Non-Lethal Weapons Human Effects

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What are NLW Human Effects?

"The definition of 'Human Effects,' as applied to NLWs, may include any of the following: health effects to the weapon user, human targets, and humans near the target, and effectiveness of the weapon against human targets."

- Human Effects Process Action Team Report, Jan 2000

Key Definitions

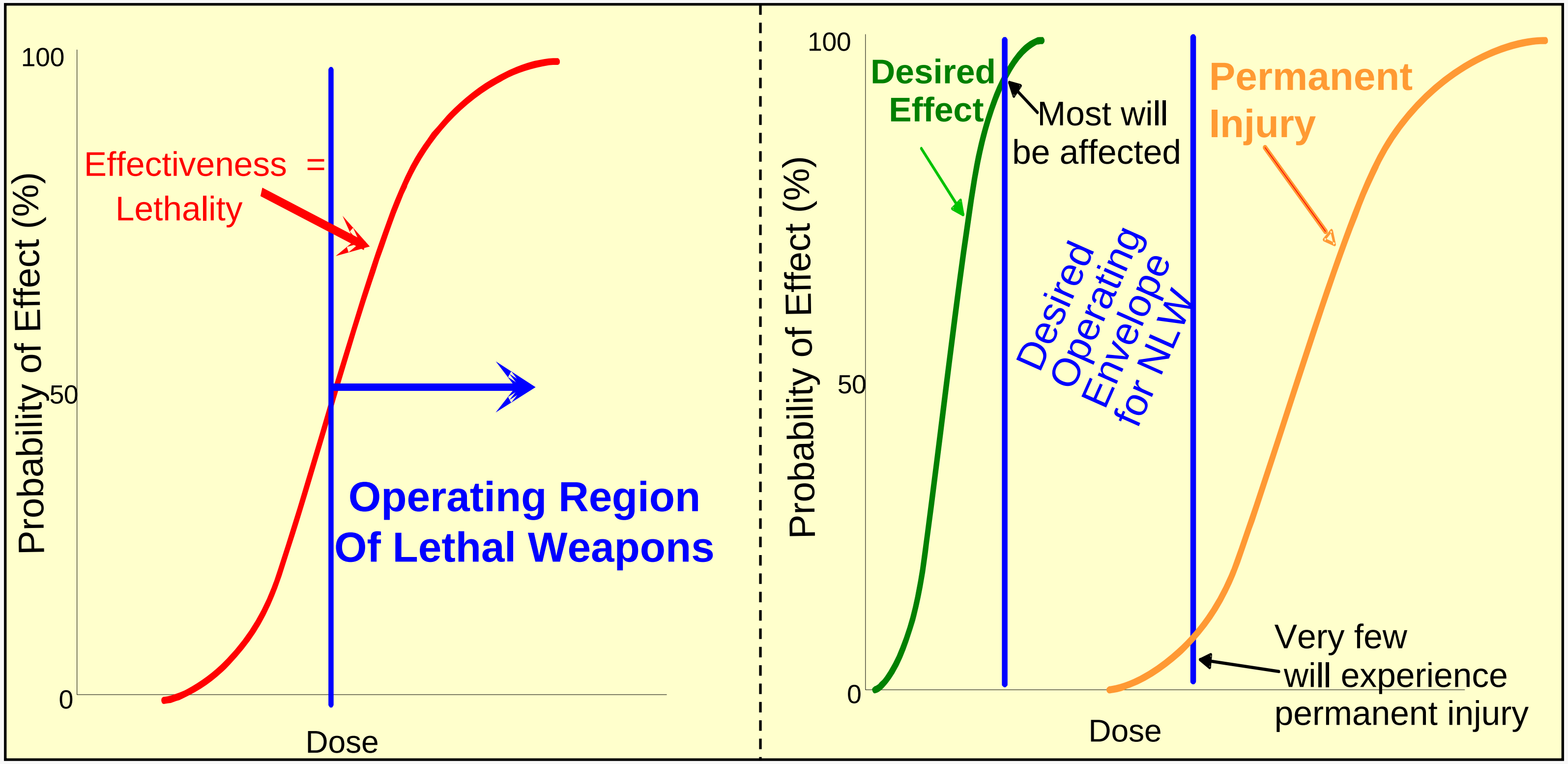
- **<u>Non-Lethal Weapons:</u>** Weapons, devices and munitions that are explicitly designed and primarily employed to immediately incapacitate targeted personnel or materiel, while minimizing fatalities, permanent injury to personnel, and undesired damage to property in the target area or environment. Non-lethal weapons are intended to have reversible effects on personnel or materiel. *(CBART)*

