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Application of Real-time X-ray Imaging in Characterizing the Abnormal Thermal Environment

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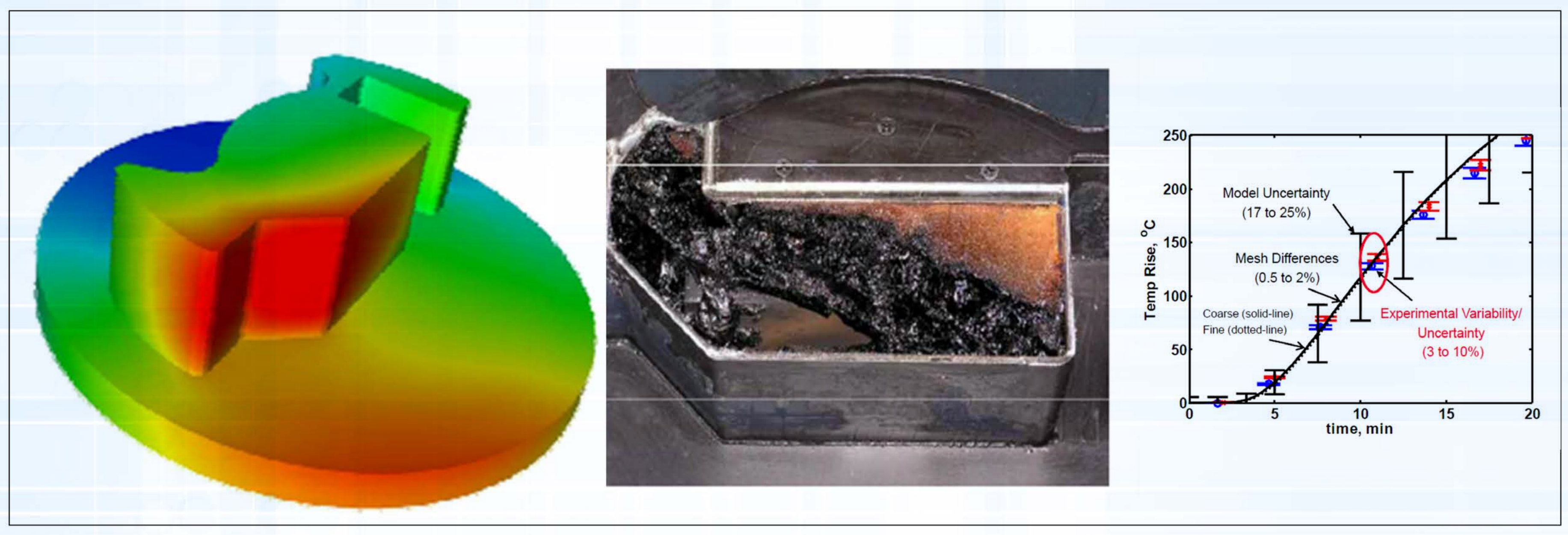
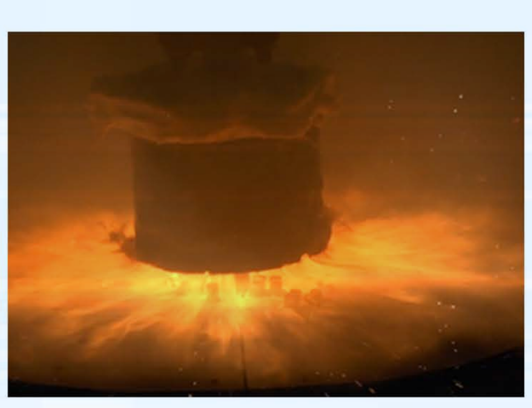
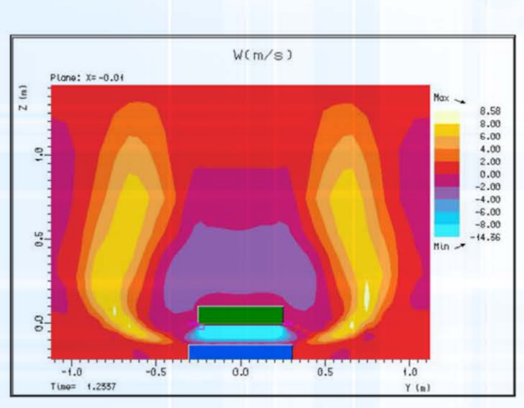


The abnormal thermal environment presents challenges in obtaining useful information. These challenges arise due to the *intense nature of the environment* and the *destructive nature of the test target response*. Real-time x-ray imaging can be used to probe tests that are specifically setup to acquire data for model development and validation.

