Synthetik applied technologies

Protection Engineering CONSULTANTS

01/22/2026

Development of enhanced computational modeling simulation tools to support explosive safety projects for confined HD 1.3 events

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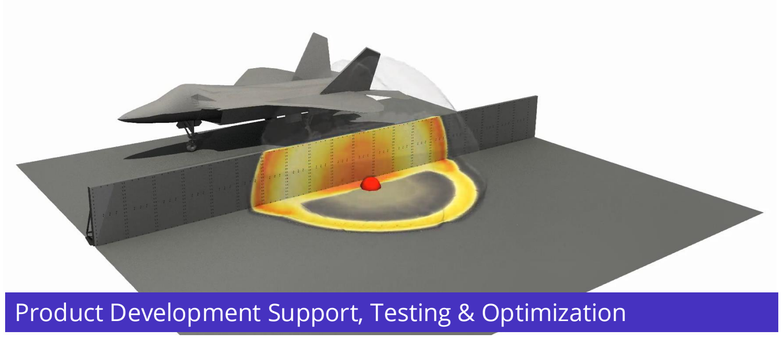
Two-Briefing Overview

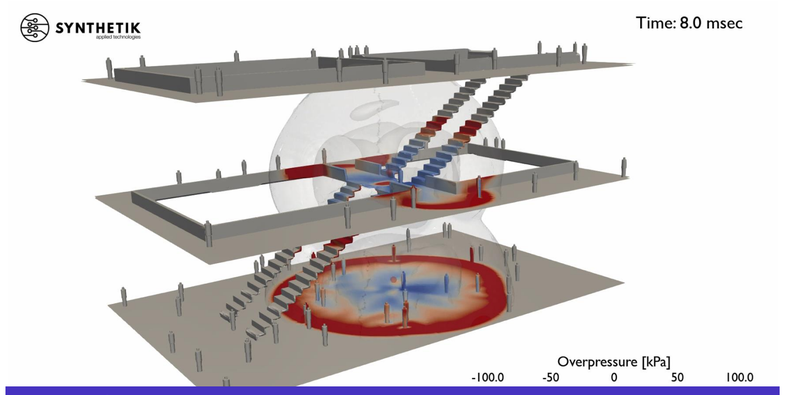
What we will be covering

- Synthetik + Protection Engineering Consultants (PEC)
- **Development of Enhanced Computational Modeling Tools for Confined HD 1.3 Events**
  - What you'll get: physics, numerics, validation path, readiness for safety workflows
- **Application of Enhanced Computational Modeling Tools for Confined HD 1.3 Events**
  - What you'll get: Validation examples, how this changes safety assessments and design choices

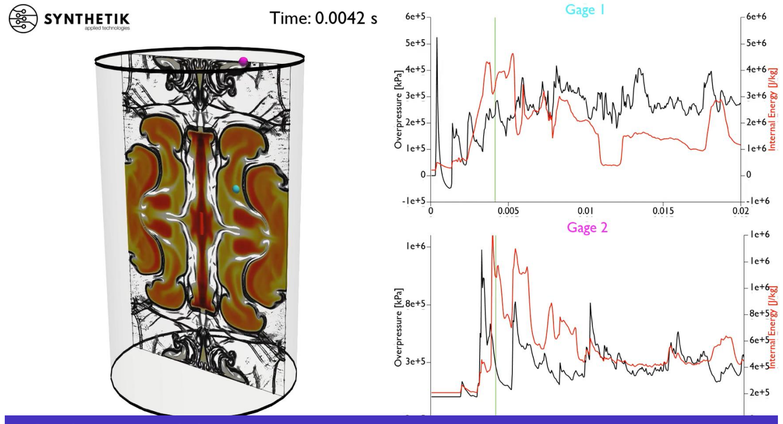
Synthetik
applied technologies



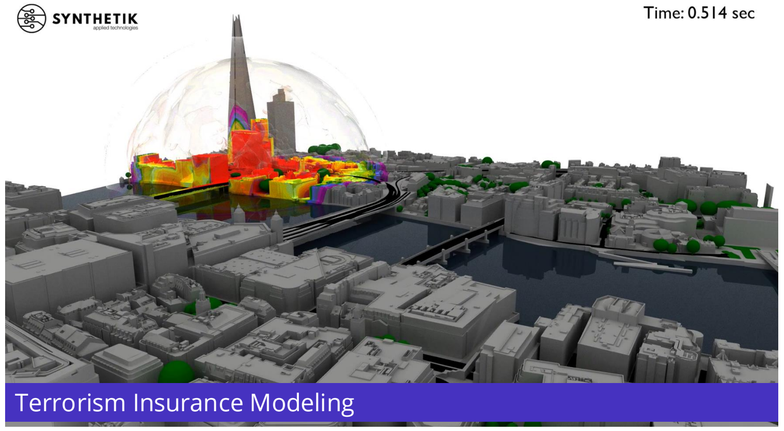
Product Development Support, Testing & Optimization