- **<u>Injury</u>:** A term comprising such conditions as fractures, wounds, sprains, strains, dislocations, concussions, and compressions. In addition, it includes conditions resulting from extremes of temperature or prolonged exposure. Acute poisonings (except those due to contaminated foods) resulting from exposure to a toxic or poisonous substance are also classed as injuries. *(JP 1-02)*

- **<u>Permanent Injury</u>:** Physical damage which permanently impairs physiological function that restricts employment and/or other activities of a person for the rest of his/her life. *(CBART)*

- **<u>Reversibility</u>:** The ability to return the target to its pre-engagement level of capability. It is usually measured by time and level of effort required for recovery of the target. *(NLRT)*

NLW Human Effects Characterization



- Generally, the goal of lethal weapons has been to maximize a single effect – lethality, while meeting the constraints of LOAC, logistics, cost, etc.
- For NLW, two competing objectives exist: cause a desired effect, while minimizing permanent injury.
- Understanding human effects is critical for legal/treaty reviews, policy acceptability, and warfighter awareness.

JNLWP Human Effects Process

JNLWD – Human Effects Branch
- Provide HE strategy
- Resource HE research
- Coordinate HE reviews

Human Effects Center of Excellence
- Portfolio (research) managers
  - Directed Energy, Blunt Impact, Acoustics, Etc.
- HE knowledge-base, Consultative Expertise
- HE – Modeling Analysis Program (HE-MAP)
- Human Effects Risk Characterizations

HERB
- Joint Service Board of Medical & Safety Officers
- Legal Treaty, & Policy SME representatives
- HE Safety, Training, Experimentation guidance

Treaty, Legal, Policy reviews

Program Manager

Milestone Decision Authority

Fielded Capability

HEAP
- Non-government Board of Bioeffects SMEs

⟶ Direction/coordination

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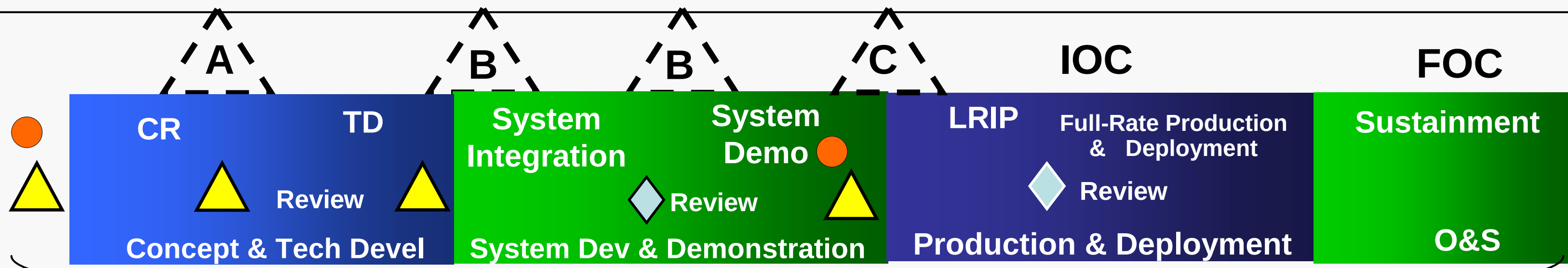
Human Effects Process and Acquisition

- **Human Effects Review Board**
  - Enumeration of significant health/operational risks
  - Recommendations to reduce or better characterize the risk

- **Human Effects Center of Excellence**
  - Repository of NLW data
  - Supplies human effects expertise to the PM

- **Human Effects Advisory Panel:** reviews performed as necessary based on Directorate needs



HECOE Support Throughout S&T and Acquisition

Pre-Mile A
- Basic research to verify HE mechanisms
- Operational utility studies
- Initial estimate of safety margin
- Front-end look at new technology

Concept Refinement
- Technology Reviews
- HE Support to AoMCs
- Preliminary payload assessment
- Mission needs definition
- Human Effects Resource Estimates

Tech Development
- Draft of THEEP*
- Begin studies to quantify and reduce risk
- Component design guidance
- Preliminary Risk Characterization

System Integration
- Execute THEEP
- Studies to determine operating envelope

System Demonstration
- T&E Support
- Live fire animal/human testing (if appropriate)
- Full Risk Characterization