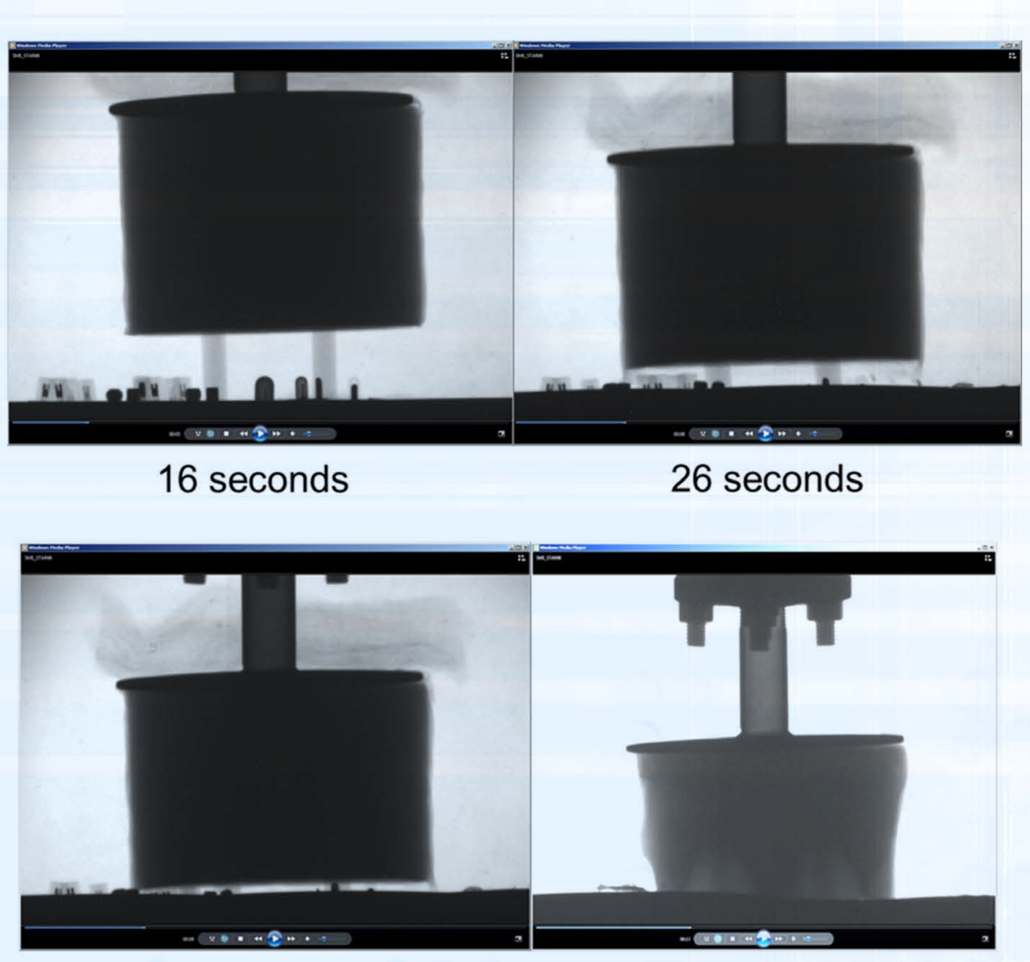
Environment Definition

The abnormal thermal environment often resists a clear definition due to the geometric details that can't be observed directly during a test event. For example, an environment specification is being developed to quantify the risk associated with a launch pad abort involving solid fueled rocket motors and high hazard payloads. The location of the environment is underneath a burning fragment of propellant ~3 cm above the ground.





