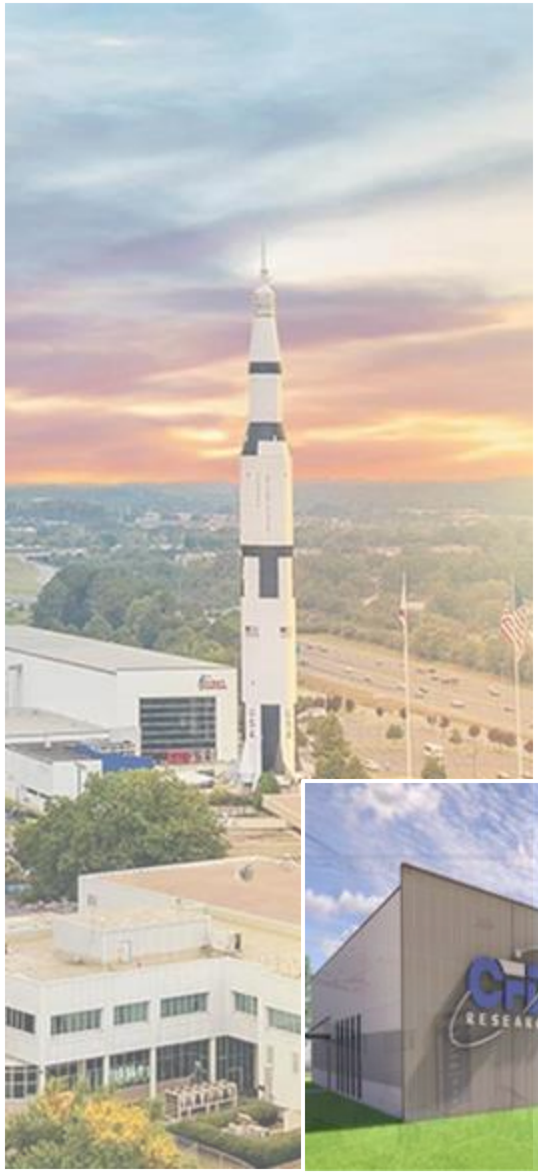

Blast-Induced Operational Combat Casualty Estimation

Military Health System Research Symposium
August 3, 2026

Breakout Session
Novel Methods for Identifying, Mitigating & Determining Health Impacts of OEH Exposures

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Disclaimer

The views expressed in this presentation are those of the author and do not necessarily reflect the official policy or position of the Defense Threat Reduction Agency, Department of War, nor the U.S. Government.

Disclosure

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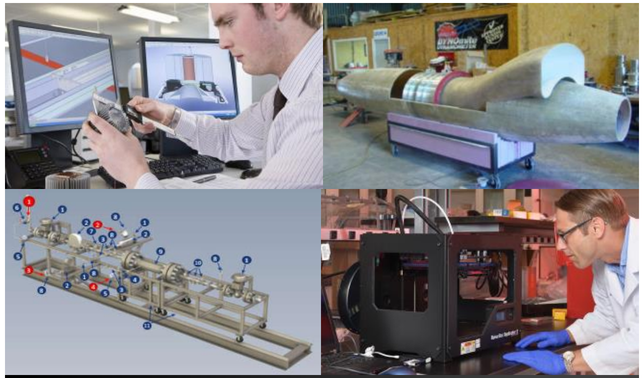
Outline

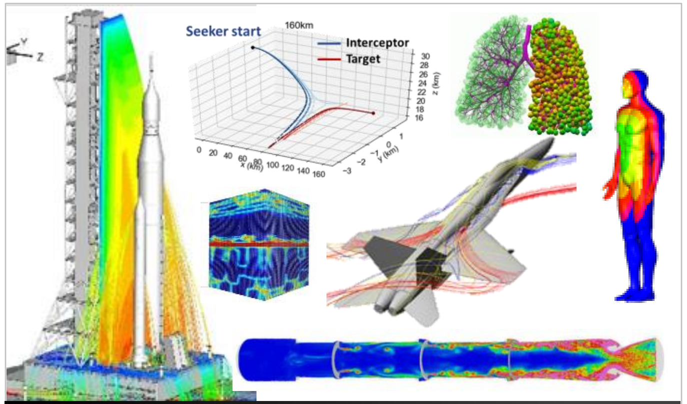
- Introduction
- Model Framework
- Results
- Conclusions
- Future Directions
- Acknowledgments