LRIP, Full-Rate Prod & Deployment
- Field data collection
- Refine modeling and simulation tools

*Target Human Effects Evaluation Plan

Increasing human effects knowledge, decreasing risk

Phase	Level	Technology Readiness Levels (TRL) Acquisition Interim Guidance (30 May 2003)	Human Effects Readiness Levels (HERL)
System Field Test and Operations	9	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.	Human or surrogate participation in operation testing. Data validated from live fire experimentation and fielding.
System / Subsystem Development	8	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Human or surrogate tests in field environment with mature prototype systems under realistic conditions.
	7	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Human studies or surrogates in lab or field environments with prototype systems under specific, highly controlled, exposure conditions.
Technology Demonstration	6	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.	Non-human primate or large animal models confirm safety. Provide basis of limited human studies in laboratory to examine effectiveness.
Technology Development	5	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.	Studies in large animal models to more fully characterize effects, demonstrate technology effectiveness and safety.
	4	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	Bioeffect mechanism accepted by scientific community; small animal studies conducted to develop dose-response relationships.
Research to Prove Feasibility	3	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of technology. Examples include components that are not yet integrated or representative.	Bioeffect mechanism clearly identified; studies to determine dose-response relationship planned or began in small animal models.
	2	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	In vitro and cellular models used to study postulated bioeffect mechanisms; important dose-response parameters are postulated.
Basic Technology	1	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.	Bioeffect mechanism postulated through paper studies, theoretical analysis.

Payloads and Associated Human Effects Knowledge

- **Variety of payloads and non-lethal stimuli with varying degrees of confidence in understanding of human effects**

- **Blunt Impact:**
  - Validated injury prediction M&S tool (HE-MAP's Advanced Total Body Model)
  - Behavioral research difficult, efforts being made to develop predictive link between blunt impact and behavioral modification

- **Acoustics:**
  - Injury thresholds well established
  - Effectiveness thresholds exist for impulse noise

- **Electromagnetic Spectrum:**
  - M&S tools and data exist for much of the EM spectrum for both injury and effectiveness

- **Limiting factor in human effects is generally ability to predict behavioral response to exposure of non-lethal stimuli**

Human Effects Characterization Process

-**Transition in way of doing business:**

- Used to do retrospective analysis
- Now will provide prospective analysis
- Design optimization
- Effects based design

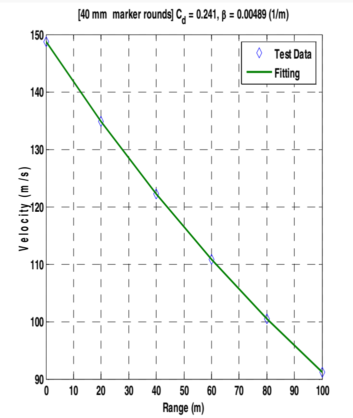
- **5 step characterization process:**

- Determine exposure
- Determine body response
- Map to injury correlation
- Determine behavioral response
- Determine if engagement meets mission objectives

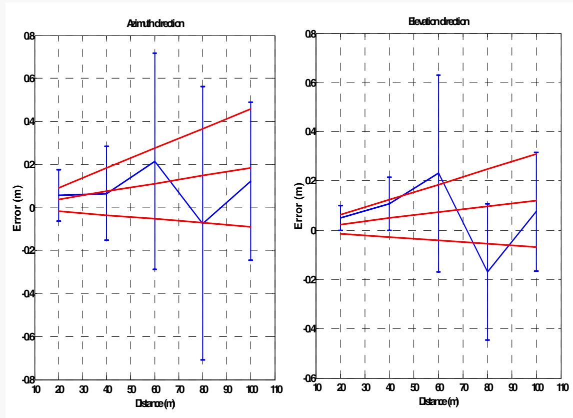
Industry and Human Effects Modeling and Simulation

- M&S analysis requires JNLWD or Service interest
- Data needs for analysis:
    - Sample munitions, projectiles, force-time histories, etc.
    - Projectile material, composition of grenade fill, etc.
    - Muzzle velocities
    - Accuracy/dispersion data
    - Light, sound, pressure, heat flux
    - etc.

