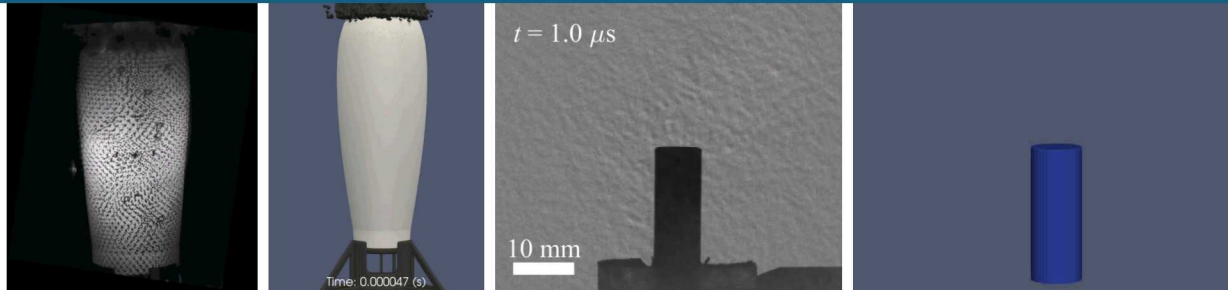


Optical Diagnostics for Cased Explosive Model Validation and Fragment Measurements

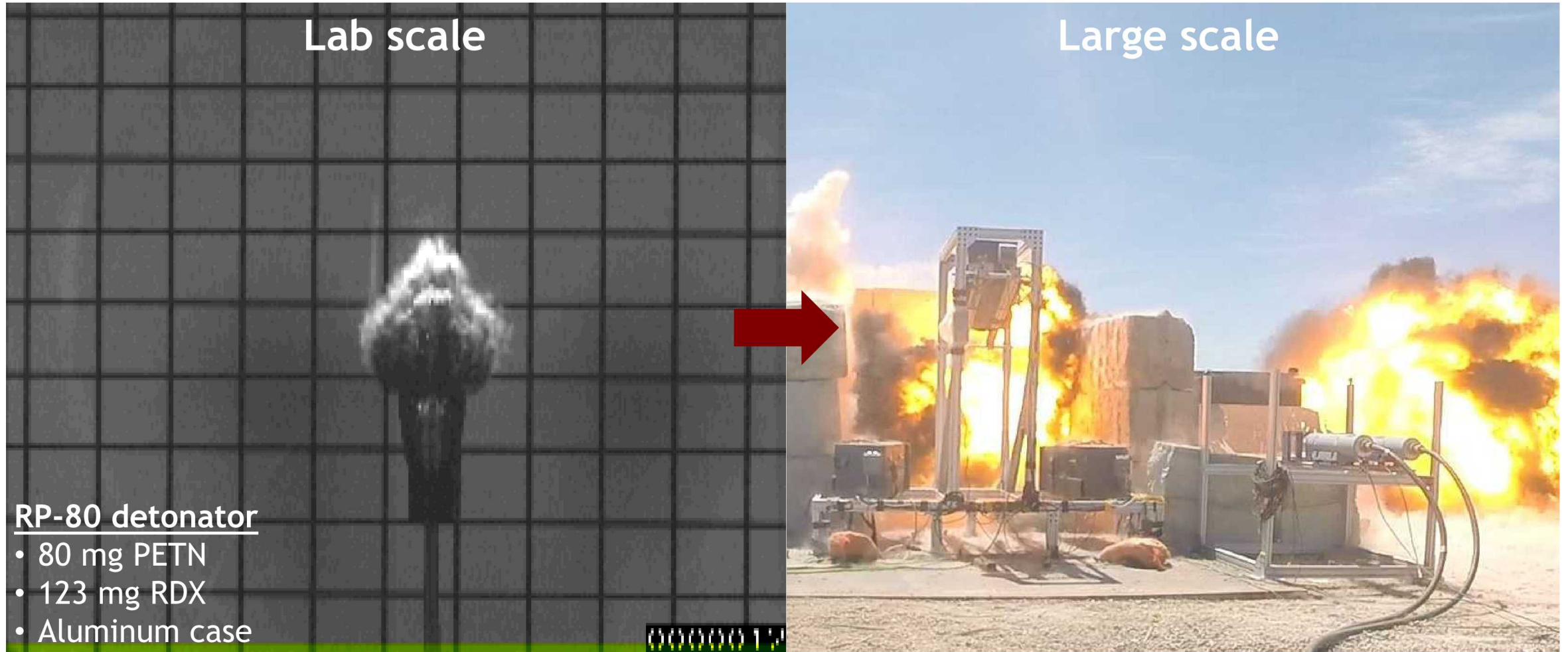


Elise Munz Hall, Phil Reu, Daniel Guildenbecher



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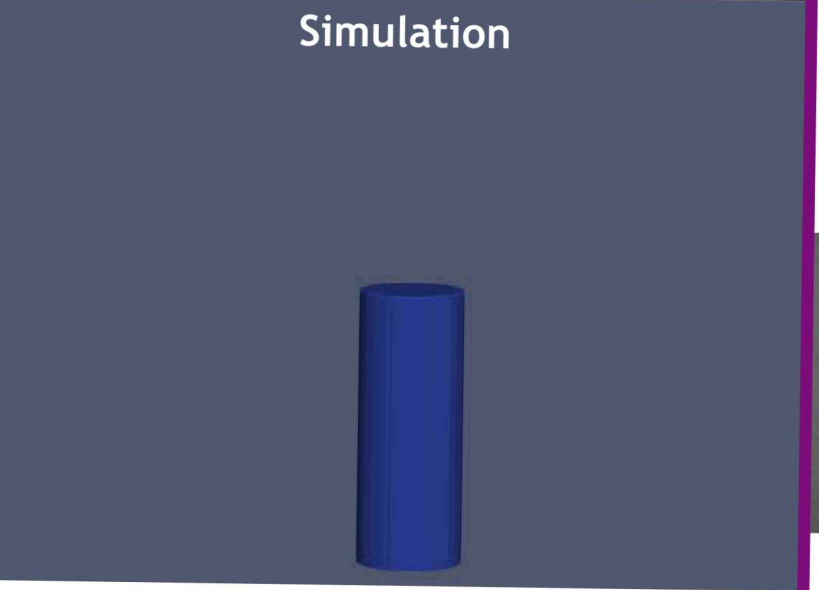
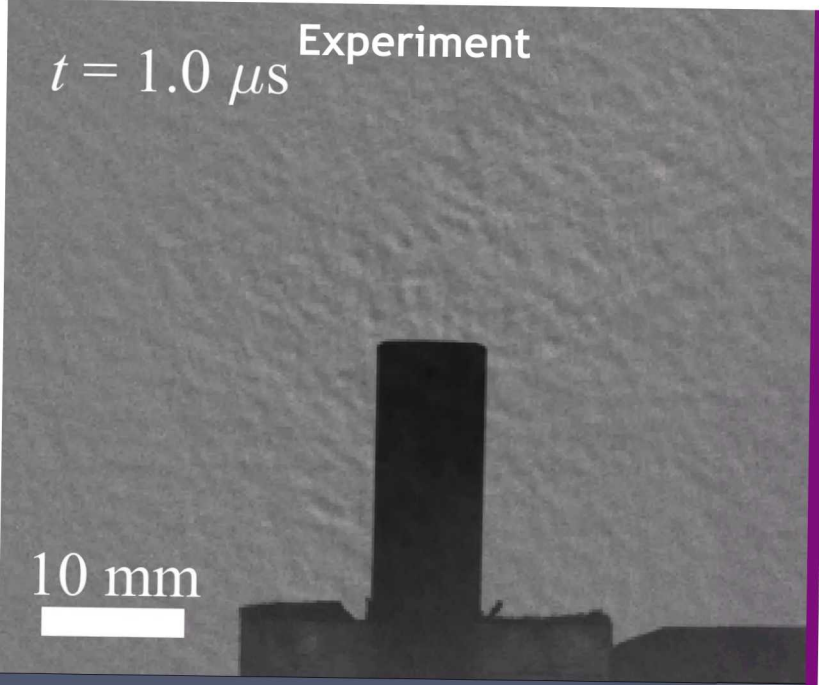
2 Our Mission: diagnostics from lab to full-scale



The work presented here is thanks to a very productive team:

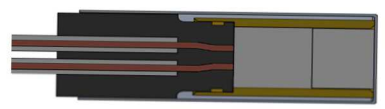
Phil Reu, Tim Miller, Daniel Guildenbecher, Steve Attaway, Mark Anderson, Russ Tetter, Paul Farias, Pat Ball, Frank Perez, John Korbin, Rudy Navarro, Mike Bejarano, Curtis Jones, Aaron Bowers, Shawn Parks, and Mark Olona, and many more

