Matched-Pair Testing is used to establish IARVs

ATD Development Standard Practice

For each body region

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

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

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

Design and test; repeat exposures to develop injury probability curves (cadaver)

Develop mechanical surrogate to withstand anticipated loading conditions, measure the desire metric, and perform consistently and accurately

Match pair testing; expose cadaver and ATD surrogate to identical loading conditions to correlate ATD response to human response. Establish IARVs and validate injury tolerance curves

ATD Development Standard Practice

For the whole ATD

Design and test to measure human whole body response in loading environment

⇩

Test new ATD in loading environment and measure system response

⇩

Correct deficiencies that inhibit the ATD to *repeatably and reliably* mimic human response and inertial properties. Repeat as necessary. Result provides *whole-body biofidelity*

ATD Development Plan

Cadaveric Testing
For each body region:

Title: Biomedically valid injury risk curve development

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

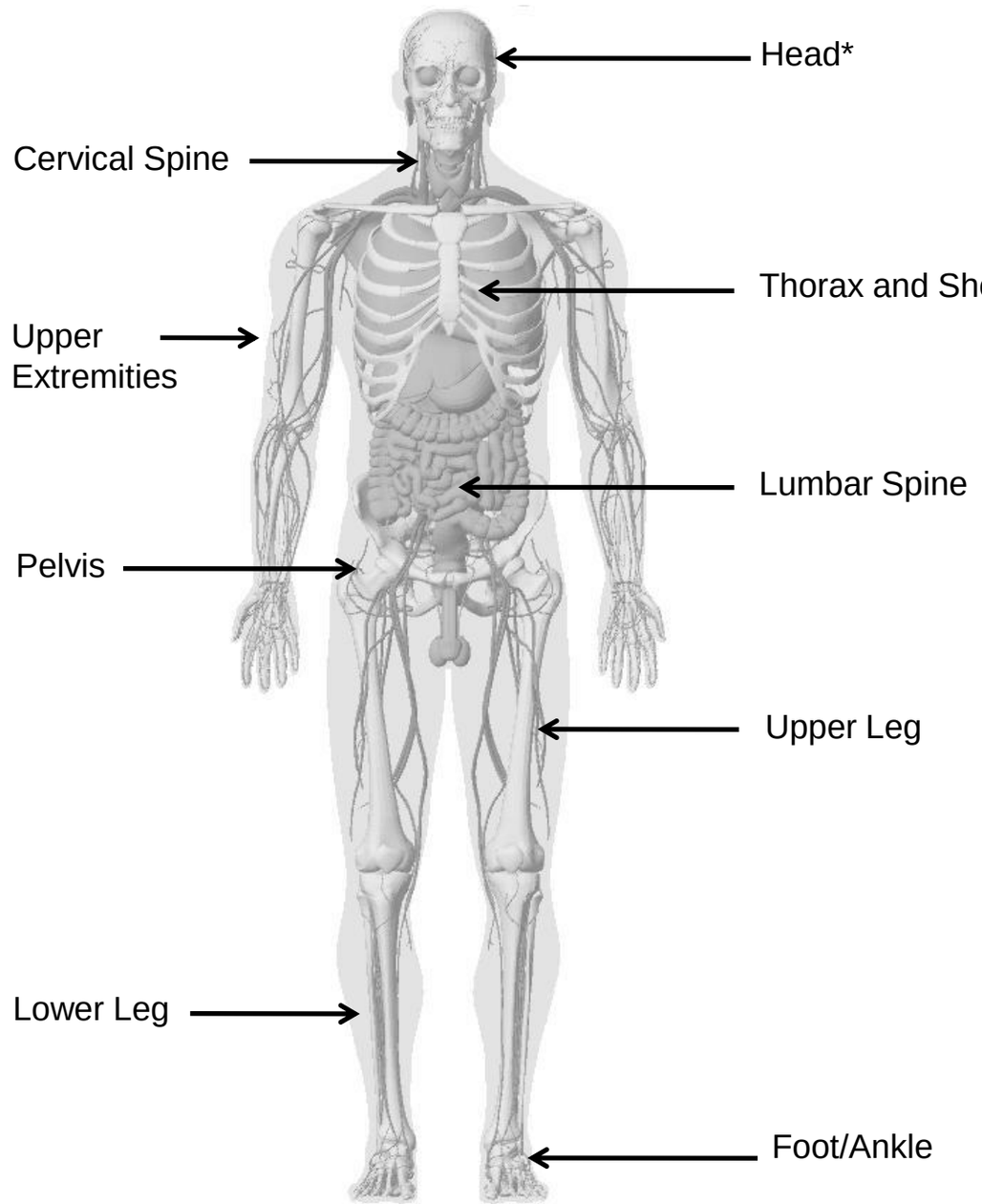
Why: Require biomechanical response corridors for surrogate development

Who: Laboratories with established cadaveric research programs

When: Q3FY12 to Q2FY16

Where: Performing entity's laboratory

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



*Does not include mild traumatic brain injury

ATD Development 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

ATD Development 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.)

