SAND2009-3188P

Overview of Sandia National Laboratories Capabilities

to support NRC NSIR

in the Development of a Regulatory Guidance Document Supporting the ISFSI and MRS Security Rulemaking

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Albuquerque, New Mexico

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

NNSA National Nuclear Security Administration
Sandia National Laboratories

Contents

- SNL Organization for NRC Program Support
- Science and Engineering Capabilities
- Past NRC Security Assessment Work
- Benchmarking
- Independent Reviews and QA

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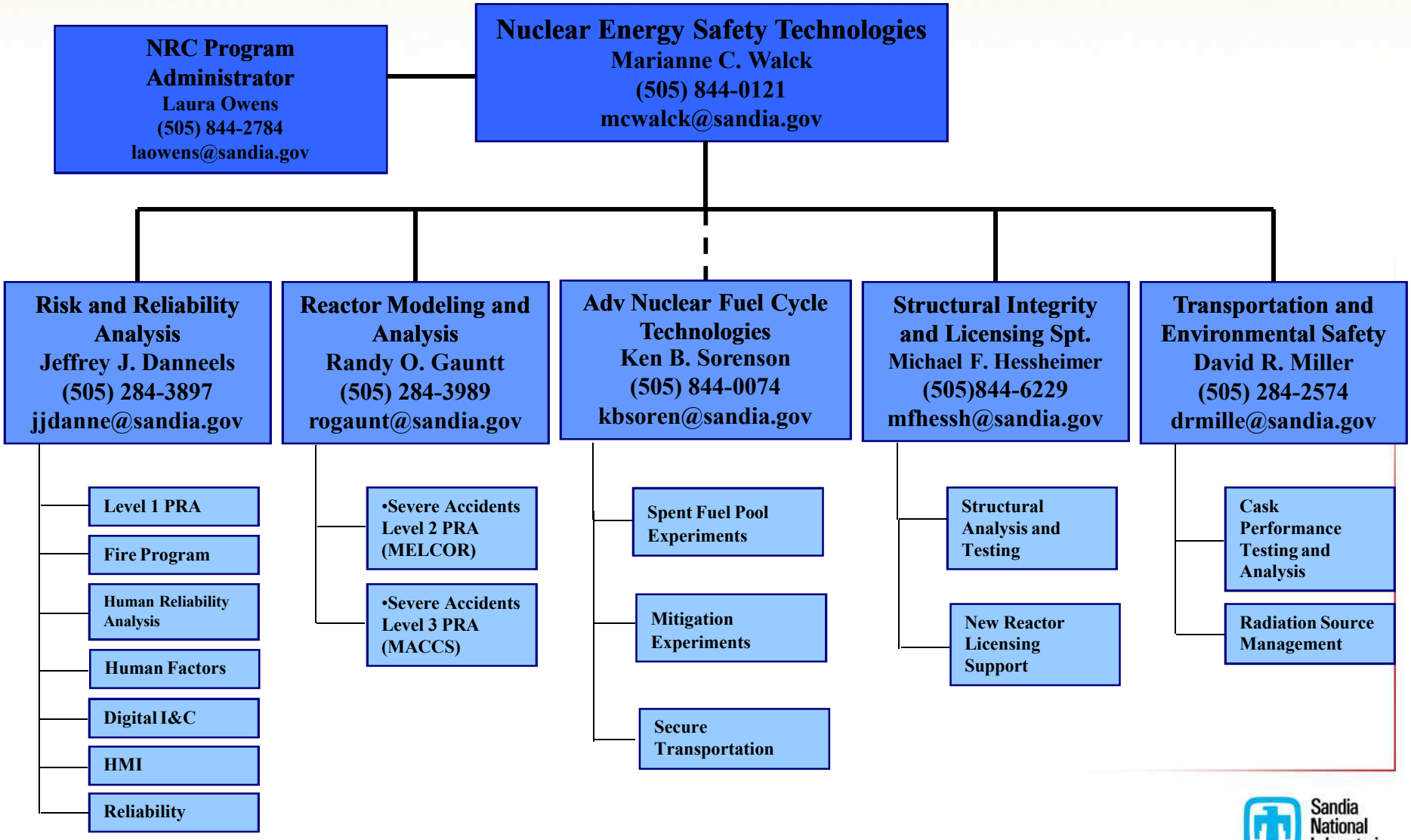
Nuclear Regulatory Commission Programs



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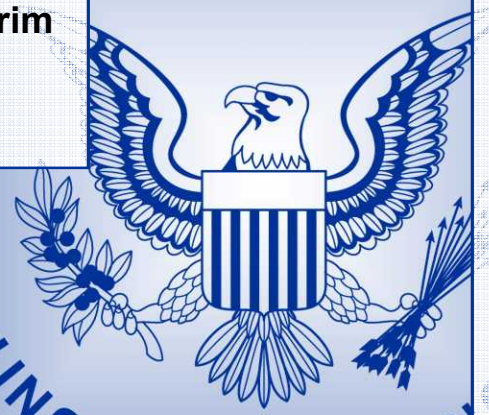
Breadth of Sandia support to NRC



NSIR
- Security for New Plants – NUREG-CR1345
- Evacuation and Emergency Response
- Incident Response Documents and Procedures
- Spent Fuel Pool explosives experiment
- Categorization Table for Radionuclides

NRR
- Fire Protection Support
- ESBWR Design Certification Support
- Alternative Source Term for License Amendment
- License Renewal: Oyster Creek (structural) and Pilgrim (MELCOR/MACCS)
- Security assessment for research and test reactors

RES
- 34 projects in FY06
- Primary areas include PRA, HRA, Fire Protection, severe accident modeling and analysis, security assessments for power reactors, structural/containment analyses, spent fuel pool experiments, State-of-the-Art Reactor Consequence Analysis (SOARCA)
- Includes Regulatory Guide revision, PRA methods and documents, HRA best practices, tech support for PTS rulemaking, fire protection standards

HR
- Training for NRC staff: Perspectives in Reactor Safety, Materials Security

NMSS
- Transportation Safety Risk Assessment
- Security Assessment for Materials

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Science and Engineering Capabilities