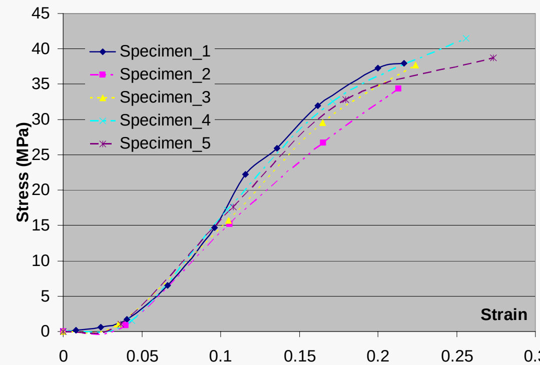
Determine Exposure

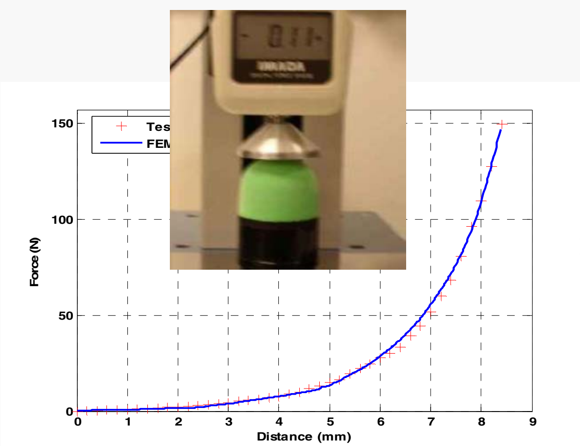


Calculation of dragging coefficient

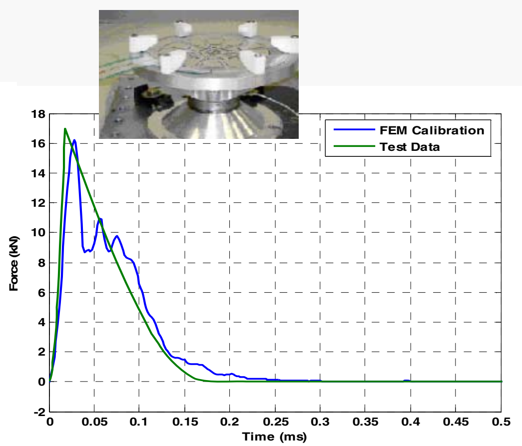


Calculation of accuracy parameters

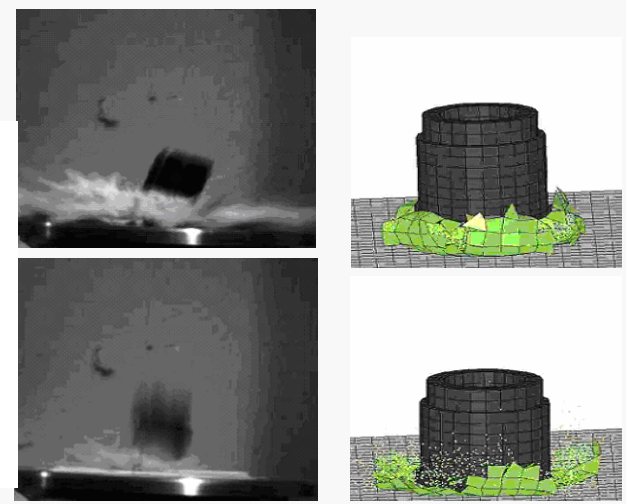




Static calibration



Dynamic calibration



Projectile modeling and impact simulation

Human Effects Modeling Analysis Program (HE-MAP)

Application Products

HEMAP-Web Application: web analysis interface
- Quick Estimator (HEQE)
- Effects Based Analysis (EBA)
- Design Optimization (DOA)

HEMAP-MSG Application: graphical simulation
- "Virtual training"
- Learn to use NLW
- Practice engagement techniques

Database of NLW system and payload based effects data
- Import into HEMAP-web and HEMAP-MSG

Research & Development

(testing → payload characterization → delivery → effects outcomes

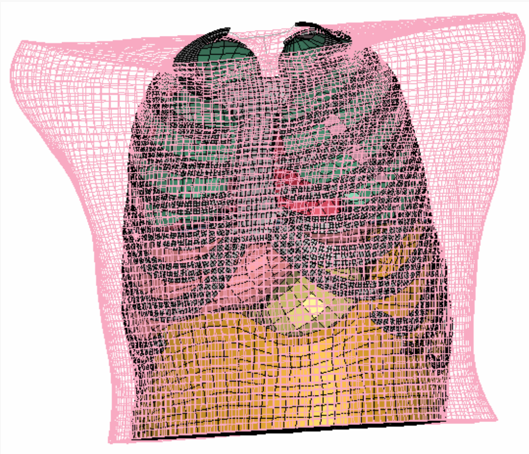
Responses/Effects	Payload delivery	Source characterization	Testing
ATBM	Projectile /fragment Delivery	Accuracy/ Impact Characterization	Firing/impact Accuracy Test
INJURY	Blast Delivery	Blast source Characterization	Blast test (BTD)
BURNSIM	Heat Delivery	Heat source Characterization	Explosion (heat flux)