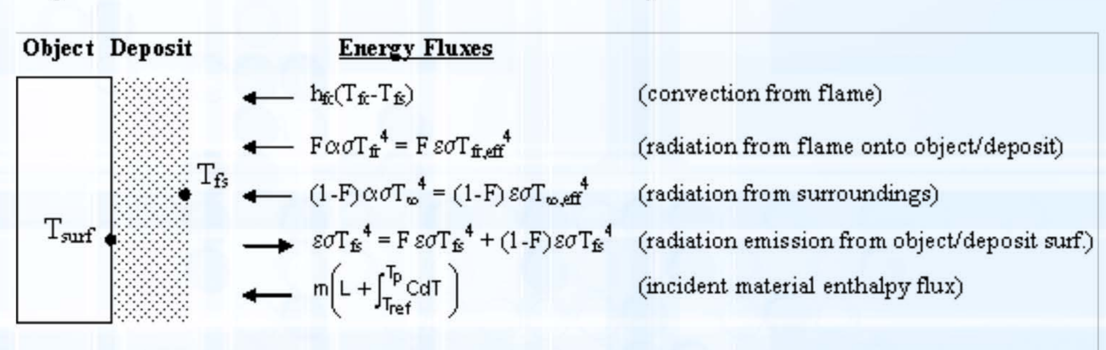
Burning in the small gap between a block of propellant and the ground underneath was previously modeled as a reacting flow between 2 parallel surfaces. However, real-time x-ray videos clearly show the development of burning cavities in the propellant created by the presence of small objects on the surface.