- **Sandia has the analytic/experimental capabilities to address complex engineering problems**
  - **Hardware**
    - **Massively parallel processing capability to handle coupled-code, large model problems**
  - **Software**
    - **Extensive library of application codes specifically developed to address high strain rate, large deformation problems**
    - **Coupled codes to address response spectra**
  - **People**
    - **Internal SNL capability to access subject matter experts**
    - **SNL has used staff from across the labs on past NRC vulnerability projects that addresses the complete problem**
  - **Experience**
    - **SNL has a large library of past projects to use as a basis for new work**
    - **SNL has a large data base of empirical data that provides a basis for benchmarking of new analytic work**
  - **Infrastructure**
    - **SNL has the facilities, processes, and cleared staff for working on sensitive and classified projects.**

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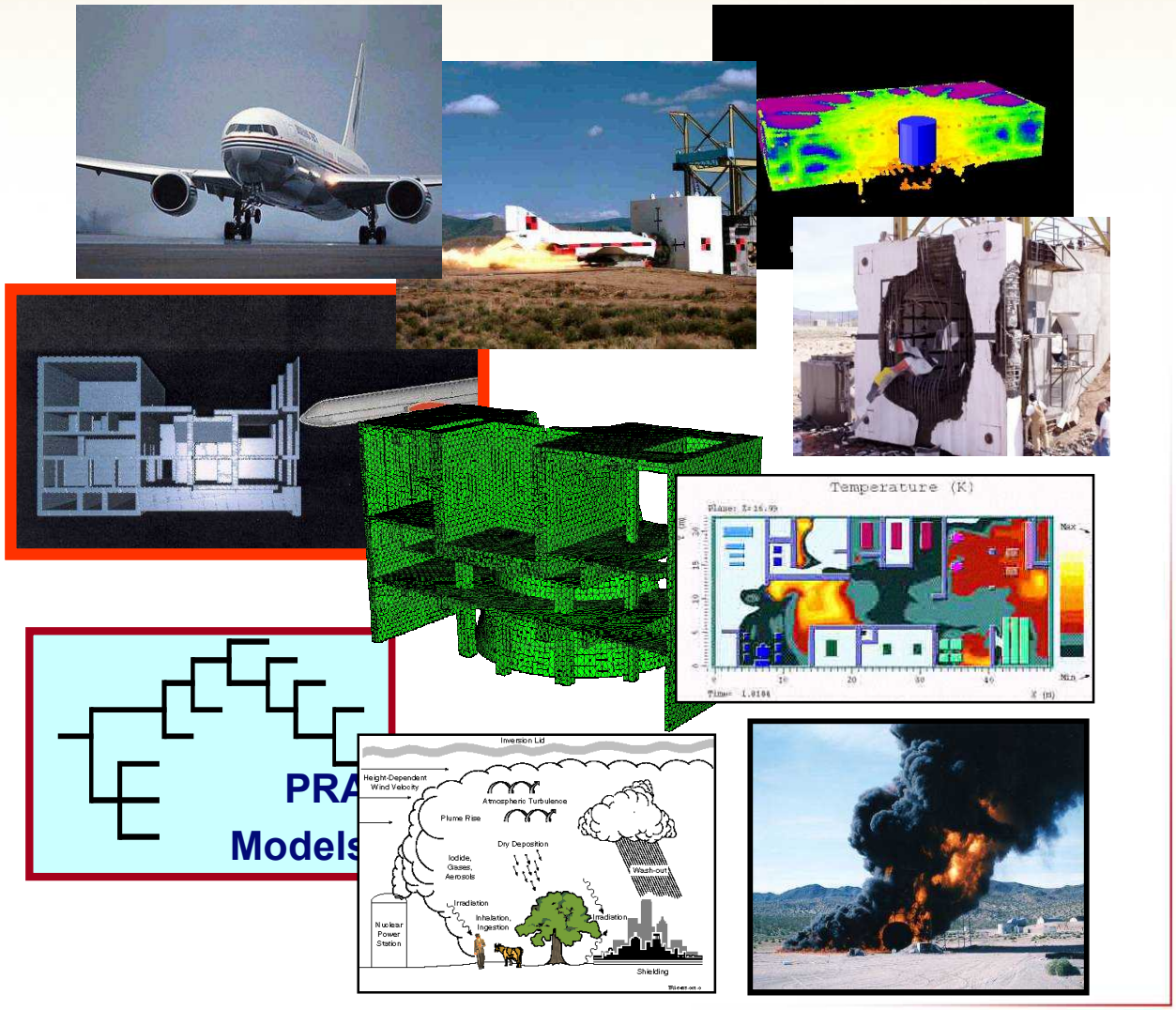
NRC Security Assessments Supported by SNL

- After the 9/11 terrorist attacks, SNL worked with NRC to understand threats and consequences to
  - Nuclear power plants
  - Fuel cycle facilities
  - Research and test reactors
  - Spent fuel and casks
- Threat Definition
  - Aircraft
- Building Response Analysis
  - Structural Damage
  - Fire Damage
  - Confirmatory Testing
- Plant Systems Response
  - Plant Damage States
  - Consequences
- Mitigation



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Past NRC Security Assessment Work

Project Title	JCN	Office	($K) Project Funding LTD	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
				1/1/03 - 12/31/06							
RDD Modeling Software Support	R1108	NSIR	$125								
								6/1/2006 - 6/1/2007			
Revision of NUREG/CR-1345	R1133	NSIR	$200								
								8/9/2005 - 9/30/2007			
Structural Pool Testing	R1137	NSIR	$1,100								
						8/31/03 - 12/31/06					
Basic Security Training	M1123	NSIR	$341								
						7/15/04 - 3/31/07					
Review NUREG	J3162	NSIR	$1,241								
				3/11/02 - 9/30/07							
Radioactive Transportation/Storage	J5412	NMSS	$6,501								
				6/15/02 - 1/30/04							
Physical Protection Vulnerabilities	J5428	NMSS	$529								
					8/12/02 - 10/28/05						
Vulnerability Assessments - Facilities	J5431	NMSS	$2,946								
					5/1/03 - 9/30/07						
Vulnerability Assessment RTR	J3094	NRR	$1,314								
					4/1/03 - 12/31/04						
Public Evacuation Studies	J3056	NRR	$290								
					8/1/03 - 12/31/04						
Redo Evacuation NUREG	J3103	NRR	$214								
							30/2005 - 6/30/200				
Security Assess for Nuclear Facilities	N6233	RES	$1,298								
					3/25/02 - 4/30/06						
New NPP Vulnerability	Y6623	RES	$18,375								
					3/27/03 - 12/30/06						
Dispersal Character. Of NRC-Lic. Mat.	Y6787	RES	$316								
						3/4/04 - 3/31/07					
Tech. Evaluation of Pool Designs	Y6856	RES	$989								
						3/26/04 - 4/30/07					
SFP Heatup & Propagation Phenomena	Y6758	RES	$4,030								
						5/1/04 - 7/28/05					
NPP/SFT Land/Sea Vulnerability	Y6825	RES	$6								
							4/15/03 - 4/30/09				
Dispersal Characteristics of SNF	Y6988	RES	$1,100								
						5/1/04 - 9/30/05					
Confirmatory Research Structural Response	Y6876	RES	$706								
						8/9/04 - 11/30/06					
Confirmatory Research VA Fire Analysis	Y6739	RES	$395								
		Total	$42,015 K								