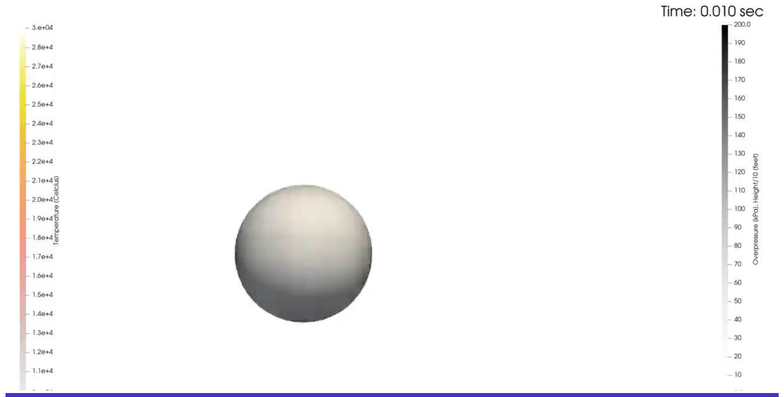
HIP Tool Integration



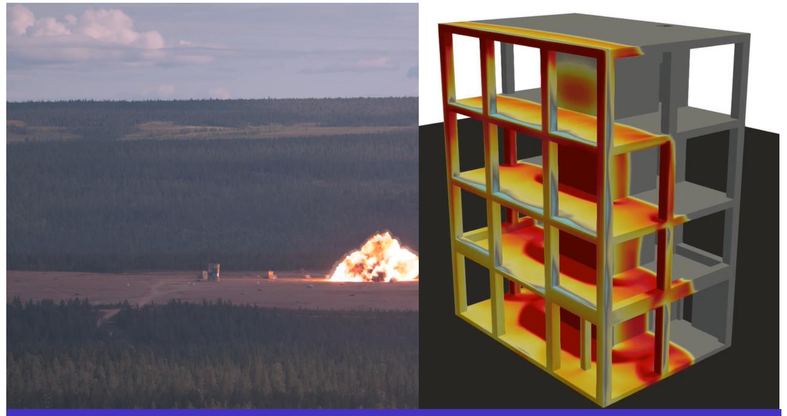
Afterburn Modeling



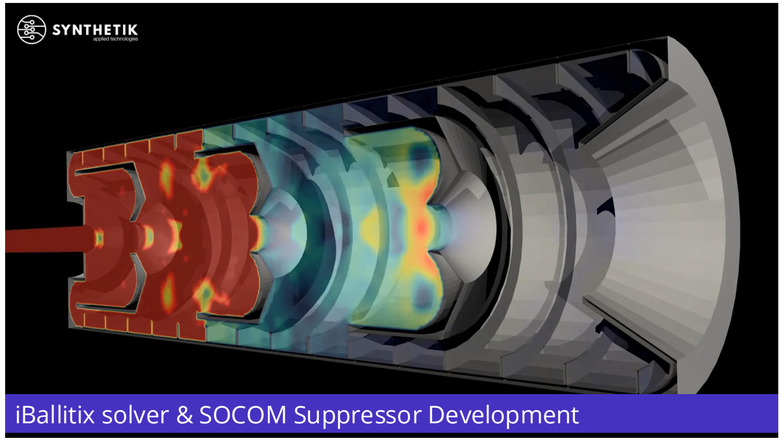
Terrorism Insurance Modeling



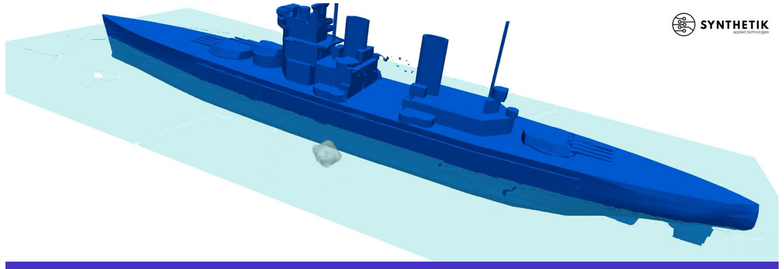
