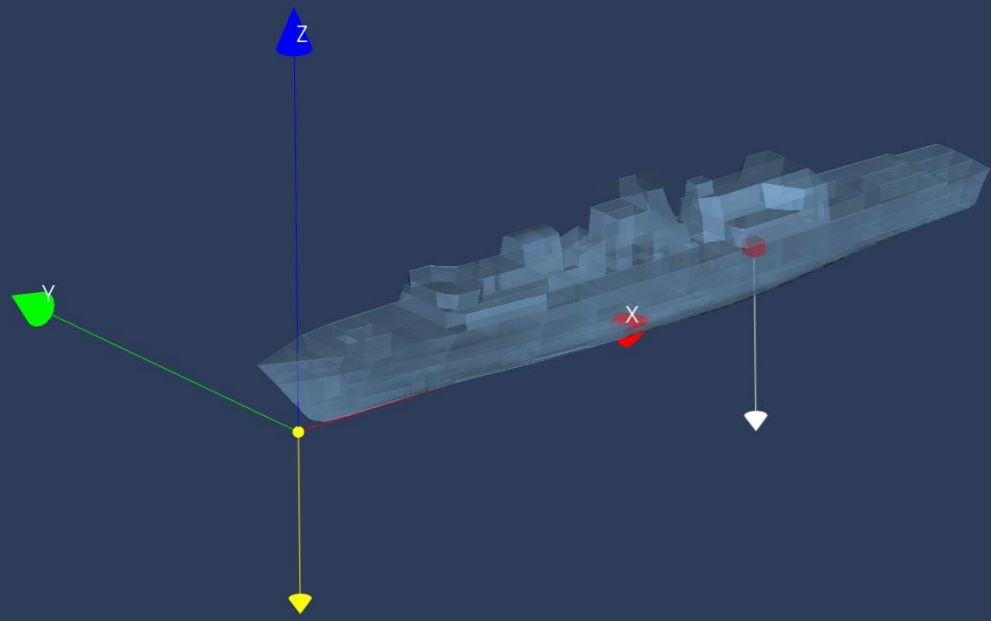
Ammunition and Explosives Consequence Analysis Tool (AECAT)

Enhancements to Support Naval Storage Explosive Scenarios



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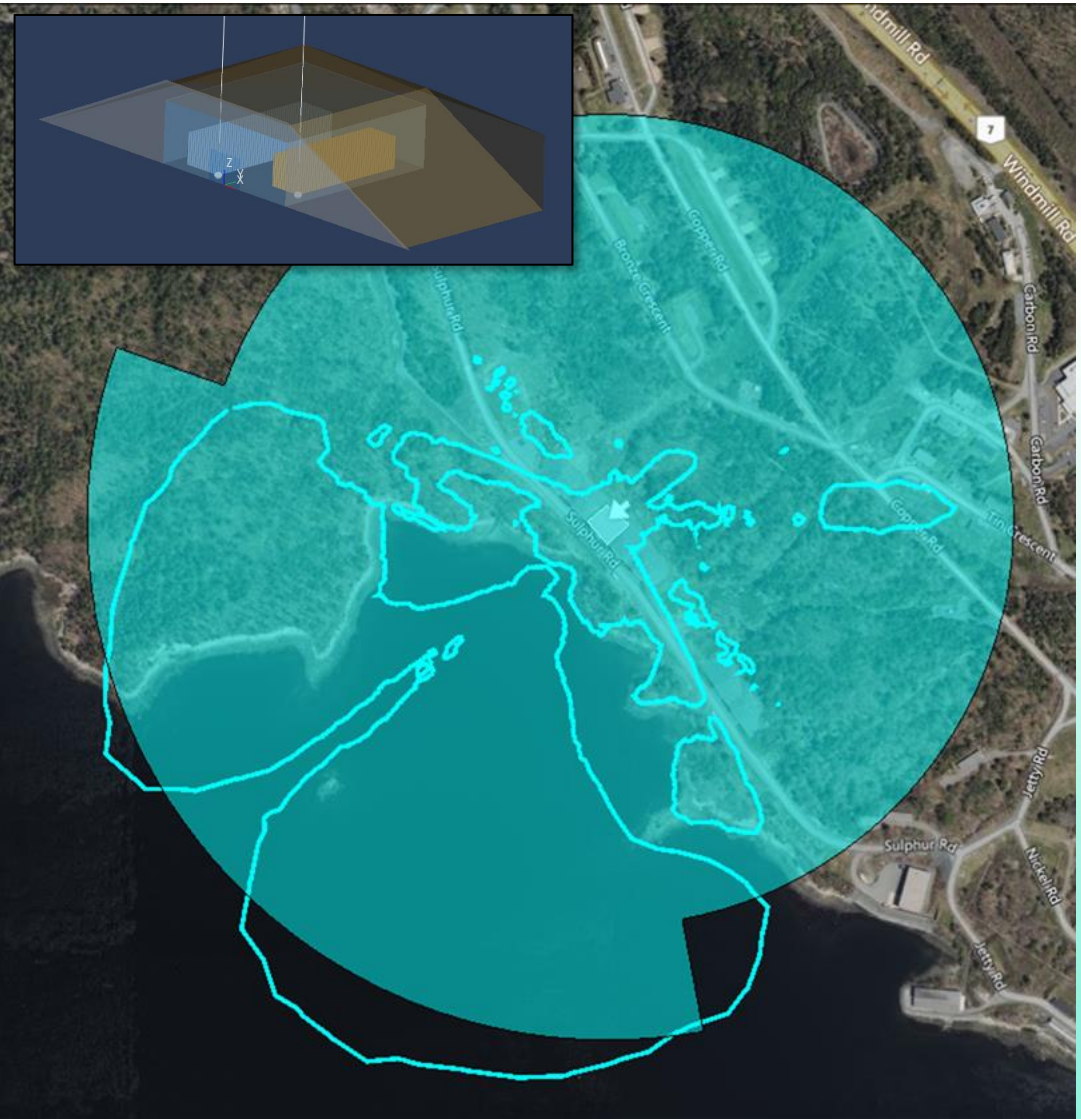
Halifax, NS, Canada

22 January 2026
International Explosives Safety Summit (IESS)
Phoenix, AZ, USA

Ammunition and Explosives Consequence Analysis Tool (AECAT)



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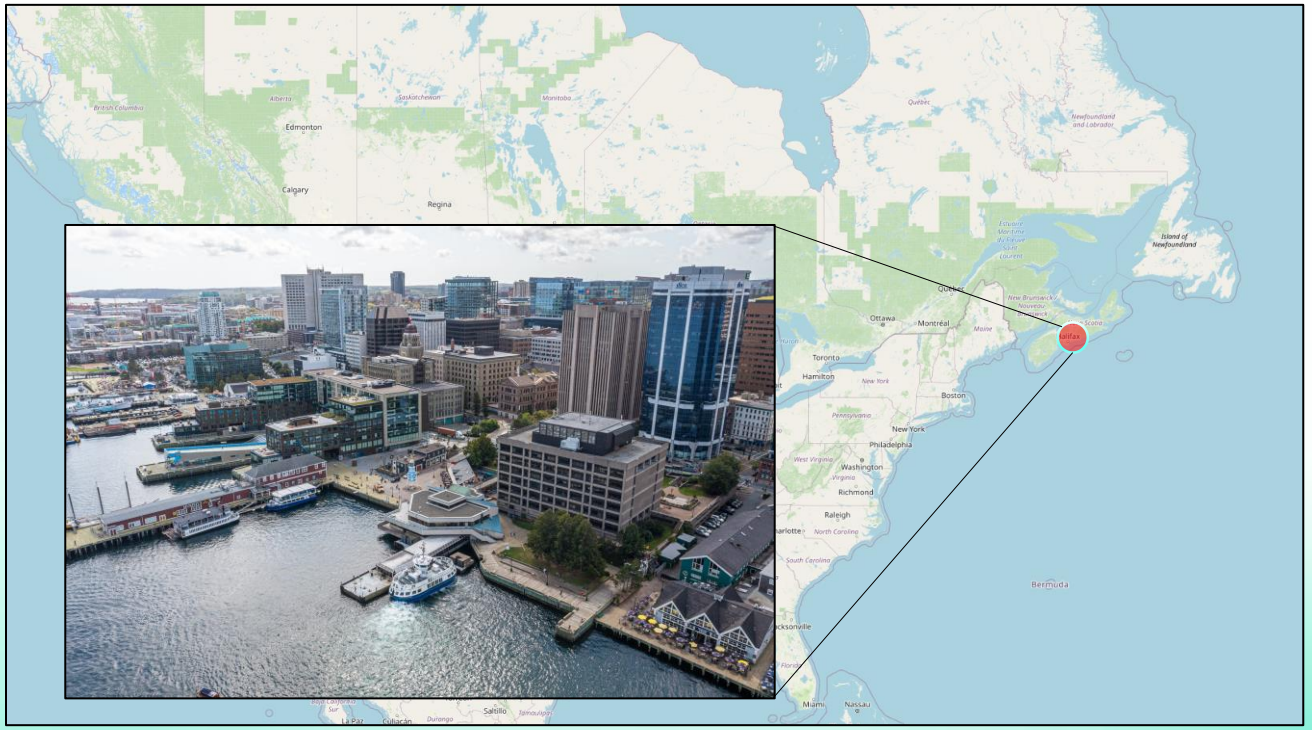
Introduction and Software Overview

Ammunition and Explosives Consequence Analysis Tool (AECAT)

AECAT Development Team

- Lloyd's Register Advisory (Martec Ltd.) based in Halifax, Nova Scotia
- **Explosion & Fluid Dynamics Team**
  - Modelling explosive events and blast effects on structures, personnel
    - Threat assessments
    - Vulnerability, damage, and injury prediction
    - Advanced modelling: FSI, UNDEX
  - In-house software development: **Chinook** (20+ years), **Integrated Platform** (e.g., RCP) (10 years)
- Leading development of AECAT for Canadian Department of National Defence / DAER