Design & Prototyping

13,300 ft^2 Bio & Energy Lab

Bioengineering

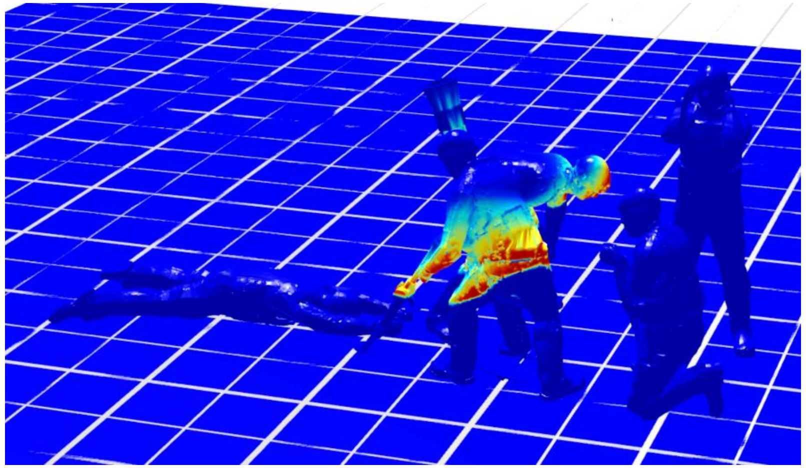


Modeling & Simulation

Introduction

- Blast environment is complex and dynamic
- Accurate assessment of service member injuries is currently impeded from meeting operationally informed timelines
- Operational combat casualty estimation using **dynamic exposure models** can be built into an **operational decision engine** to improve outcomes

Exposure Models



Introduction

Current State

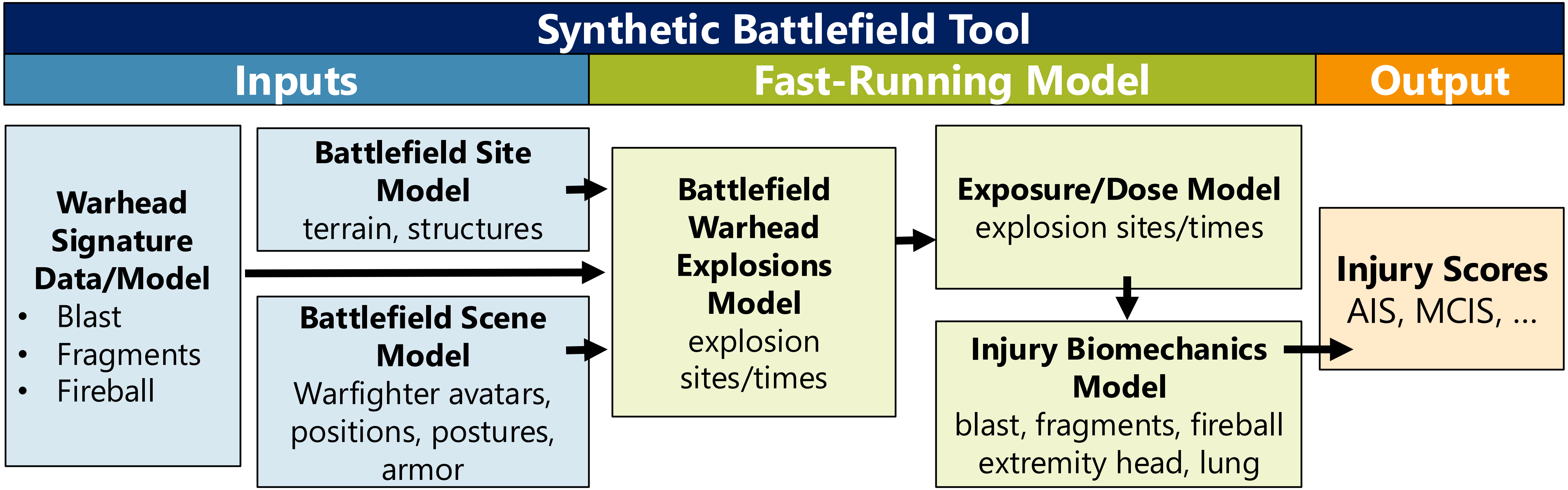
- Threat Analysis: Siloed models for isolated individual hazards
- Environment: Static
- Computational Speed: Slow and resource heavy
- Output Utility: Academic and delayed reporting

New Capability

- Threat Analysis: Multi-hazard aggregation (blast, thermal, fragmentation)
- Environment: Synthetic battlefield topography with populated scenes
- Computational Speed: Fast-running framework calibrated for rapid assessment
- Output Utility: Shareable and interoperable unit level triage outputs

Blast Injury Modeling

Multi-step approach was implemented to **demonstrate the predictive capability for modeling blast exposure-injury in combat scenarios**