ATD Development 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

- Cadaveric RFP issue start of FY12 (based on Oct 1, FY12 receipt of funding)
- Cadaveric testing contract award 6 months after RFP
- 4 month allowance between ATD RFP and award for each generation
- 18 month allowance between ATD contract award and delivery

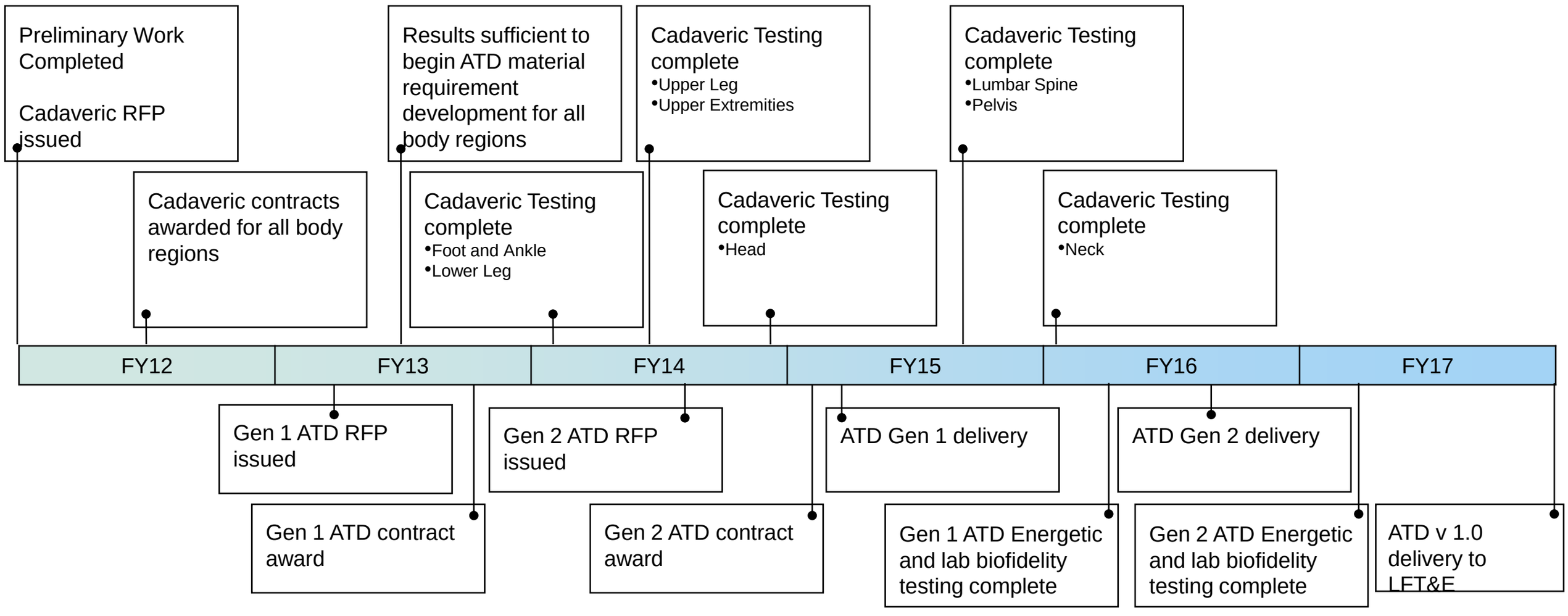
ATD Development Plan

Task	FY11				FY12				FY13				FY14				FY15				FY16				FY17			
	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Cadaveric Work																												
- Contract Mod & Awards (1)																												
- Human response testing (2)																												
- Injury mechanisms and tolerance (3)																												
- Injury assessment risk curves (4)																												
- Establish and document injury thresholds (5)																												
Surrogate Development																												
- Develop RFP package (6)																												
- Issue RFP & award contracts (7)																												
Prototype Development																												
- Design and fabrication (8)																												
- Laboratory testing (9)																												
- Vehicle and energetic testing (10)																												
Technology Demonstrator Development																												
- Design and fabrication (11)																												
- Laboratory testing (12)																												
- Vehicle and energetic testing (13)																												
Surrogate Complete and Final Delivery (14)																												