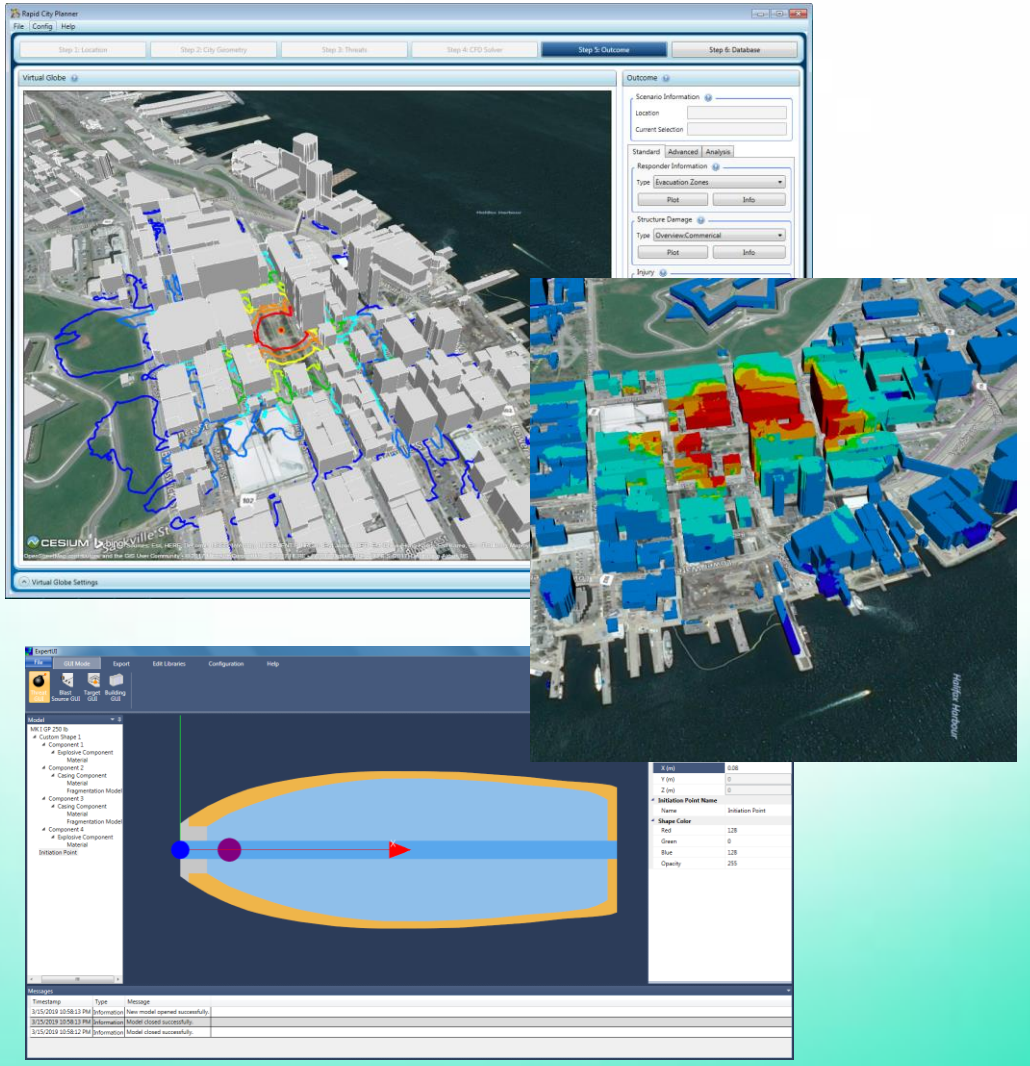


Halifax Waterfront and Downtown Halifax [Source: developns.ca]

Ammunition and Explosives Consequence Analysis Tool (AECAT)

Integrated Data Fusion Platform

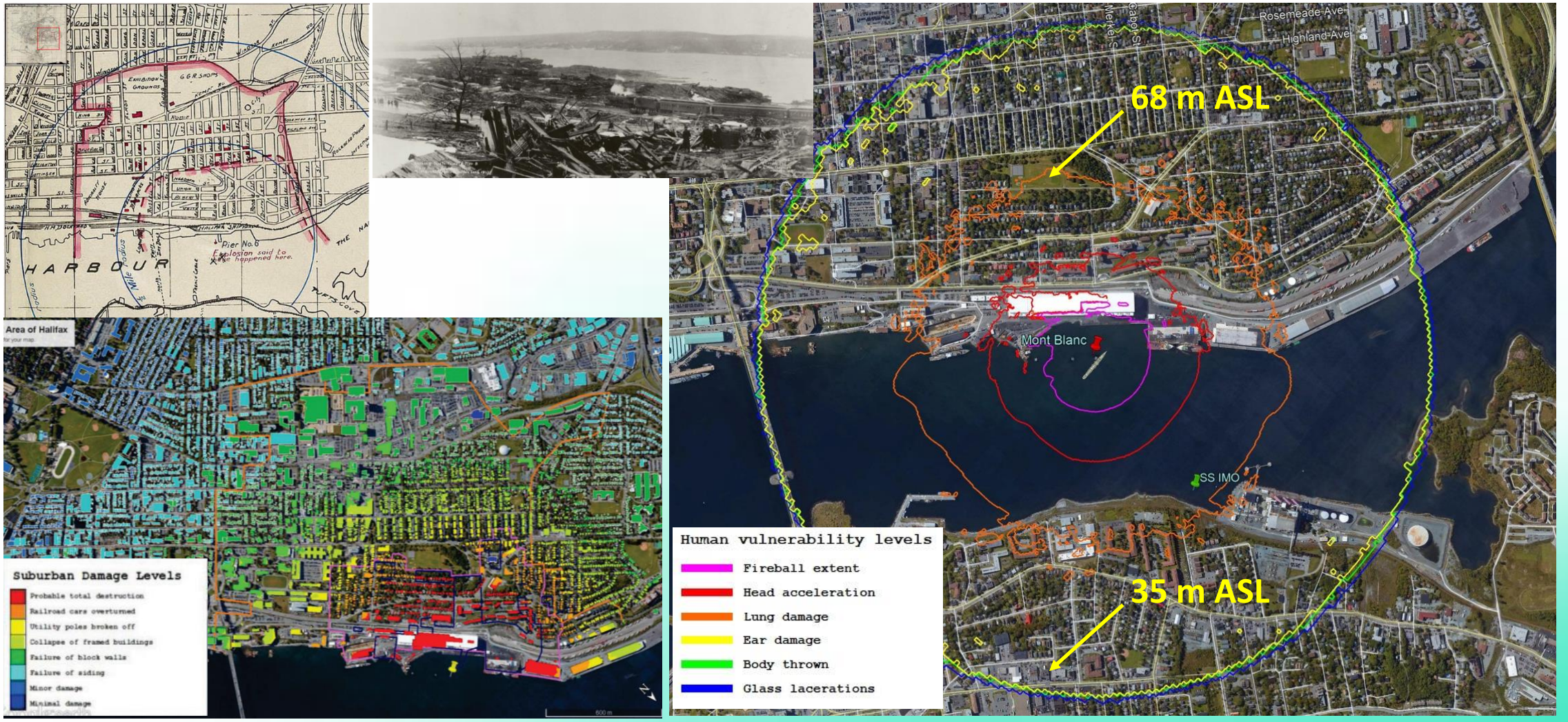
- Fast and physically-accurate blast assessments in real-world, **GIS**-based coordinates
- **Fusion** of geospatial data from multiple sources
- Capability highlights:
  - CFD-based fast air blast solver (blast effects)
  - Fast primary fragmentation and trajectory solver (frag effects)
  - Fragment injury/lethality (statistical)
  - Collateral damage estimation methodology
- Target performance on laptops / workstations
  - **10 minutes** (minimal fidelity)
  - **60 minutes** (standard fidelity)



Example urban blast outcomes from RCP calculation (top, right), detailed threat definition in RCP Expert User Interface (bottom)

Ammunition and Explosives Consequence Analysis Tool (AECAT)

Historical Event Reconstruction – Halifax Explosion of 1917

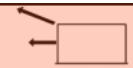


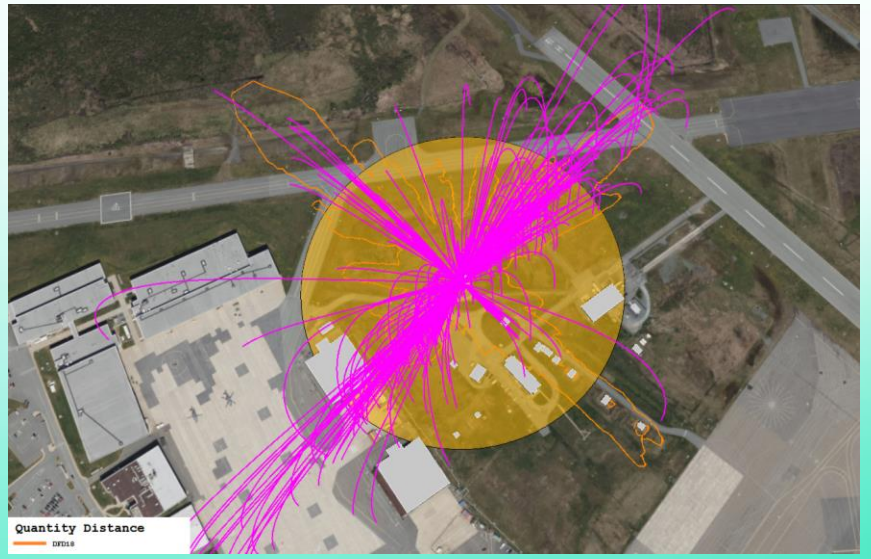
Reconstructed blast outcome for Halifax Explosion of 1917 [Source: Ripley, R.C., 2018 (left), Baingo, D. 2017. DRDC (right)]

Ammunition and Explosives Consequence Analysis Tool (AECAT)

Primary AECAT Programme Objectives

- **Physics-based** M&S capability to support risk assessment of A&E storage and licensing
  - First-principles computation of **blast** and **fragmentation** effects in A&E storage environments
  - **Fragmentation** and **debris** effects from A&E storage structures and bulk ammunition
- Build upon established **data fusion platform** for consequence analysis of storage-based explosive scenarios
- Prediction of **vulnerability** and **damage** from explosive event at PES
- Fusion of **physics-based** and **QD-based** outcomes

PES → E S ↓	EFFECT	 Open-air stack or light structure, barricadedd. Truck, trailer, rail-car or freight container loaded with munitions, barricaded. (i)	 Open-air stack or light structure, unbarricaded. Truck, trailer, rail-car or freight container loaded with munitions, unbarricaded. (j)
 **19** Explosives Workshop without protective roof, barricaded (1.3.1.12)	BLAST	BD18 Limited degree of protection for personnel	BD18 Limited degree of protection for personnel
	DEBRIS & FRAG	DFD20 Limited degree of protection for personnel	DFD18 Limited degree of protection for personnel

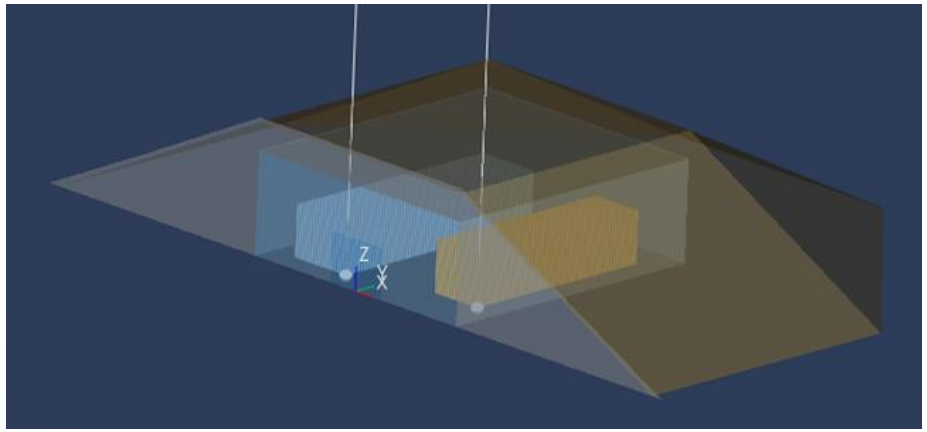


Primary fragmentation outcome in AECAT (bottom), and DFD18 QD table entry (top) *[Source: AASTP-1 Ed. C]*

Ammunition and Explosives Consequence Analysis Tool (AECAT)

AECAT Motivation and Use Cases

- Provide support for A&E **risk-based licensing** tasks
- Review existing QD approaches with site-specific details not captured in standard approaches
    - Effects of **terrain**, **structures**, **barricades**, **infrastructure**, etc.
- Facilitate analyses for:
    - Marginal and/or atypical storage scenarios
    - Expeditionary/deployed storage scenarios
    - Consequence mitigation / sensitivity studies
    - Risk and loss assessments
    - Forensic or event reconstruction