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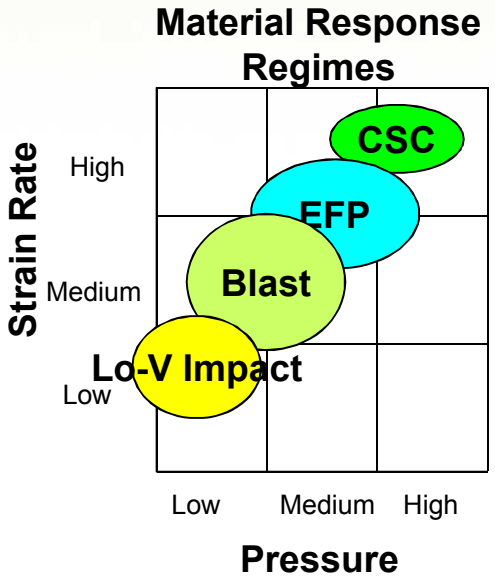
Past NRC Security Assessment Work

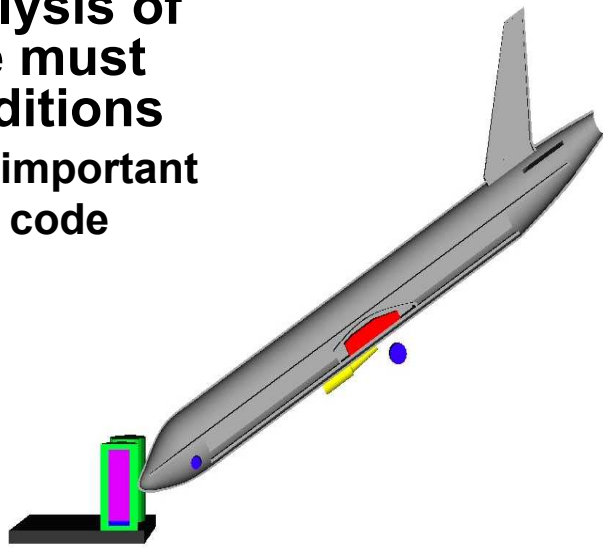
Problem Statement:

- **Threat environments represent a wide range of physics and response phenomena:**
  - **Problem spans a wide range of engineering and science disciplines**
  - **Problem spans a wide range of physical and time scales**
  - **Different physics phenomena must be modeled**



- **Blast**
  - Explosive charge
- **HEDD**
  - CSC
  - EFP
- **KE/Lo-V(elocity)**
  - Bullet/Penetrator

- **Modeling and analysis of material response must simulate true conditions**
  - **Benchmarking is important**
  - **Understanding of code V&V is important**



Example Problem

Physical Dimensions
- **< 10 microns to > 100 meters**

Material Form
- **Liquid**
- **Solids**
- **Gases**

Time Scales
- **milliseconds (impact) to hours (dispersion)**

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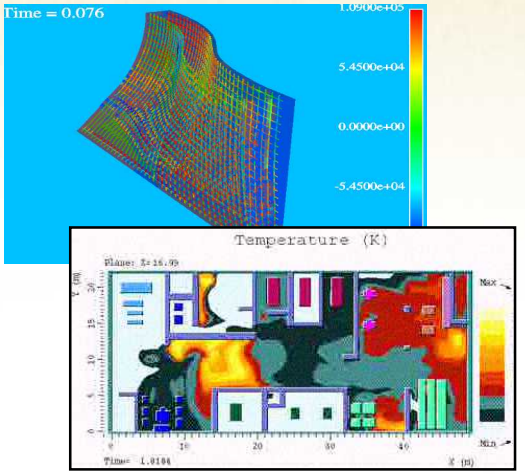
Past NRC Security Assessment Work
Facility Assessments:



- Conduct Vulnerabilitiy Assessments of the U.S. NPP fleet: 3 Phases
  - Quick look survey of all plants
  - In-depth study of selected plants
  - Address uncertainties and perform mitigation studies

- SNL Peer Review of NRC Dry Cask Storage PRA Report
  - Technical peer review of a dry cask storage PRA using ASME PRA guidance

- Conduct Vulnerability Assessments of 3 U.S. Irradiator Facilities
  - Physical Protection Vulnerabilities Assessment and Guidance Development for 10CFR36 Licensees, September 2003
  - Develop guidance needed to implement any new physical protection requirements
  - Scope: Consider only explosives and not required to consider a thermal driver in the analyses

- Parametric Evaluation of Seismic Behavior of Freestanding Spent Fuel Dry Cask Storage Systems: NUREG/CR-6865
  - Used coupled models to investigate the soil/rock foundation interaction with nonlinear friction contacts at interfaces
  - Results provided in nomograms to facilitate safety reviews of LAs by NRC staff
    - e.g., classes of casks evaluated for tipping ~ *f* (ground acceleration)

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Past NRC Security Assessment Work

Transportation and Storage of SNF & other RAM

- **Estimate SNF package response to airplane impacts and large blast events in response to 9/11**
  - **Two transport casks**
  - **Four storage casks**
  - **Analyses of licensed casks conducted using benchmarked codes**
  - **Potential source terms and consequences estimated**
- **Develop source term guidance for additional sabotage events**
  - **Expert panel – qualitative in nature**
  - **Spent fuel transport and storage packages**
  - **Non-SF packages**
- **Used as a basis for the NRC framework document**

