Verification, Validation and Selected Applications of the VULCAN and FUEGO Fire Field Models

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Fire Science & Technology

Sandia National Laboratories

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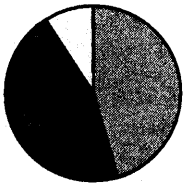
Start FY02 Fire Program Profile

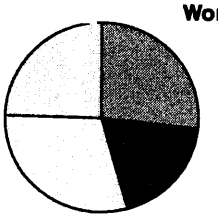
FY02 Funding Directly Related to Fire > 6.5 $million

Work Type

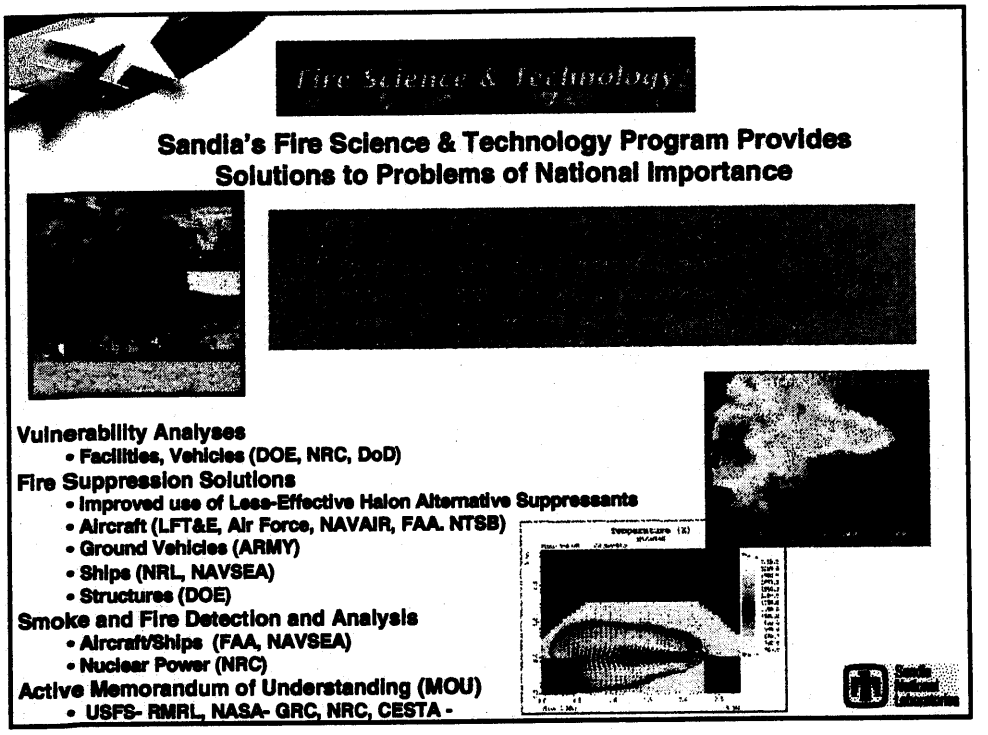


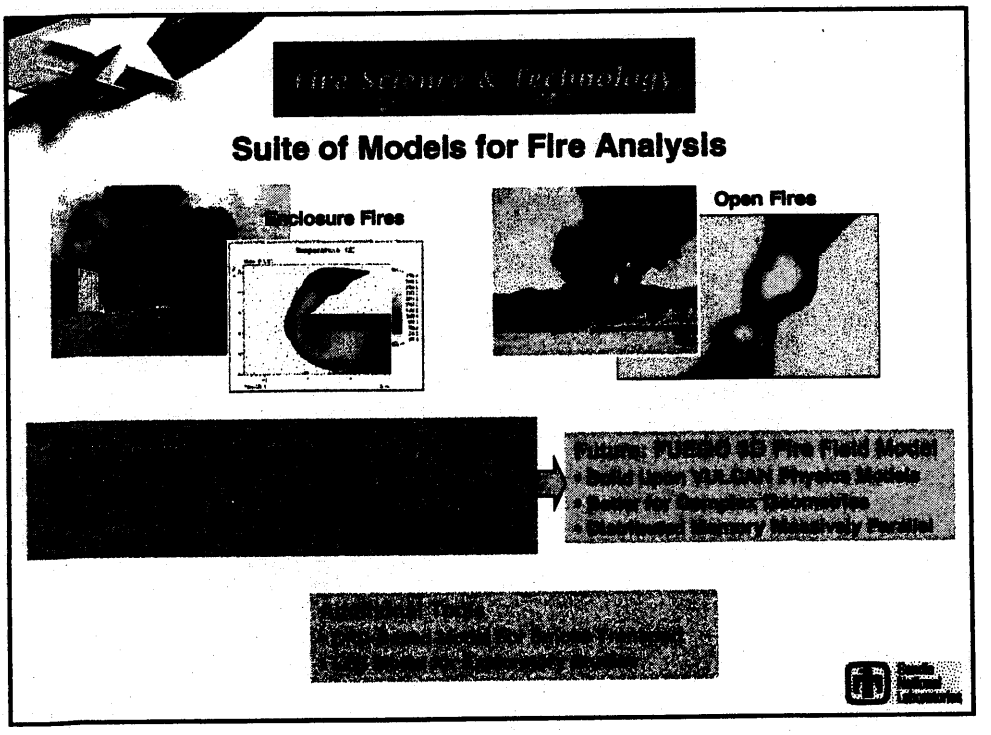
- Computational
- Experimental
- Analytical