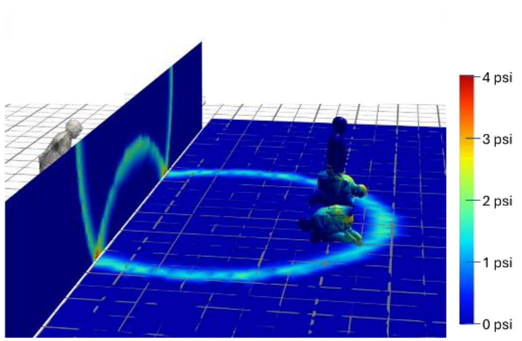


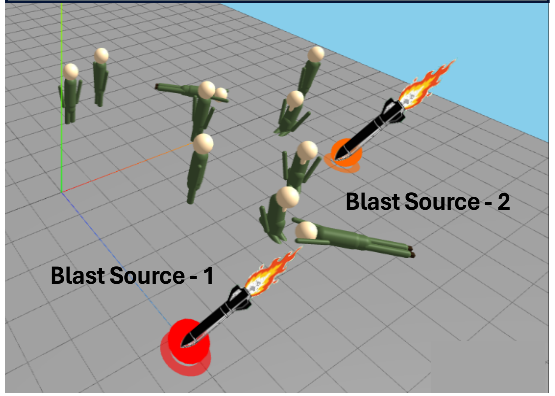
Blast Injury Modeling

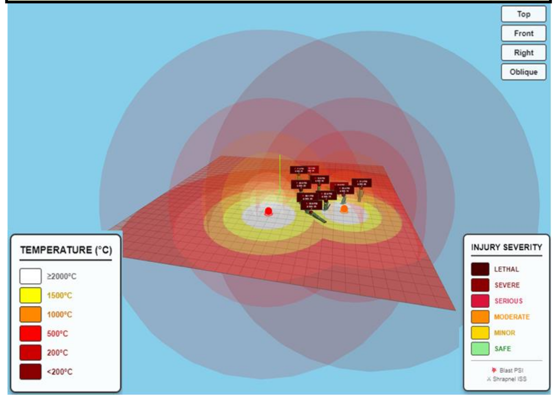
Today we will share **a few** of the capabilities, limitations, and future advancements within the injury prediction module.

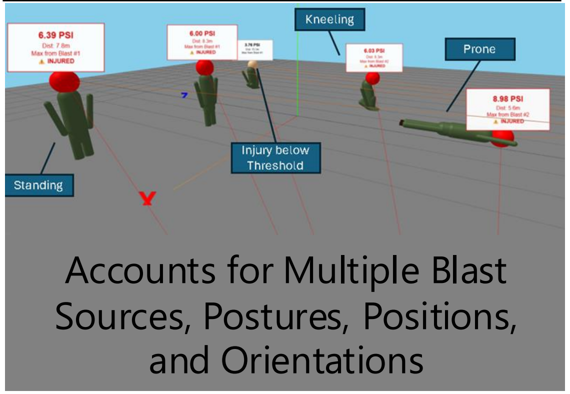
Synthetic Battlefield Tool

High-Fidelity Modeling of Battlefield Scenarios → **Fast-Running Simulation** → **Exposure Estimation** → **Injury Prediction**