3 Diagnostics Born at Lab Scale for DOE Missions

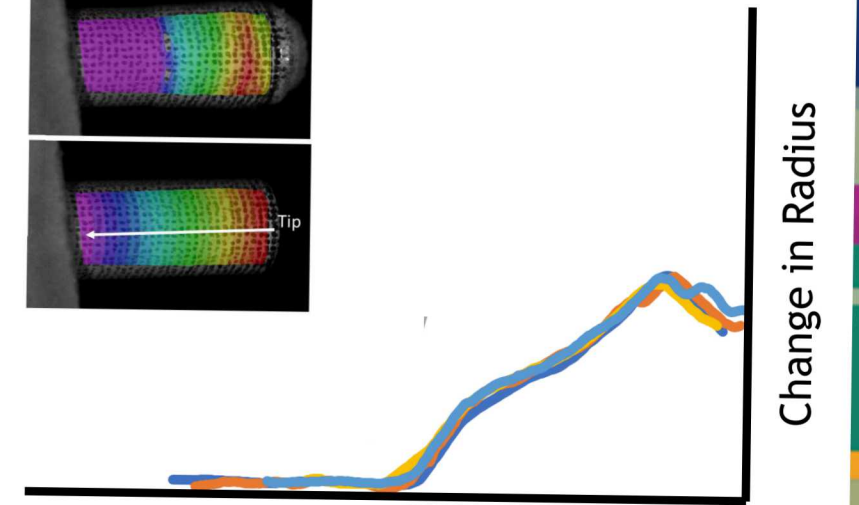
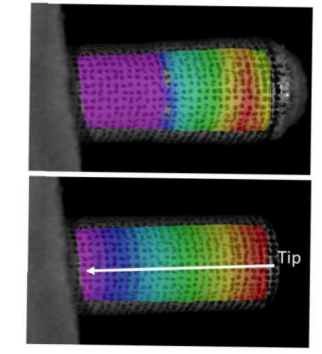
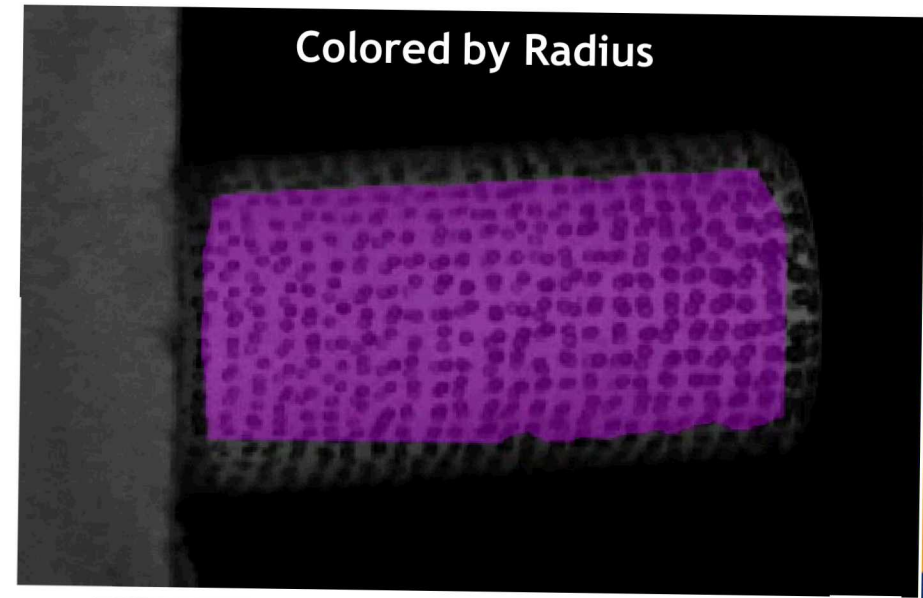
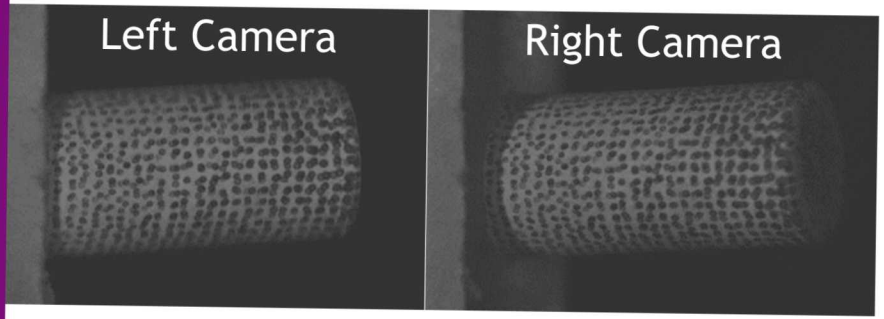


Digital Image Correlation (DIC)

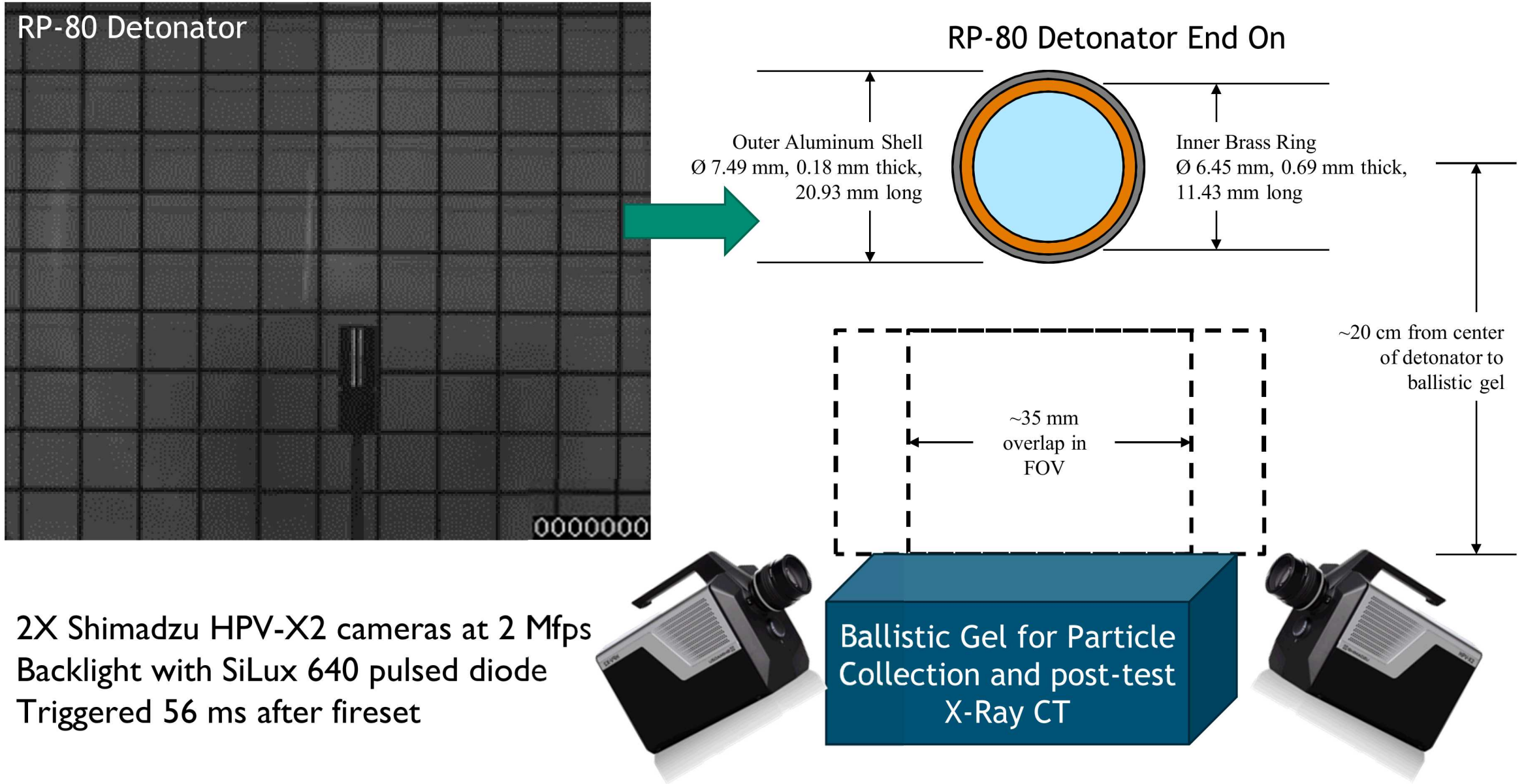
Full-field surface tracking used extensively for solid-mechanics investigations