Legend: △ Planned Start ▽ Planned End □ Planned Milestone ◇ Planned Significant Milestone

ATD Development Plan

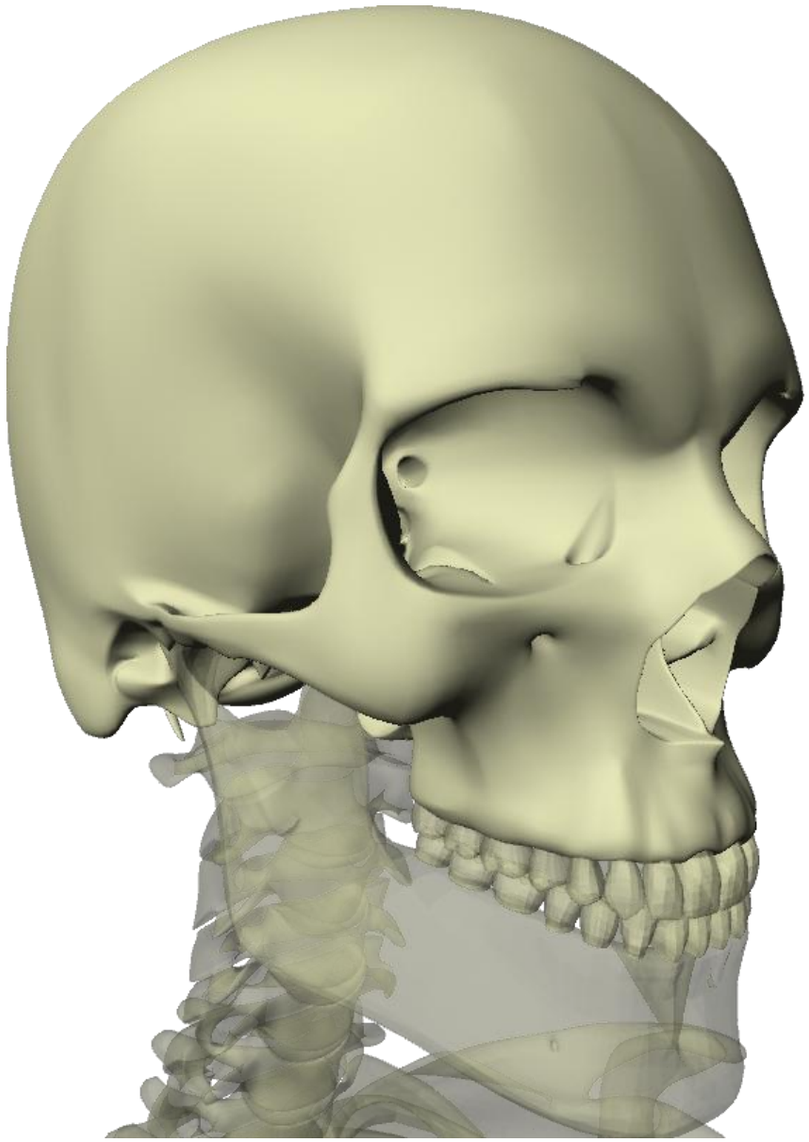
Medical and ATD Milestone Overview



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