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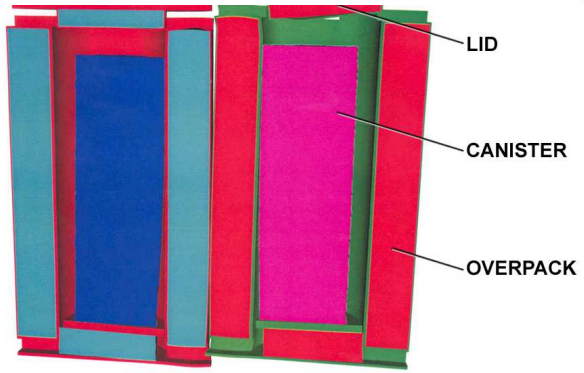
Past NRC Security Assessment Work

Aircraft Impact Analysis Methodology

- Global analyses evaluated overall crash response
  - Transient force on cask: impulse as well as momentum transfer
  - Cask velocity & displacement
  - CTH was used for these calculations
- Local analyses evaluated cask and canister detailed response
  - Cask integrity to impacts from aircraft & components
  - Penetration from hard components
  - Cask-to-cask impacts
  - Canister response
  - Analyses conducted using FEM



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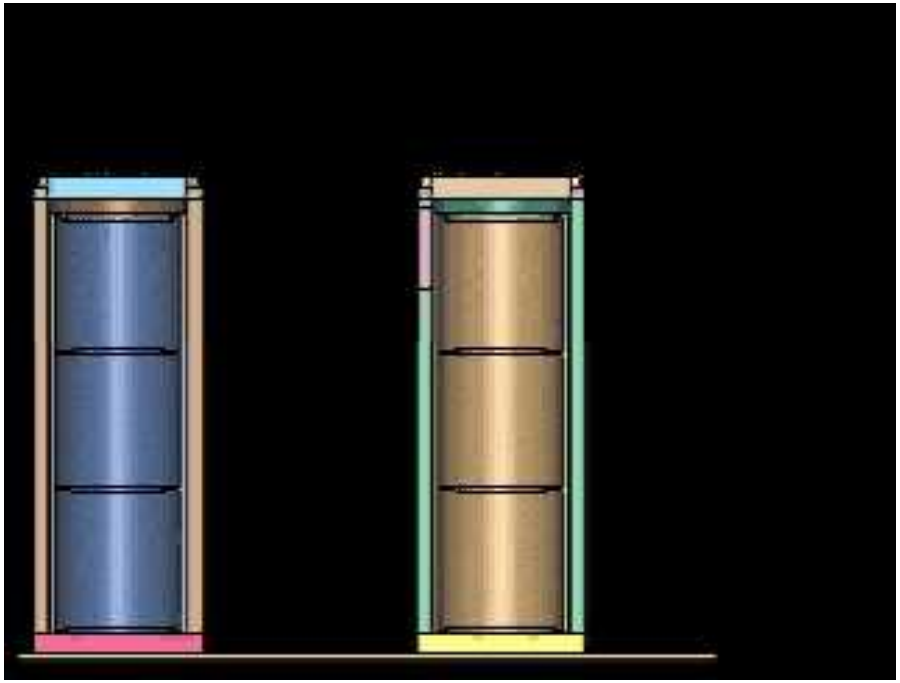
Past NRC Security Assessment Work

Aircraft Impact Analysis

Global Analysis



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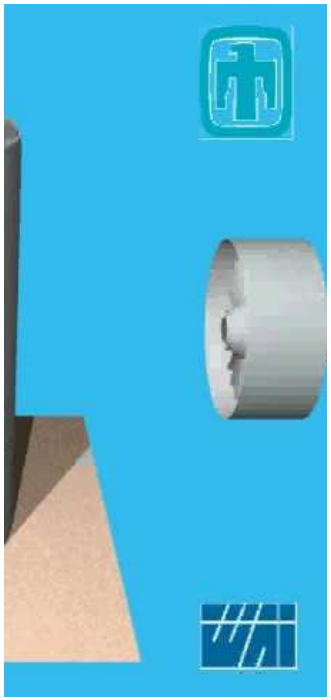
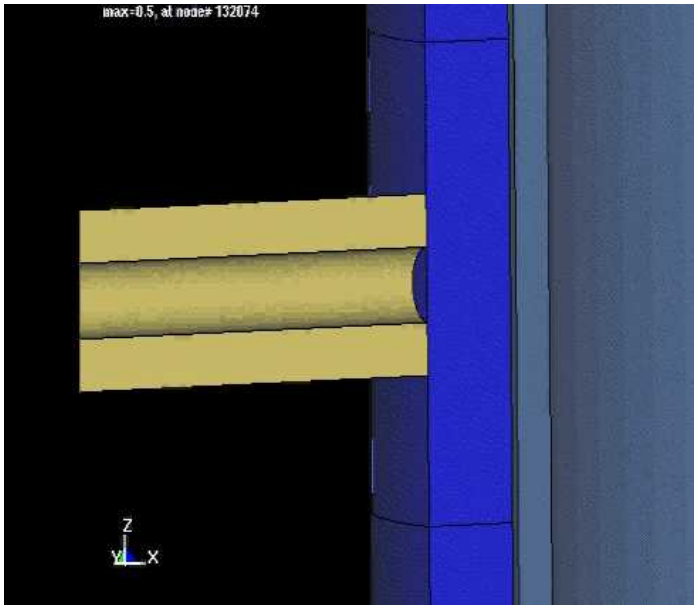
Past NRC Security Assessment Work