RP-80 Detonator



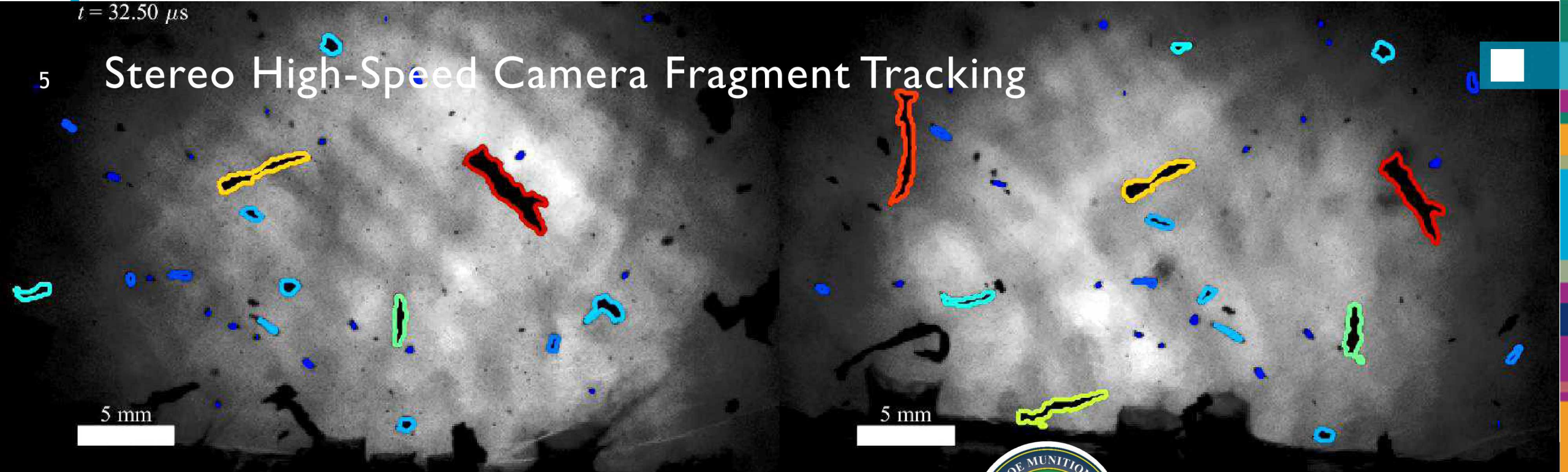
Stereo High-Speed Camera Fragment Tracking



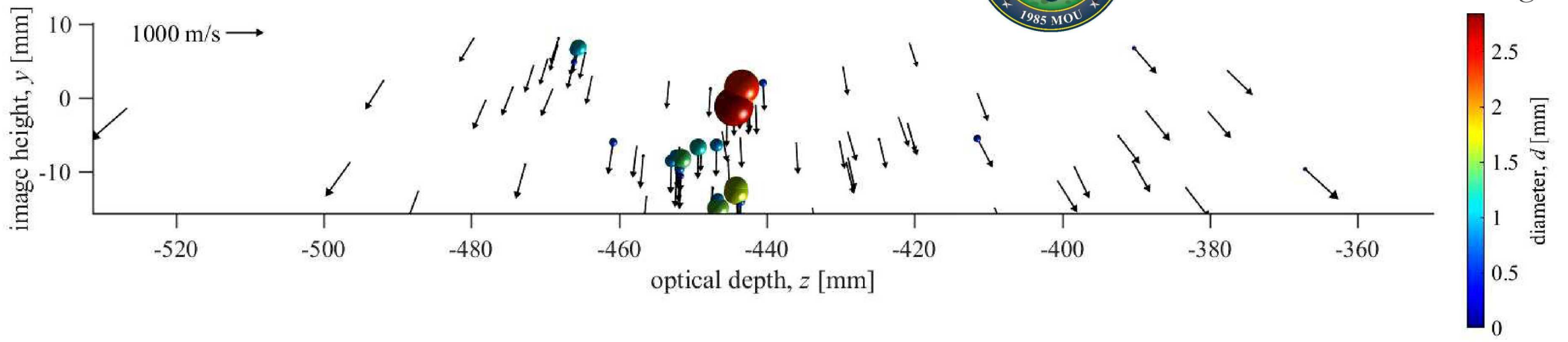
$t = 32.50 \mu\text{s}$

5

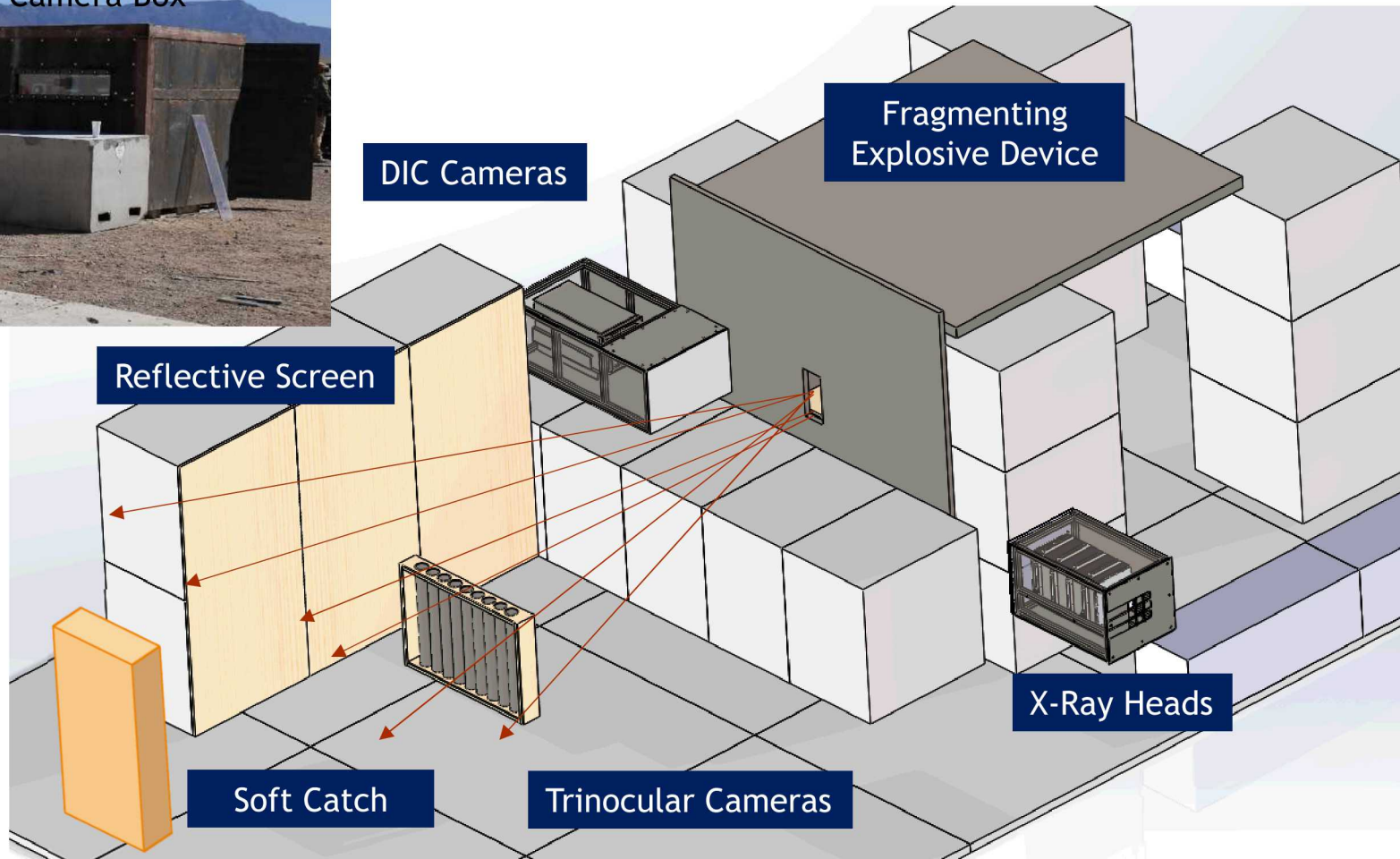
Stereo High-Speed Camera Fragment Tracking