Nuclear Weapons Effects



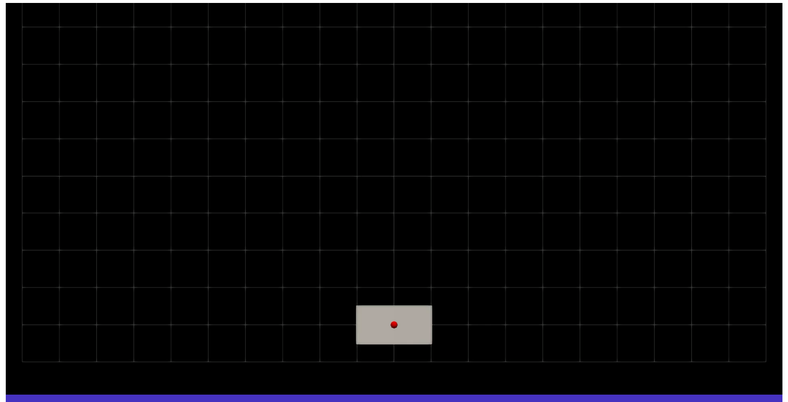
DoD Explosive Test Support



iBallitix solver & SOCOM Suppressor Development



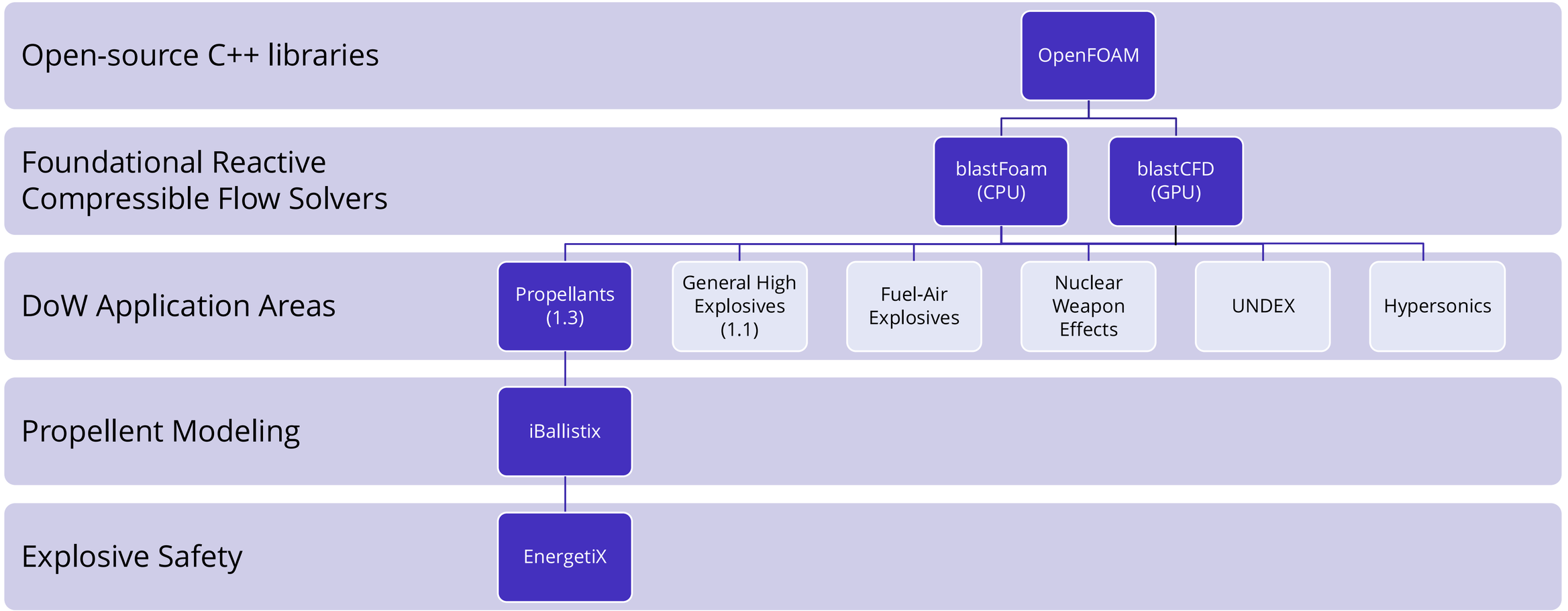
Maritime Lethality (UNDEX)