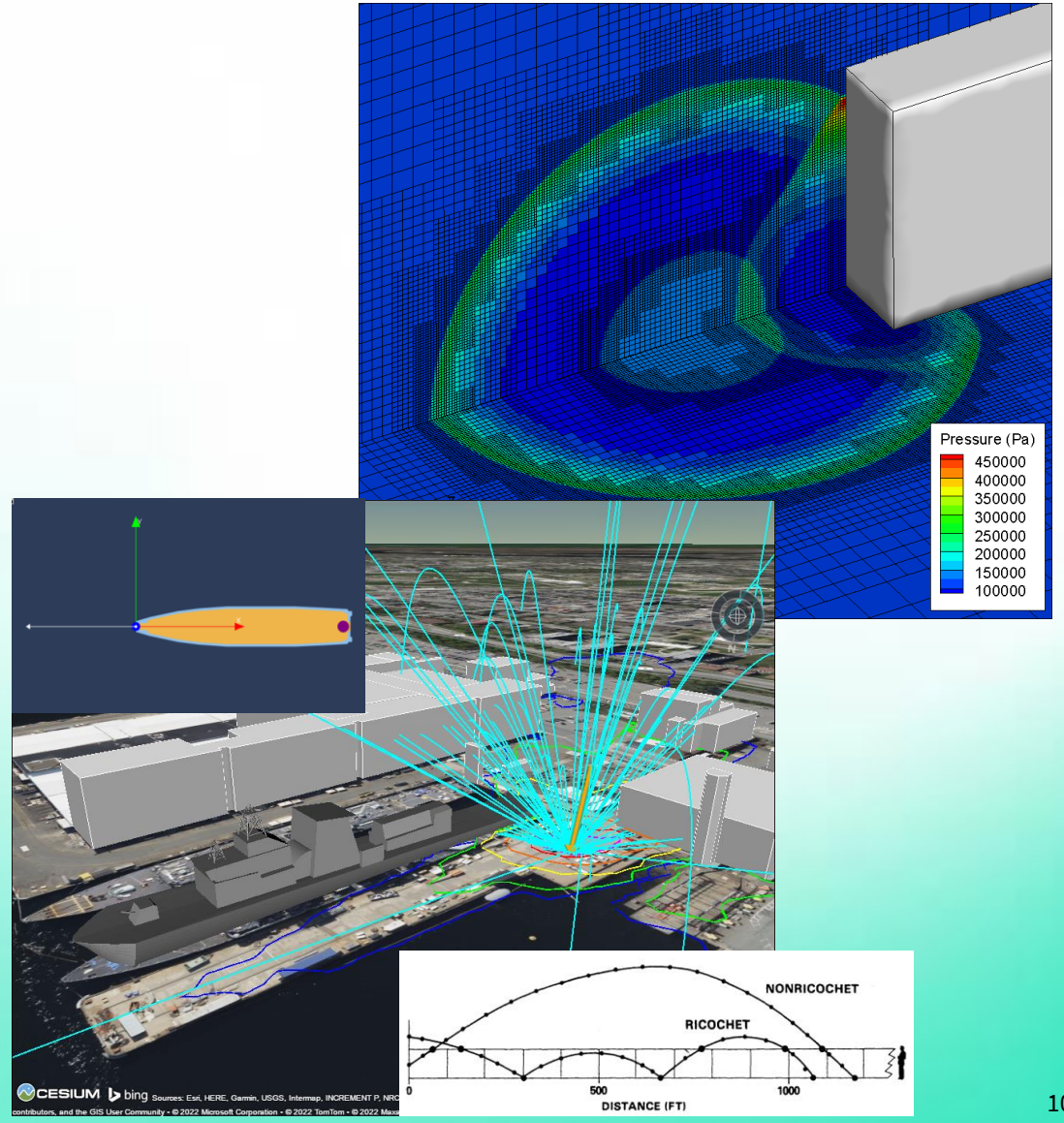
ECM and stacks modelled in AECAT (top), and non-standard ammunition storage magazines at CFAD Bedford (bottom)
[Source: Google Maps]

AECAT Modelling Approach

Ammunition and Explosives Consequence Analysis Tool (AECAT)

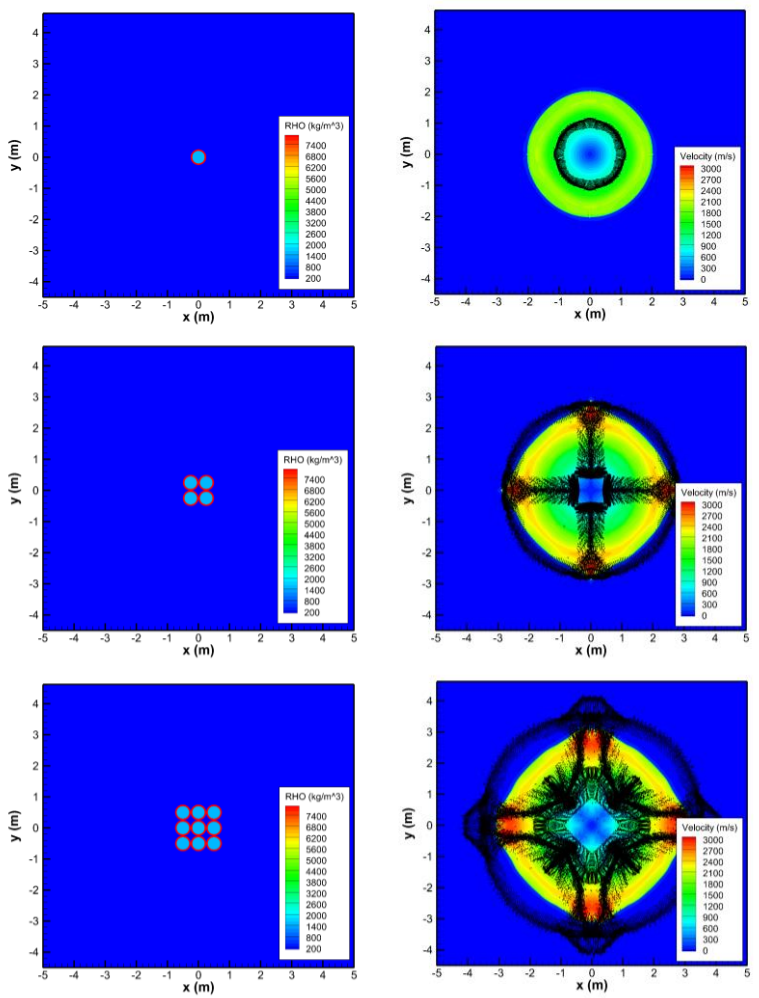
Blast and Fragmentation Modelling

- Full-physics, **computational fluid dynamics** (CFD)
  - Fast blast solver
  - Detailed solver (continuum breakup, scientific tool)
- **Fast primary fragmentation** solver
  - Generalized 3D Gurney model (initial fragments)
  - Fragment size distribution
    - Grady theory (strain based)
    - Mott size distribution
  - Equivalent bare charge
- **Fragment/debris trajectories** solver



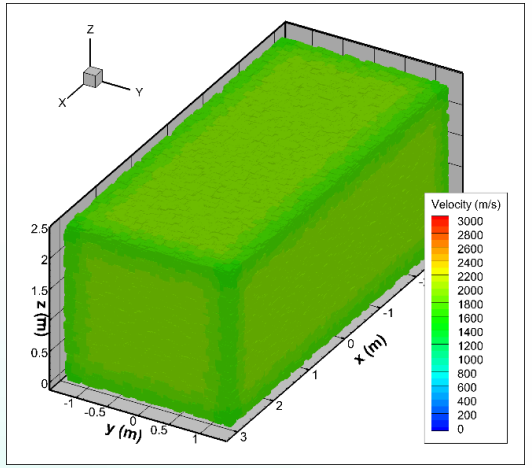
Ammunition and Explosives Consequence Analysis Tool (AECAT)

Munition Storage Modelling

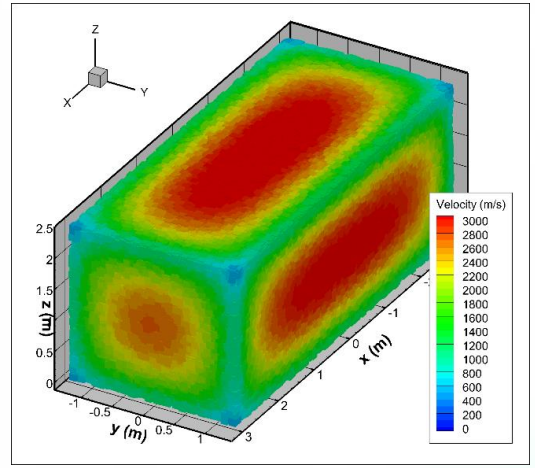


Combined fragmentation effects from stacks, with contours of fluid velocity and fragments in black

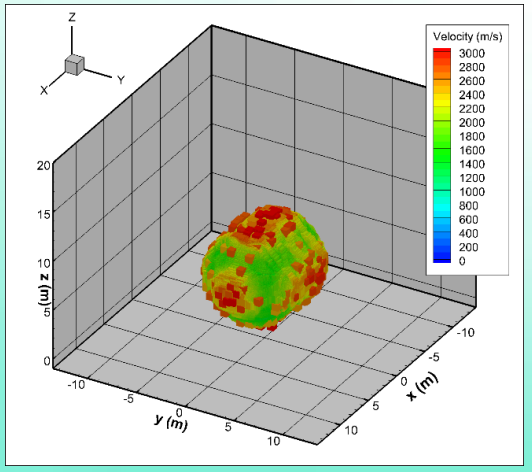
Debris Launch Velocity (DLV)



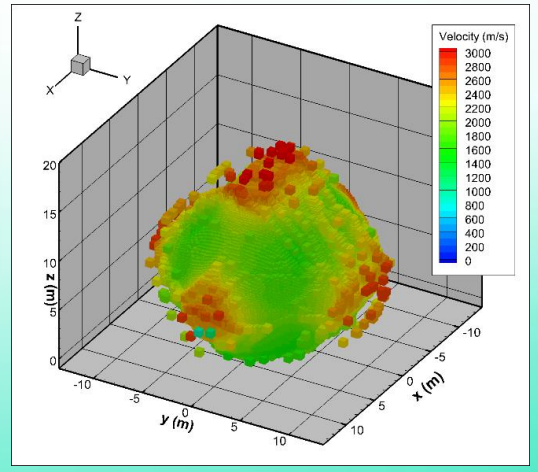
Fast fragmentation (Gurney)