Partially supported by the Joint DoD/DOE Munitions Program



6 Fragmenting explosive device at SNL

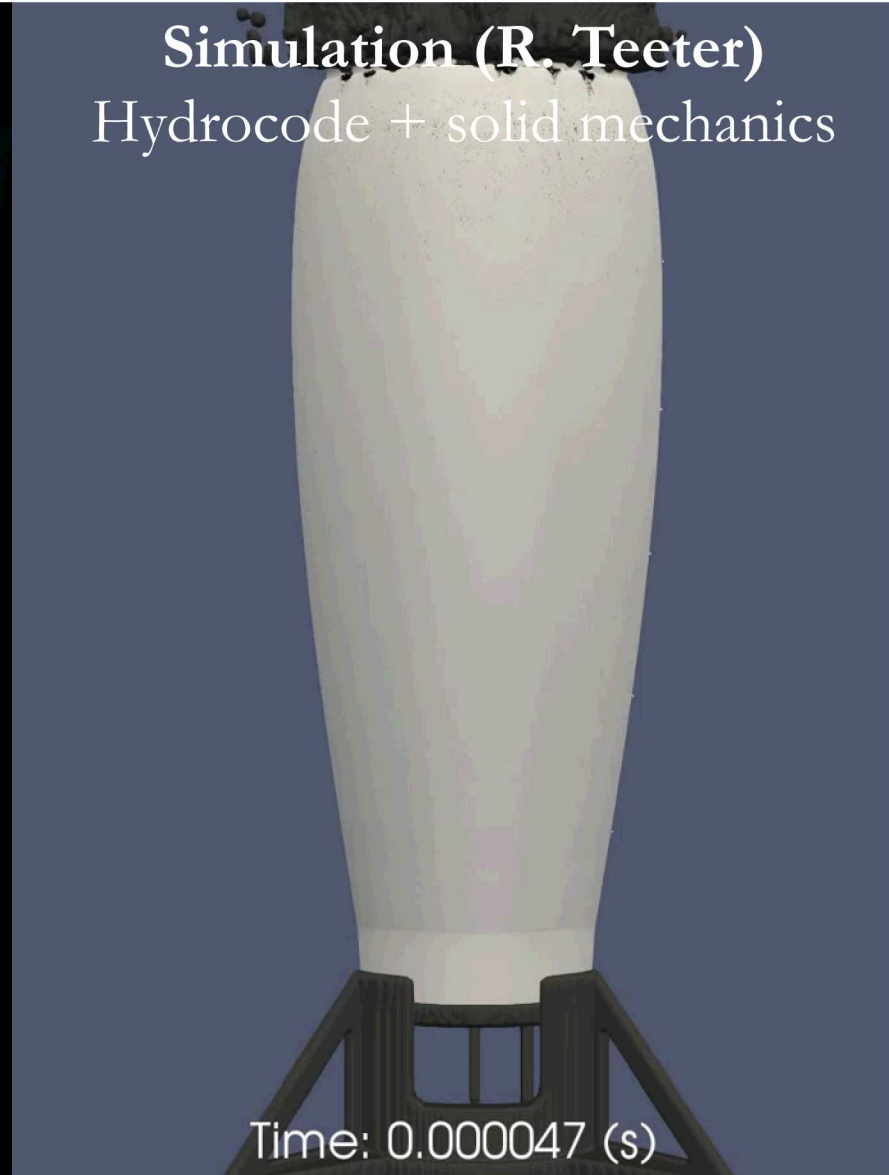


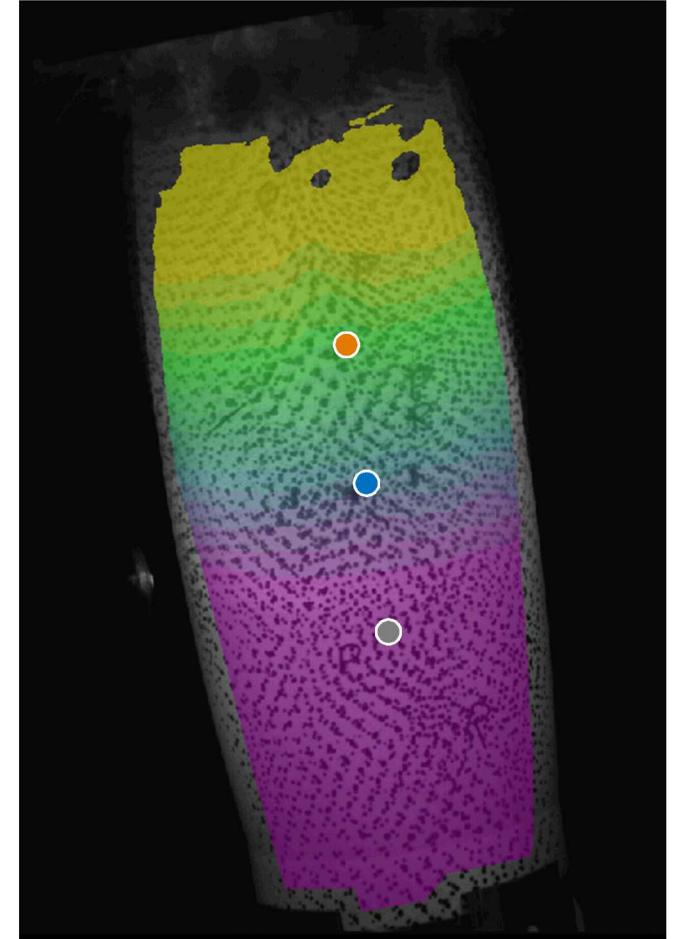
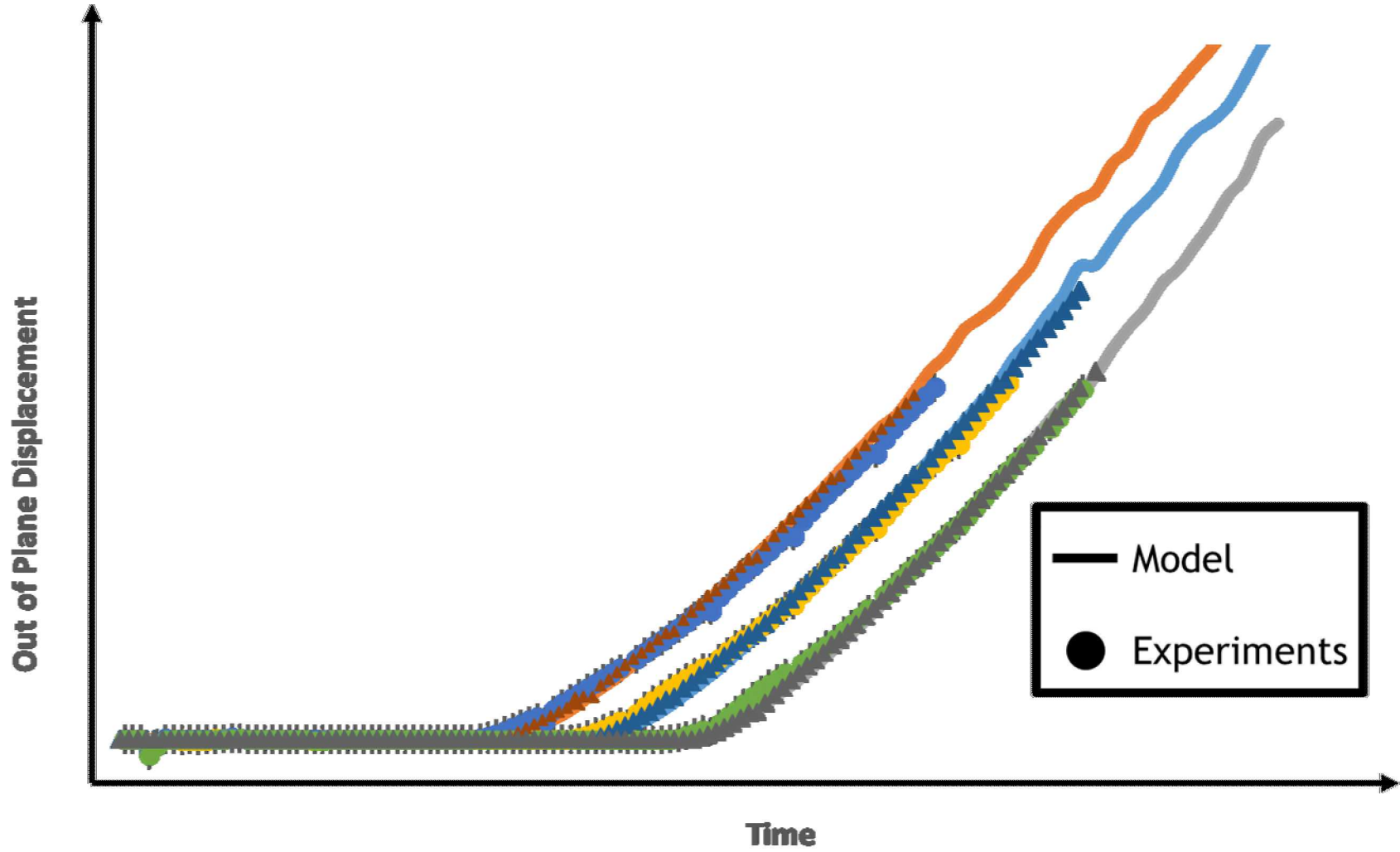
7 | Fragmenting explosive device at SNL

DIC Imaging (P. Reu, T. Miller)