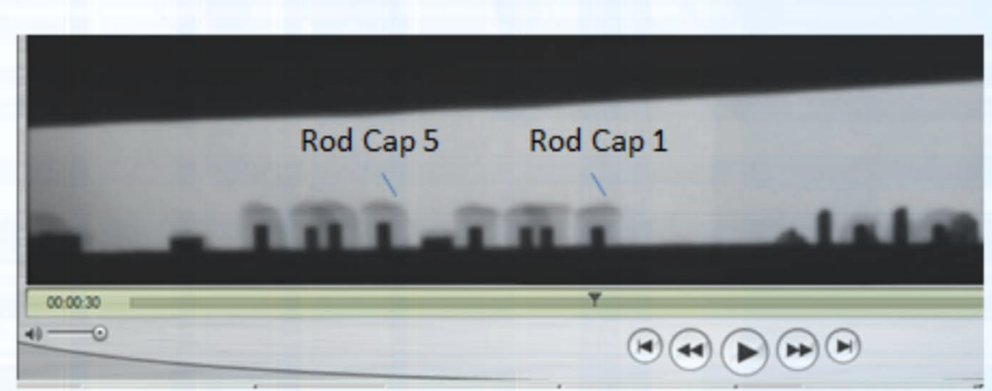


16 seconds | 26 seconds | 30 seconds | 34 seconds

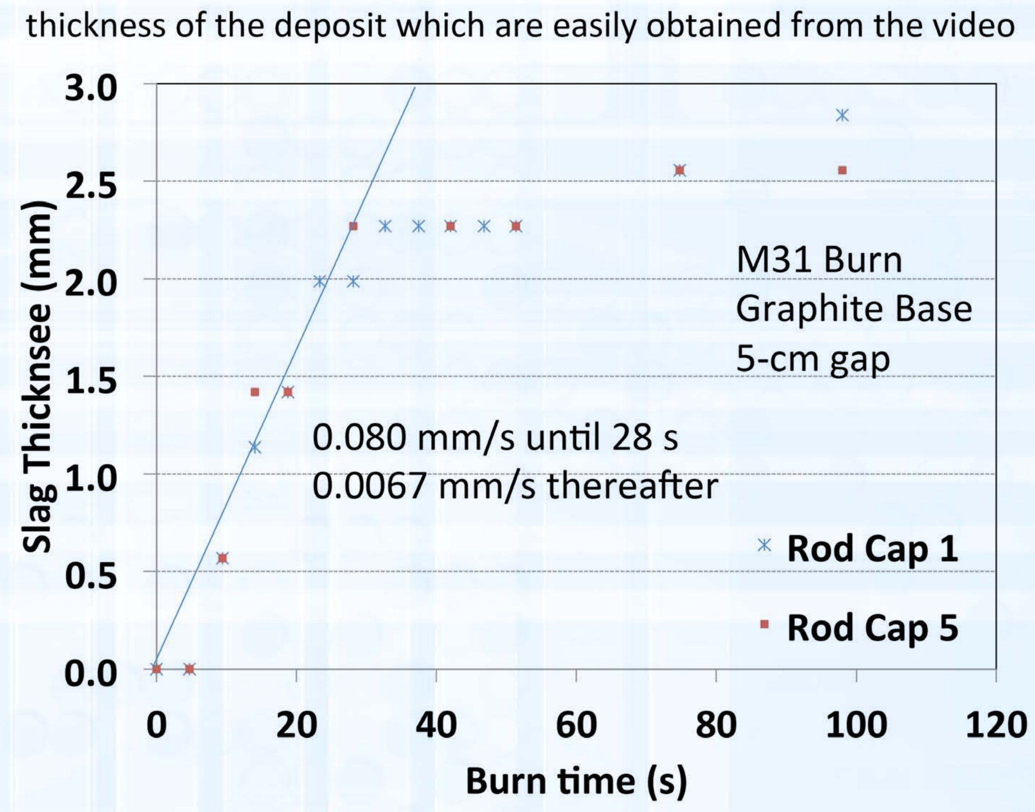
Environment-Target Interaction

Often the test target and the environment will interact producing an emerging parameter that must be measured in-situ. The flame in the gap between a burning block of propellant and the ground is a high temperature gas flow heavily loaded with sub-millimeter burning aluminum droplets and micron sized particles of aluminum oxide. This solid material condenses on objects in the flow and is a significant source of heat flux into the objects.



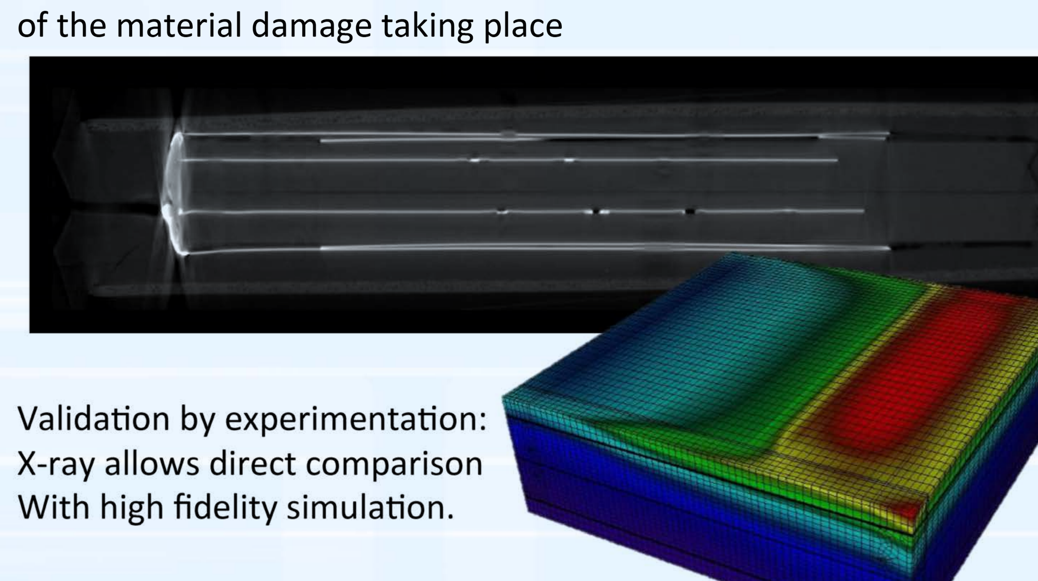


The emerging parameters are the deposition rate and maximum thickness of the deposit which are easily obtained from the video