IMPULSE NOISE, RF, OPTICAL, ELECTRICAL (TASER), …

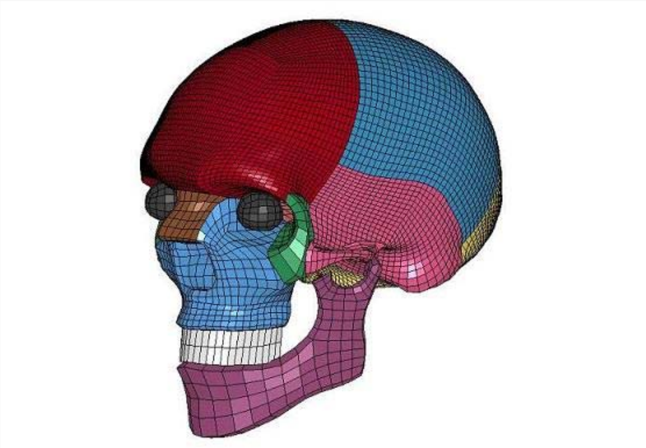
HEMAP Research: develop, integrate, validate, and verify models, data, and analysis methods
- Model development
- Model integration
- Model VV&A
- Data collection (Human, PMHS, Animal)
- Testing method, procedure, standard

- R&D: better integration of human effects models for all types payloads of interests;
- Application products: better support users' needs for analysis, design, training capabilities