Simulation (R. Teeter)
Hydrocode + solid mechanics

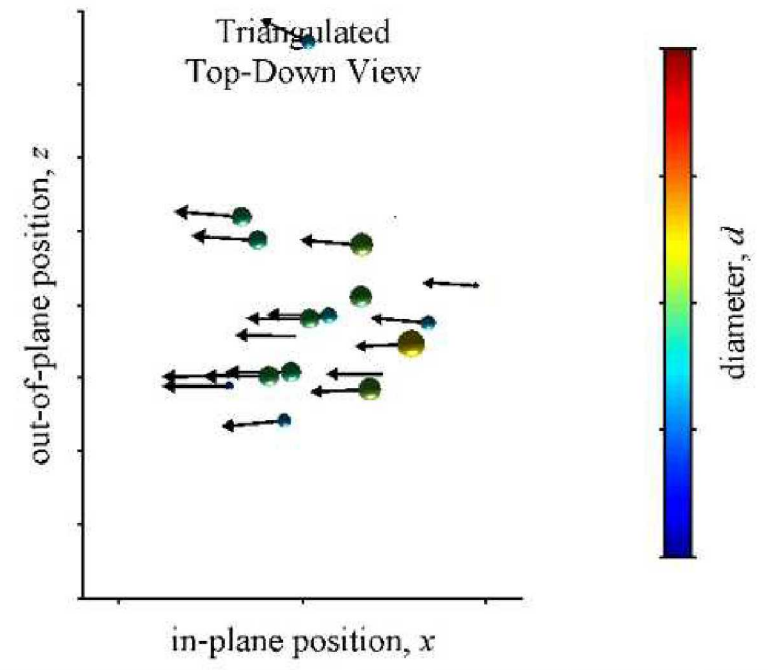
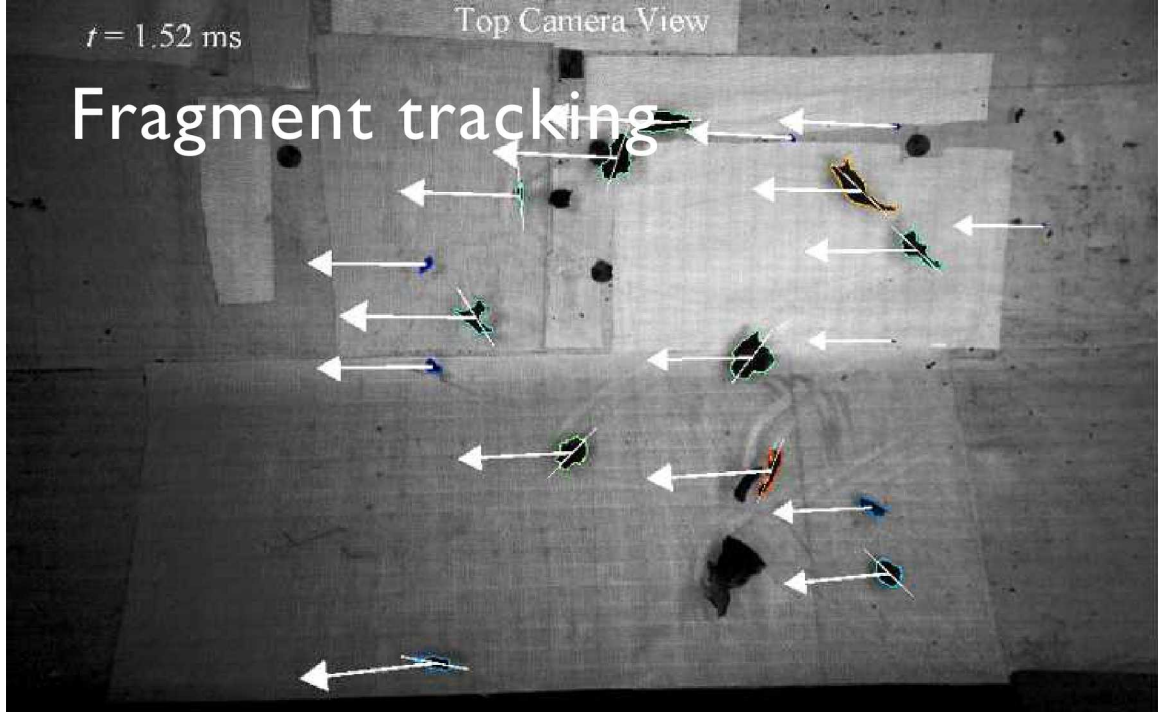