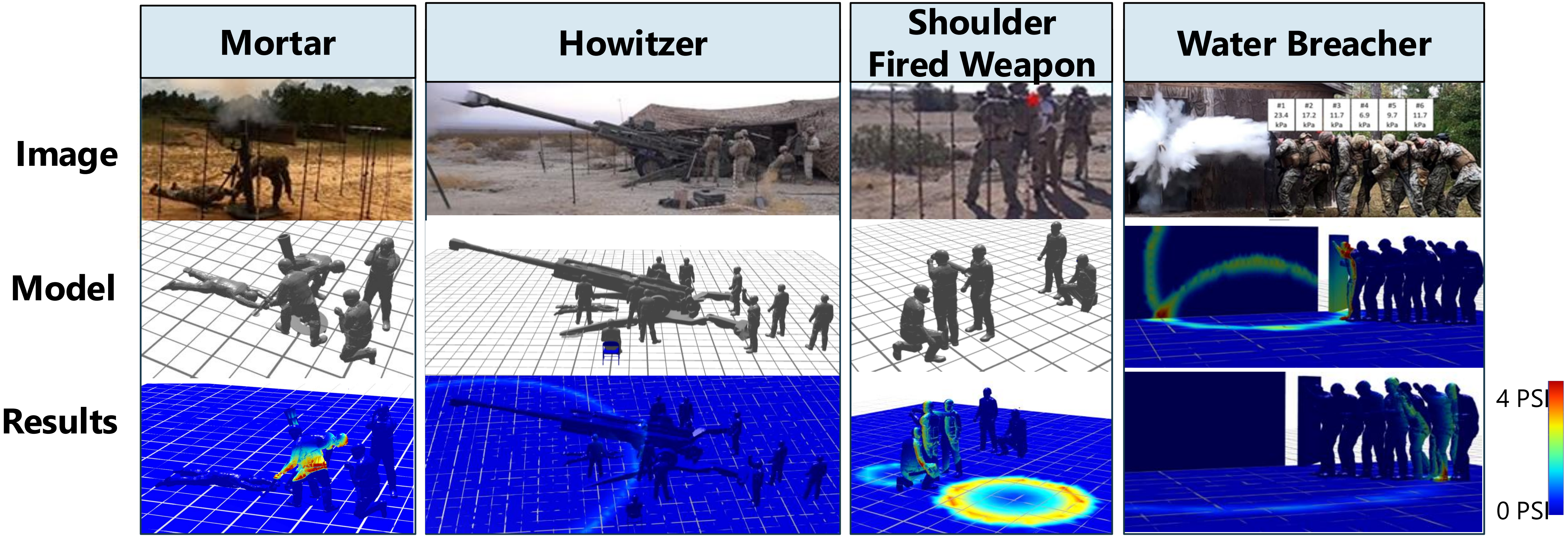






Blast Dose Validation

- Blast injury models are only as strong as the blast dose and exposure predictions
- CoBi-Blast and BOP blast dose predictions extensively validated for weapon firing scenarios



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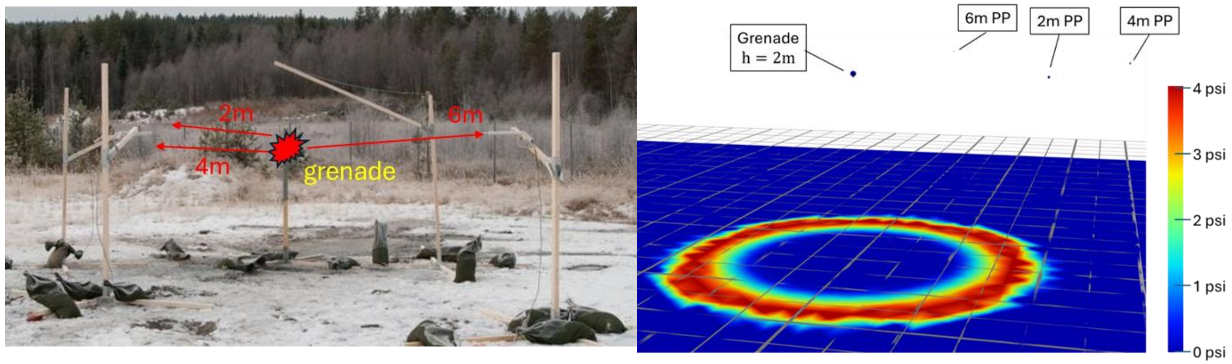
Blast Dose Validation

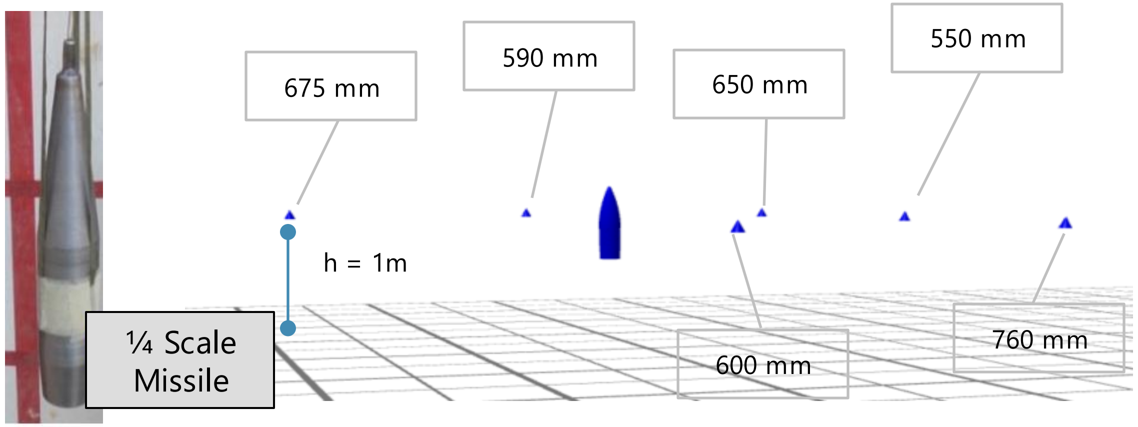
- Exposure models validated for incoming fire targeting the crew (grenade and missile)
- Average % difference between experimental and predicted Pmax was 2.1% for the grenade model and 10.1% for the warhead model, **instilling confidence in associated predicted injuries from these simulated battlefield scenarios**

Free-Field Grenade



(Bjerke et al., 2023)

Warhead Explosion



(Ahmed et al., 2021)

