Presented to:

INSENSITIVE MUNITIONS & ENERGETIC MATERIALS TECHNOLOGY SYMPOSIUM

THE UNKNOWN DETONATION TRANSITION (XDT) MECHANISMS ASSOCIATED WITH DAMAGED ROCKET PROPELLANT IMPACTING A SURFACE: UNDERSTANDING AND APPLICATIONS TO IM

AMRDEC

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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U.S. Army Aviation and Missile Research, Development, and Engineering Center

AMRDEC Mission

Deliver collaborative and innovative aviation and missile capabilities for responsive and cost-effective research, development and life cycle engineering solutions.

Who is AMRDEC?

~9,211 FY17 Strength

2,945 Civilian

16 Military

6,250 Contractor

907 / 5343

SETA Non-SETA

FY17

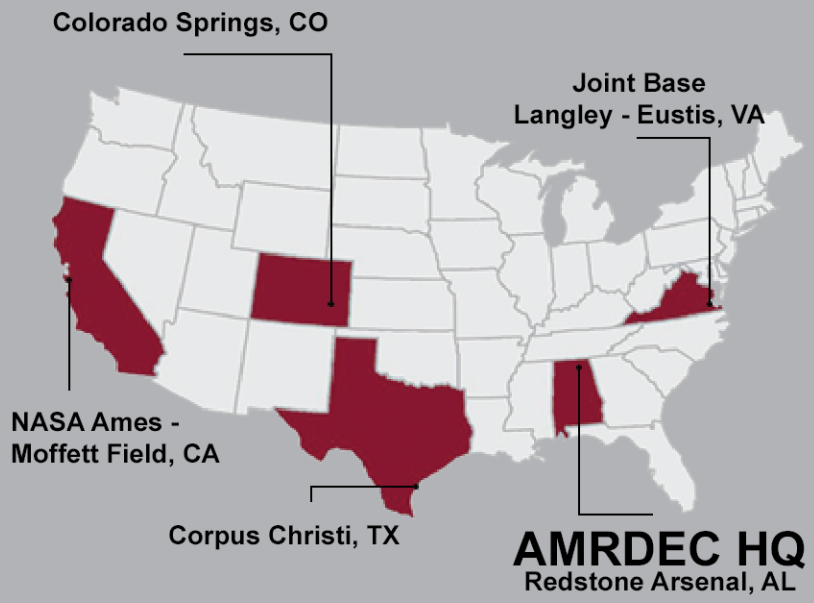
$2,904M

6% Aviation S&T

7% Missile S&T

63% Army

24% Other



Core Competencies

- Life Cycle Engineering
- Research, Technology Development and Demonstration
- Design and Modification
- Software Engineering
- Systems Integration
- Test and Evaluation
- Qualification
- Aerodynamics/ Aeromechanics
- Structures
- Propulsion
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- Autonomy and Teaming
- Radio Frequency (RF) Technology
- Fire Control Radar Technology
- Image Processing
- Models and Simulation
- Cyber Security

Priorities

#1: Readiness

Provide aviation and missile systems solutions to ensure victory on the battlefield today.

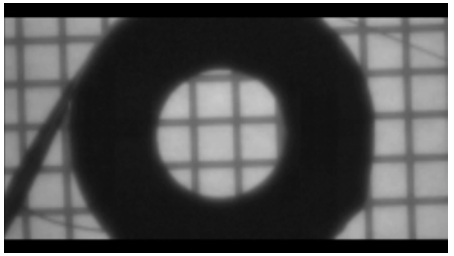
#2: Future Force

Develop and mature Science and Technology to provide technical capability to our Army's (and nation's) aviation and missile systems.