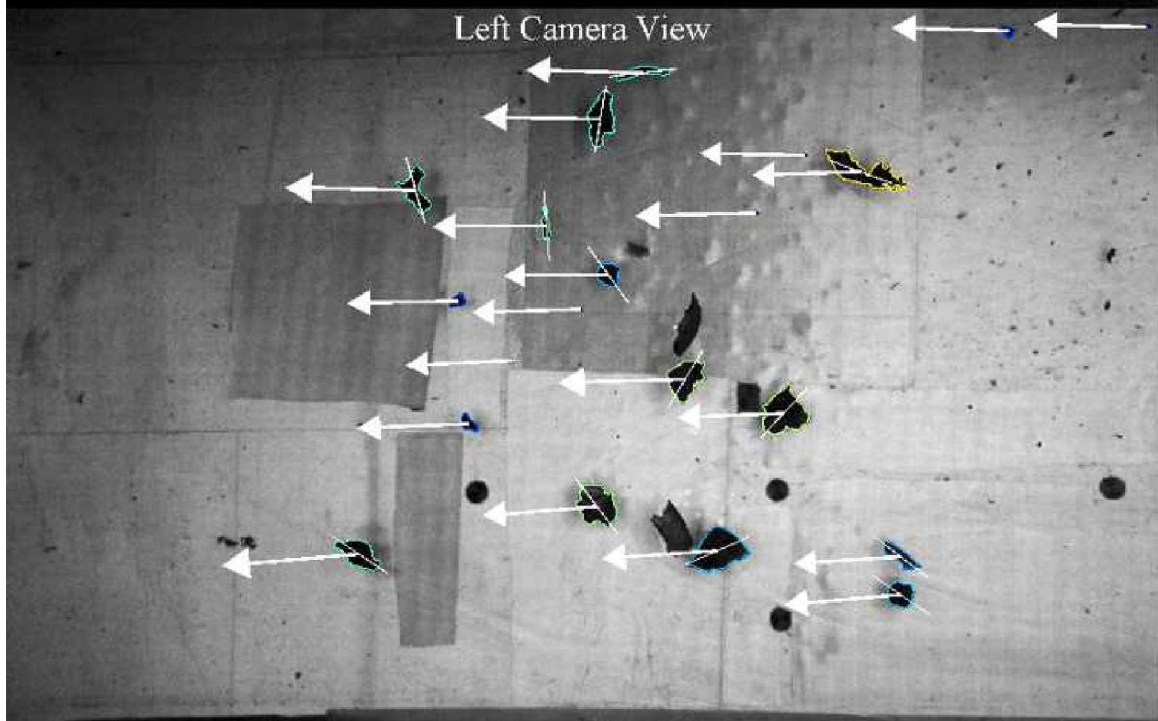
$t = 1.52 \text{ ms}$

Top Camera View

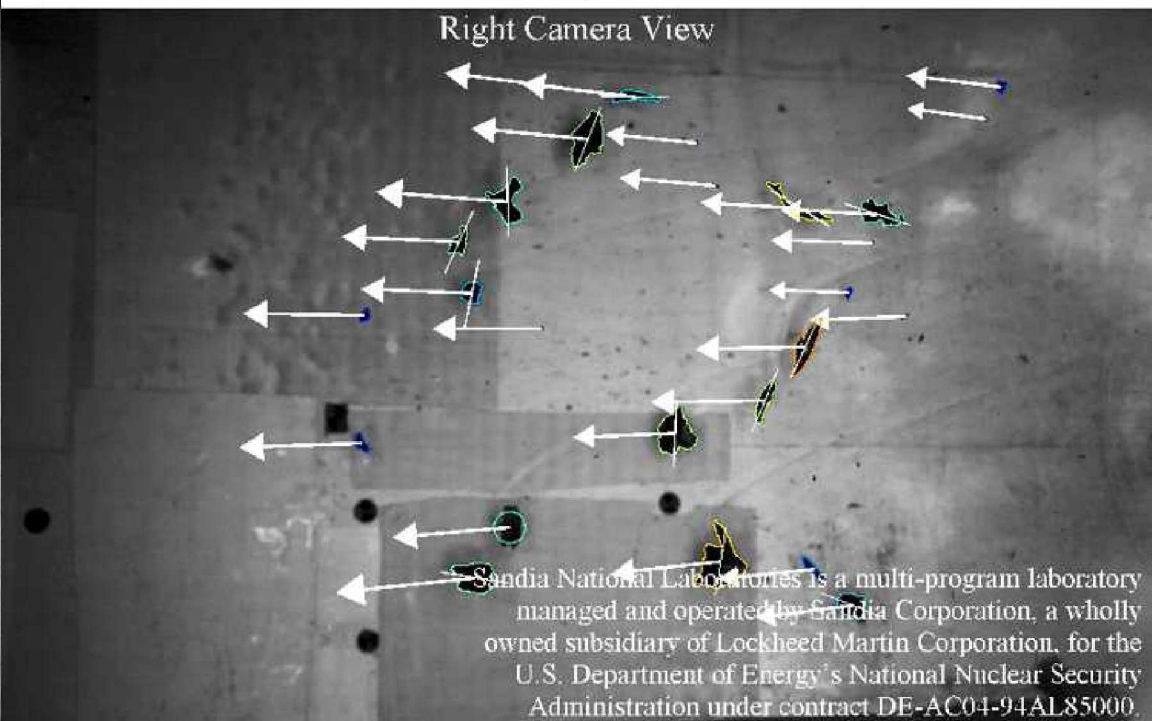
Fragment tracking



Left Camera View

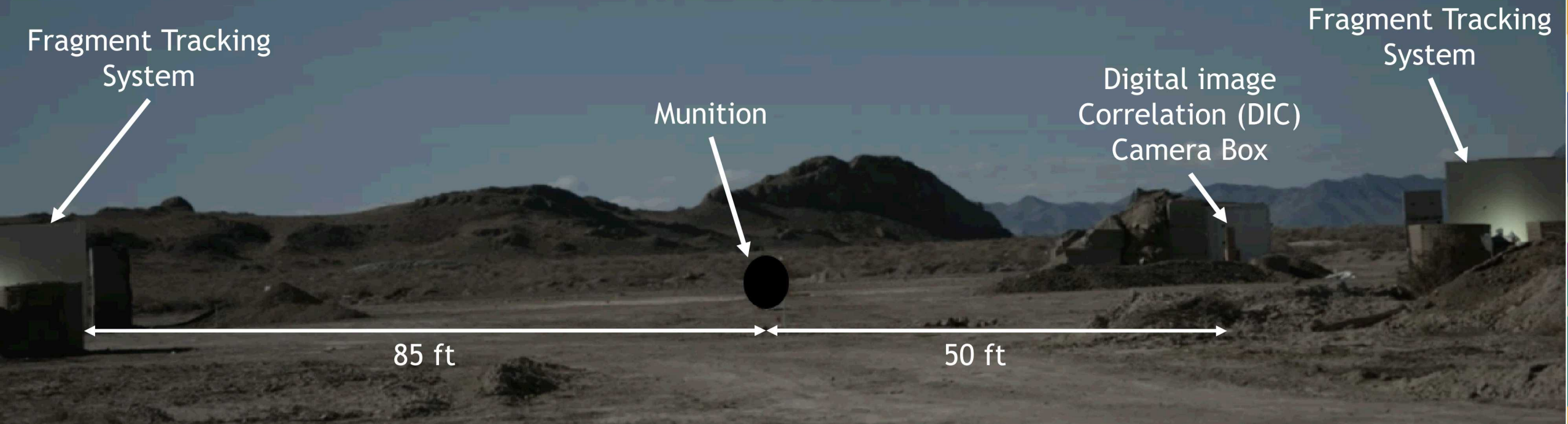


Right Camera View



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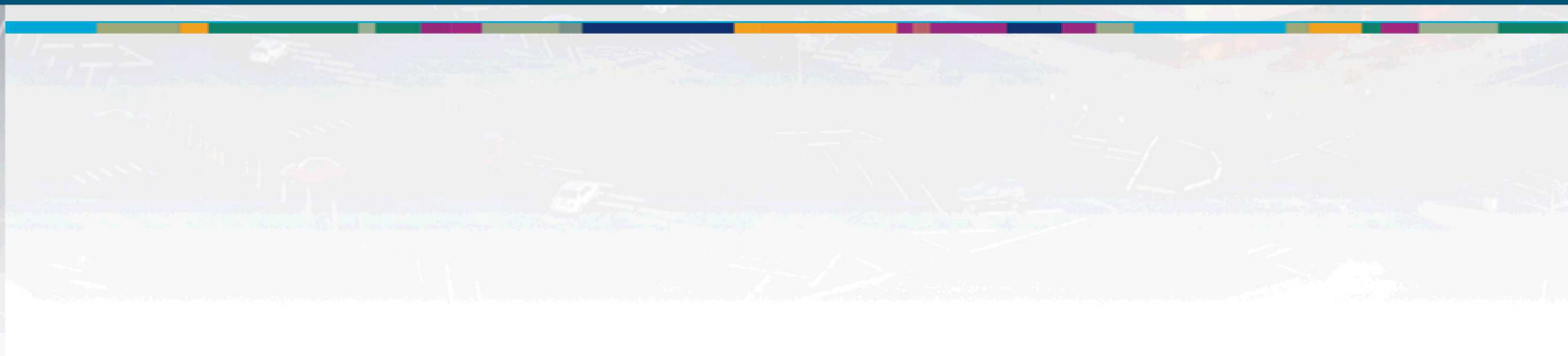
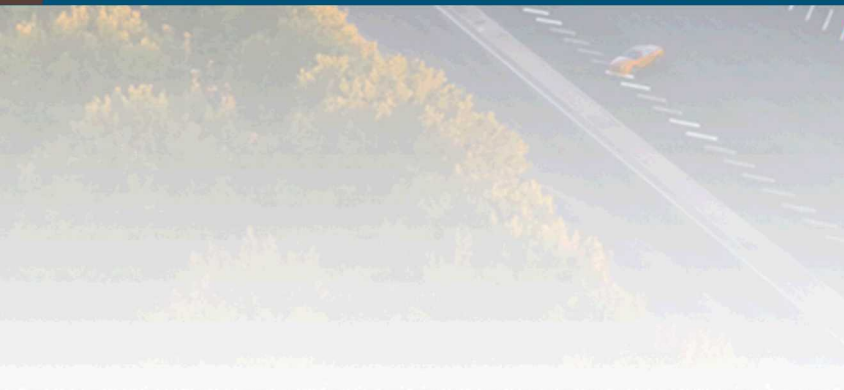
Successful tests conducted up to ~1000 NEW