ATD Development Plan

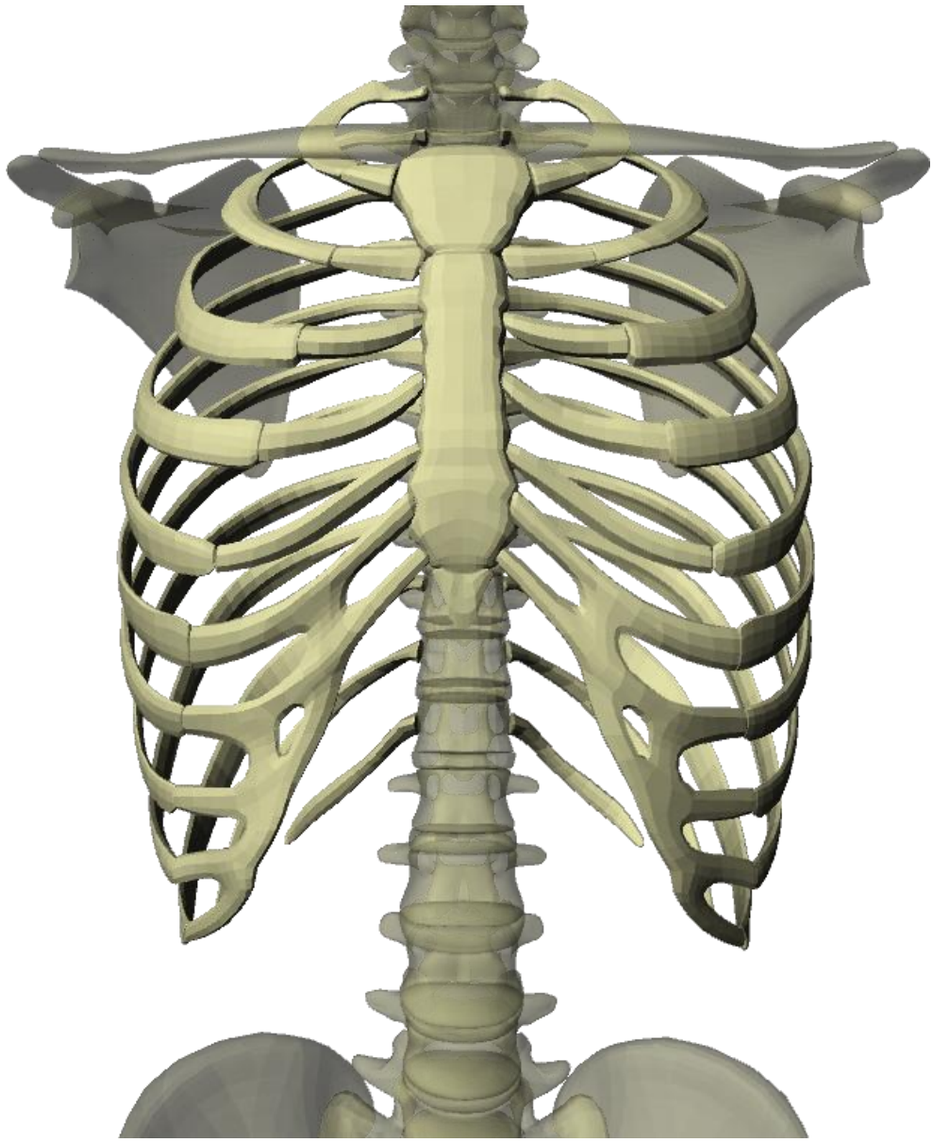
Cervical Spine

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

ATD Development Plan

Thorax and Shoulder