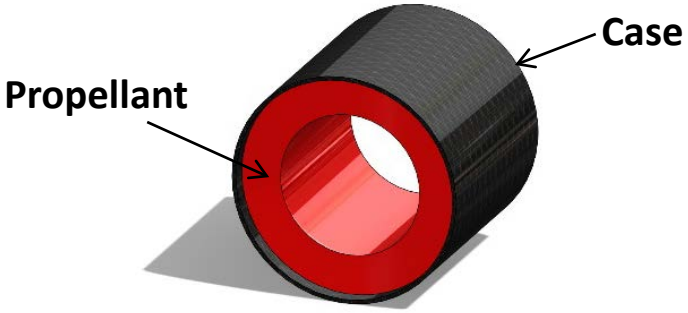
#3: Soldiers and People

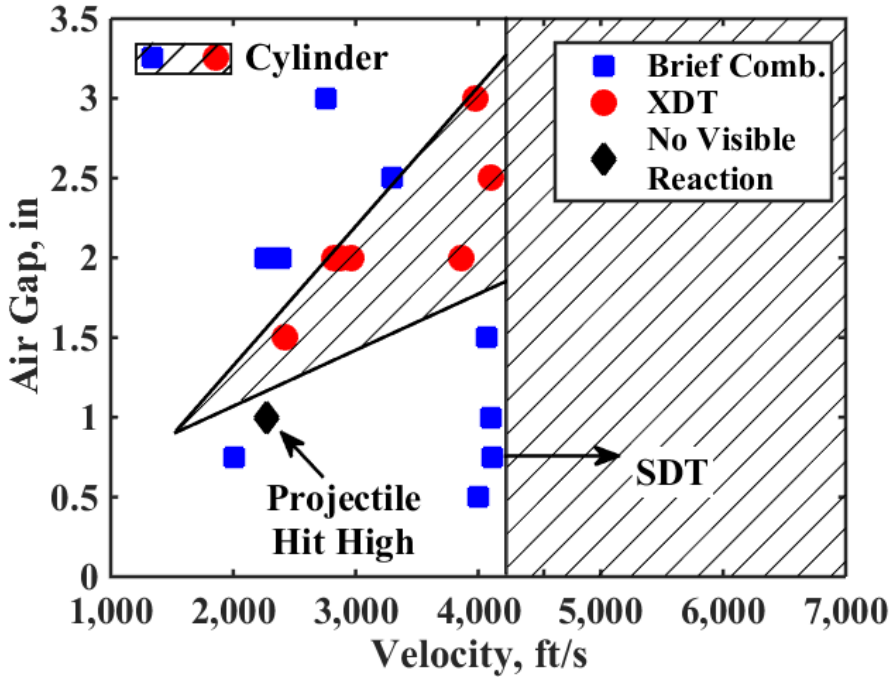
Develop the engineering talent to support both Science and Technology and the aviation and missile materiel enterprise