Thanks to: Trevor Foust, Dave Johnson, and Brian Sellers

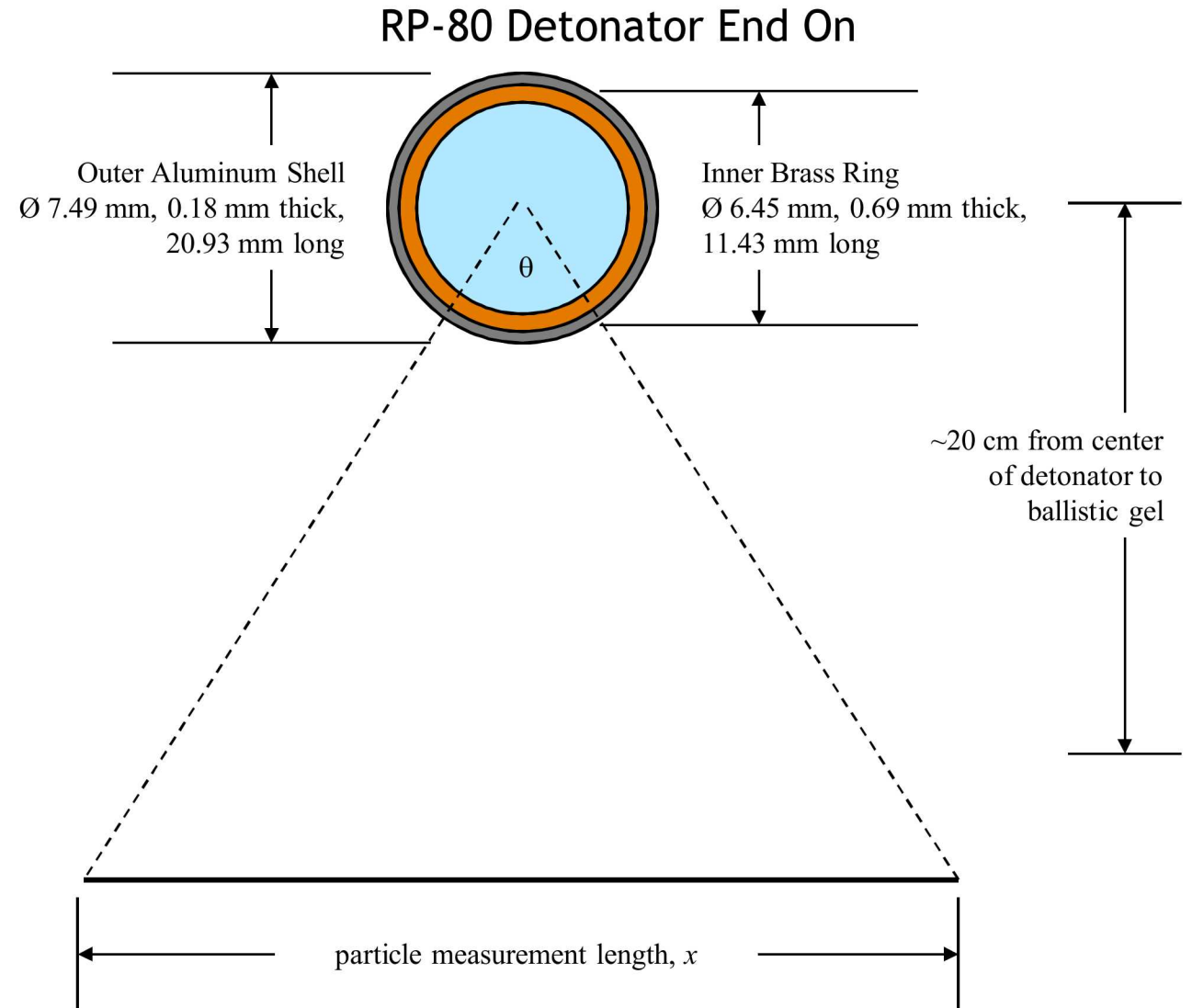


Uncertainty: an ongoing question

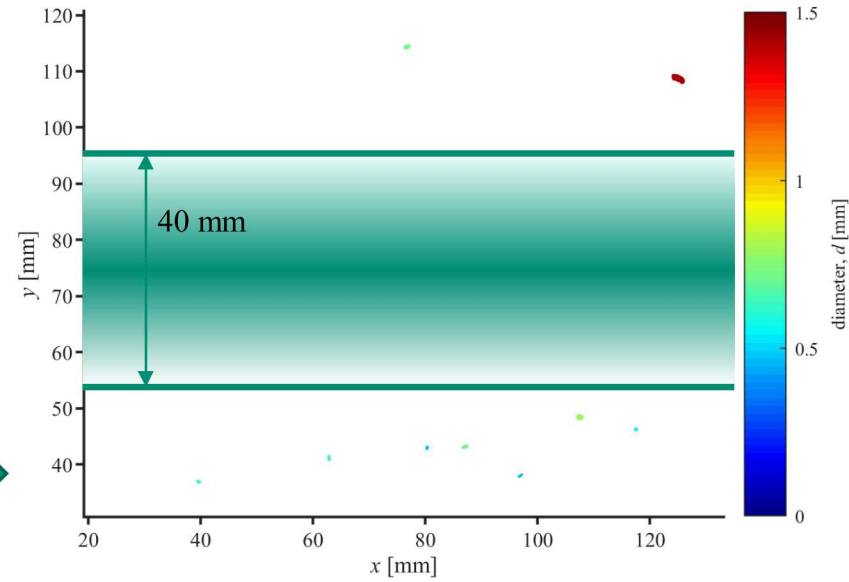
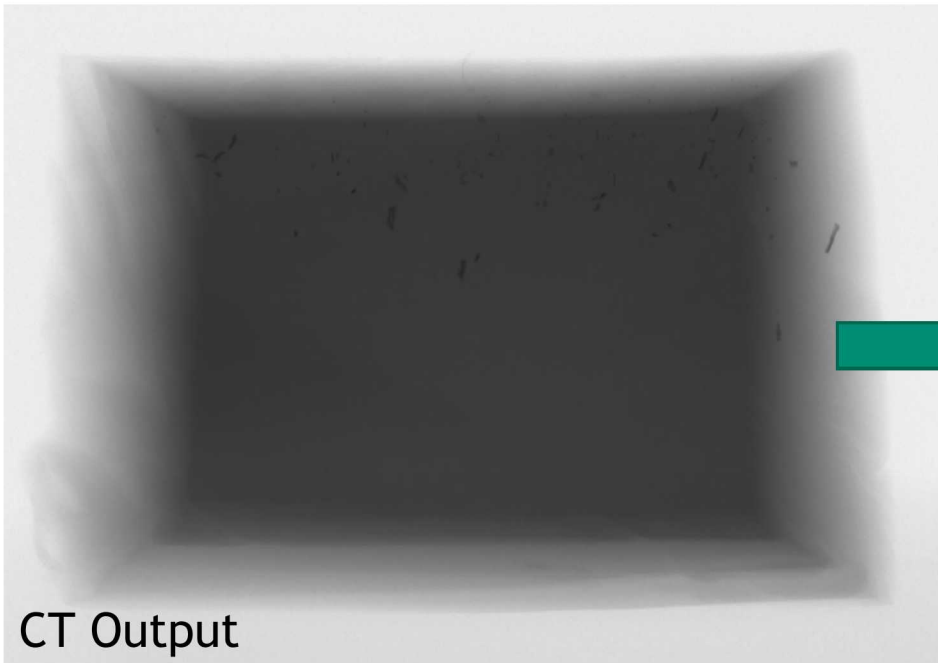


Stereo High-Speed Camera Fragment Tracking

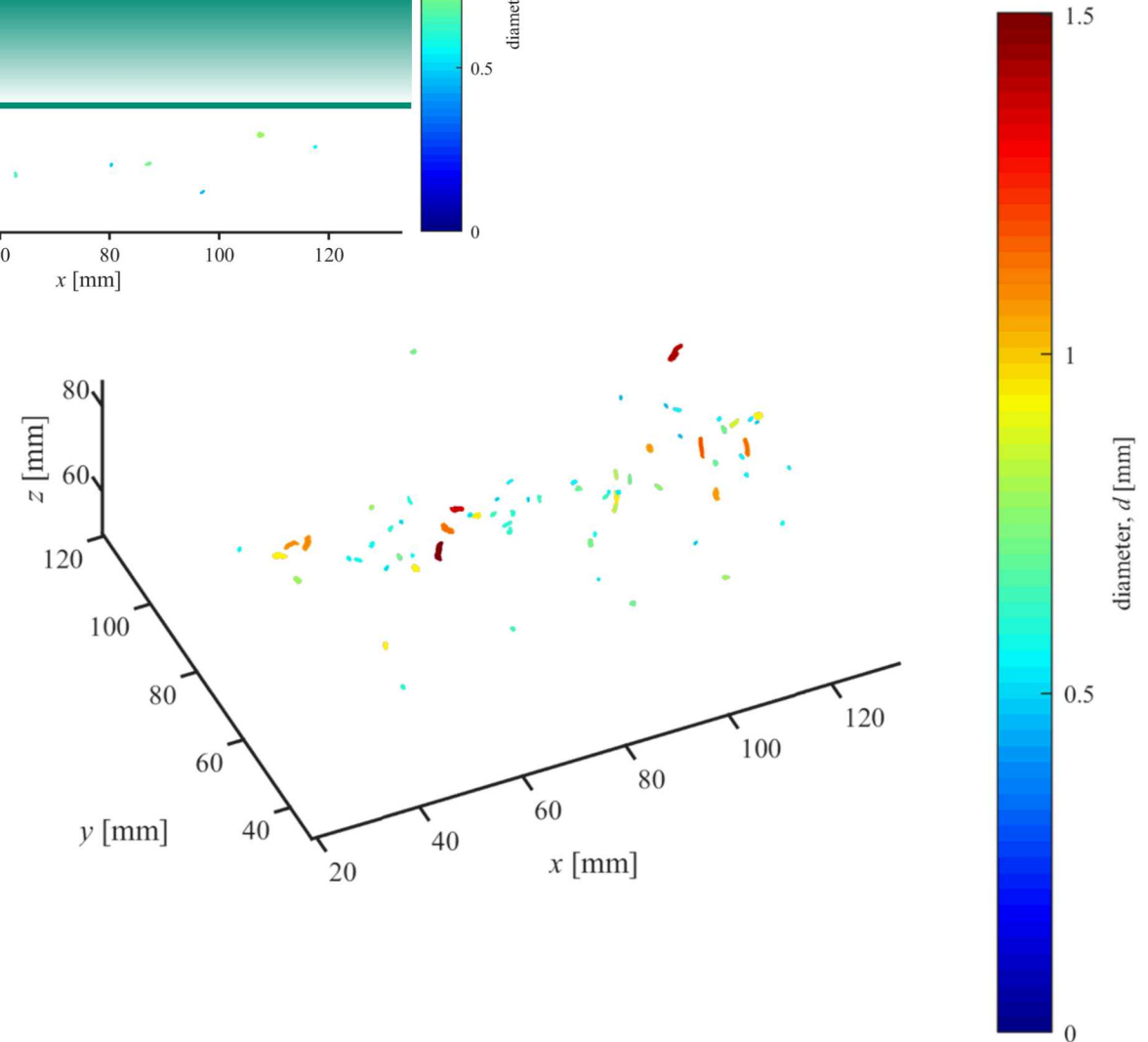
- $\theta = 2 \operatorname{atan}(\frac{1}{2} \cdot x / 20 \text{ cm})$
- Arc length = $\frac{1}{2} \cdot \theta \cdot \text{Diameter}$
- Expected particle volume = Arc length \cdot Thickness \cdot Length



X-ray CT of Ballistic Gel



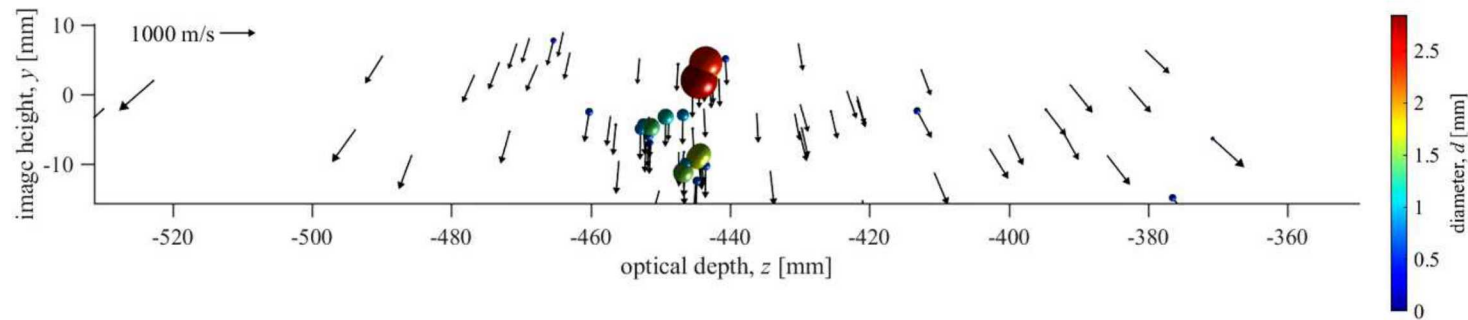
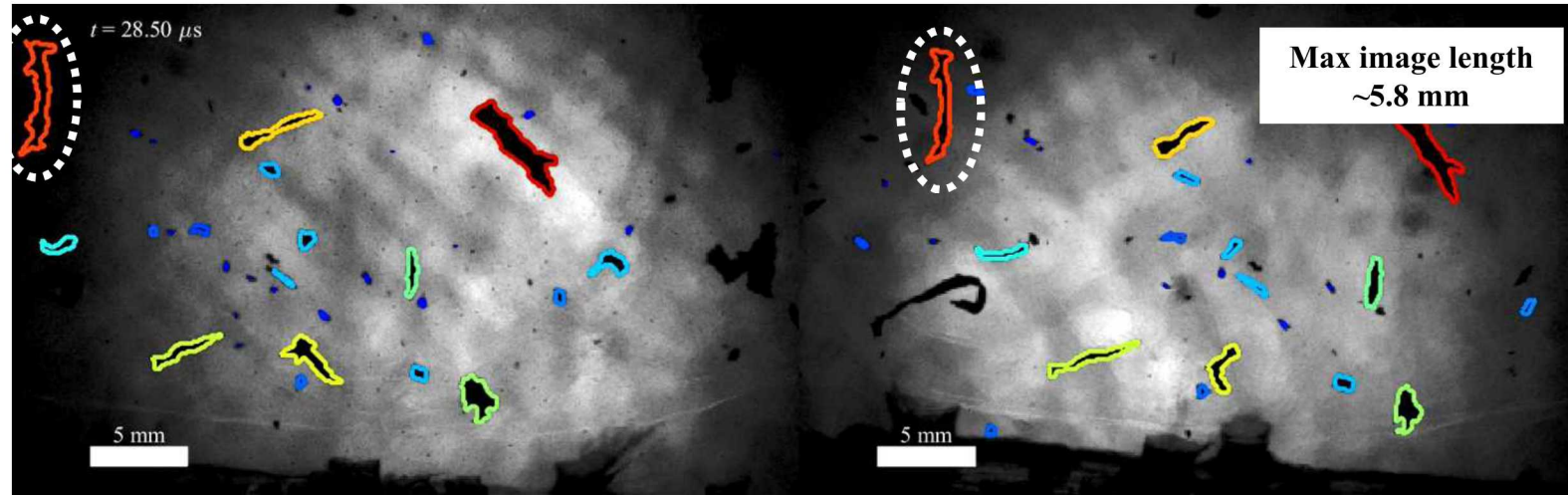
Measured fragment size/positions