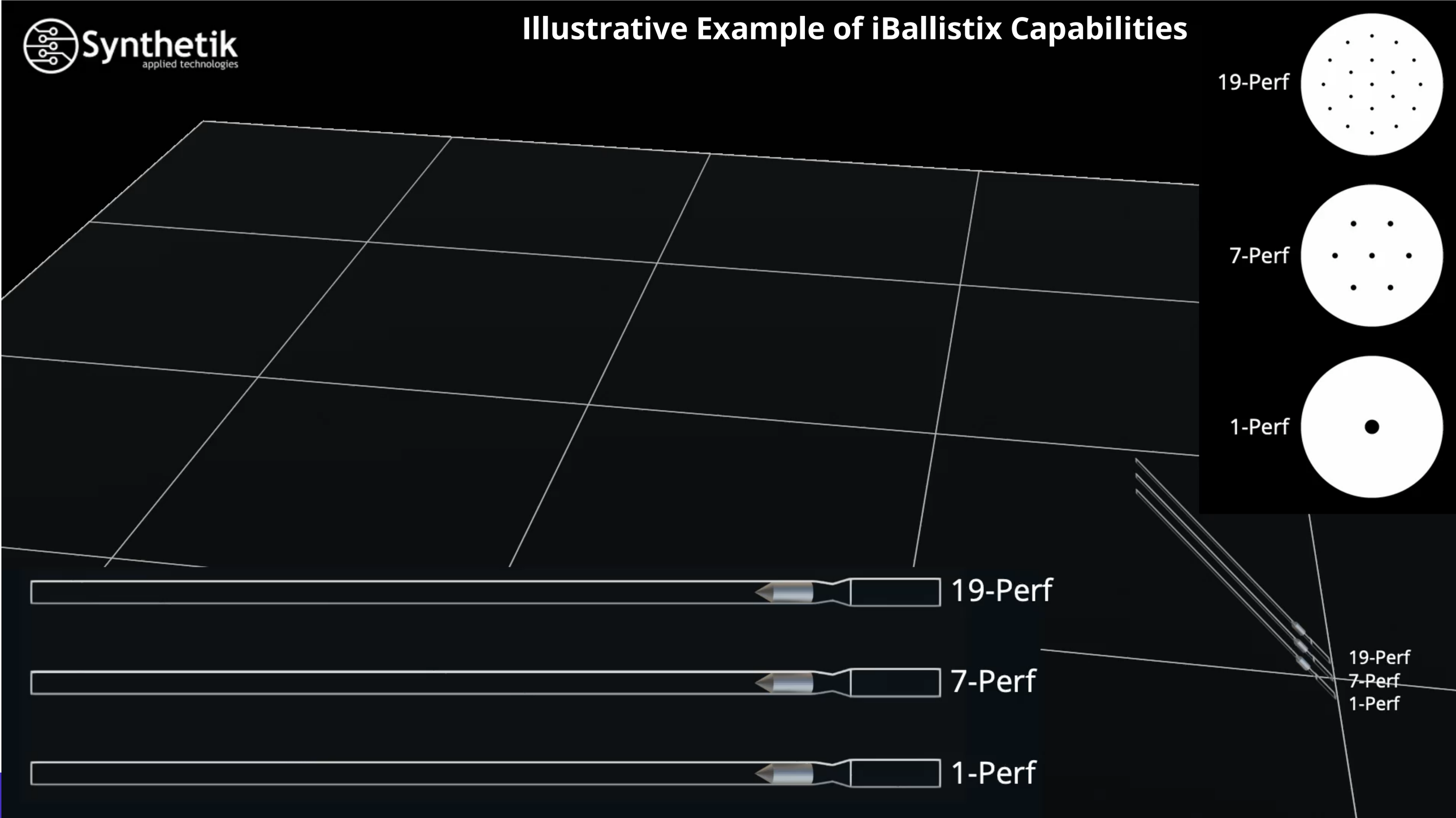
Fuel-Air Explosions

Synthetik Solver Ecosystem

Open-source suite of solvers



Illustrative Example of iBallistix Capabilities



iBallistix at a Glance: What It Models and What Makes It Different

iBallistix Capabilities

- **Multiphase + multi-dimensional interior ballistics CFD** built to represent gas/solid interactions and propellant combustion behavior at higher fidelity.
- **Run-time selectable models** for grain shapes, ignition approaches, burn rates, and thermochemistry - designed so key sub-models remain **independent** and avoid non-physical coupling.
- Supports **gun-cycle simulations** (including projectile motion / recoil options) and also **static environments** using arbitrary geometries (open/closed vessel style boundary conditions).
- Includes a **grain regression capability** that can compute regression curves from **STL or primitive geometry definitions**.
- Provides multiple **ignition criteria options** (e.g., time/pressure/thermal triggering) suitable for different study needs.
- Provides multiple **burn rate options** (e.g., temperature/pressure related).

iBallistix: Replacing Legacy Interior Ballistics Codes

Why the Army needs a modern solver approach (and why that matters to safety)?

- Legacy tools provide value, but make it hard to extend to modern needs (novel charges/ignition/geometry + coupled mechanics)