Response of Rocket Motors Subject to Fragment Impact

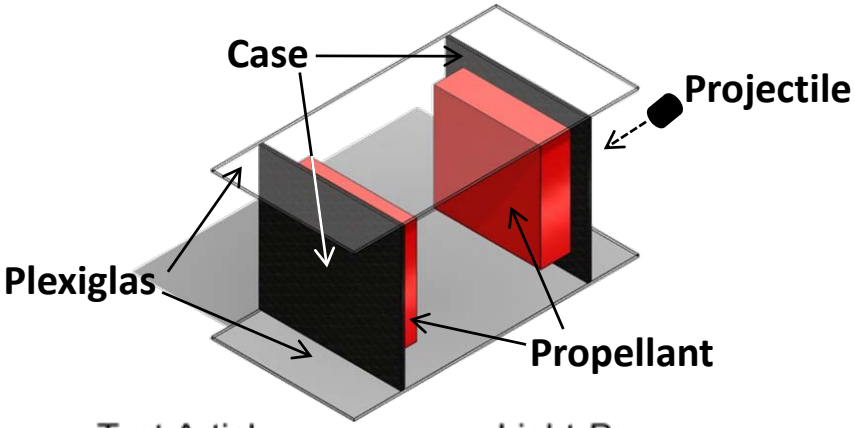


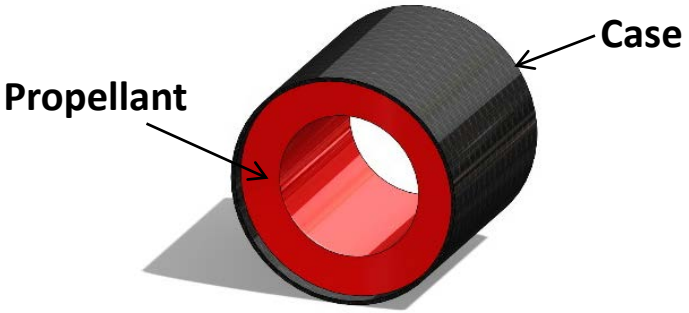
- **Motors need to pass insensitive munition fragment impact requirements**
  - **Better understanding of motor reaction needed**
- **Motors containing 1.1 propellant can detonate via**
  - **Shock to Detonation Transition (SDT)**
  - **Unknown Detonation Transition (XDT)**
    - **More prevalent problem than previously thought**

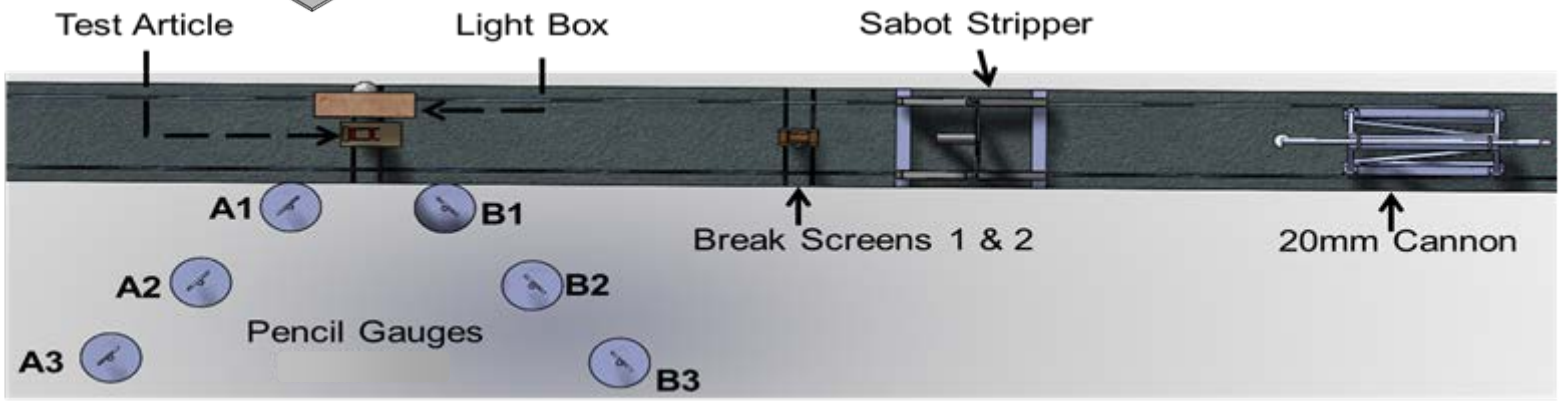




Testing Setup – ABVR and Cylinders







- **MSP-1 propellant**
  - **ABVR web thickness – 1.25 or 2.50 in**
  - **Cylindrical web thickness – 1.09 or 2.34 in**
- **Pressure gauges set at a 45° offset**
- **High speed cameras used to optically record event**