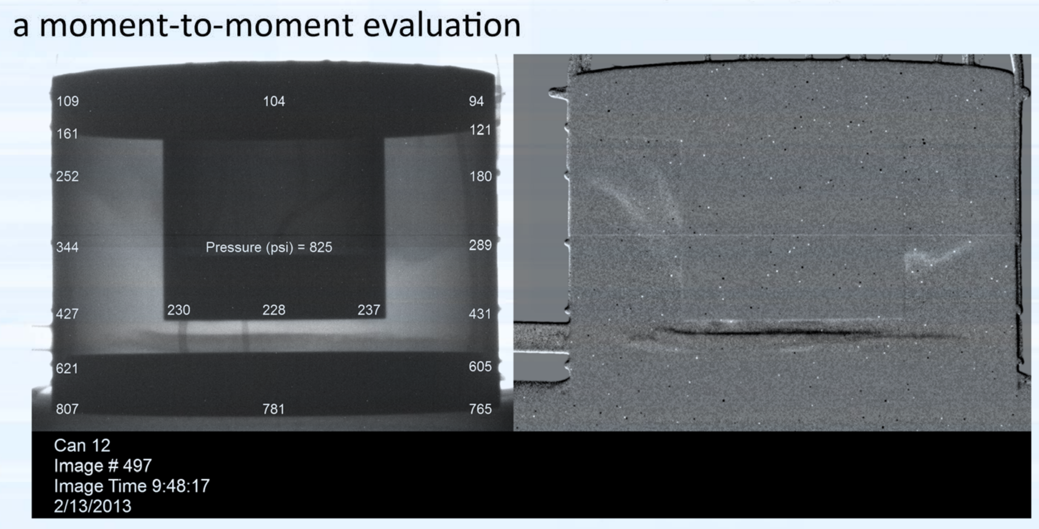
Target Response

Without the use of real-time x-ray, diagnostics of internal components of the test targets are limited to time-temperature traces and switch closures. This information while valuable and necessary is greatly enhanced when coupled with a physical picture of the material damage taking place

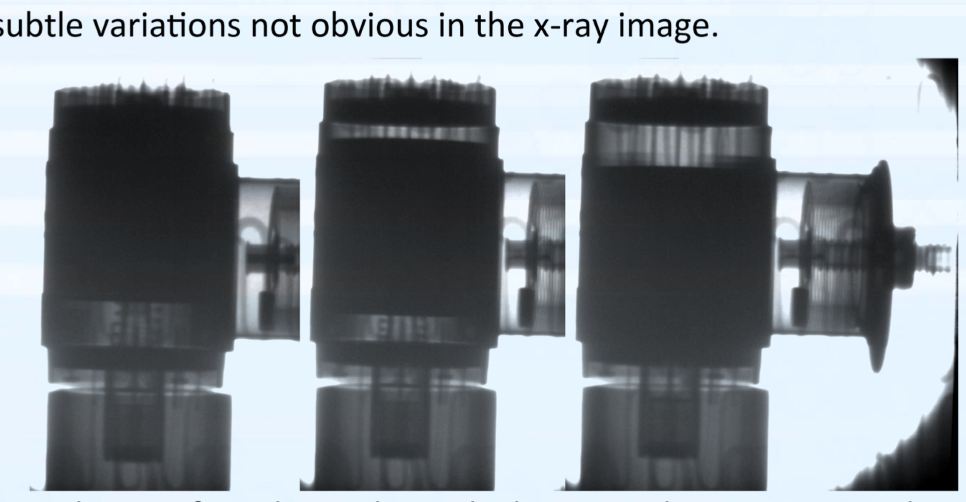


Validation by experimentation: X-ray allows direct comparison With high fidelity simulation.

Often the final damage is destructive which doesn't allow a post-test analysis. The real-time attribute of the x-ray imaging systems allows a moment-to-moment evaluation



Decomposing polyurethane foam in a welded stainless steel container 30 seconds before breach. Difference image (right) shows subtle variations not obvious in the x-ray image.



Correlation of mechanical switch closure with environmental temperature

The combined experimental/computational approach to complex problems is realized with modern diagnostics for discovery, validation, and uncertainty quantification.

- "Integral Level Validation and Accreditation of Multiple-Physics Codes for Computational Fire Simulations", Gill, W., Brown, A., Figueroa, V., Evans, G., and Weckman, E. , INTERFLAM 2004: 5-7 July 2004, Edinburgh Conference Centre, Scotland, UKLAM 2004: 5-7 July 2004, Edinburgh Conference Centre, Scotland, UK
- "Digital Imaging Hardware for X-ray Applications", Quintana, E., ASNT Digital Imaging XII, Mashantucket, CT, June 2009
- "Physical Behavior and Container Pressurization During Thermal Decomposition of Polyurethane Foams", Erickson, K., Dodd, A., and Quintana, E., Proceedings BCC Research Annual Flame Conference, Stamford, CT, May 2011

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