- Examples of legacy approaches and limits:
  - **IBHVG**: well-stirred/0D assumptions; rapid parametrics but limited physics
  - **NOVA/XKTC**: quasi-1D two-phase with empirical closures; ignition via prescribed profiles
  - **NGEN**: multidimensional/multiphase with Eulerian–Lagrangian structure; complex to evolve/maintain
- **iBallistix objective:** a modern, maintainable, extensible multiphase CFD solver for charge + ignition + launch-cycle physics
- iBallistix is a 5-year effort with the Army, via NAC DOTC, to deliver a **state-of-the-art multiphase CFD capability** for ignition/propellant problems in multi-D.

‘Beyond the Barrel’

General Geometries, Motion, and Boundary Conditions

- iBallistix supports moving boundary problems (projectile motion; optional recoil model)
- Supports rifling/smoothbore options and geometry variations to represent real launch environments
- Also supports **static environments** with arbitrary geometry:
  - boundary conditions can represent **open environment** or **closed vessel**
- Roadmap aligns with **Explosive Safety** multi-physics needs (e.g., ignition stimuli, integrating regression interface, etc.)

Multi-scale Modeling

How we leverage iBallistix capabilities for Explosive Safety Applications

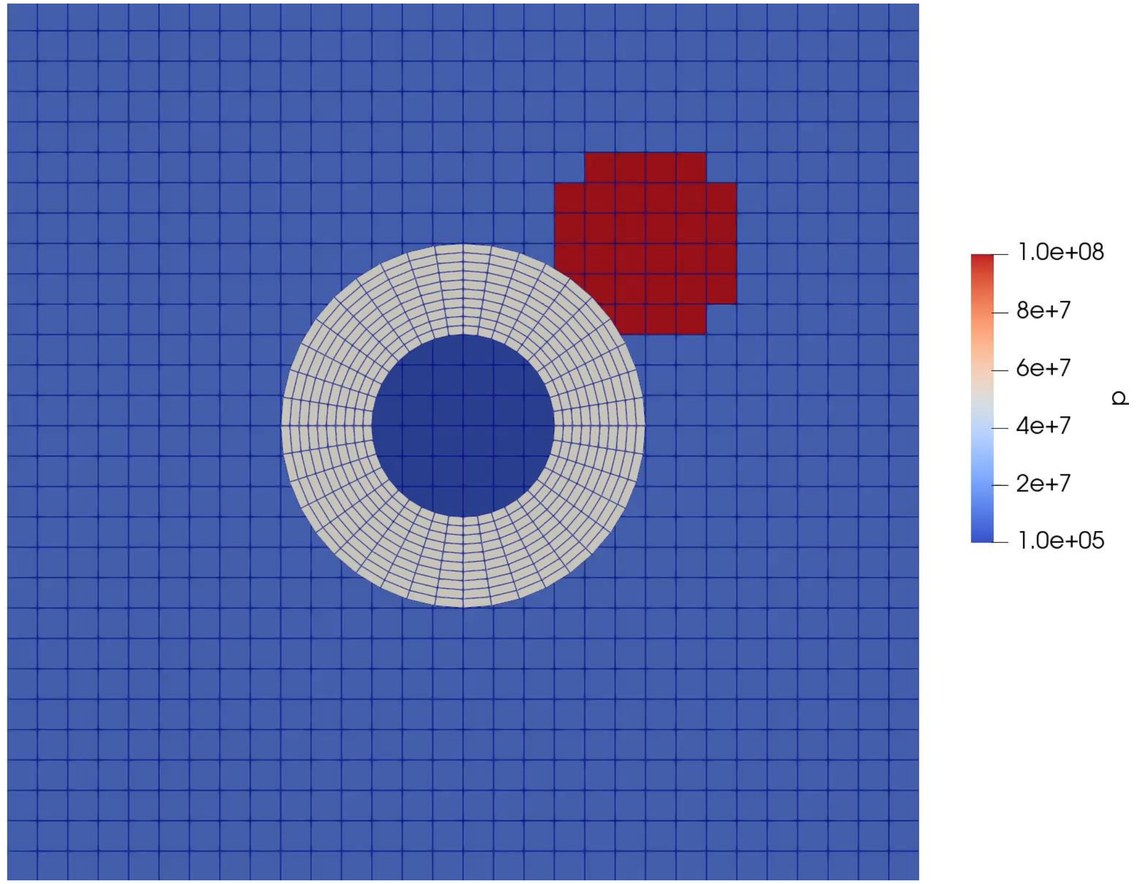
Micro-scale:
- Individual propellent grain