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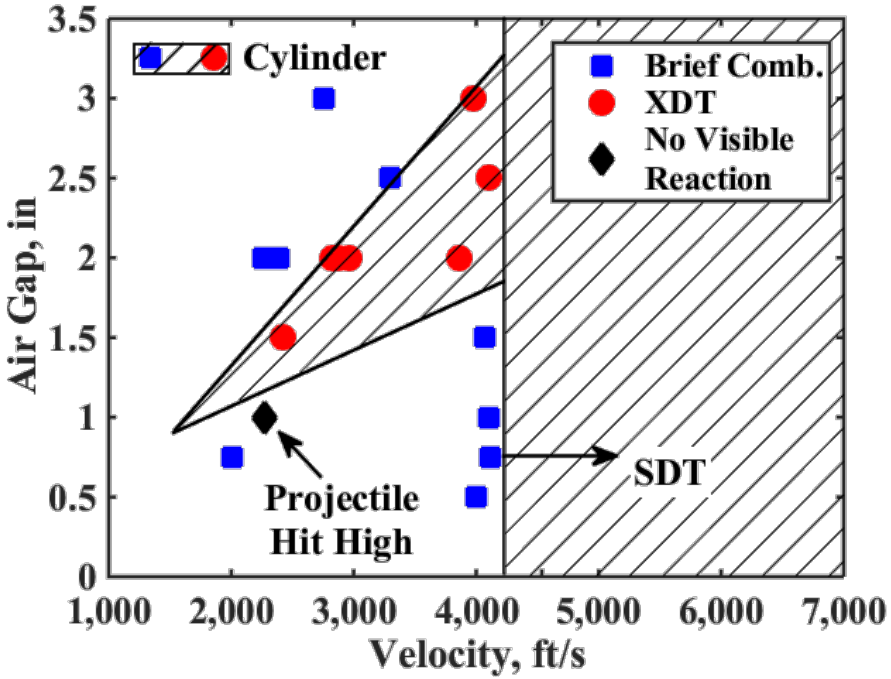
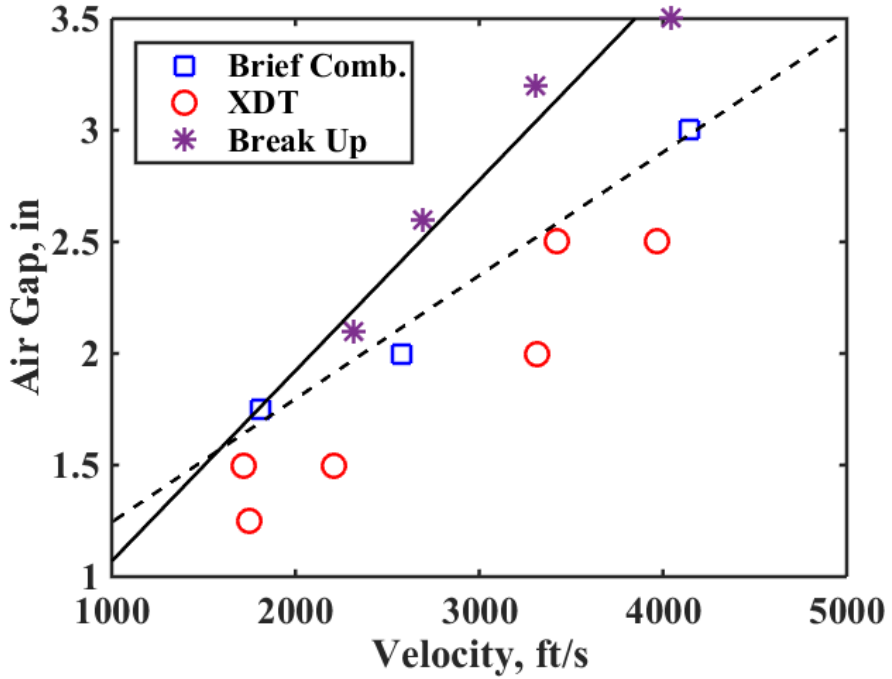
Upper XDT Limit

- **Change from XDT to brief combustion caused by debris cloud porosity**
  - **Visual break up of cloud correlates to XDT limit**