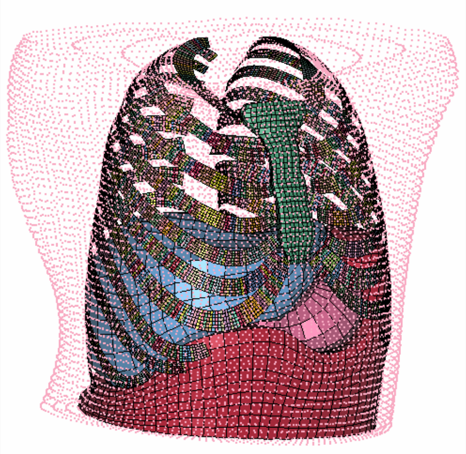
Predict Body Response and Injury



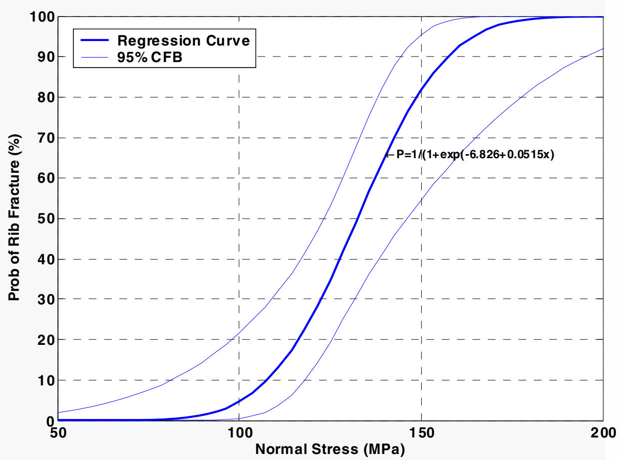
Thorax FE modeling



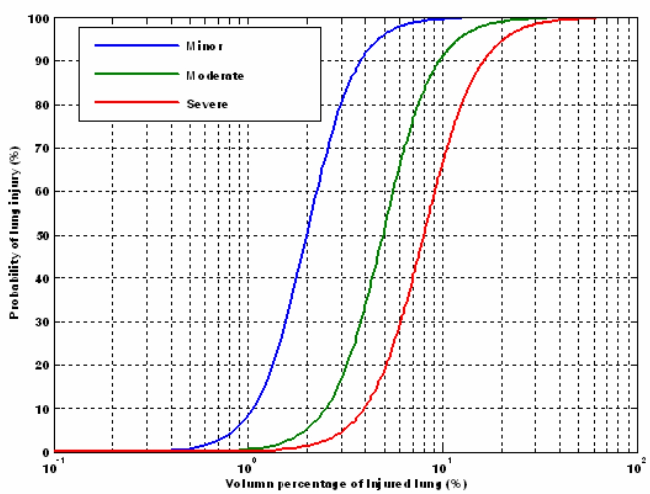
Head FE modeling



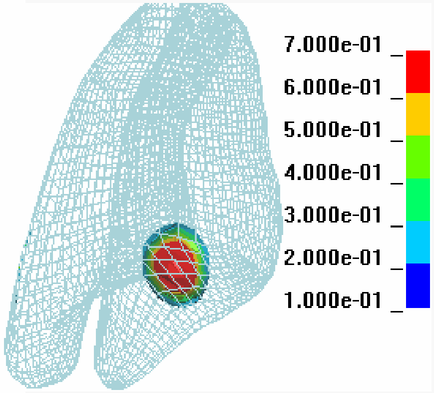
Abdominal FE modeling



Rib fracture correlation



Lung injury correlation



Mission Assessment

The software model and simulation environment can account for complex human effects and behavior outcomes

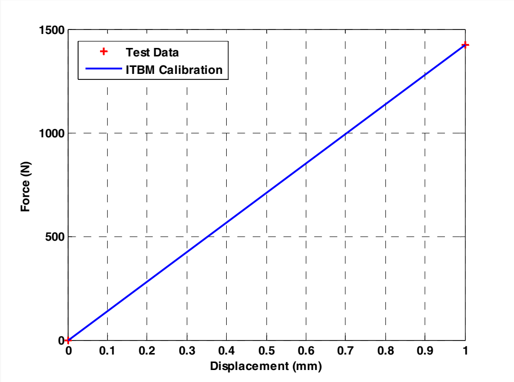
Using semi-immersive technologies (headset and weapon) to engage in the training in Virtual Reality. The headset can be connected wirelessly to the main station and display.

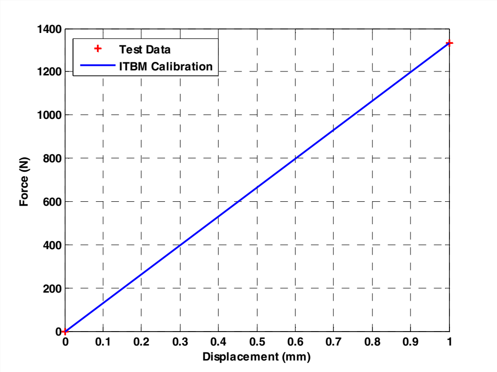
Blunt Impact Example

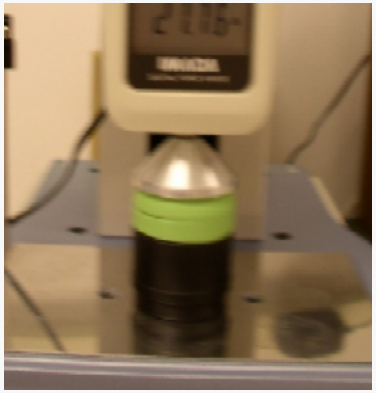
- **NL PM asked HECOE to perform analysis for two candidate projectiles**
- **Injury analysis expected to aid PM in down-selecting to final design**

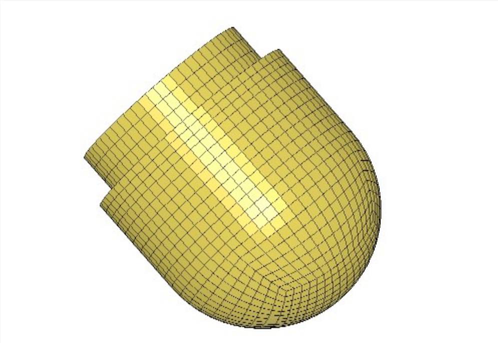
Exposure

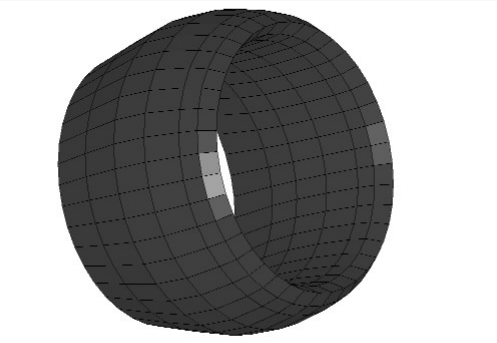
- Determine down-range velocities (impact velocities)
- Determine accuracy and hence probability of strike and strike location
- Mechanical characterization of projectiles and Finite Element (FE) model development