- Expected particle volume over ~ 100 mm length = 12.5 mm^3 (brass) + 6.9 mm^3 (Al) = 19.4 mm^3
- Threshold selected to match this volume

Optical tracking to CT comparison

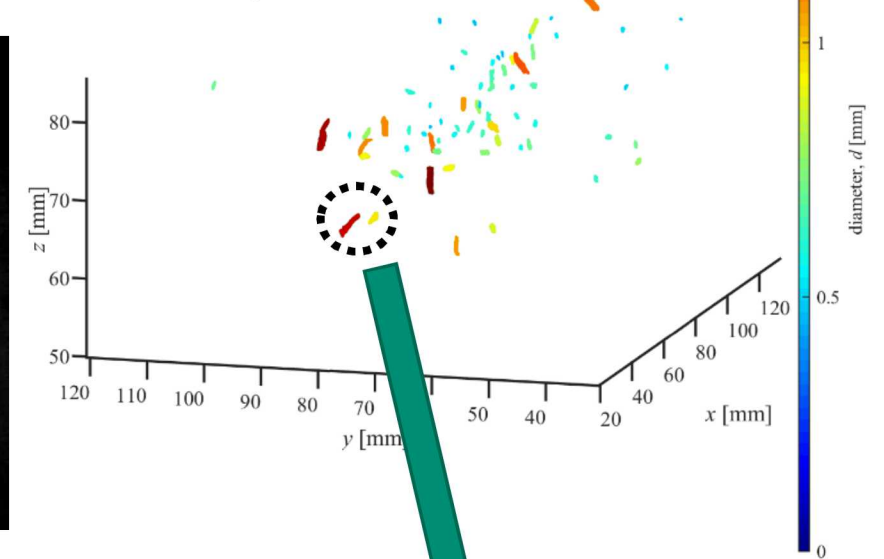
Stereo tracking measured size/position/velocity



Triangulated image length (5.8 mm) matches total x-ray length (5.7 mm)

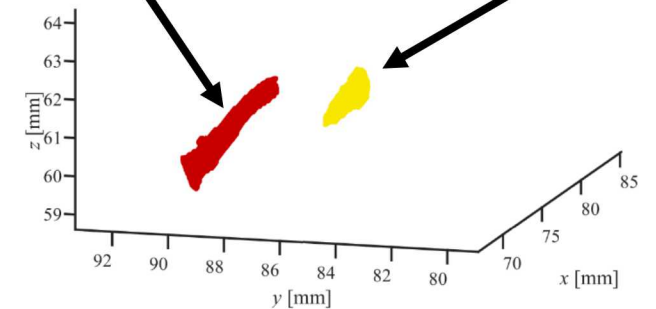
Particles breakup upon impact

CT measured fragment size/position

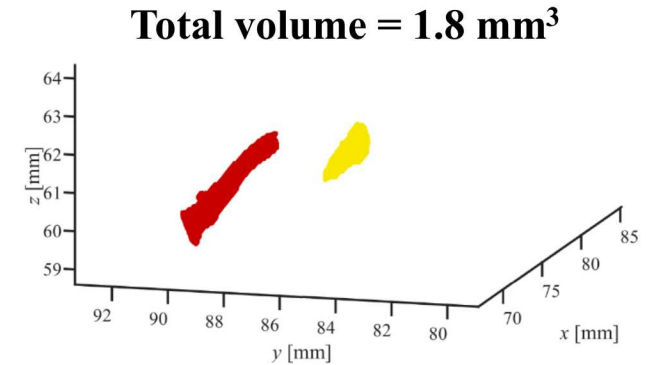
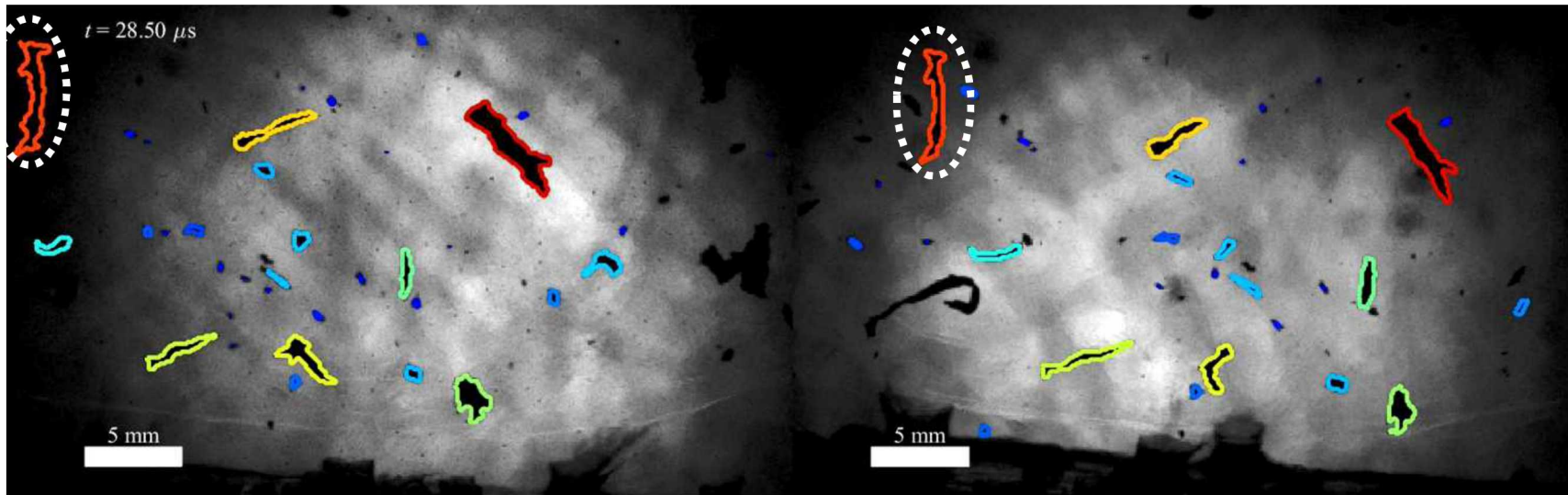


3D length
~3.9 mm

3D length
~1.8 mm



Mass uncertainty questions



- Average image area = 4.5 mm²
 - Area equivalent diameter = 2.4 mm
 - Volume from area equivalent diameter = 7.1 mm³ (+300% error)
- We can assume the thickness based on the initial geometry
 - Volume from image area × initial thickness of brass (0.69 mm) = 3.1 mm³ (+70% error)
 - Volume from image area × initial thickness of Al (0.18 mm) = 0.8 mm³ (-60% error)
- Estimated actual thickness from x-ray = 0.6 mm
 - Volume from image area × measured thickness = 2.7 mm³ (+50% error)



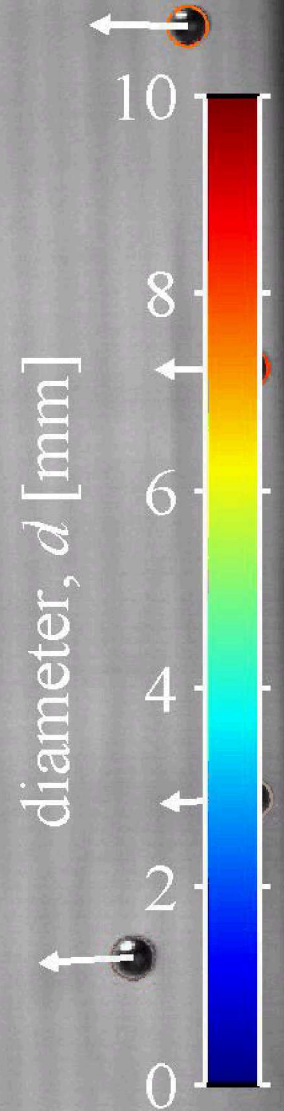
Mass uncertainty remains a significant caveat to optical tracking measurements

$t = 3.00 \text{ ms}$

350 m/s →

Questions?

5 cm



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