Continuum breakup *2 ms*



4 ms



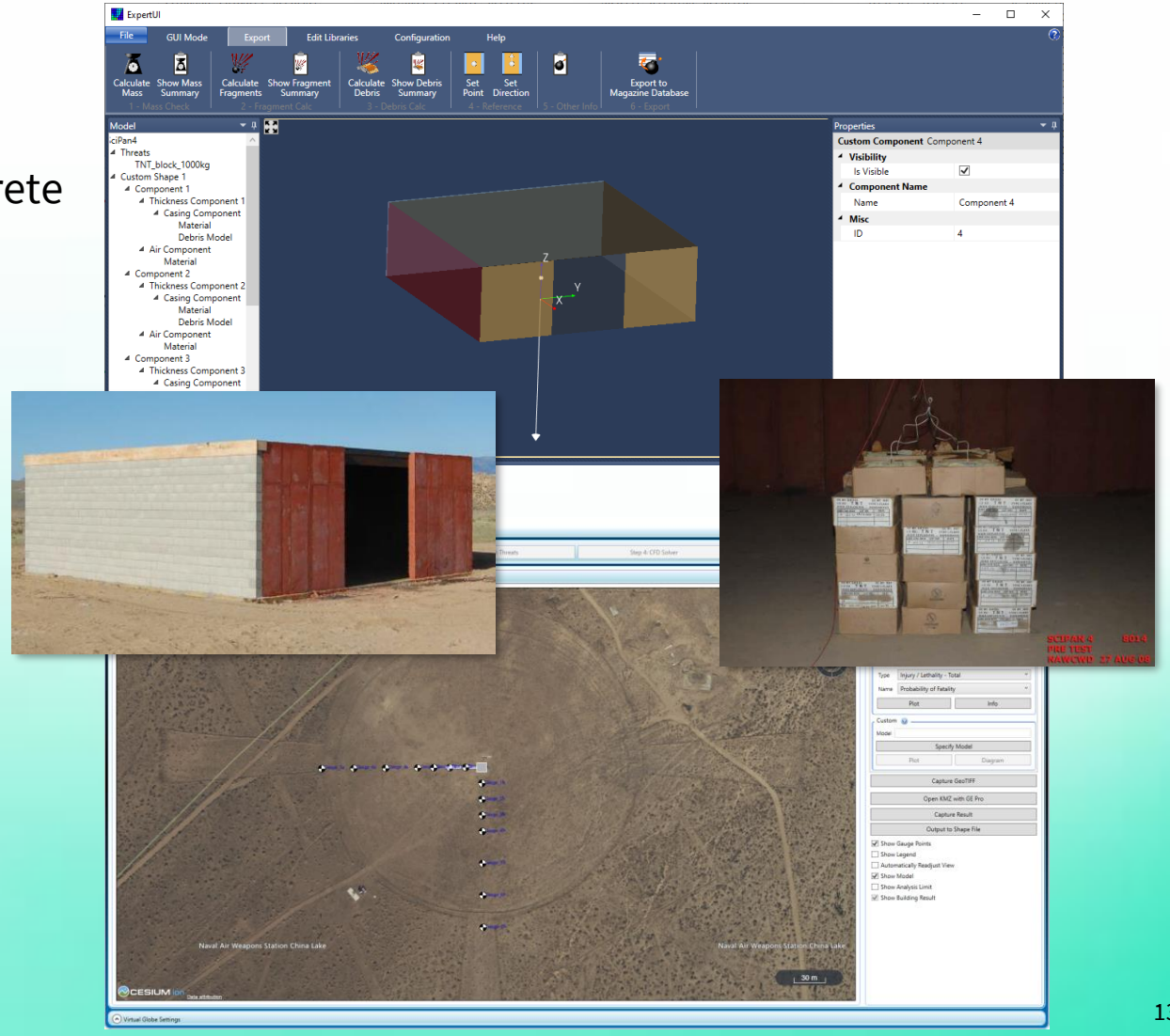
Light confinement debris launch verification using Debris Launch Velocity (DLV), Generalized 3D Gurney, and detailed continuum breakup

AECAT Validation Study – SciPan 4

Ammunition and Explosives Consequence Analysis Tool (AECAT)

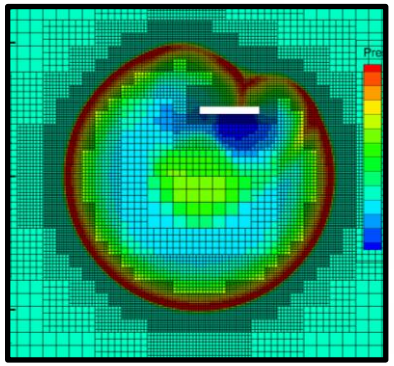
AECAT Validation Study – SciPan 4

- Reinforced concrete, masonry structure
  - 14- and 17-cm reinforced concrete, 20-cm concrete masonry units
- 1000 kg NEQ, centre of PES, low loading density
- Naval Air Warfare Center, China Lake
  - Gauge measurements at 180° and 270°
  - Door, barricade towards 0°
- Simulation effects
  - Barricade effects (receptor)
  - Blast loading (pressure, impulse, timing)
  - Debris loading (PSD, spatial distribution)

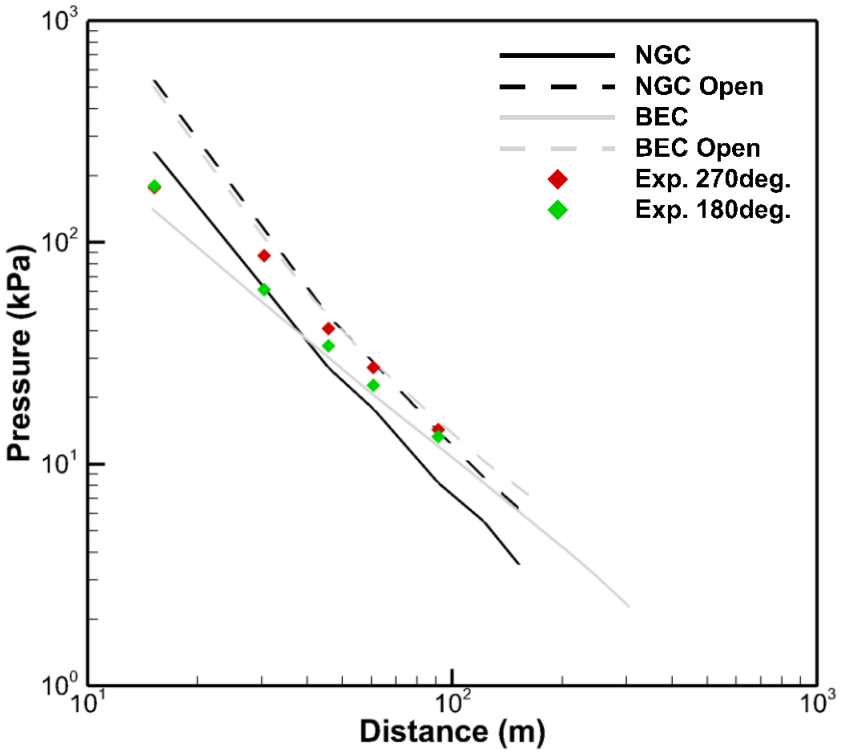


Ammunition and Explosives Consequence Analysis Tool (AECAT)

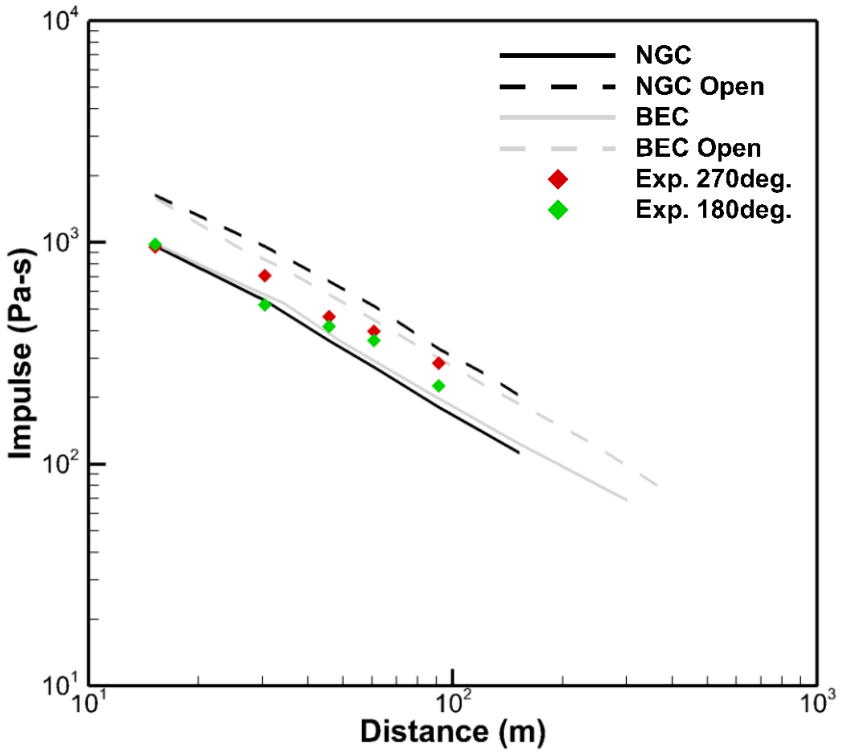
AECAT Validation Study – SciPan 4 – Gauge Results