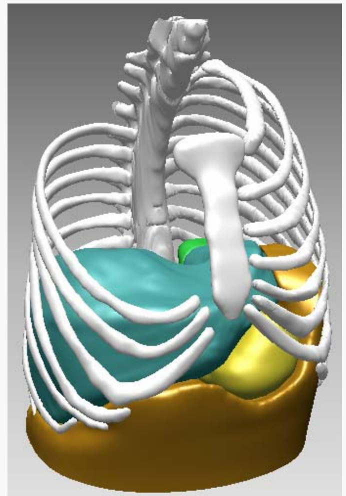


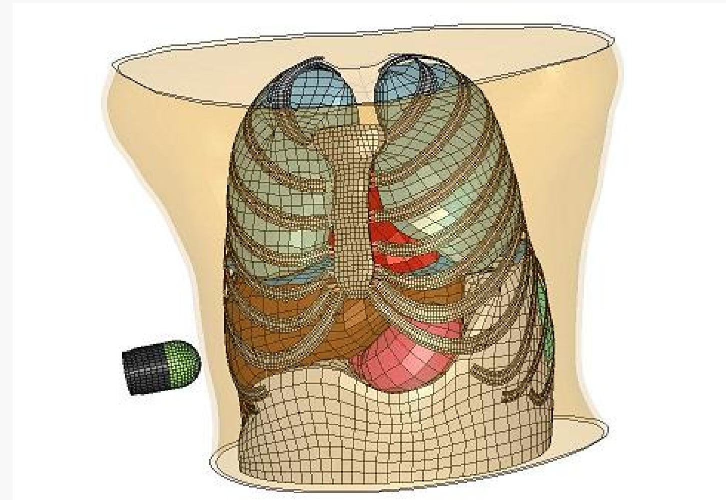


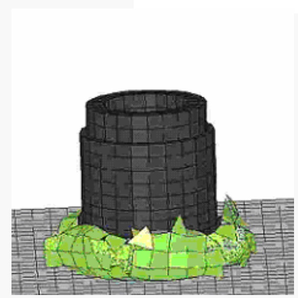


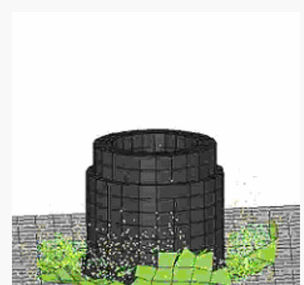
Advanced Total Body Model (ATBM)

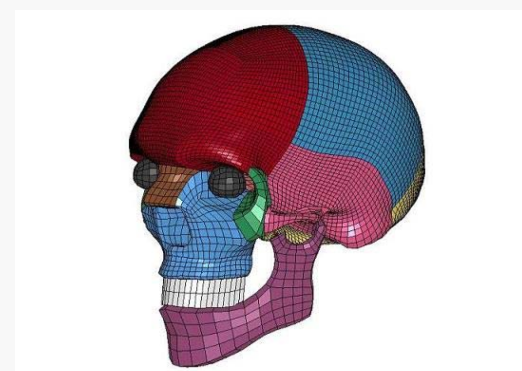
- Advanced Total Body Model (ATBM) is a JNLWP sponsored finite element based blunt trauma injury prediction model
- Biomechanically based, applicable for NLW impacts and validated against animal and cadaveric data
- Predicts a variety of injuries for the head, neck, thorax, abdomen, skin and extremities
- Includes design optimization and probability of hit modules
- Established projectile characterization process including static and dynamic loading to develop projectile FE model