Aircraft Impact Analysis

Local Analyses





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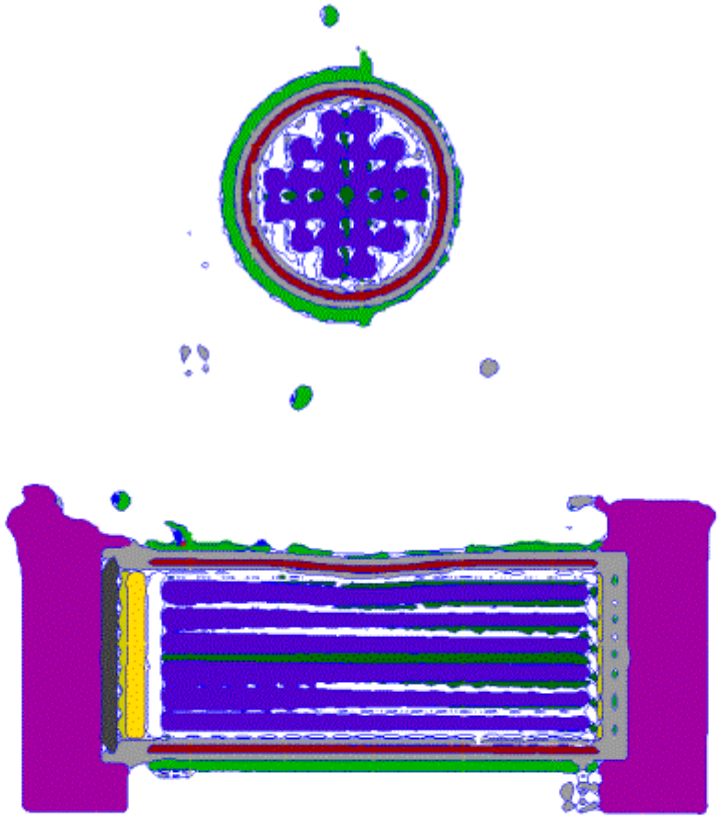
Past NRC Security Assessment Work

Blast Analysis

- **Loading and standoff specified by NRC**
- **Standoff representative of a realistic delivery scenario**



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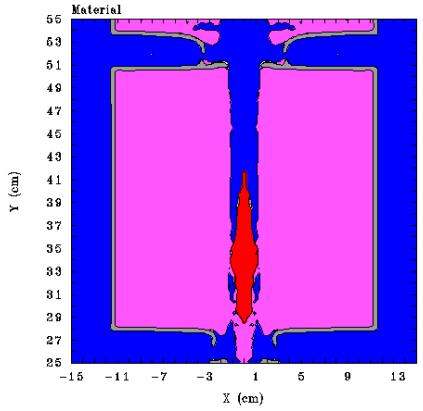
Past NRC Security Assessment Work

Guidance Documents & Qualitative Vulnerability and Threat Assessments

- **Non-Spent Fuel Radioactive Materials Source Term Guidance Document**
  - **6 packages, 180+ scenarios, August 2004**
- **Spent Fuel Source Term Guidance Document**
  - **7 packages, 150+ scenarios, November 2004**
- **16 scenarios were included in these evaluations**

➢ **Documents provide basis for estimating public health consequences**



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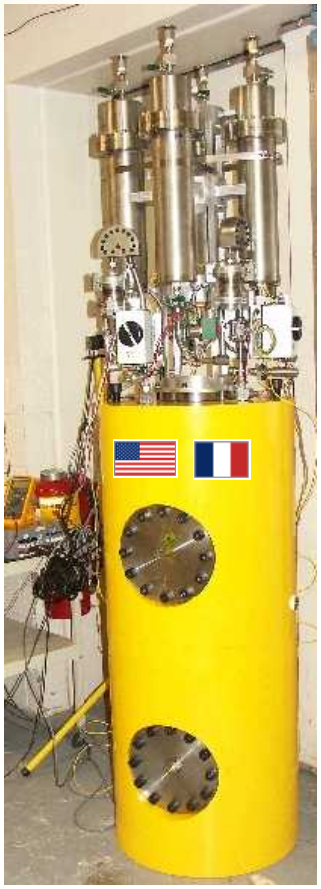
Past NRC Security Assessment Work

Sabotage - Aerosol Testing

- SCENARIO: plausible sabotage attack on nuclear transport casks by HEDD
- GOALS: Quantify source-term data and conduct aerosol analyses on CeO_2, DUO_2, and SNF to determine:
  - Measure respirable fractions
  - Calculate enrichment factors
  - Determine spent fuel ratio
- Supported jointly by DOE & NRC
- Collaboration with an International Working Group
- Four Phase Test Program:
  - Phase 1: CSC characterizations, glass targets (2001-2002)
  - Phase 2: CeO_2 ceramic pellet rodlets, ~ 30 tests (2002-2005)
  - Phase 3: DUO_2 pellets/rodlets, 6 tests (2006-2007)
  - Phase 4: TBD – testing real spent fuel Surrey and H.B. Robinson



DUO_2 Aerosol – Explosive Test Chamber

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Past NRC Security Assessment Work

Sabotage - Aerosol Testing (cont.)

- Reliable source-term data and supporting analyses will determine the release of respirable aerosol particles
  - YMP EIS conservatively assumed 5% respirable fraction
- Guide and validate the technical basis for transport & storage regulations (10 CFR Parts 71, 72, and 73)
- Support security/safeguards procedures & mitigation strategies
- Provide basis for evaluating appropriate levels of physical protection for SNF shipments & site operations
- Significant results to date:
  - CeO_2 respirable fraction = 1.4% +/- 0.6%
  - DUO_2 respirable fraction = 1.3% +/- 0.4%
  - ➡ Results predicting reduced consequences