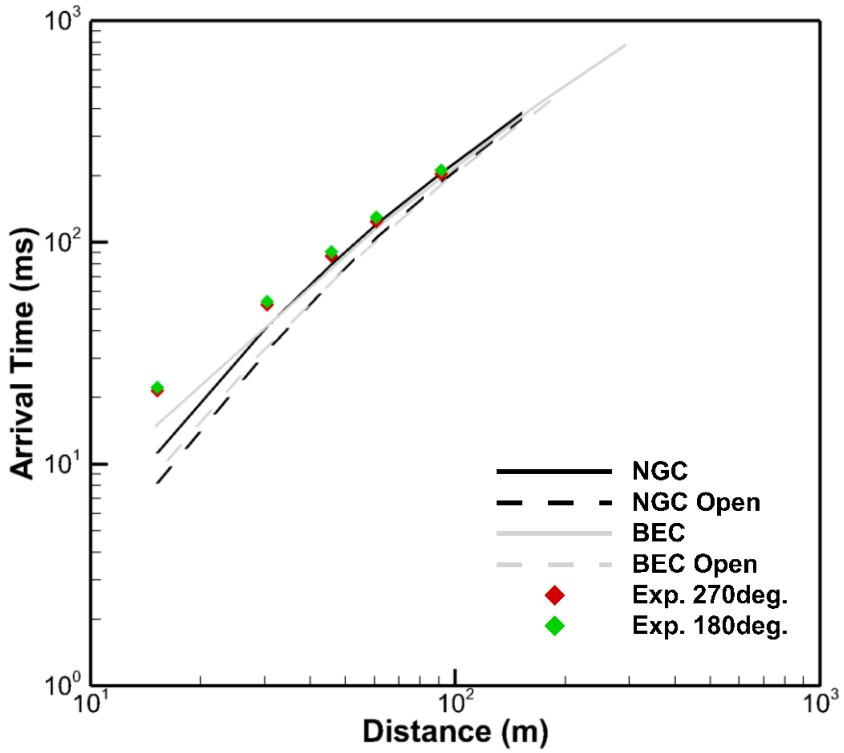
Overpressure



Impulse

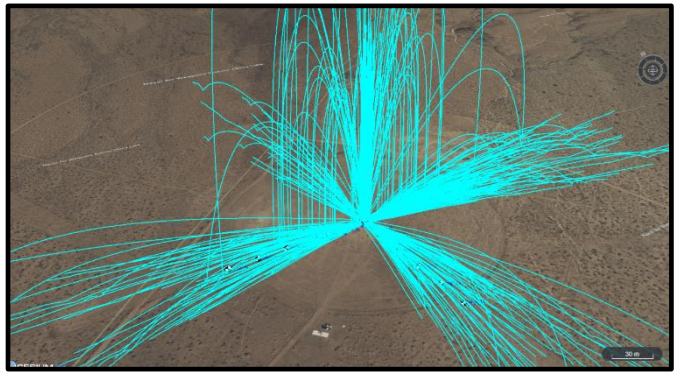


Arrival Time

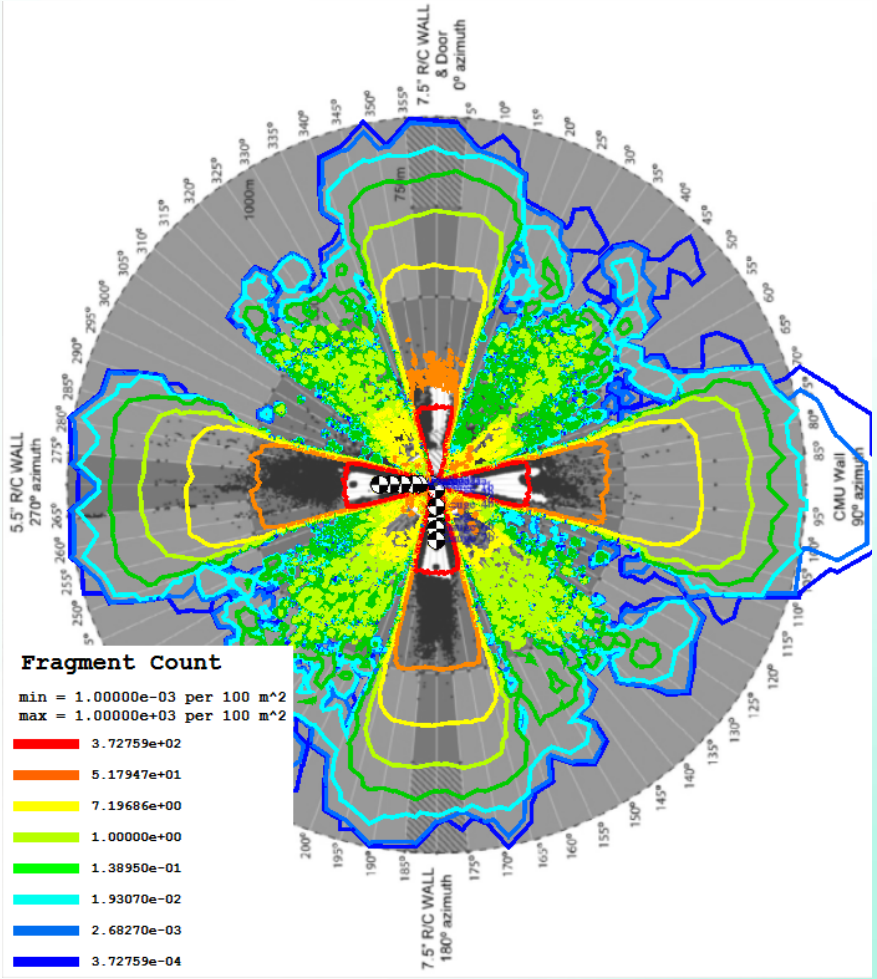


Ammunition and Explosives Consequence Analysis Tool (AECAT)

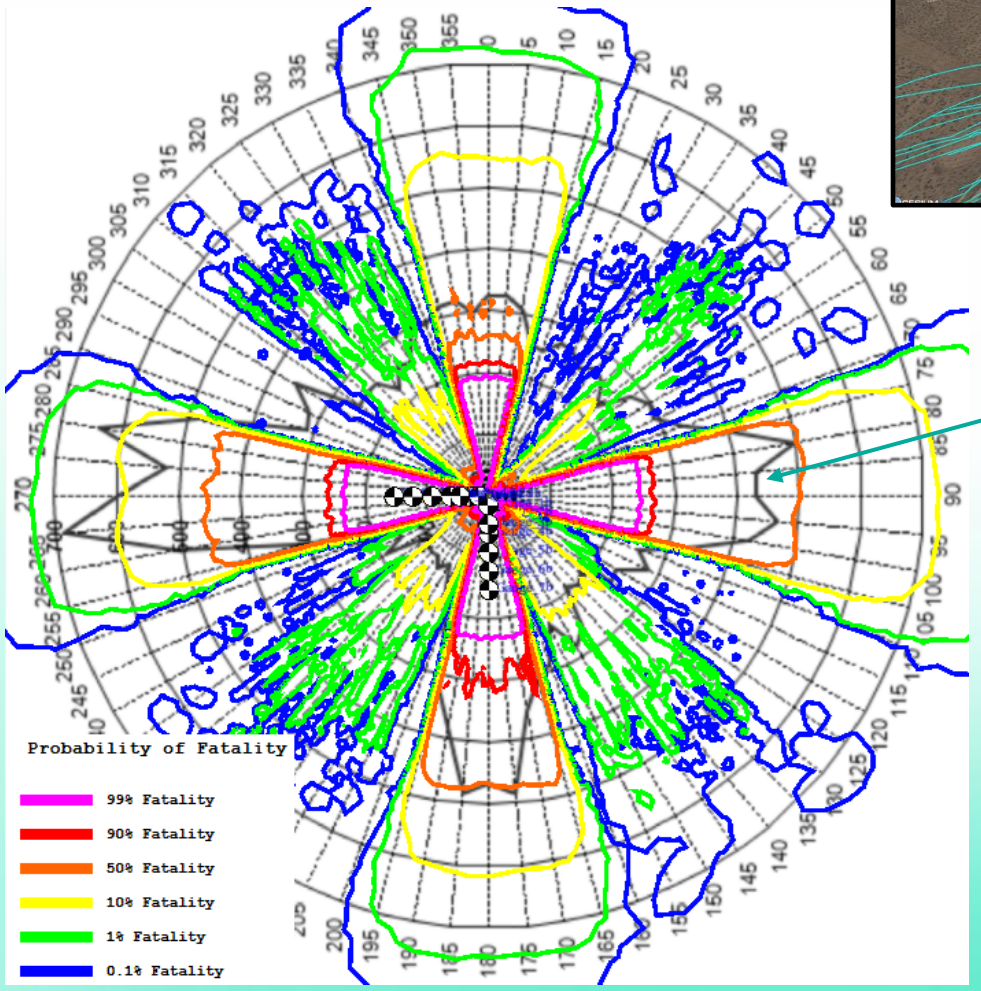
AECAT Validation Study – SciPan 4 – Debris throw



Debris Count



Probability of Fatality

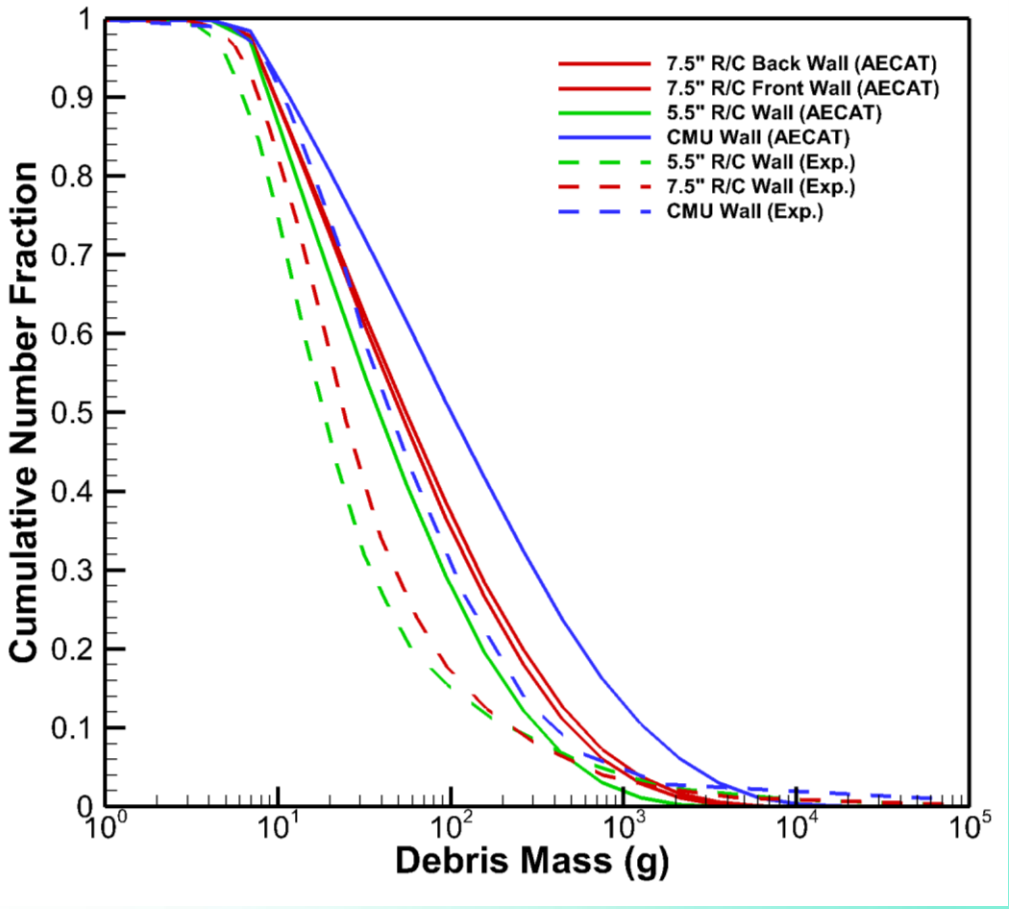


IBD

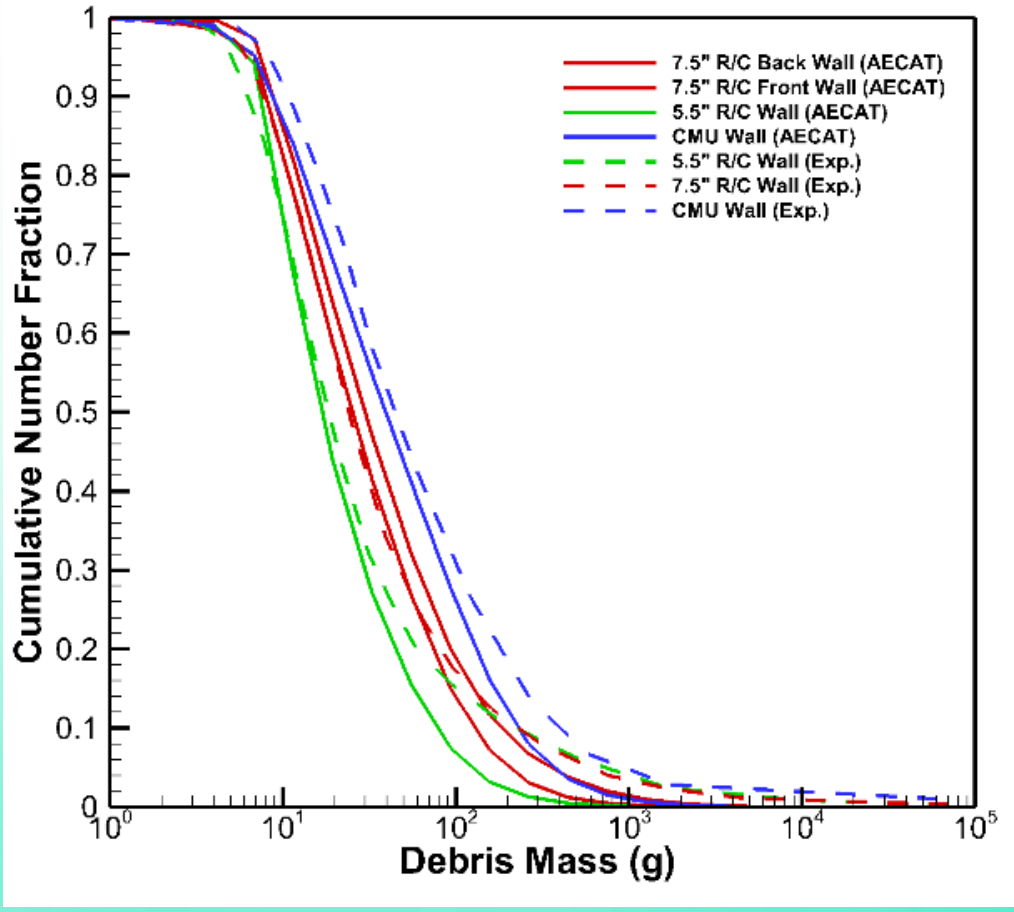
Ammunition and Explosives Consequence Analysis Tool (AECAT)

