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X-ray Computed Tomography (XCT) of Confined Ceramics

S&T Campaign: Sciences for Lethality & Protection
Tier 2 Dynamic Failure of Materials

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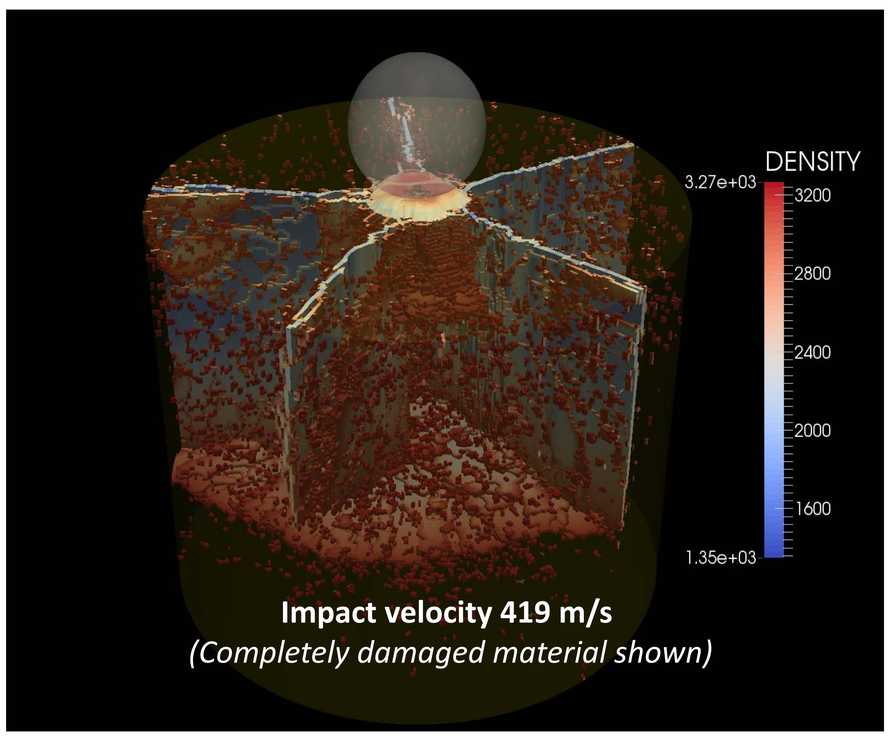
Research Objective

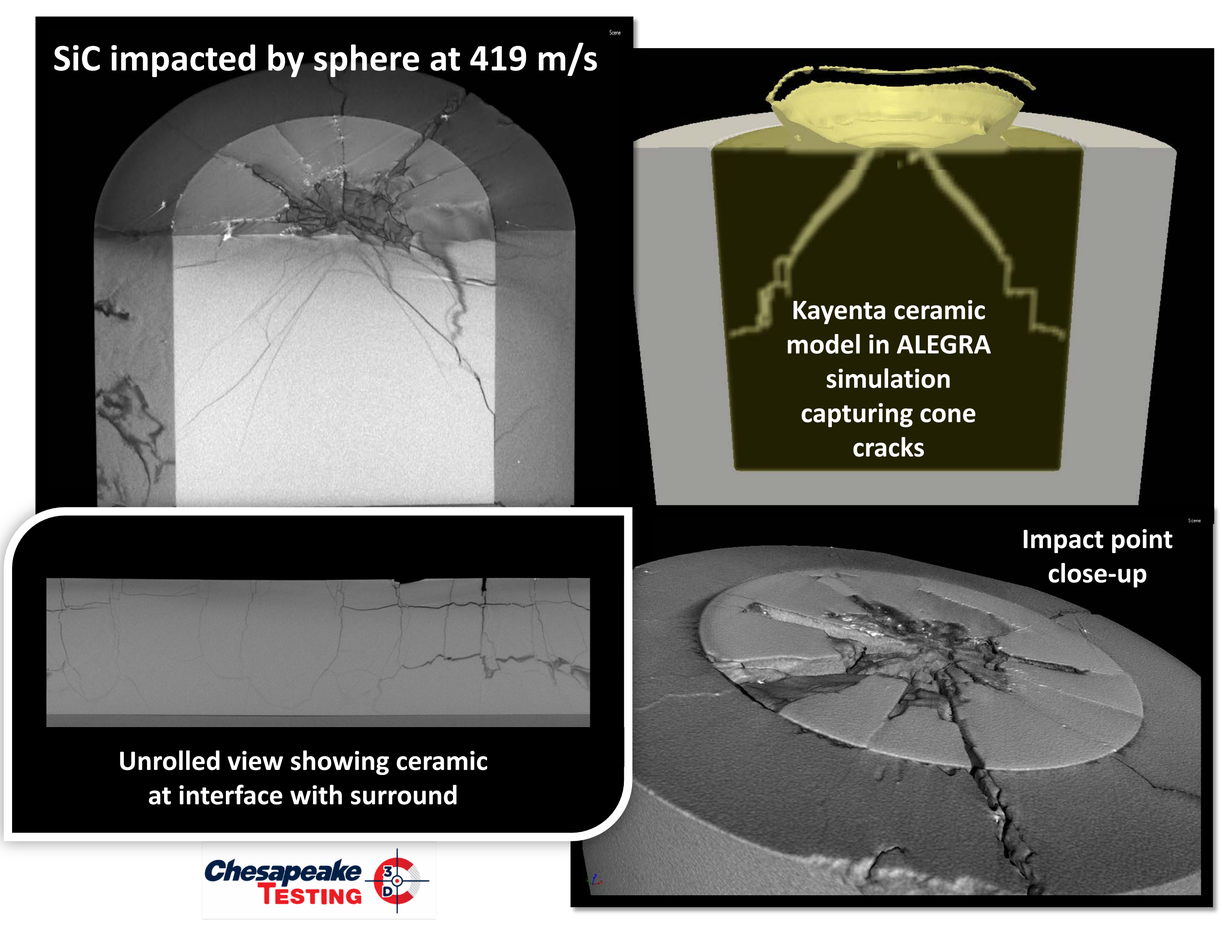
- Understand the complexities of brittle material dynamic failure
- Apply understanding to impact-resistant materials
- X-ray computed tomography (XCT) with improved resolution and enhanced size capabilities