Meso-scale:
- Multiple propellent grains

Macro-scale:
- Container(s) of propellent

Internal Ballistics (iBallistix)

Explosive Safety (EnergetiX)



Illustrative example of surface regression. Note 1) the asymmetric ignition source and subsequent burn, 2) the pressure build-up and release in the enclosed center of the ring

Validation: Closed bomb - burn-model fidelity

Burn-model fidelity

1) What we were trying to achieve

- Prove that iBallistix reproduces correct mass & energy release from propellant regression
- Demonstrate that complex multilayer thermochemistry is handled without “tuning”

2) Why this matters for propellant-burn simulation

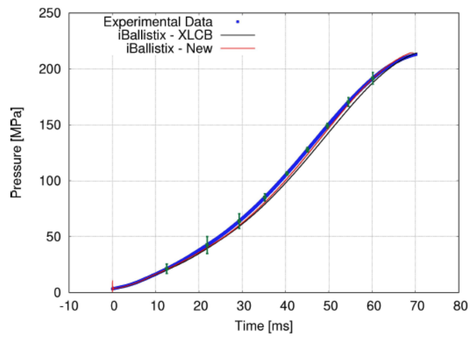
- Closed bombs are the primary sub-scale burn-rate characterization test
- Dynamic vivacity (dP/dt normalized) is a direct proxy for evolving burning surface area

3) What the validation is simulating

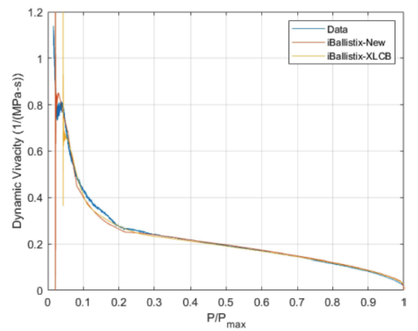
- Three experimental cases: homogeneous, deterred, layered grains

4) Results / successes

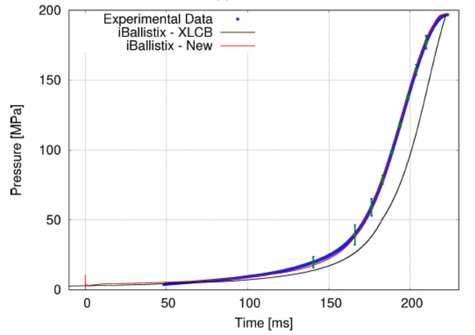
- Mean pressure error vs experiment: 3.3% (Case 1), 6.8% (deterred), 3.7% (layered).
- Legacy closed-bomb reduction can be non-predictive for complex grains