⬅ post-test DUO_2 rodlet

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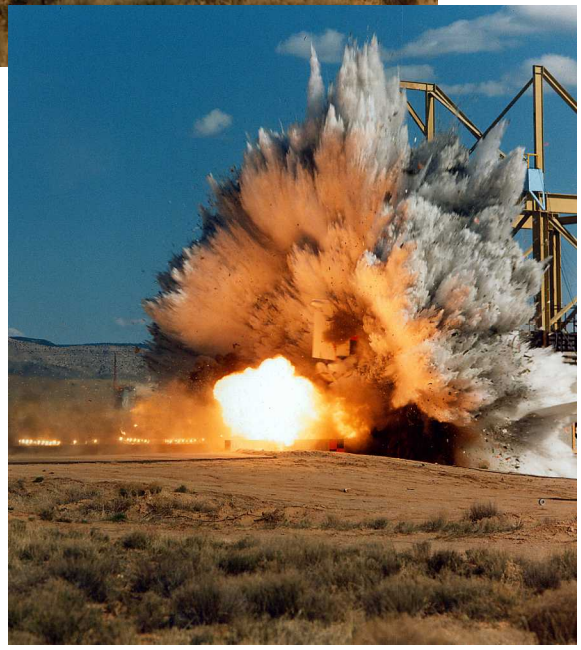
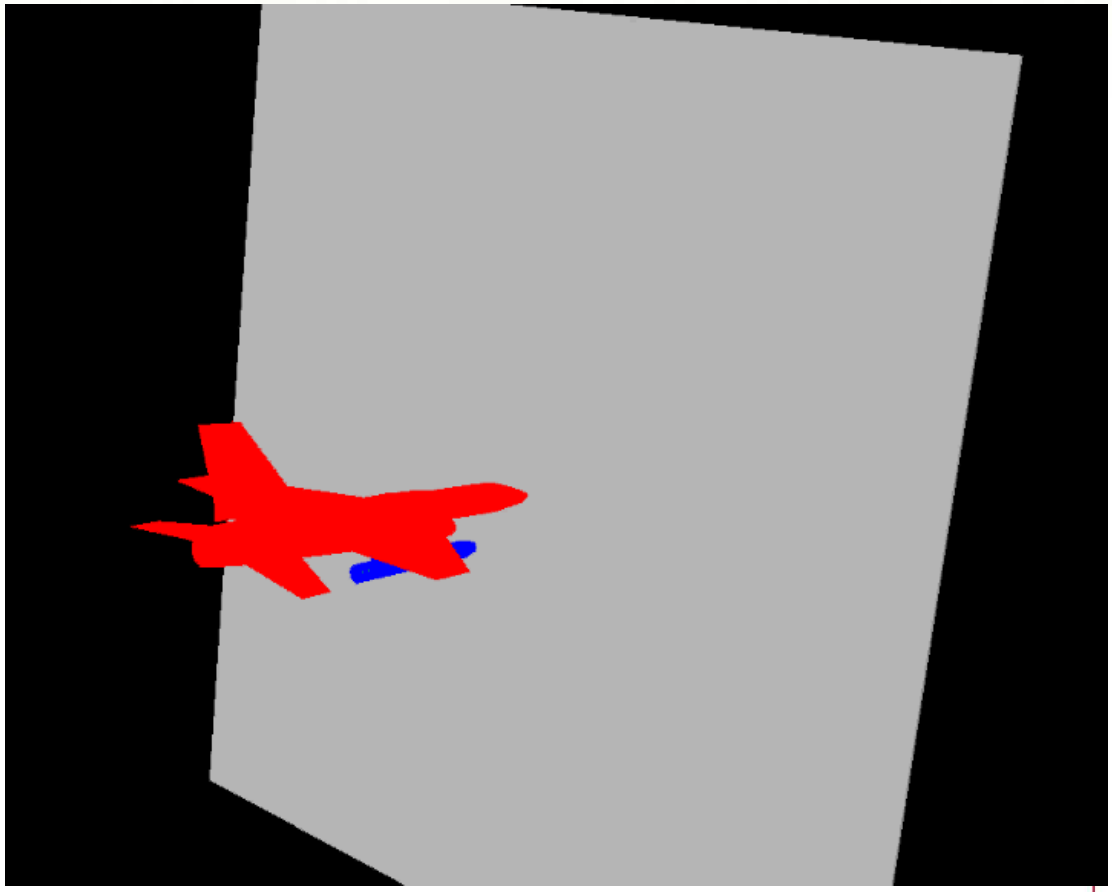
Past NRC Security Assessment Work

Independent Analysis for Licensing of PFS



Sandia F-4 Crash Test & F-16 Simulation



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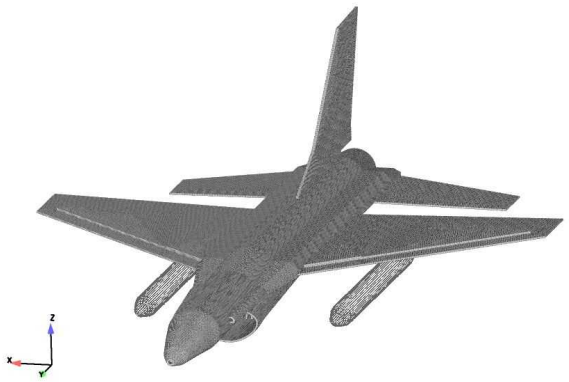
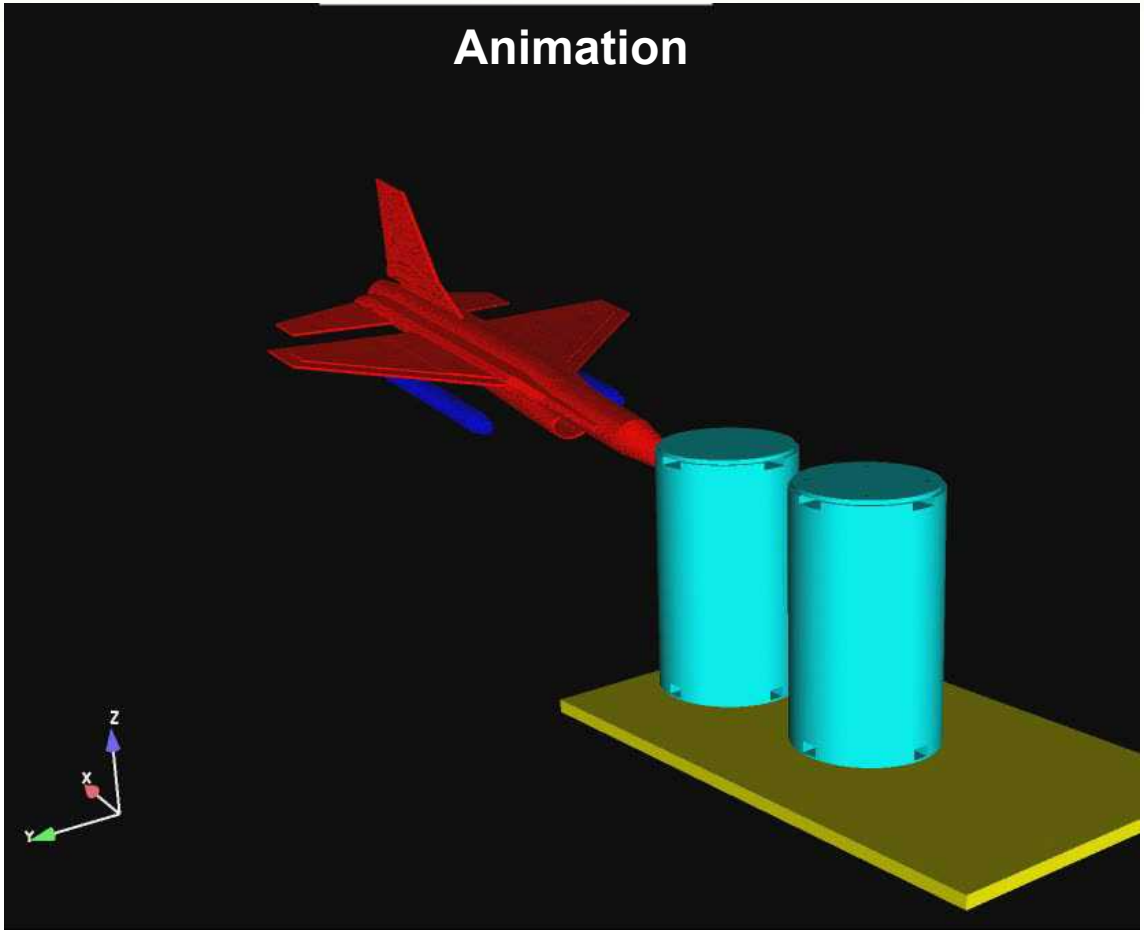
Past NRC Security Assessment Work