Simulation of tungsten carbide sphere impact of a silicon carbide (SiC) target confined by a plastic cup

Challenges

- Current capabilities place a significant size restriction on target
- Existing XCT can only resolve large scale cracks and other features
- The examples seen here are small scale lab experiments with reduced dimensions displaying the current capabilities



X-ray computed tomography results after impact, and simulation demonstrating cone cracking

ARL Facilities and Capabilities Available to Support Collaborative Research

- XCT Capabilities:
  - Bruker SkyScan 1172, 100kV, micro-focus, 5μm resolution, small soft samples
  - North Star Imaging, 450kV, 125μm resolution, medium size samples
- Advanced Ballistic Impact Laboratory Facilities:
  - Small scale gas and powder guns from 30 caliber to 25mm, velocities from 50-1000 m/s
  - Medium sized indoor reverse and direct ballistics powder guns from 30 caliber to 50mm with velocities from 500-2000 m/s
  - Large outdoor powder guns from 25mm to 120mm with velocities from 800-2000 m/s
  - X-ray "stop-action" imaging (1MV, 450kV, 150kV)
  - Photon Doppler Velocimetry (PDV) diagnostics
  - Hi-speed digital cameras (1 M frames per second)
- Modeling and Simulation:
  - DoD High Performance Computer (HPC) supercomputers (IBM iDataPlex - 420 TFLOPS)
  - Department of Energy shock physics hydrocodes (ALEGRA, CTH, Sierra, ALE-3D)
  - Advanced constitutive models for brittle materials (Kayenta)
- References:

•Strack, O.E, Leavy, B., R. M. Brannon, (2014) Aleatory uncertainty and scale effects in computational damage models for failure and fragmentation. Int. J. Numerical Methods in Engineering, electronic version: http://dx.doi.org/10.1002/nme.4699
•Leavy, B., R. M. Brannon, Strack, O.E. (2010) The Use of Sphere Indentation Experiments to Characterize Ceramic Damage Models. Int. J. Applied Ceramic Technology, electronic version: http://dx.doi.org/10.1111/j.1744-7402.2010.02487.x
•Wells, J.M. and R.M. Brannon (2007) "Advances in X-ray Computed Tomography Diagnostics of Ballistic Impact Damage." *Metallurgical and Materials Transactions A, p. 2943-2949*

Complementary Expertise/ Facilities/ Capabilities Sought in Collaboration

- Dynamic in-situ imaging of material deformation and failure during ballistic impact
- Temporal and spatial improvements in XCT capabilities
- Mapping of XCT results with computational failure mechanics
- Novel computational approaches for dynamic fracture/failure

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