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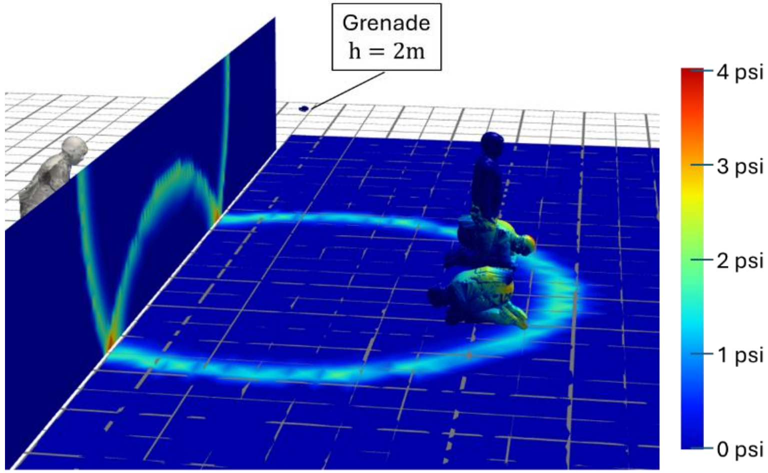
Exposure Estimation

- **Multi-surface reflections**, **position**, **posture**, and **orientation** relative to the blast overpressure all influenced max pressure, highlighting the need for models to integrate and maintain these capabilities

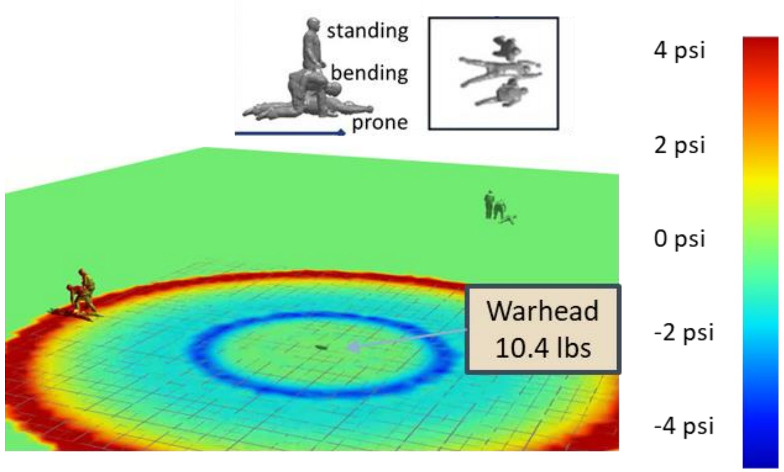
<u>Current Limitations</u>

- Limited data to validate complex exposures from outside threats
- Modern battlefield is complex and dynamic (i.e. drone-delivered ordnance, thermal exposures, shrapnel, etc.)