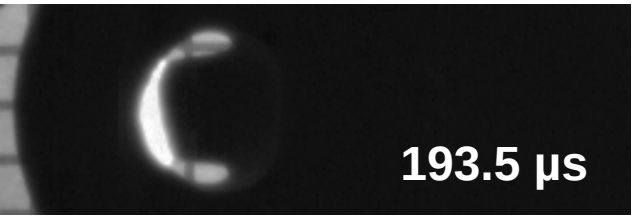


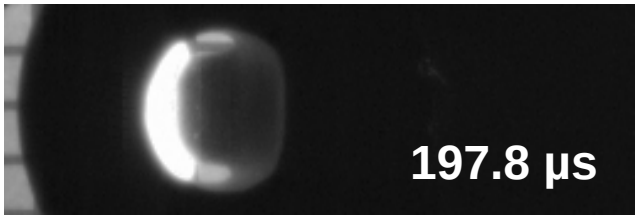


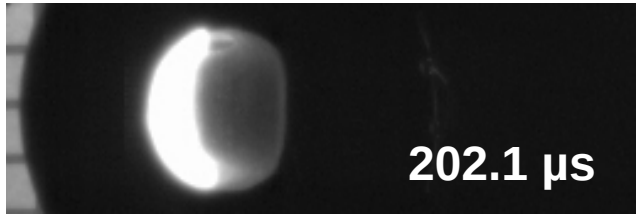
Data from Finnegan et al., Int. J. Impact Eng., 1993.