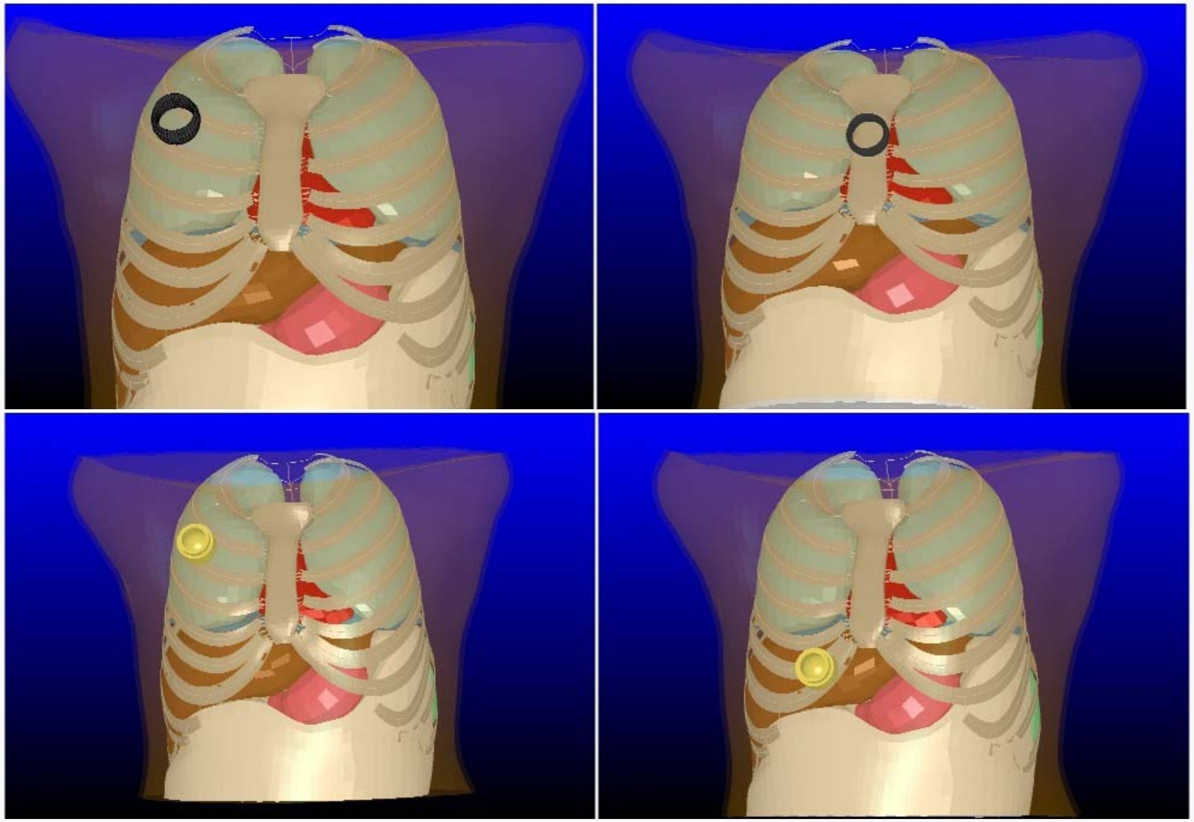


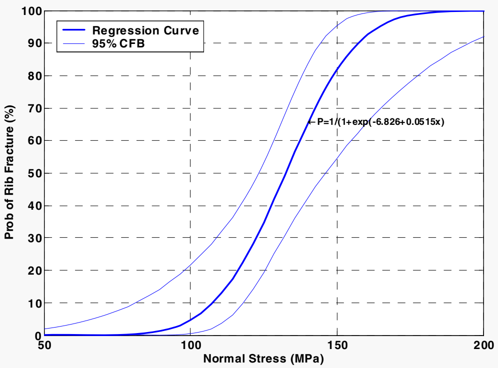


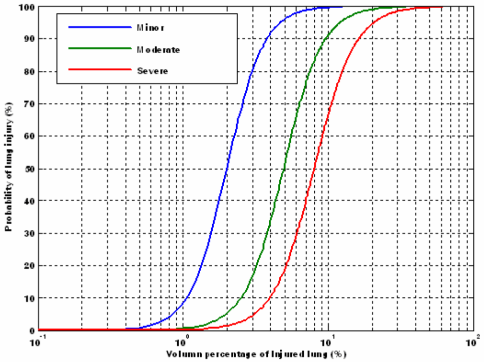


Body Response and Injury Correlation

- Thousands of FE simulations performed for various impact velocities and impact locations
- Yields predicted body response (i.e. strain in the rib) as a function of applied stress
- Predicted response mapped to injury correlations for various tissues and organs
- Injury predictions generated for various injury modalities







Summary

- Understanding the human effects and effectiveness of non-lethal weapons is fundamental to their development.
- The JNLWP has developed a process to facilitate understanding these human effects and to support the JNLW community.
- The process will be codified in a Department of Defense Instruction on NLW Human Effects Characterization.
- Modeling and simulation tools aiding non-lethal community in predicting effects and effectiveness from non-lethal weapon deployment