Grenade Toss Over Wall

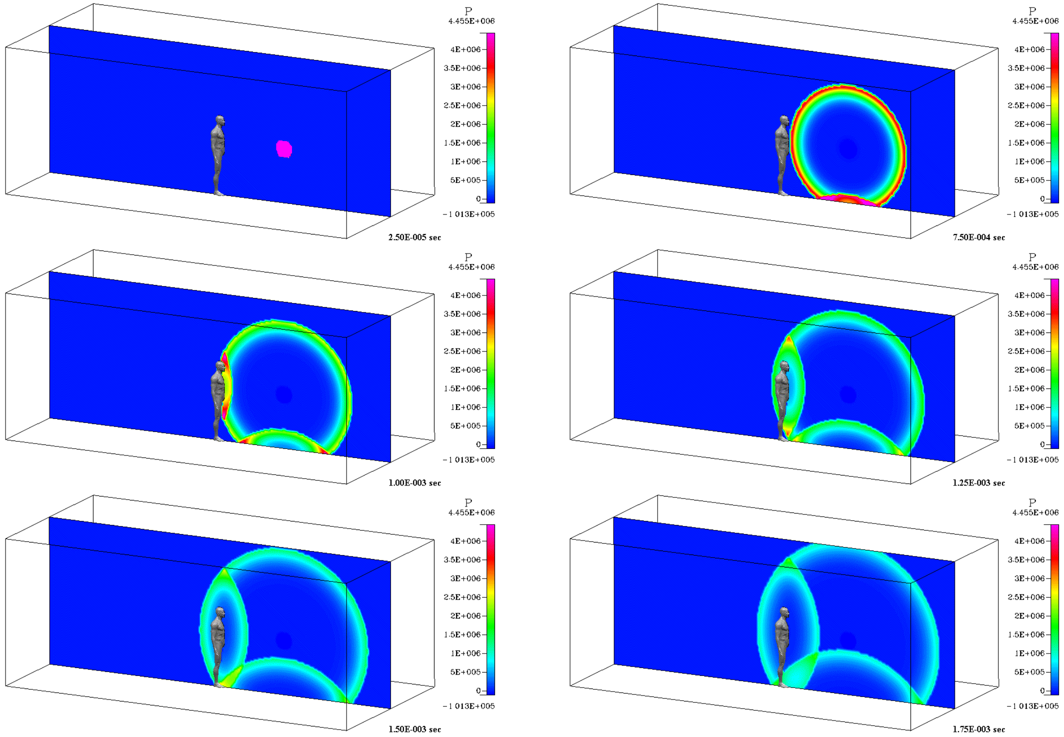


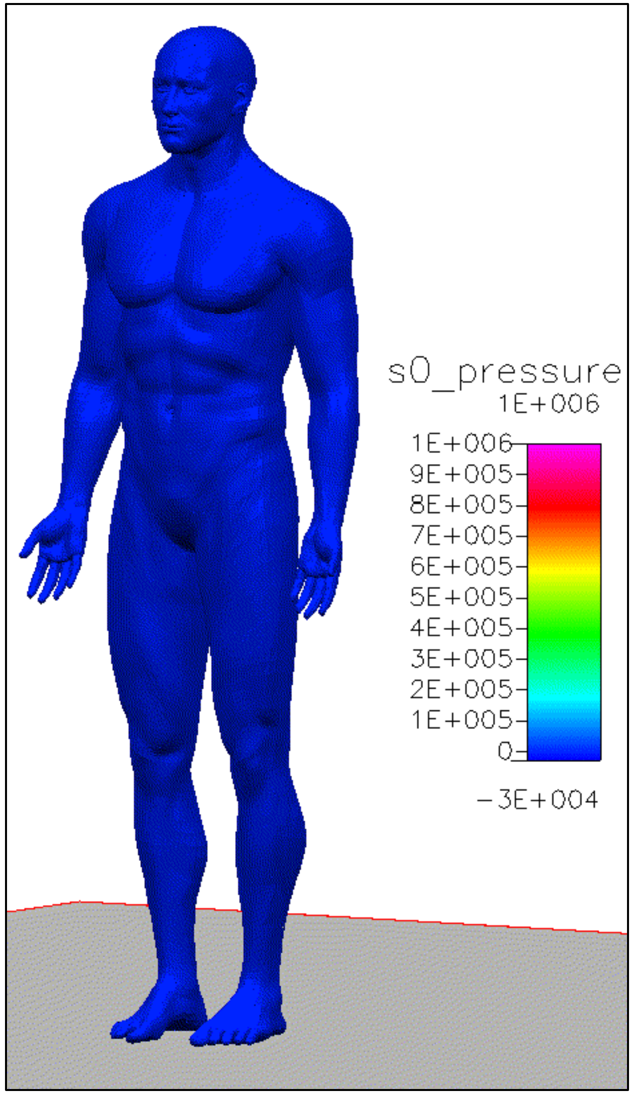
Incoming Missile on Ground



Exposure Estimation

- **Fast Running CoBi-Blast BOP** simulation results compare well with 3D CFD simulations.
- **BOP** can simulate blast exposure to multiple articulated human avatars immersed in 3D battlespace with multiple explosions

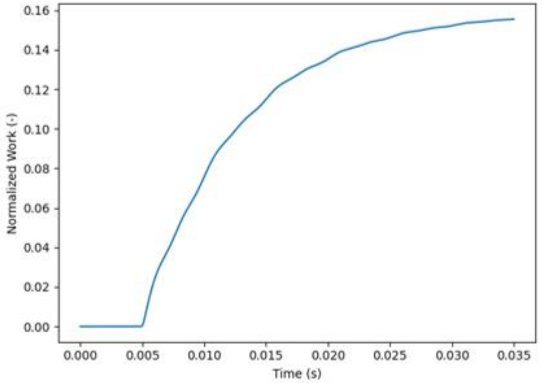


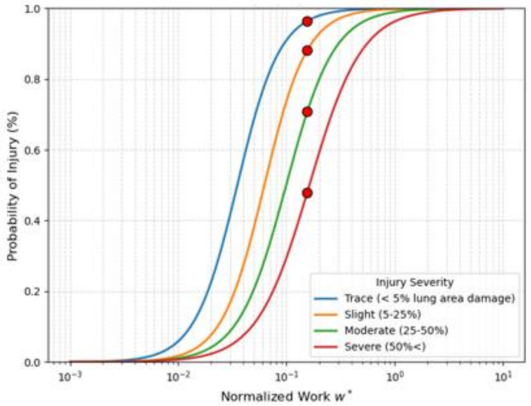


Injury Prediction

- **Lung Injury:** Modeled effects of orientation relative to the blast on the predicted outcome accounting for the **increased risk of injury for side-on blast compared to frontal**

Frontal Blast (0°)