PRONTO SPH Aircraft Impact



SPH Model

SPH Model
(Fuel Tanks and Engine)



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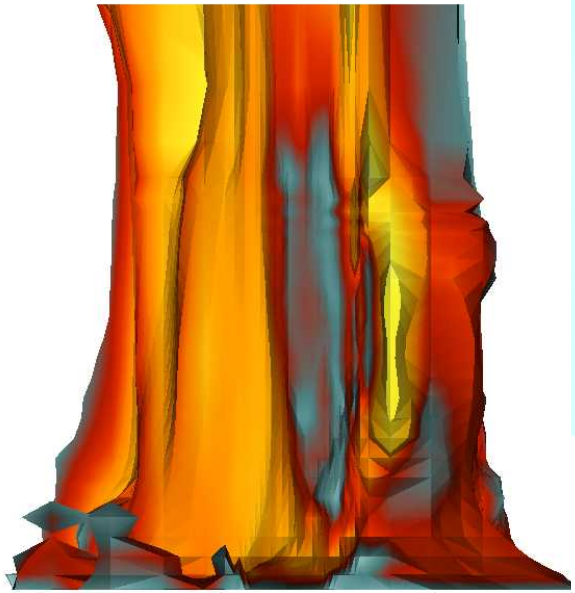
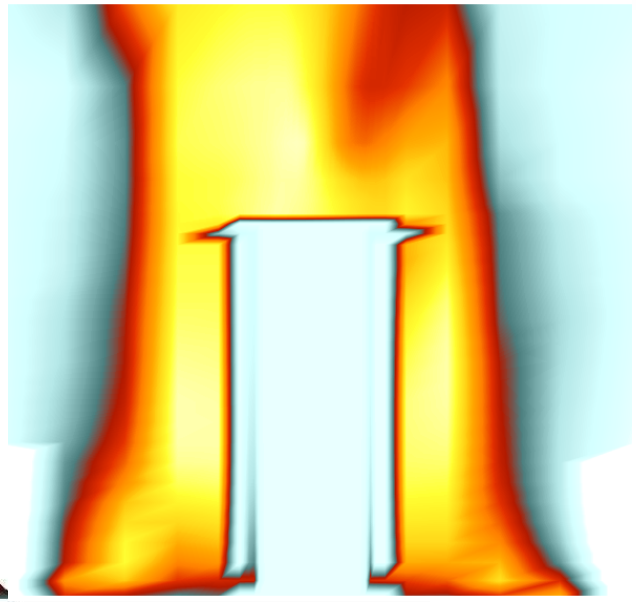
Past NRC Security Assessment Work