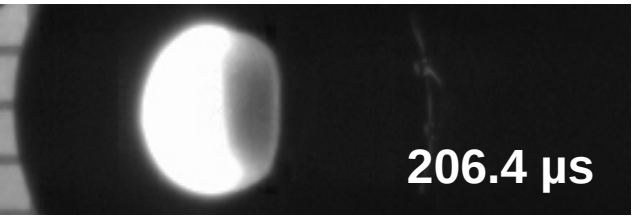
Upper XDT Limit

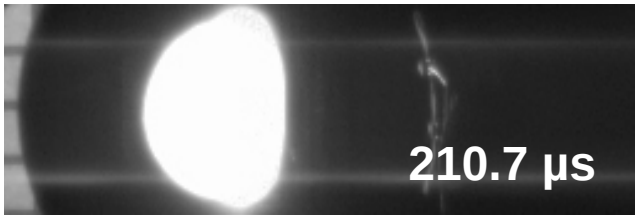
XDT – 3976 ft/s



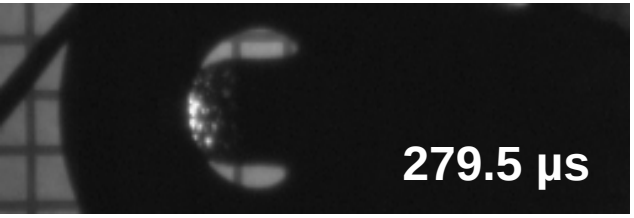


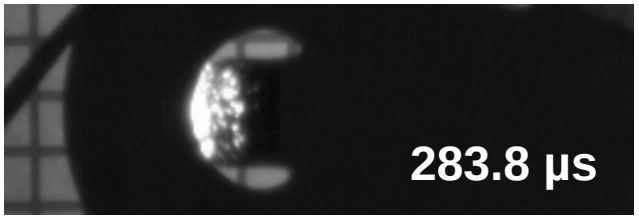


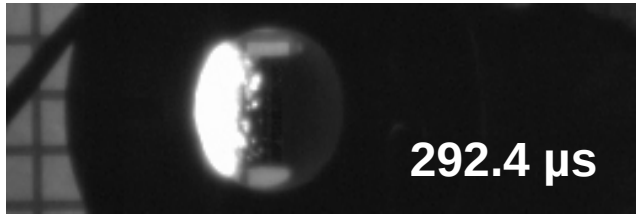


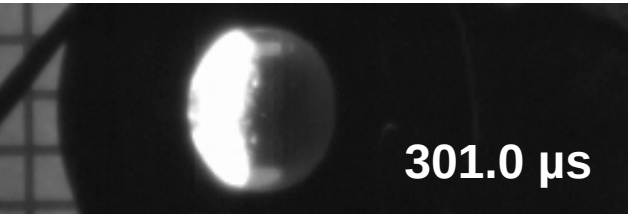


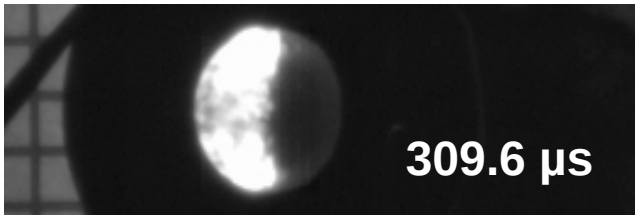
Brief Combustion – 2756 ft/s

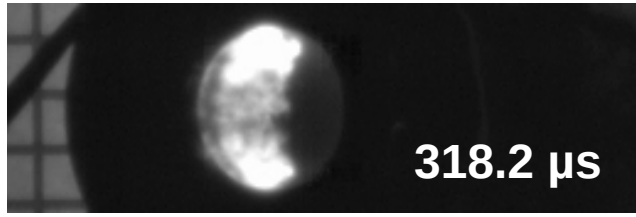