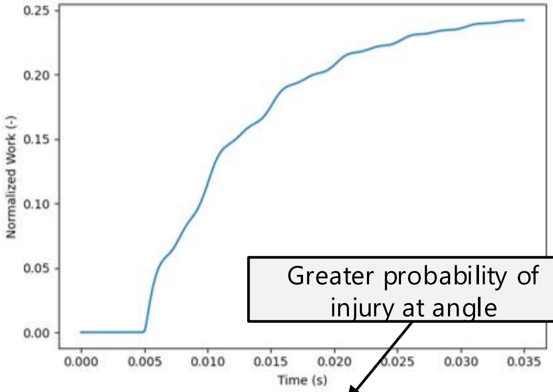


Expected AIS Lung Injury Score: 3.51

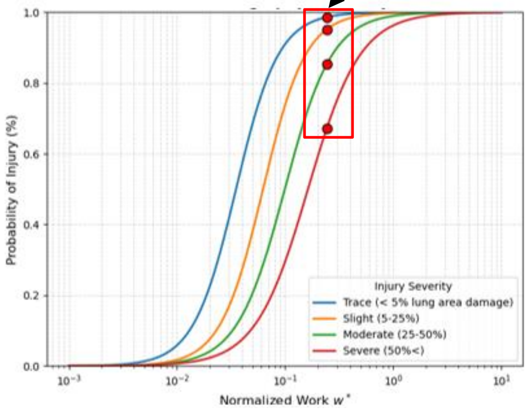
Discrete AIS Category: 4

Clinical Interpretation: Major contusion, multi-lobar involvement

Anterolateral Blast (60°)



Greater probability of injury at angle



Expected AIS Lung Injury Score: 4.13

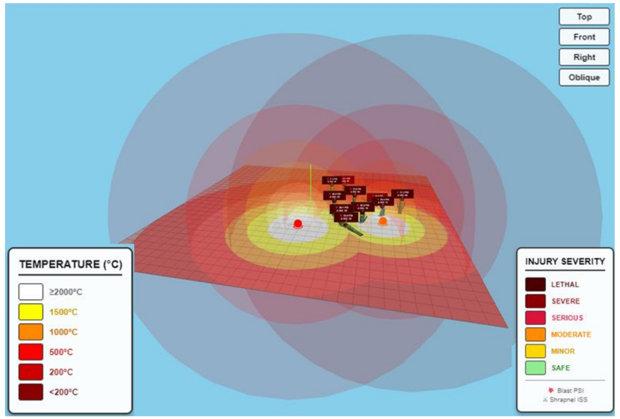
Discrete AIS Category: 4

Clinical Interpretation: Major contusion, multi-lobar involvement

Converts injury probability to AIS and clinical interpretation

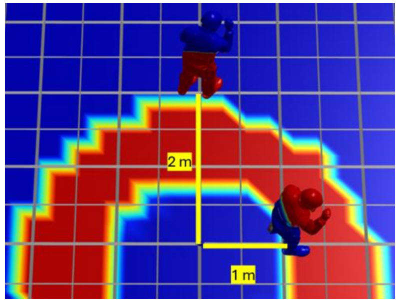
Injury Prediction

- **Thermal Injury:** Estimate cumulative thermal dose using the charge mass and distance from the explosion



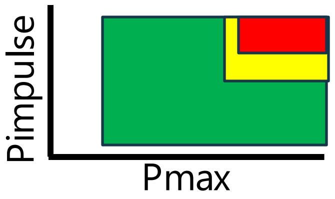
Thermal Dose [kJ/m2]	Injury Description
65	Skin Pain
125	First-Degree Burn
172	Flesh Wound
250	Second-Degree Burn
375	Third-Degree Burn
392	Seriously Injured
592	Fatally Wounded

- **Brain Injury:** Determine relationship between max pressure & impulse at the head



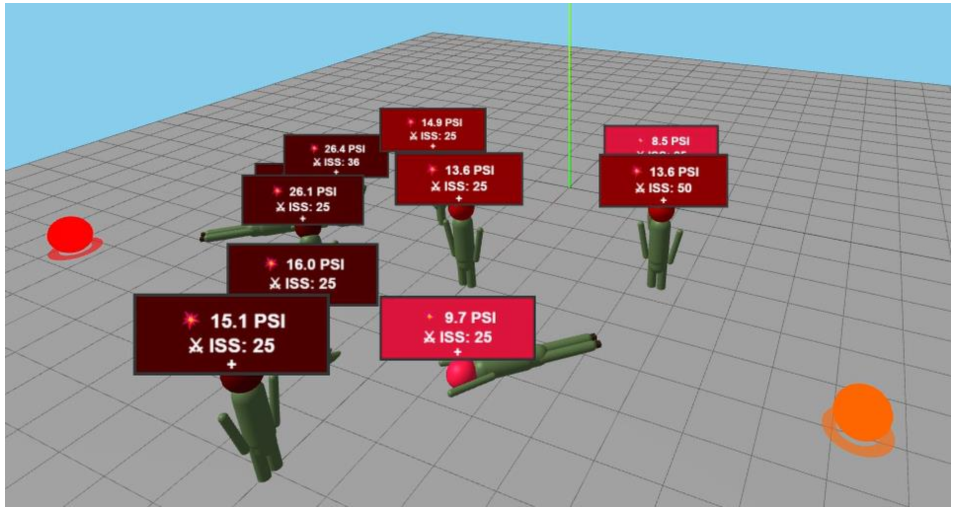
Estimated Injury Severity	Max Pressure [kPa]	Impulse [kPa-ms]
Mild	17.7	7.2
Moderate	190	935
Severe	319	1467

Rutter et al.