AECAT Validation Study – SciPan 4 – Debris size distribution

Before shattering



After shattering

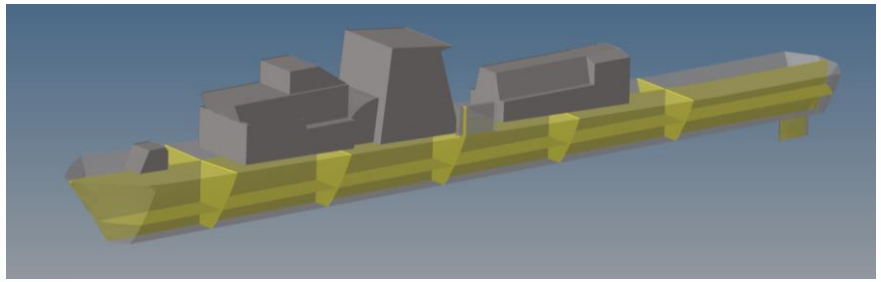


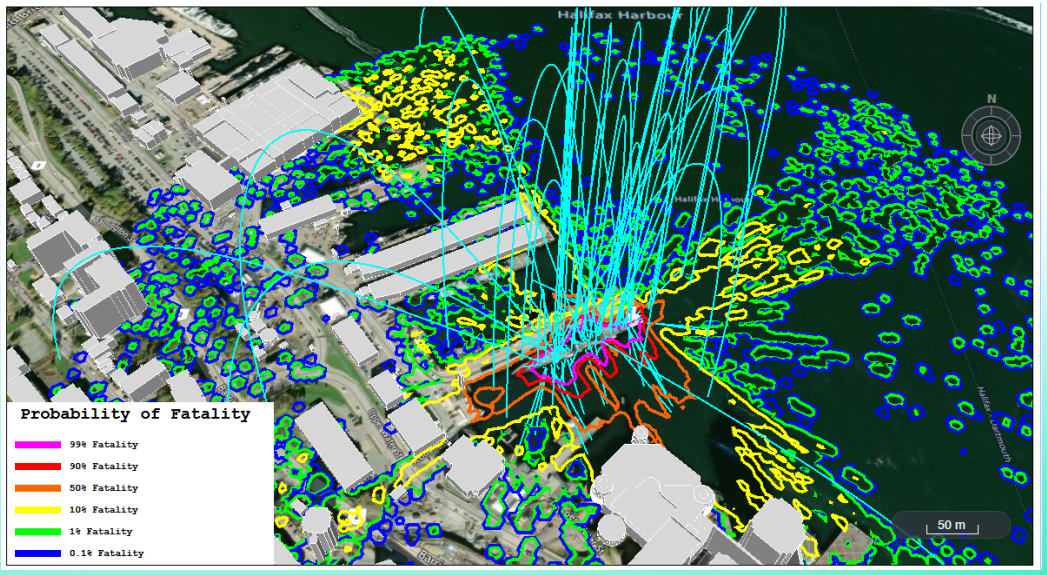
Enhancements for Naval Storage Scenarios

Ammunition and Explosives Consequence Analysis Tool (AECAT)

System Enhancement for Naval Storage (SENS)

- **Advance capabilities** to support risk analysis of munitions scenarios with **naval ships**
  - Stack/magazine definition within ship compartments
  - 3D terrain visualization and water surface
  - Water response, low energy effects, large fragments, sympathetic detonation
- **Improve performance**, usability, and sustainability
  - Testing and workflow updates
  - Batched calculations for parametric UQ
- **Validation** of modelling approaches
- **Deployment** and support within Canada



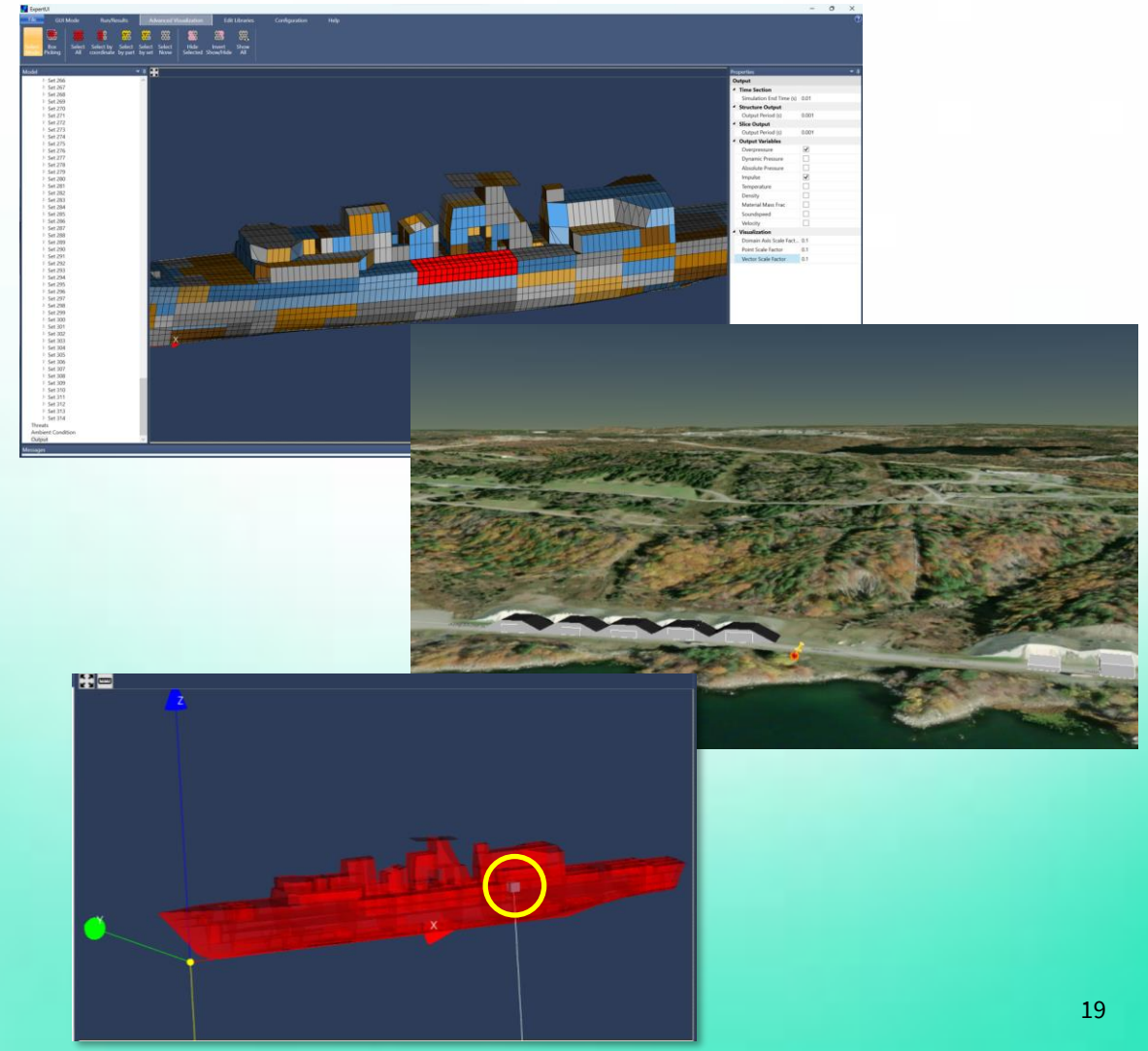


Hypothetical naval ship storage scenario in Halifax Harbour in AECAT with simplified ship compartment geometry

Ammunition and Explosives Consequence Analysis Tool (AECAT)

Naval Storage Enhancements

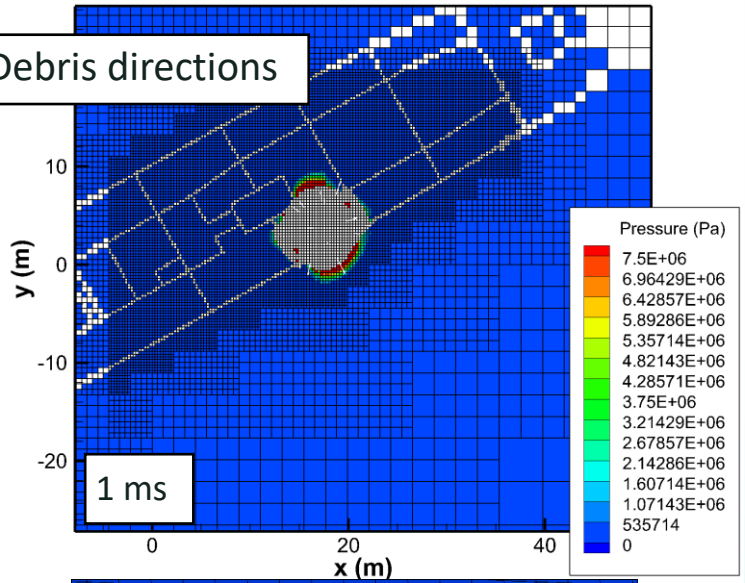
- System enhancements
  - Visualization of elevation in Virtual Globe
  - Interaction with multi-compartment models
- Use case definitions and workshop
  - Review of AASTP-1 (Ed. D, V.1) Part IV, Ch. 6 “Naval and Military Ports
  - Vessel scenarios and barricades
- Solver enhancements
  - Fragmentation solver speedup (parallelization, GPU)
  - Ship storage magazine modelling
    - Halifax Harbour scenario (20,000 kg TNT, uncased)