Fire and Heat Transfer Analyses

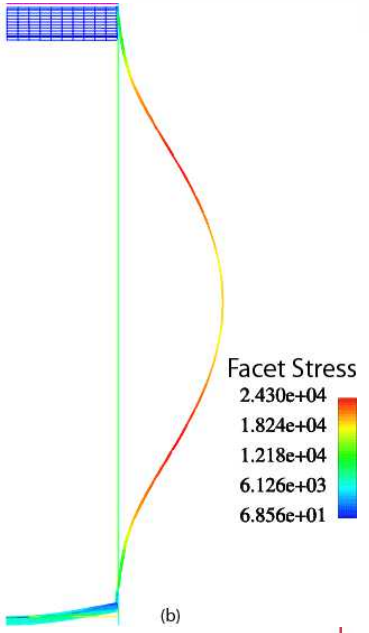
Fire

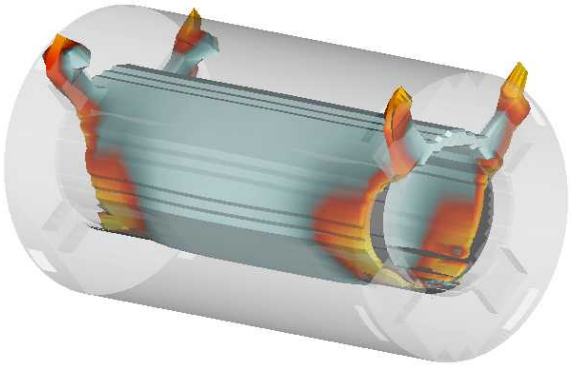




Heat Transfer

Thermo-Mechanical





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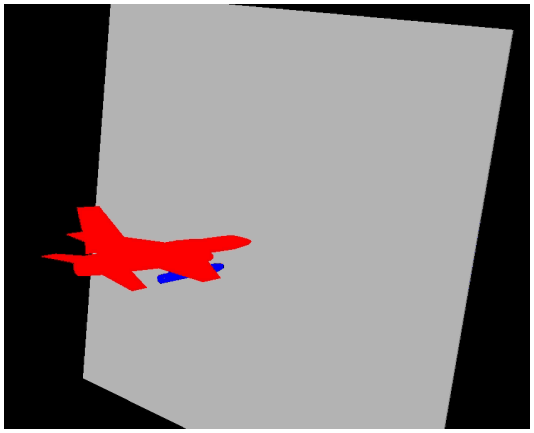
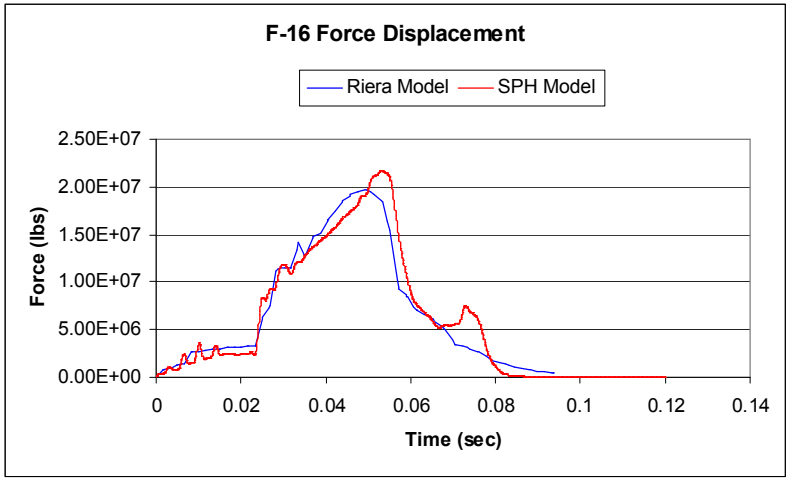
Benchmarking of Analytical Tools

Sandia is cognizant of the need to properly verify computer models, codes, and results. Direct benchmarking is not always possible. Verification is done in various ways;

- comparison to first principles
- comparison to empirical data
- comparison between independent codes, analysts





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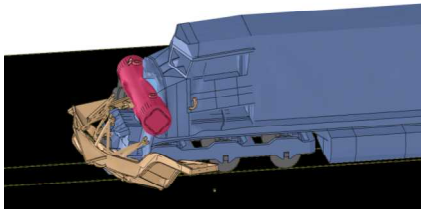
Benchmarking of Analytical Tools

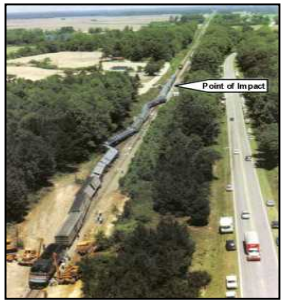
Rail car impact into a LWT SNF Type B cask

- Qualitative links between testing, analysis, real-life accident

Test performed @ SNL



Analysis performed @ SNL



Accident in South Carolina 1995

Pool Fire Test and Modeling Comparison

- Validated fire models can be used with confidence to estimate heat flux on target surface

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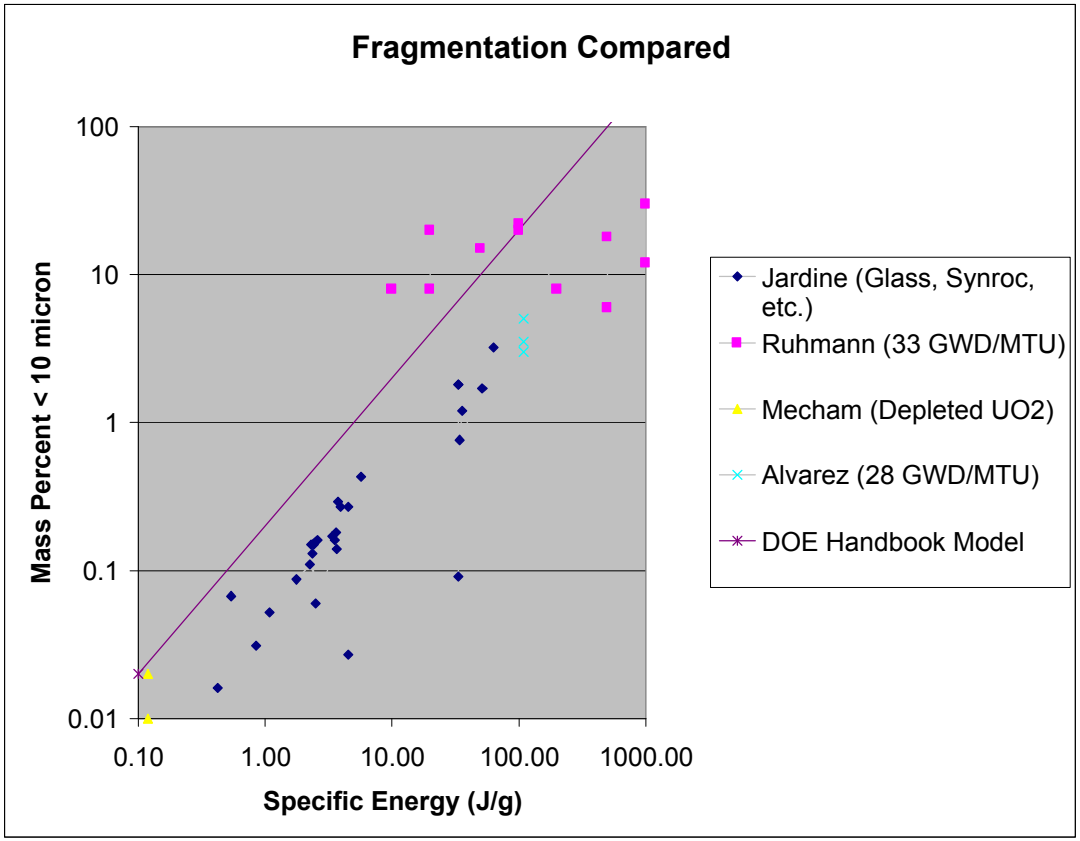
Benchmarking of Analytical Tools

Benchmarking of particle size production as a function of input energy



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Independent Reviews and QA

- **The NRC asked the National Academy of Sciences to perform and independent review of SNL's security Assessment work:**
  - **The NAS conducted extensive reviews of the Nuclear Power Plant and Transport/Storage Cask vulnerability work. In general, the reviews;**
    - **indicated acceptance of basic approaches and assumptions**
    - **indicated acceptance of basic results**
- **SNL has a long history of managing NRC projects with the proper level of QA**
  - **Corporate processes are linked to NRC requirements**

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