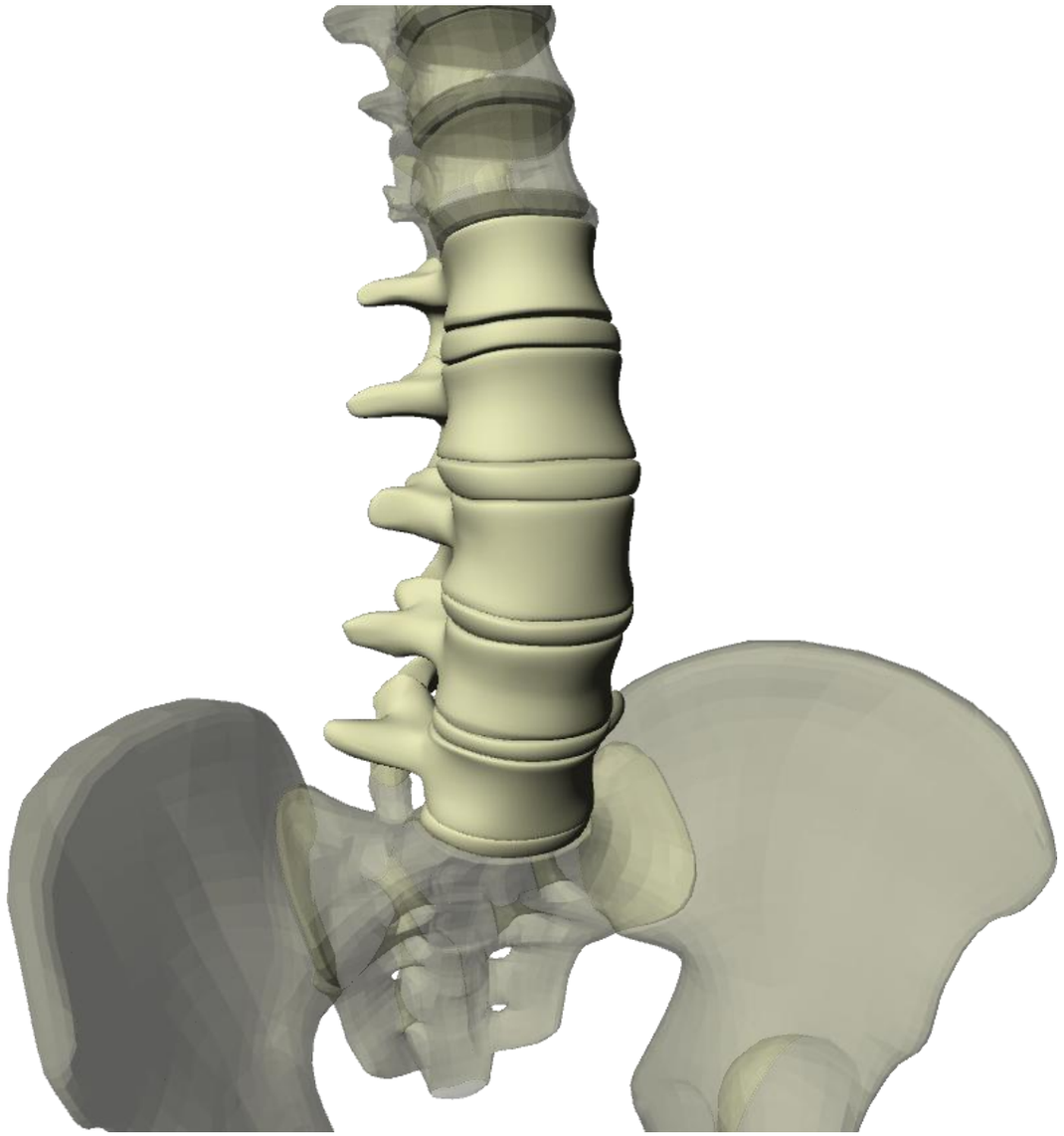


Anticipated Enhancement:

- 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

ATD Development Plan

Lumbar Spine continued

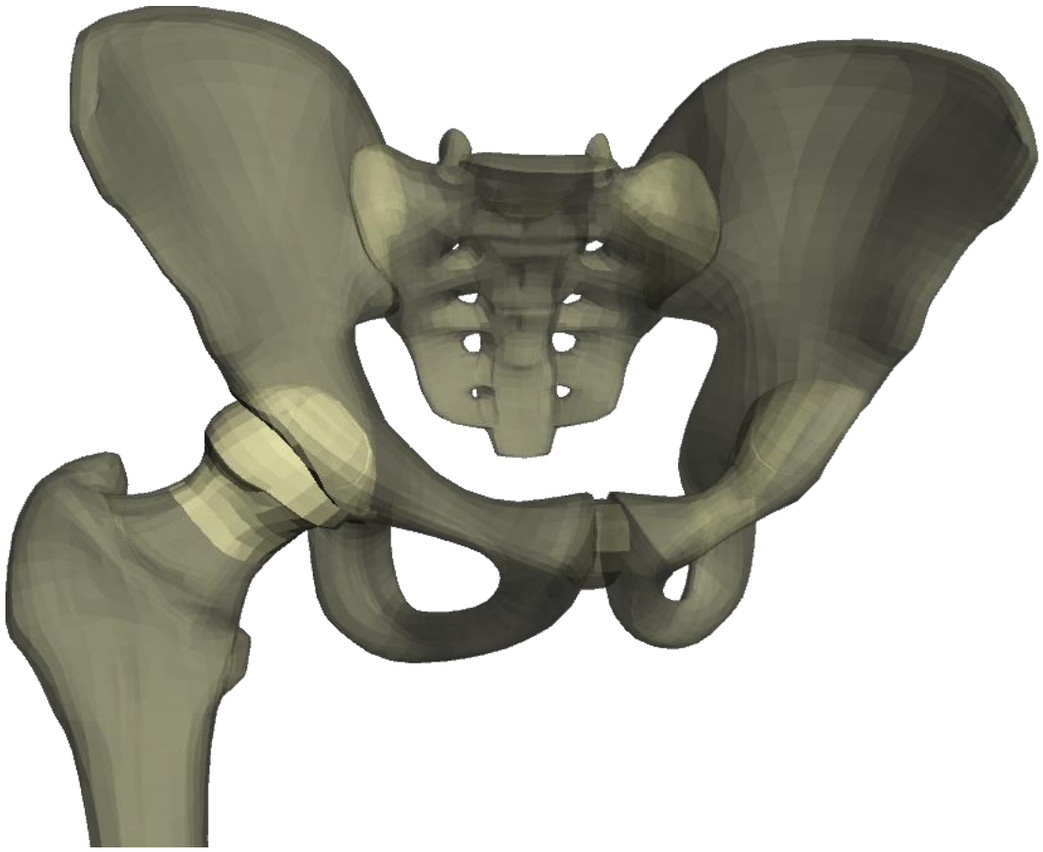


Anticipated Enhancement:

- 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

ATD Development Plan

Pelvis and Pelvis/Femur Interface

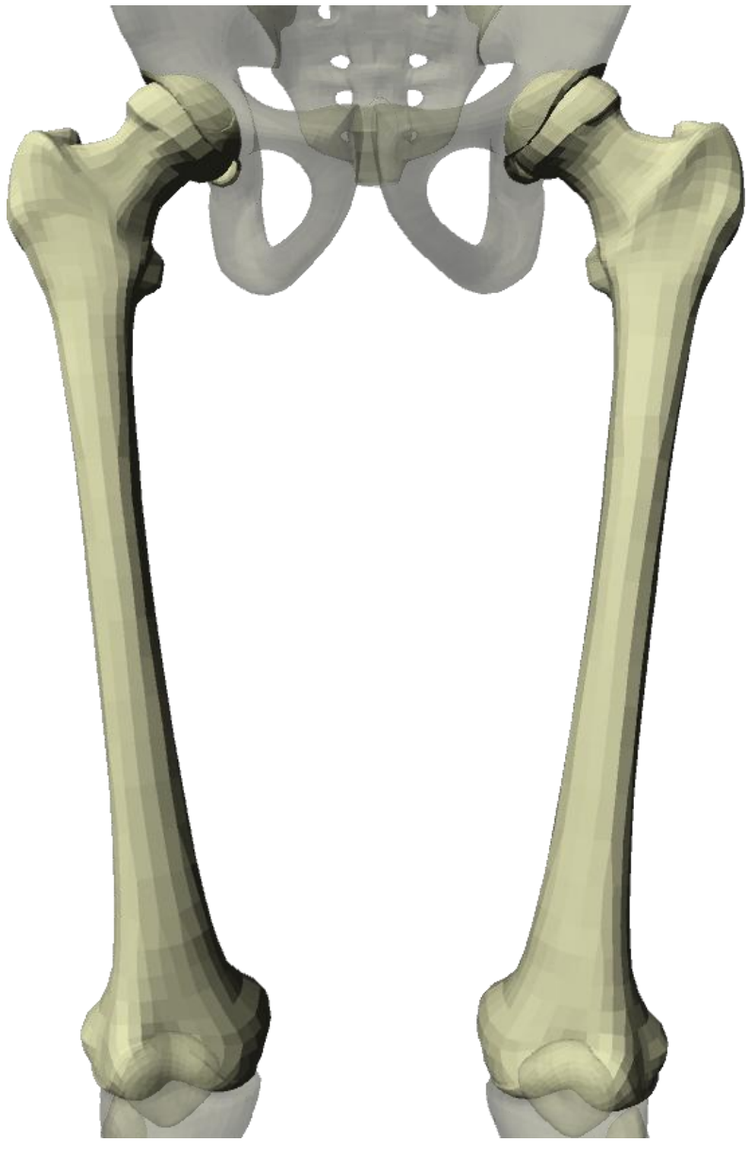


Anticipated Enhancement:

- 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*

ATD Development Plan

Upper Leg

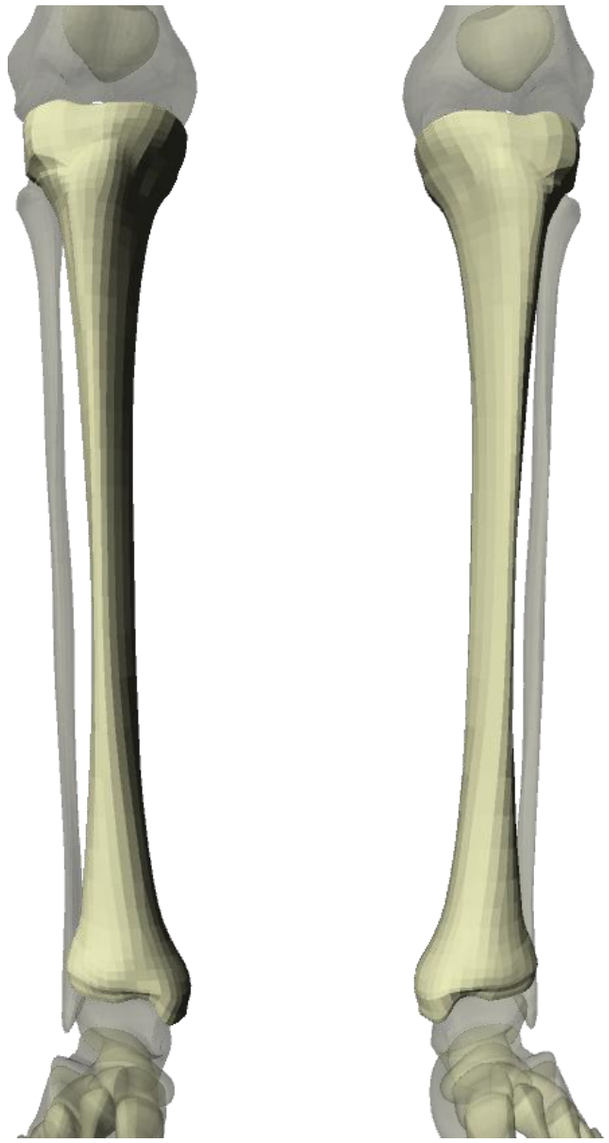


Anticipated Enhancement:

- 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)

ATD Development Plan

Lower Leg and Knee

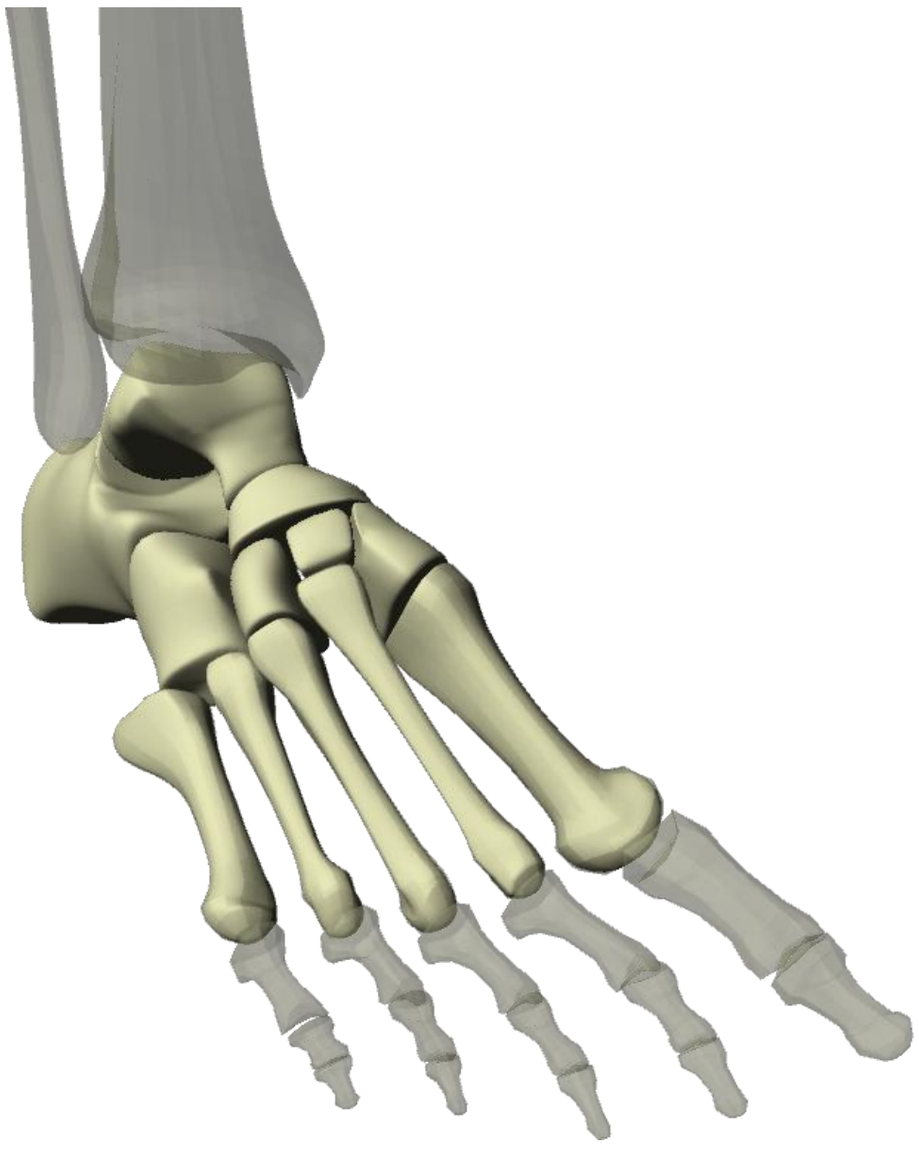


Anticipated Enhancement:

- 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

ATD Development Plan

Foot and Ankle

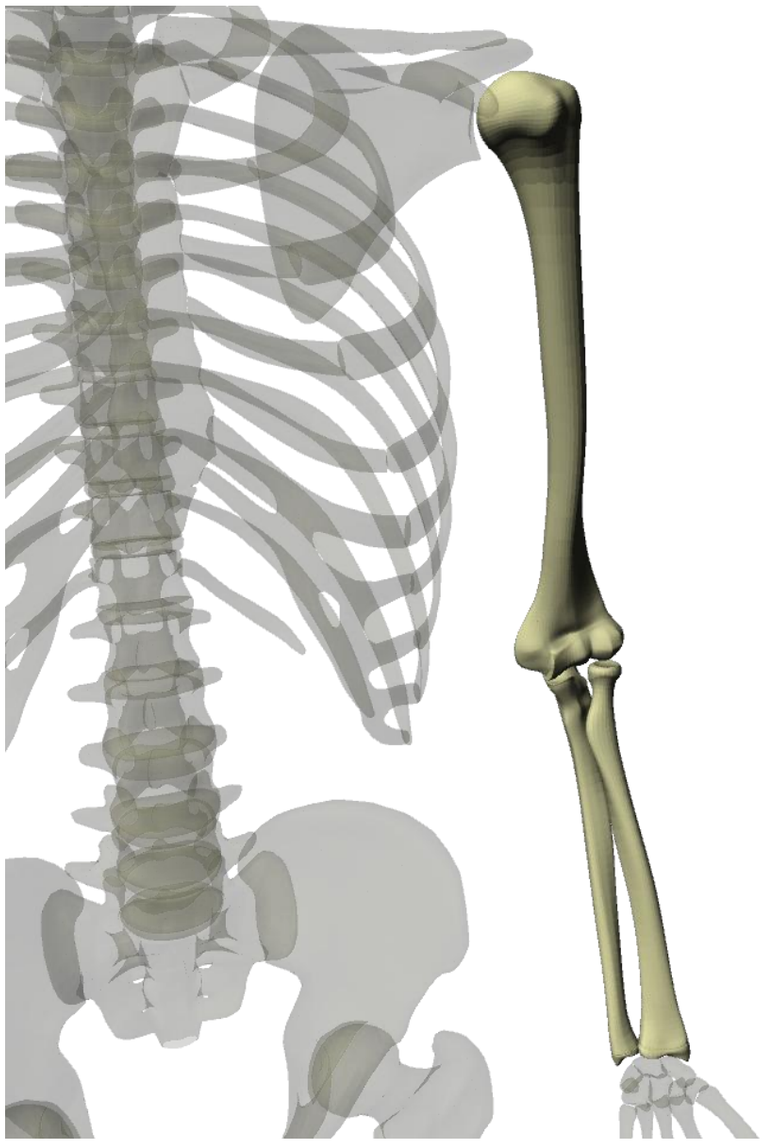


Anticipated Enhancement:

- 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

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

ATD Development Plan

ATD and Biofidelity Verification

Proposed Simulated ATD Biofidelic Testing

- Whole-body inertial property testing
- Head: (8) Loading Directions, (3) Loading Rates
- Neck: (7) Loading Directions, (3) Preload Conditions, (12) with Whole Spine, (3) Loading Rates
- Chest: (5) Loading Directions, (3) Preload Conditions, (3) Loading Rates
- Lumbar Spine: (6) Loading Directions, (3) Pre-load conditions, (12) with Whole Spine, (3) Loading Rates
- Pelvis: (3) Loading Directions, (4) Hip Orientations, (3) Pre-load conditions, (3) Loading Rates
- Femur: (3) Loading Directions, (6) Orientations, (3) Loading Rates
- Tibia: (3) Loading Directions, (3) Orientations, (3) Loading Rates
- Foot/Ankle: (3) Orientations, (3) Loading Rates

Proposed Energetic and Vehicle ATD Biofidelic and Performance Testing

- Whole-body inertial property response including verification of component biofidelic corridors
- ATD Reproducibility, durability, repeatable, vehicle environment, and DAQ/sensor performance