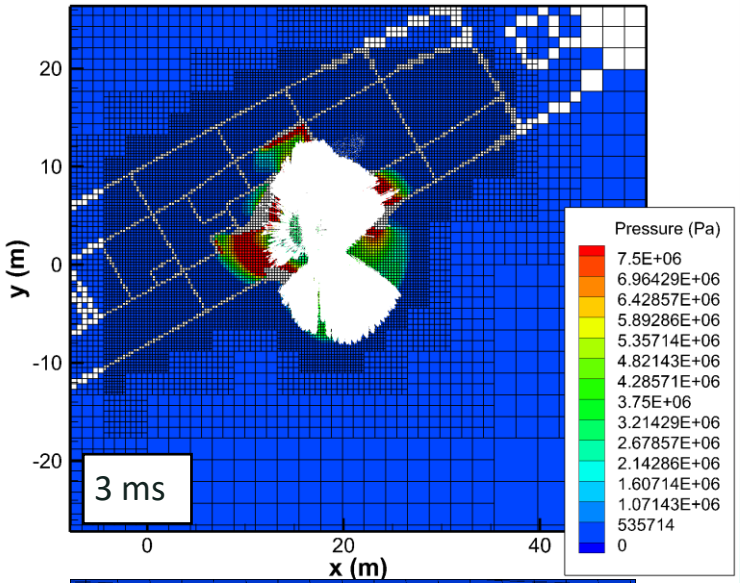


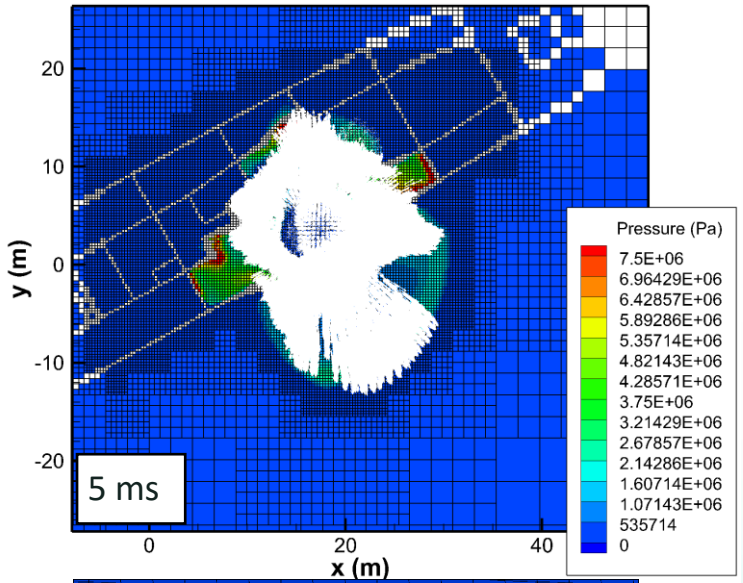
Ammunition and Explosives Consequence Analysis Tool (AECAT)

Naval Storage Enhancements – Debris breakup (Detailed solver)

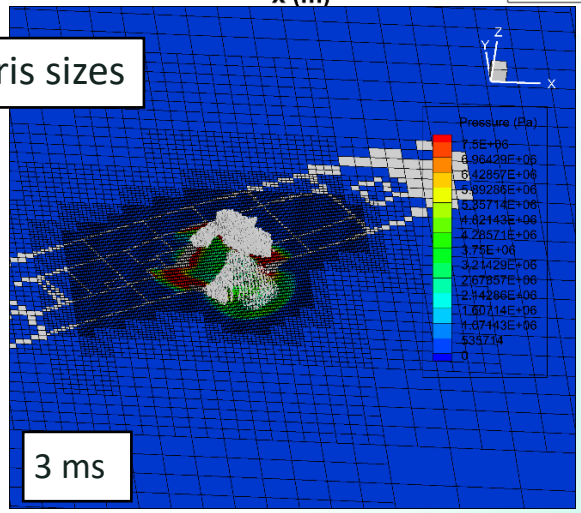
Debris directions

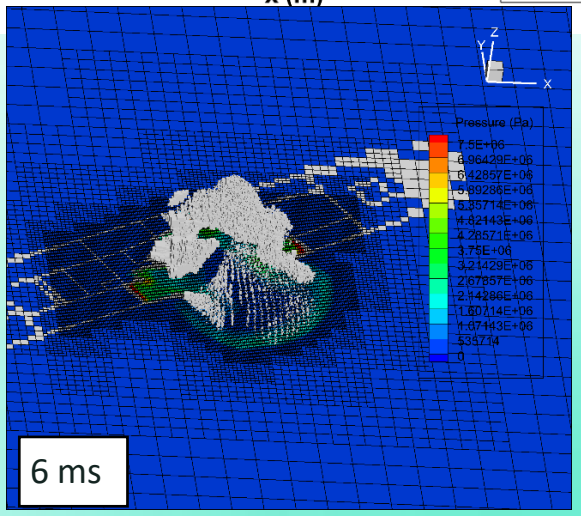


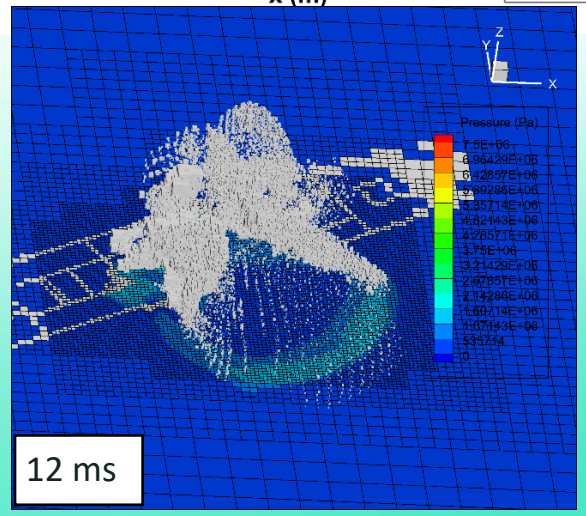




Debris sizes

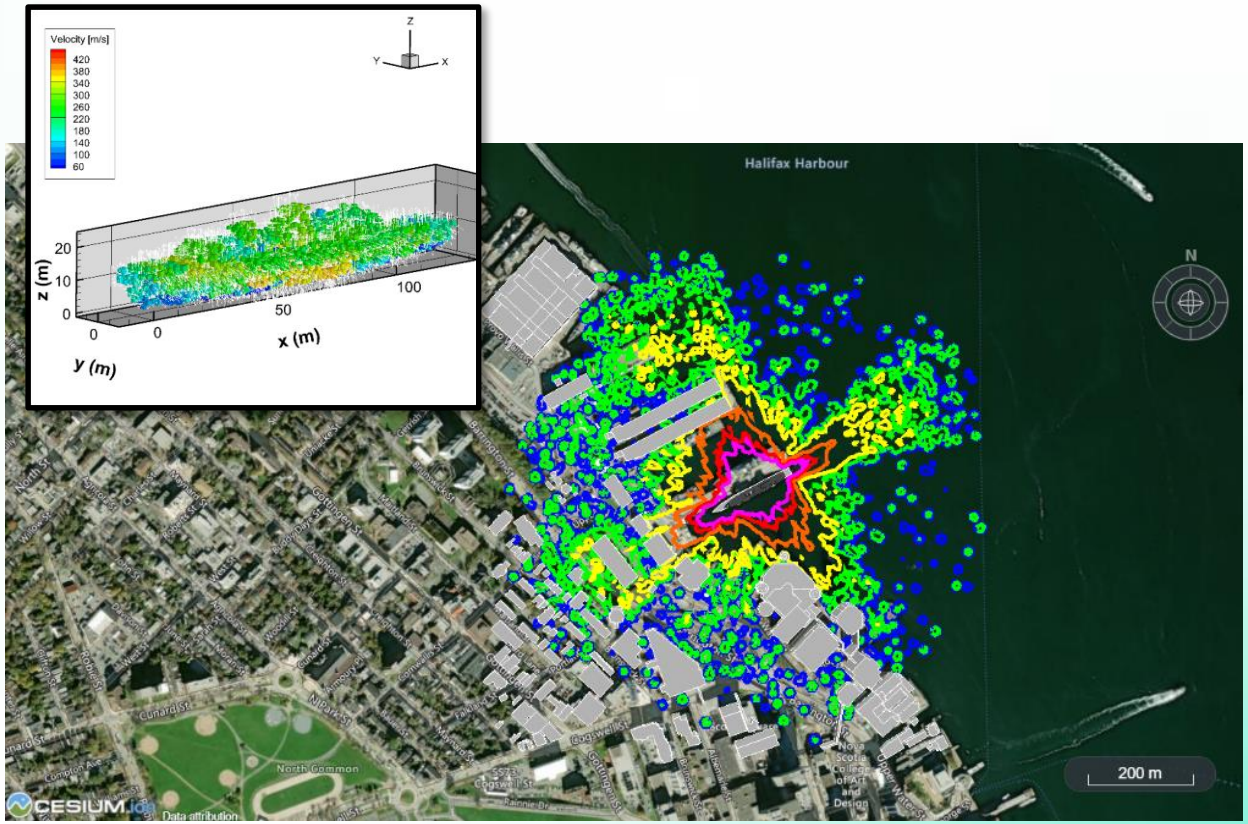




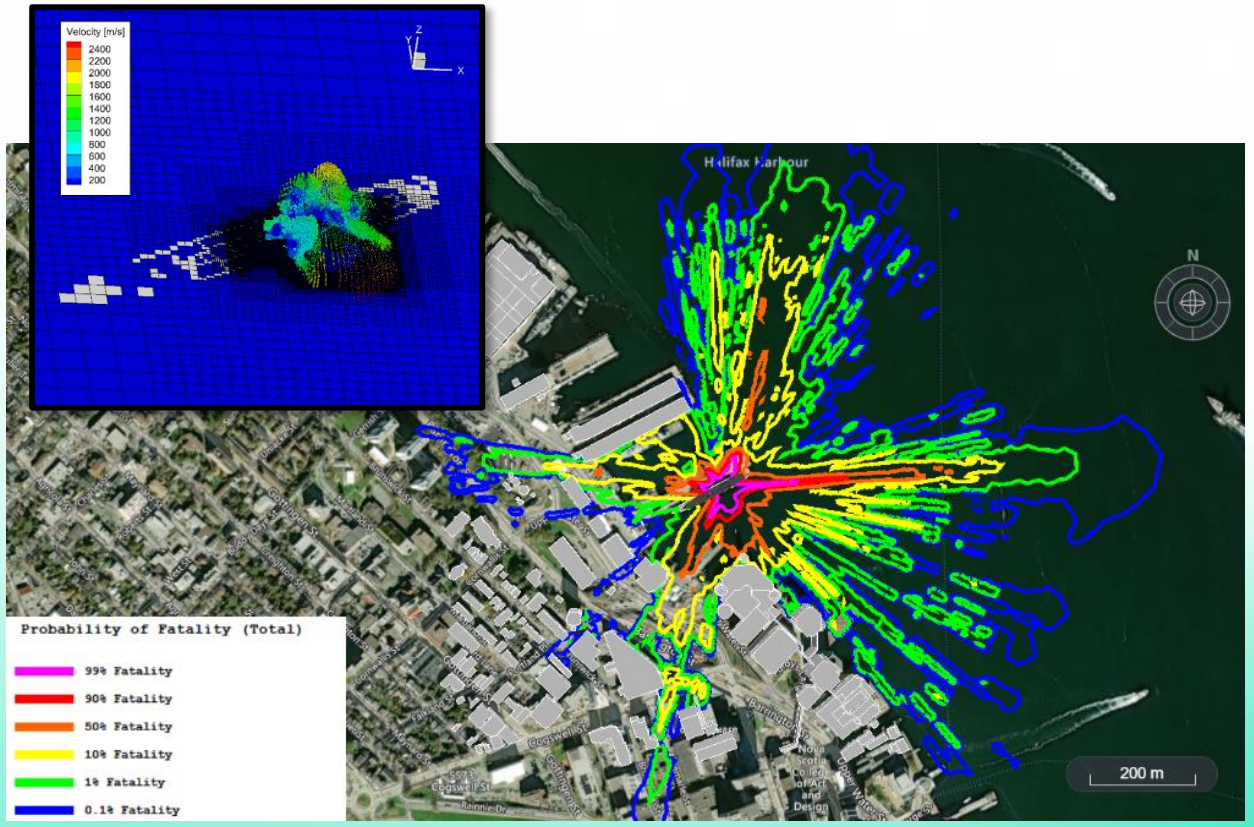


Ammunition and Explosives Consequence Analysis Tool (AECAT)