Work Area



- Research
- Code Development
- Code Validation
- Applications


Fire Science & Technology
Sandia's Fire Science & Technology Program Provides Solutions to Problems of National Importance
Vulnerability Analyses
• Facilities, Vehicles (DOE, NRC, DoD)
Fire Suppression Solutions
• Improved use of Less-Effective Halon Alternative Suppressants
• Aircraft (LFT&E, Air Force, NAVAIR, FAA. NTSB)
• Ground Vehicles (ARMY)
• Ships (NRL, NAVSEA)
• Structures (DOE)
Smoke and Fire Detection and Analysis
• Aircraft/Ships (FAA, NAVSEA)
• Nuclear Power (NRC)
Active Memorandum of Understanding (MOU)
• USFS- RMRL, NASA- GRC, NRC, CESTA -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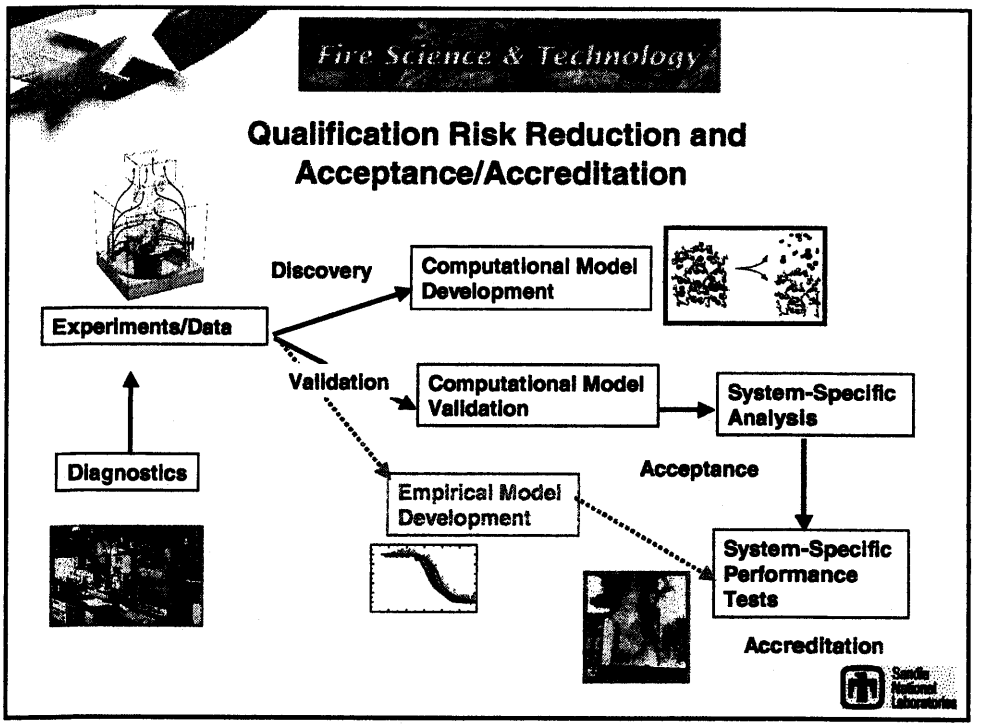