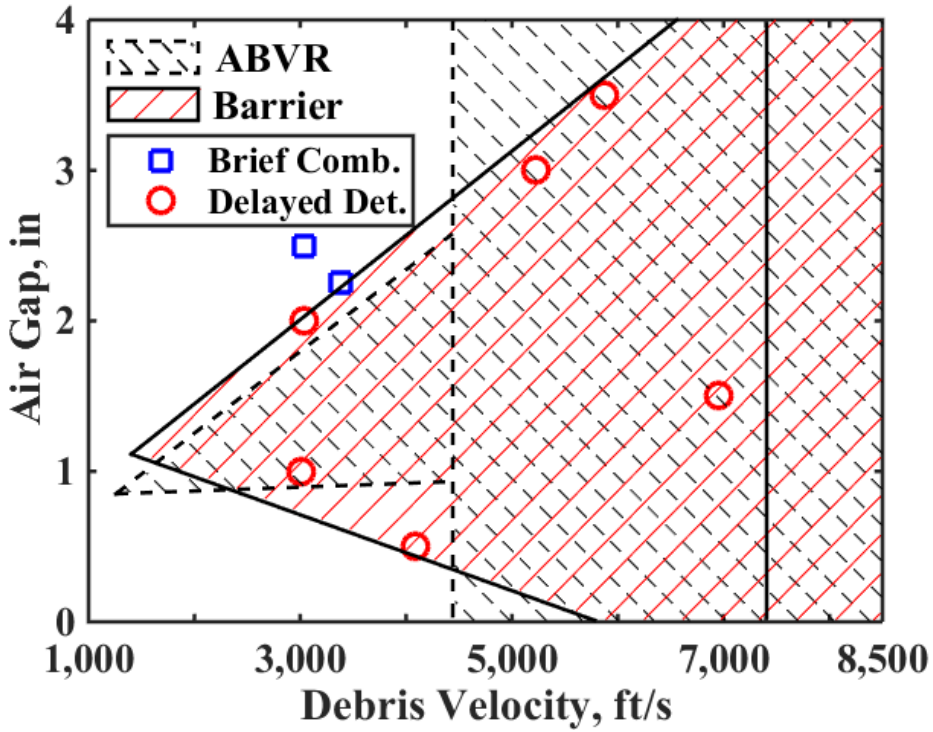


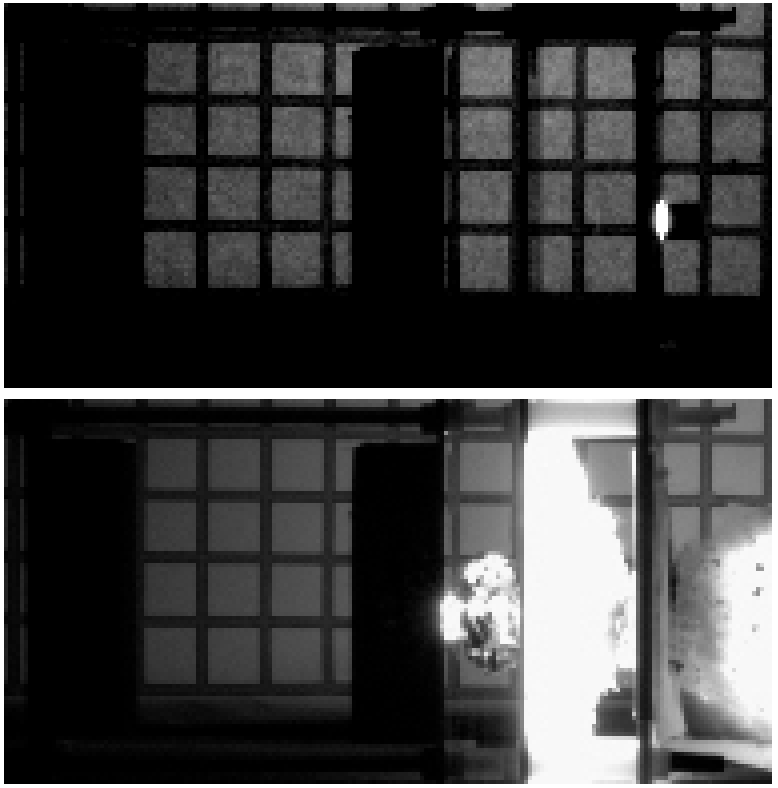




Upper XDT Limit

- **The variation with fragment velocity appears to correlate with the amount of material in debris cloud**
  - **Material in debris cloud ∝ kinetic energy of fragment, thickness of propellant, and presented area of fragment**
  - **More material means longer length required to obtain porosity necessary to mitigate XDT**