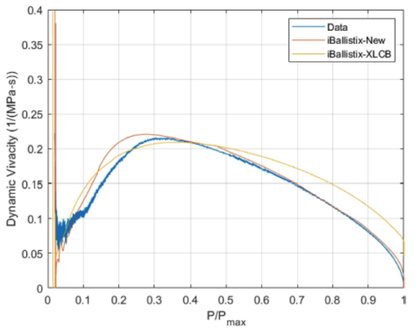
(a) Case 1



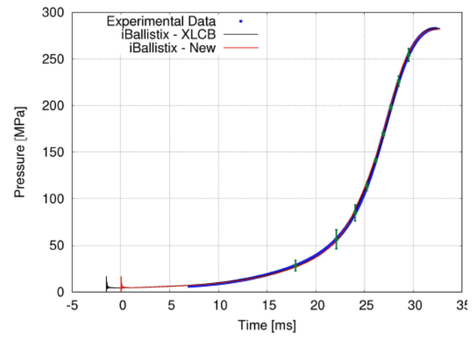
(a) Case 1

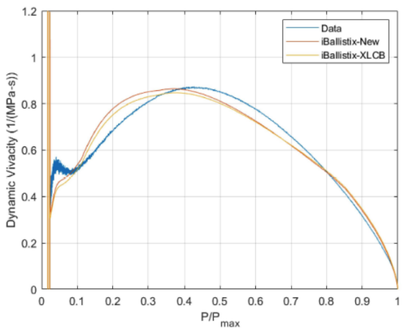


(b) Case 2



(b) Case 2





Houthuysen, C., and Parziale, N., “A Numerical Determination of Complex Solid Gun Propellant Burn Rates Through Closed Bomb Simulation,” Propellants, Explosives, Pyrotechnics, Volume 49, Issue 6, May 2024.

Validation: AGARD gun

Full-cycle interior ballistics

1) What we were trying to achieve

- Demonstrate correct system-level coupling
- Burn → gas generation → pressure waves/gradients → bed dynamics → projectile motion.
- Benchmark iBallistix predictions against established interior ballistics solvers

2) Why this matters for propellant-burn simulation

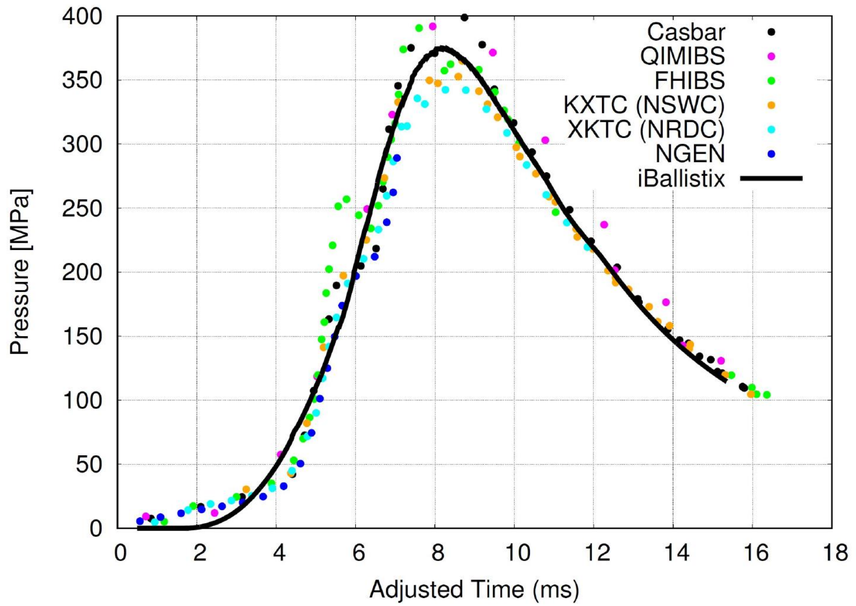
- Real guns are not “well-stirred”
- Solver must match BOTH closed bombs and compressible, 2-phase gun environment