Suite of Models for Fire Analysis
Enclosure Fires
Open Fires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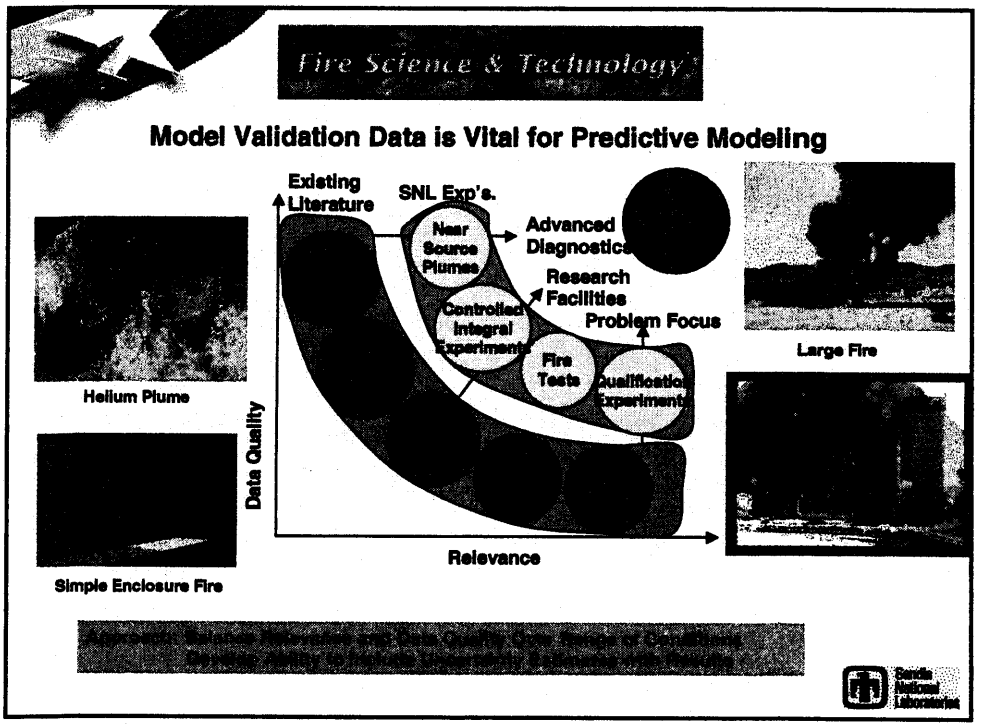
Qualification Risk Reduction and Acceptance/Accreditation
Discovery
Computational Model Development
Experiments/Data
Validation
Computational Model Validation
System-Specific Analysis
Diagnostics
Acceptance
Empirical Model Development
System-Specific Performance Tests
Accreditation


Fire Science & Technology
Model Validation Data is Vital for Predictive Modeling
Existing Literature
SNL Exp's.
Near Source Plumes
Advanced Diagnostics
Research Facilities
Problem Focus
Controlled Integral Experiments
Fire Tests
Qualification Experiments
Helium Plume
Large Fire
Simple Enclosure Fire
Data Quality
Relevance