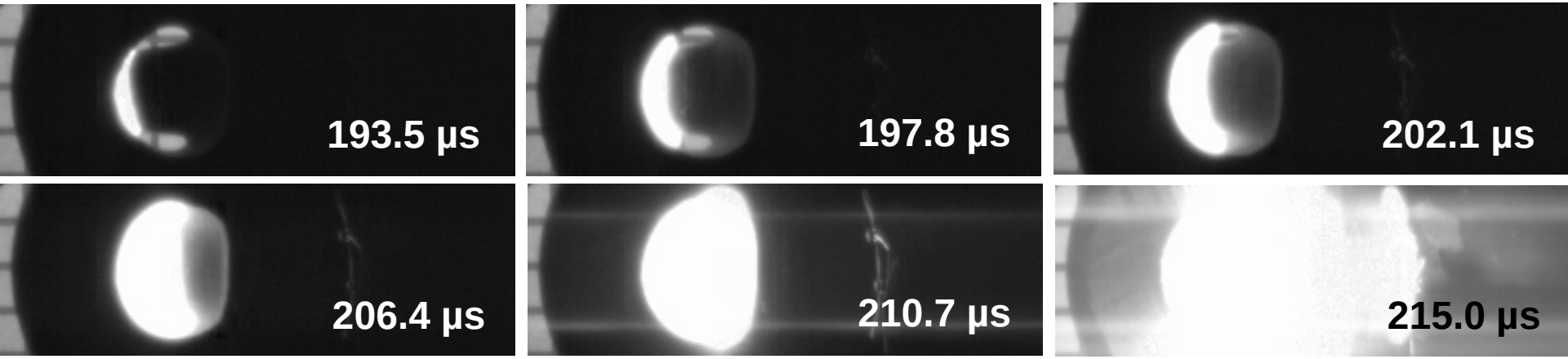




Initiation

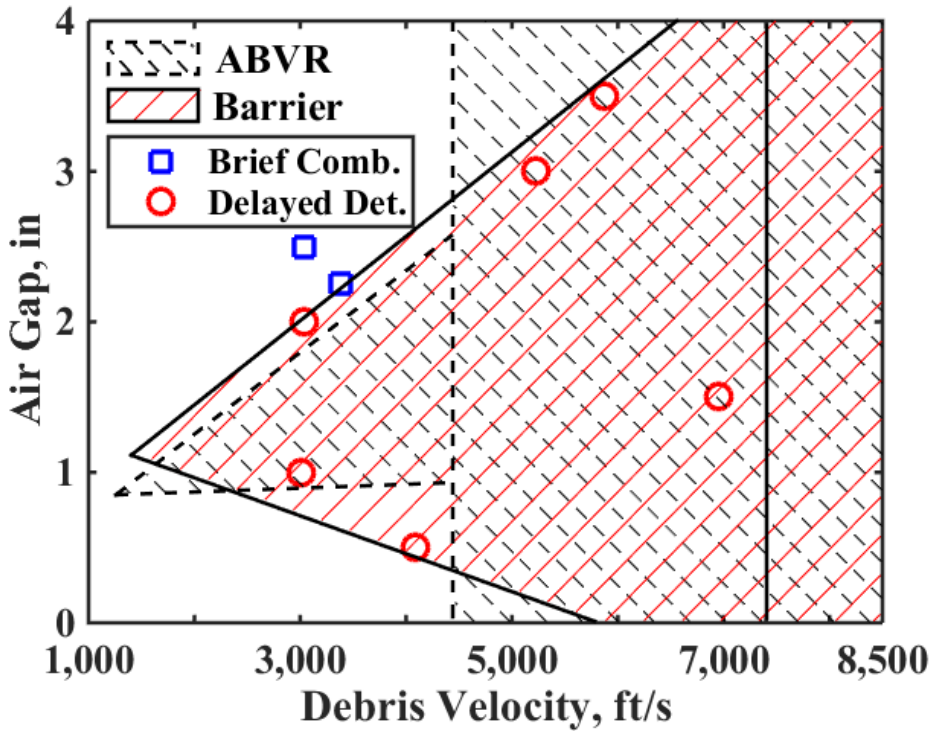
- **Impact of debris cloud appears to cause localized SDT on leading edge of propellant debris cloud**
  - **Reaction propagates back through debris cloud at the velocity typical of a detonation through highly porous material**
    - **Velocity increases as porosity decreases**

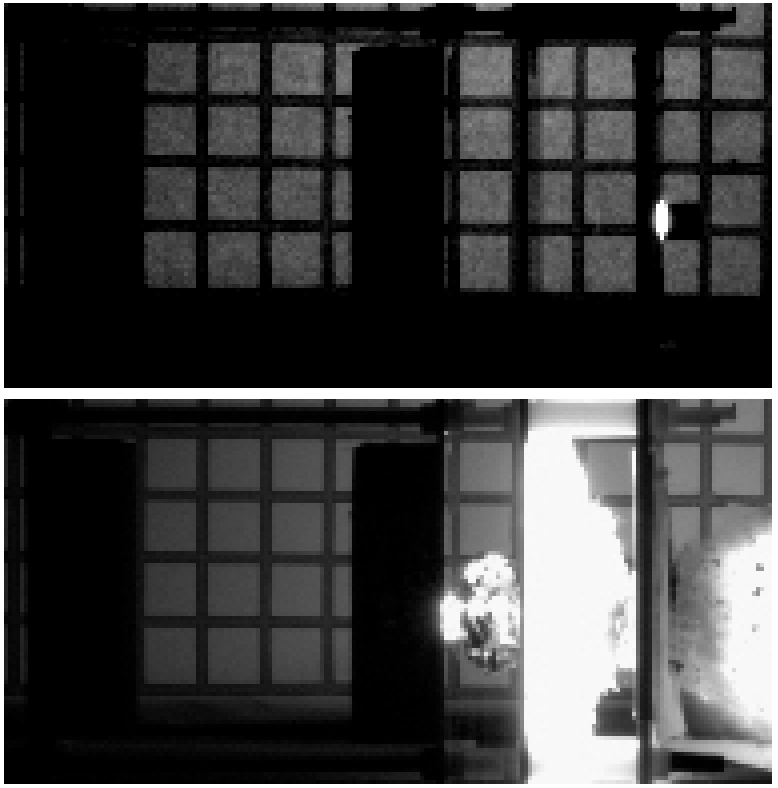
XDT – 3976 ft/s



Lower XDT Limit

- Decreasing cloud porosity decreases sensitivity to SDT
- Increasing cloud temperature increases sensitivity to SDT





Conclusions

- XDT is likely a prominent detonation mechanism in real rocket motors and needs to be mitigated
- XDT can be controlled by influencing properties of the propellant debris cloud
  - Porosity
  - Temperature
- Mitigation strategies
  - Eliminate cavity
    - Completely solid fuel grain
    - Insert material
  - Design cavity to negate hazards associated with debris cloud

Acknowledgements

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