Naval Storage Enhancements – Probability of Fatality Contours



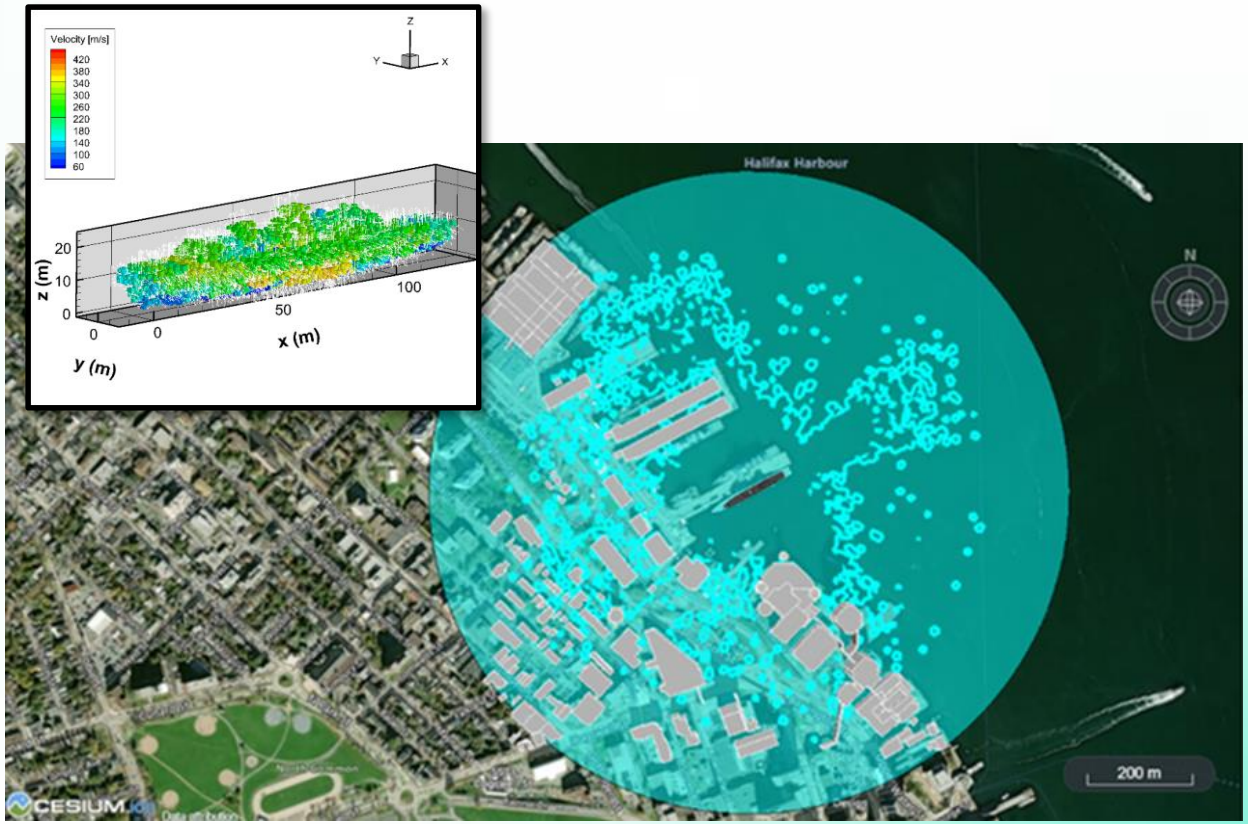
Fast fragmentation (3D Generalized Gurney) – Preliminary Result



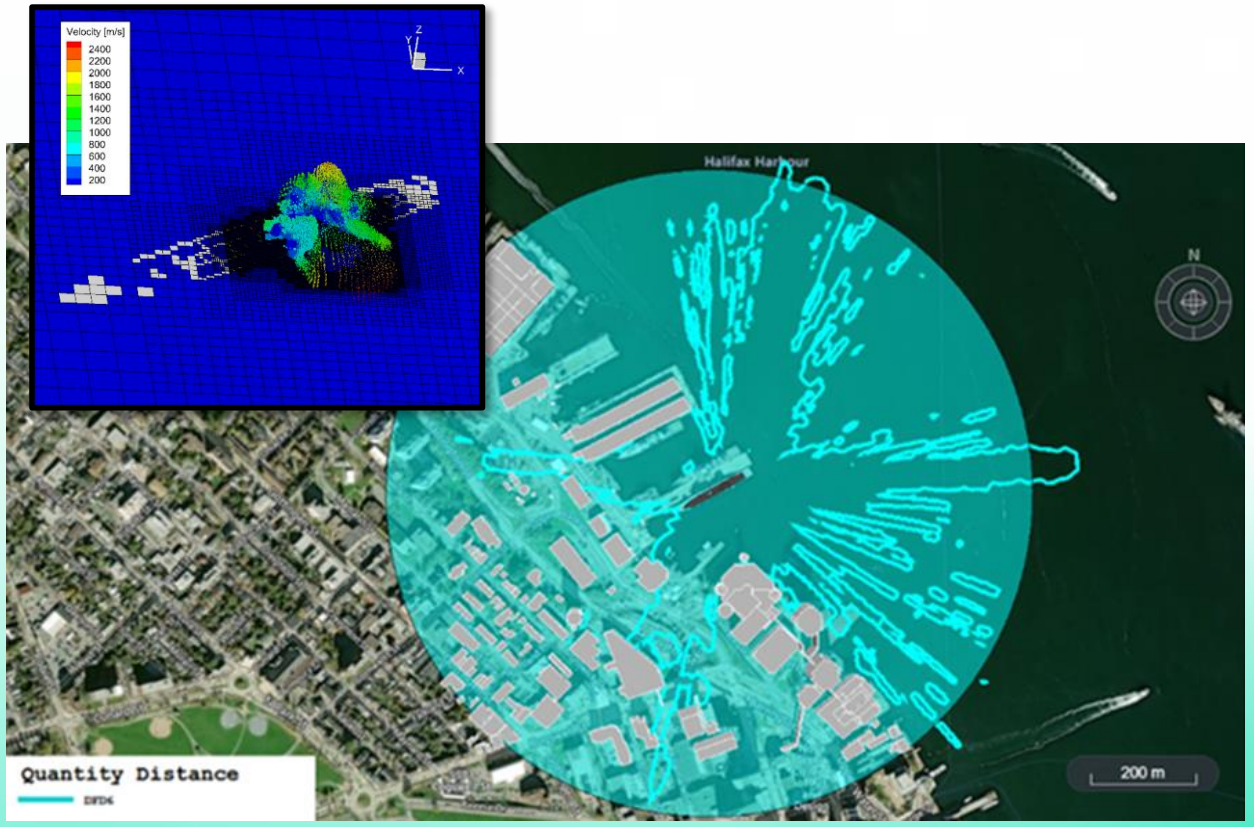
Detailed (continuum) breakup

Ammunition and Explosives Consequence Analysis Tool (AECAT)

Naval Storage Enhancements – 1% prob. Fatality and DFD6 (IBD)



Fast fragmentation (3D Generalized Gurney) – Preliminary Result



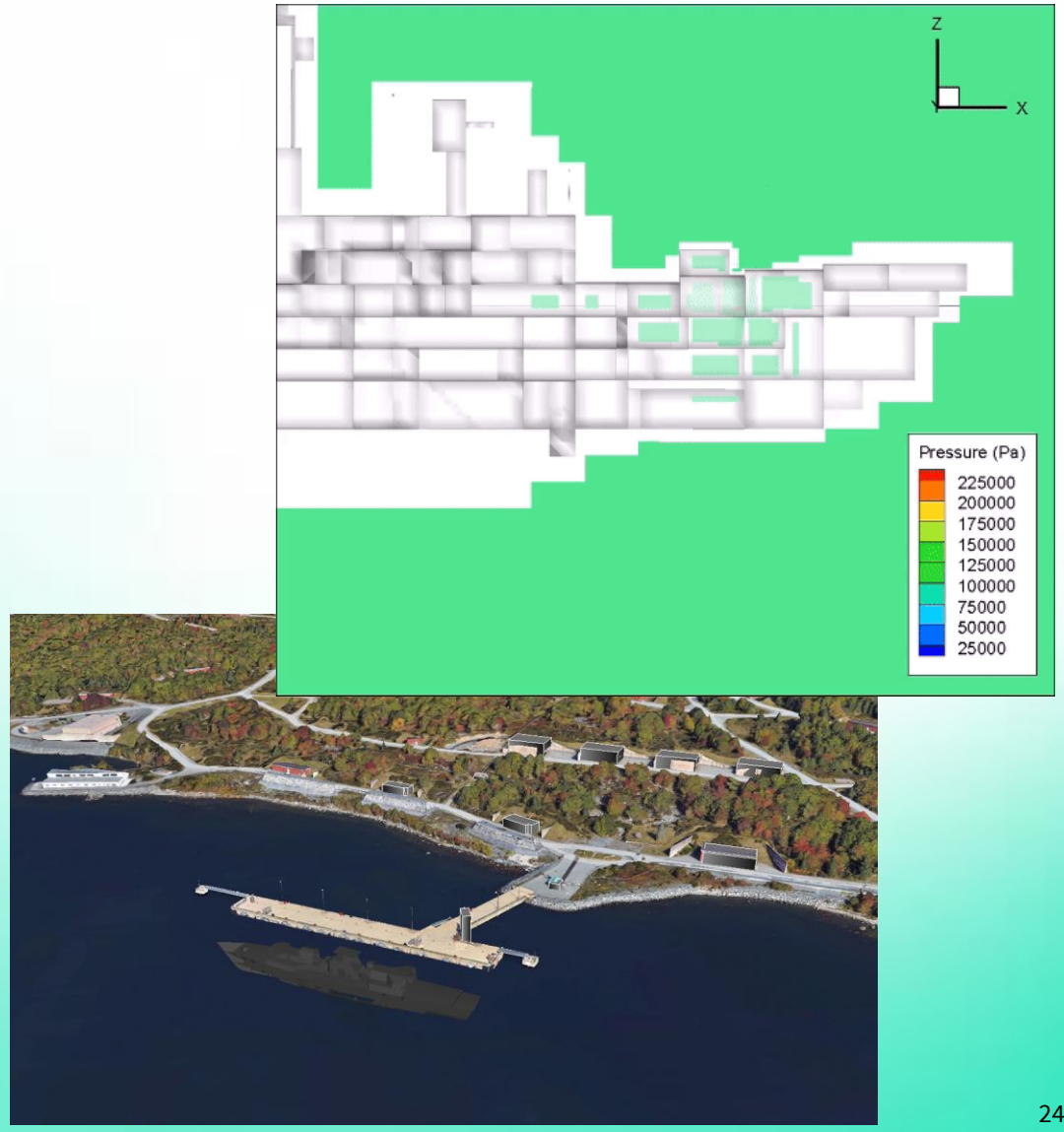
Detailed (continuum) breakup

Future Work

Ammunition and Explosives Consequence Analysis Tool (AECAT)

Future Work

- Validation of existing modelling approaches
  - USA MERCURY 10 Trial (October 2025)
  - Singapore ECM Trial (Planned 2027)
  - Germany NATO ECM 146 (Planned 2028)
- Naval enhancements
  - Inter-compartment propagation
  - Successive failure of adjacent volumes
  - Sympathetic detonation
- Platform enhancements
  - Risk assessments and event likelihoods
  - Expanded capability for siting and licensing activities



Thank you

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