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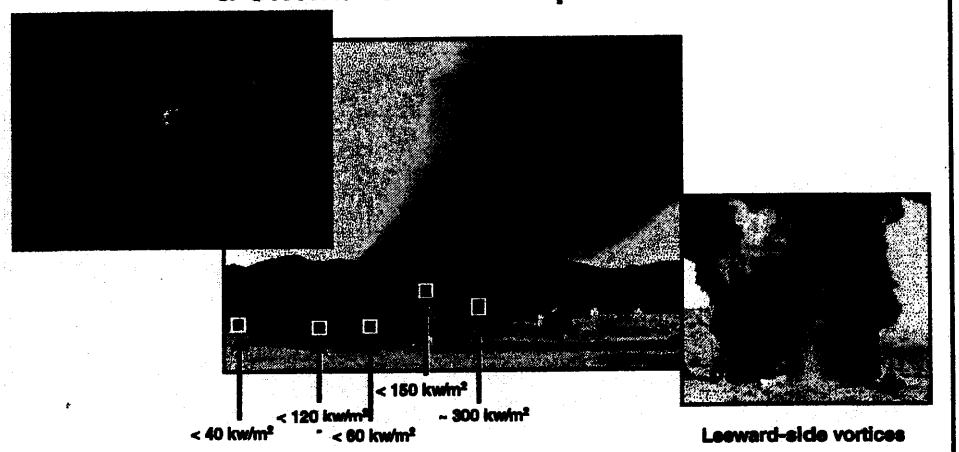
Thermal Insult Depends on Location & Orientation with Respect to Fire



Measured heat fluxes in large open fires

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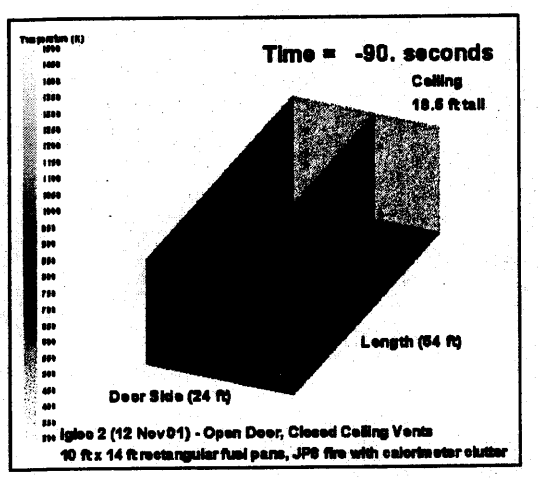
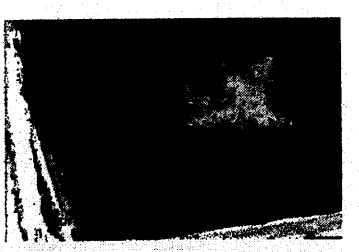
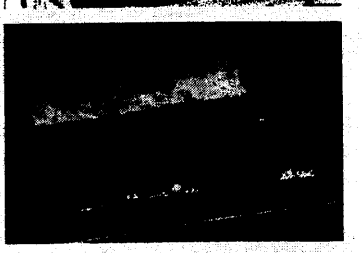
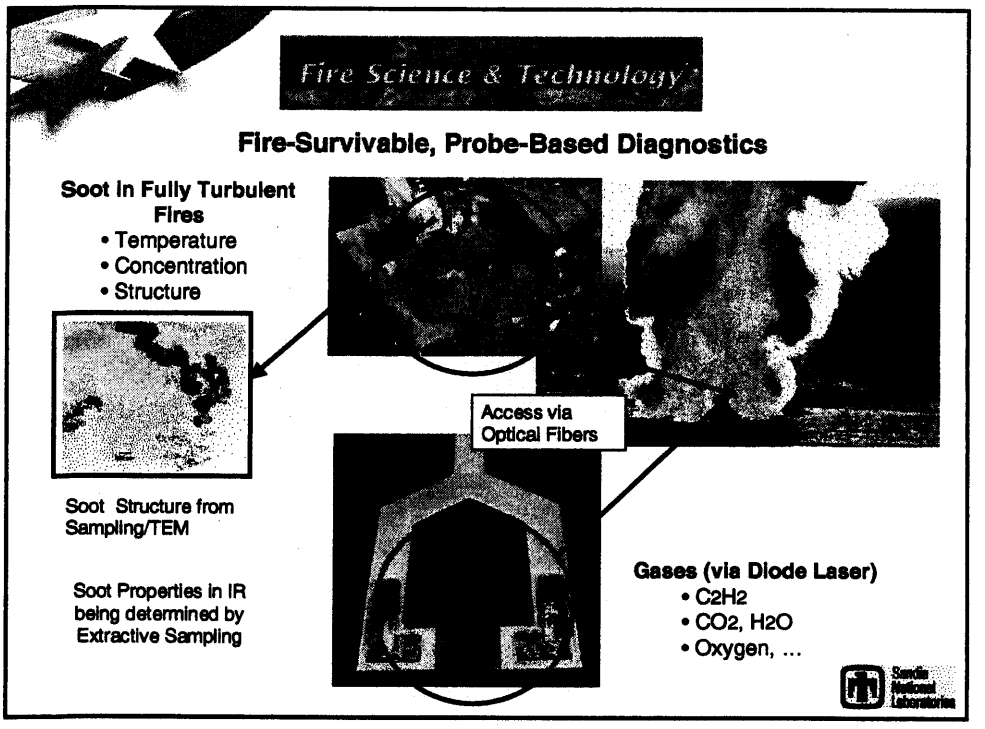
Enclosure Fire Heat Fluxes Characterized