3) What the validation is simulating

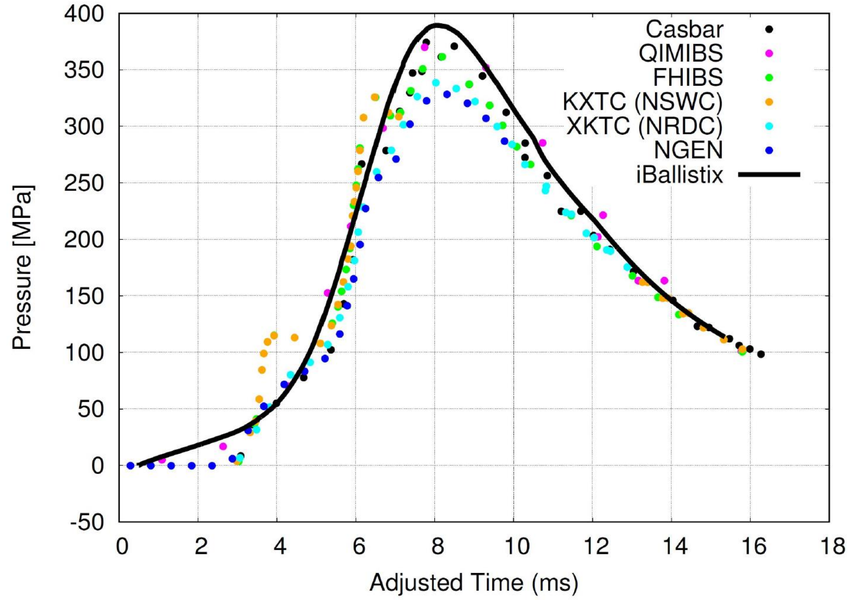
- Fictitious large-caliber AGARD gun
- Two cases: (1) uniform ignition/no ignitor; (2) ignitor mass injected over 10 ms

4) Results / successes

- Pressure-time curves at both gauges closely track the “cloud” of legacy solver predictions
- Peak pressure at the rear gauge is in-family with established codes
- Confirms iBallistix remains sta predictive when burn is coupled to compressible 2-phase flow and ignition physics.



(a) Rear Gauge Pressure-Time Curve



Houthuysen, C., Heylmun, J., Parziale, N., “Initial Development of Multiphase Interior Ballistics Solver in Modular Open-source Environment”, Proceedings from JANNAF 69th JPM Subcommittee Meeting; Newport News, VA, June 2022.

Why This Matters for Explosive Safety (EnergetiX)

Shared Physics, Shared Workflow, Shared Safety Outcomes

- EnergetiX is built on the **same blastFoam foundation** to model **HD 1.3 deflagration in confined environments** with coupled multi-physics.

- EnergetiX enhancements mirror the kinds of extensions pioneered across the blastFoam ecosystem:
  - solid regression modeling
  - multi-species afterburn chemistry
  - fluid-structure interaction for breach/door/hatch behavior
  - 3D resolution + adaptive mesh strategies

- Both solvers emphasize **workflow practicality**: OpenFOAM tools for pre-processing and **ParaView/Python-based post-processing**, deployable on desktops and clusters.

- EnergetiX is explicitly aimed at **explosives safety** deliverables: supporting hazard analyses, ESQD siting, protective design, and DDESB-aligned submissions.

- “Bottom line” relevance: iBallistix demonstrates the **architecture + validation philosophy** that enables EnergetiX to be a credible, extensible tool for safety-critical energetic events—just in a different application space.

Why HD 1.3 in confinement is a challenging problem

What matters most?

- HD 1.3 outcomes vary widely (moderate burn to violent deflagration)
- Confinement/venting controls pressure rise, structural response, hazard severity
- Modern energetic systems + facility constraints increase demand for defensible predictions

What legacy approaches struggle to capture

Take into the design

- Empirical / simplified thermodynamics often lack needed granularity for real structures
- **Key challenges:**
  - gas expansion/venting;
  - transition to violent pressurization;
  - Structural response dependence on structure and thermodynamic state

EnergetiX: what it is (in one picture)

Energy-to-hazard pipeline

- An open-source computational framework for **confined HD 1.3 event analysis**
- Built by extending blastFoam with models tailored to HD 1.3 phenomena
- Goal: improve predictive accuracy while staying computationally tractable

Energy-to-hazard pipeline

EnergetiX: Core capability additions (high level)

Energy-to-hazard pipeline

Solid propellant regression modeling

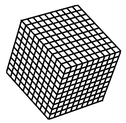
- Temperature/Pressure-dependent burn laws
- Geometry-aware mass addition options
- Provides physically grounded burn-rate feedback into pressurization

Multi-species afterburn chemistry

- Captures secondary combustion and delayed energy release
- Arrhenius-based kinetics for time-dependent chemical source terms
- Helps resolve scenarios where legacy tools under/over-predict late-time pressure

Basic coupled structural interaction

- Simplified FSI capability for doors/hatches (rigid body dynamics)
- Predicts opening motion, changing vent area, changing pressure relief rate
- Connects internal blast to structural response timing



3D resolution + spatial adaptability

- Finite volume on unstructured 3D meshes
- Adaptive resolution near steep pressure gradients / flame fronts
- Practical deployment on desktop or clusters

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