Summary & Limitations

Synthetic Battlefield Tool Outputs

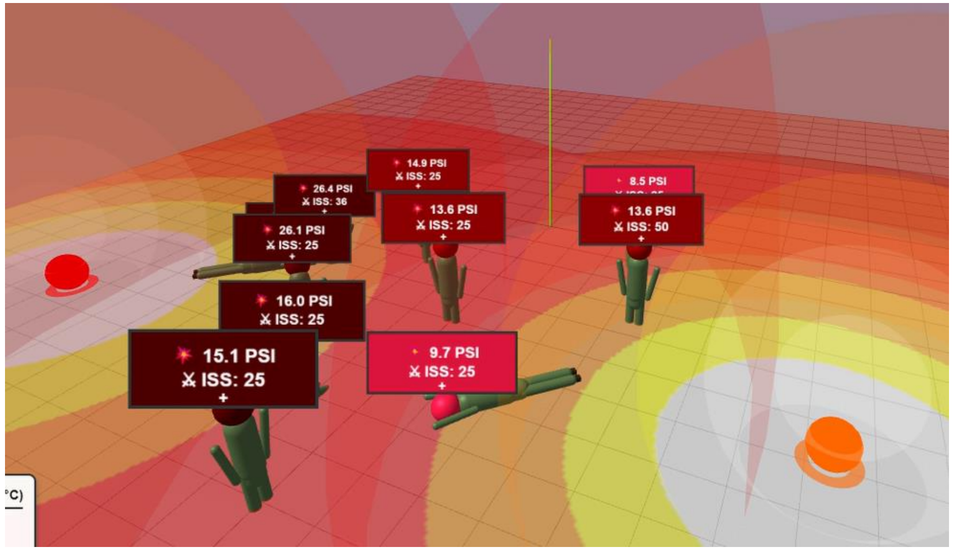


Summary

- Incoming munition applications
- Multiple blast sources
- Position, posture, and orientation
- Multiple injury criteria
- Estimates blast and thermal

Limitations

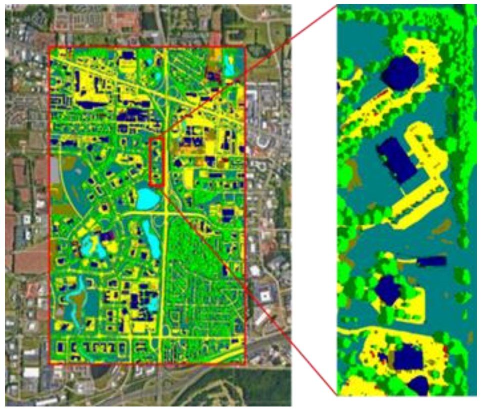
- Model predictions for penetrating injuries are lacking
  - Injury based on penetration depth of small fragments in isolation
  - Assumes that the fragment is a rigid body with a straight-line trajectory as it travels through the body
  - No shedding of secondary fragments

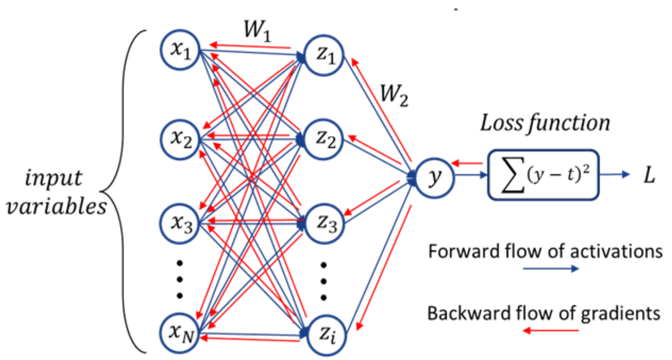


Future Directions

Next steps include expansion of the Synthetic Battlefield Tool capabilities to **enable real-time operational decision making**

Scene Reconstruction	Exposure Estimation & Injury Prediction	Machine Learning Approximation & Injury Classification





- Inform model inputs from FLASH AI reconstruction

- BOP estimation extended for landmines, trenches, incoming munitions, etc.
- Advance high-fidelity penetrating injury models, focusing on extremity injury from large fragments

- Advance models of injury classification
- Use machine learning to improve computational efficiency

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