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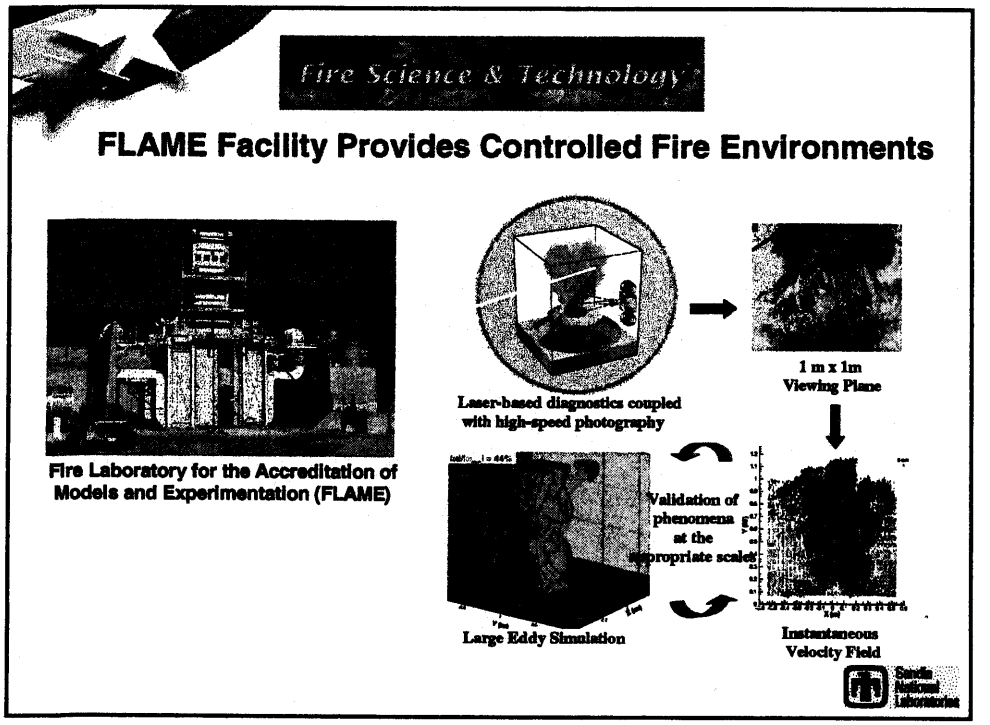
Fire-Survivable, Probe-Based Diagnostics
Soot In Fully Turbulent Fires
• Temperature
• Concentration
• Structure
Soot Structure from Sampling/TEM
Soot Properties in IR being determined by Extractive Sampling
Access via Optical Fibers
Gases (via Diode Laser)
• C2H2
• CO2, H2O
• Oxygen, ...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FLAME Facility Provides Controlled Fire Environments
Fire Laboratory for the Accreditation of Models and Experimentation (FLAME)
Laser-based diagnostics coupled with high-speed photography
1 m x 1m Viewing Plane
Validation of phenomena at the appropriate scale
Large Eddy Simulation
Instantaneous Velocity Field

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Integral Validation Experiments Underway in FLAME

Key Set of Fire Data for FUEGO Validation

- Airflow Control (<10% variation with Grid-Scale Resolution
- Temperature Distributions
- Soot Measurements
- TDL Measurements
- Fast-Scanning IR Data

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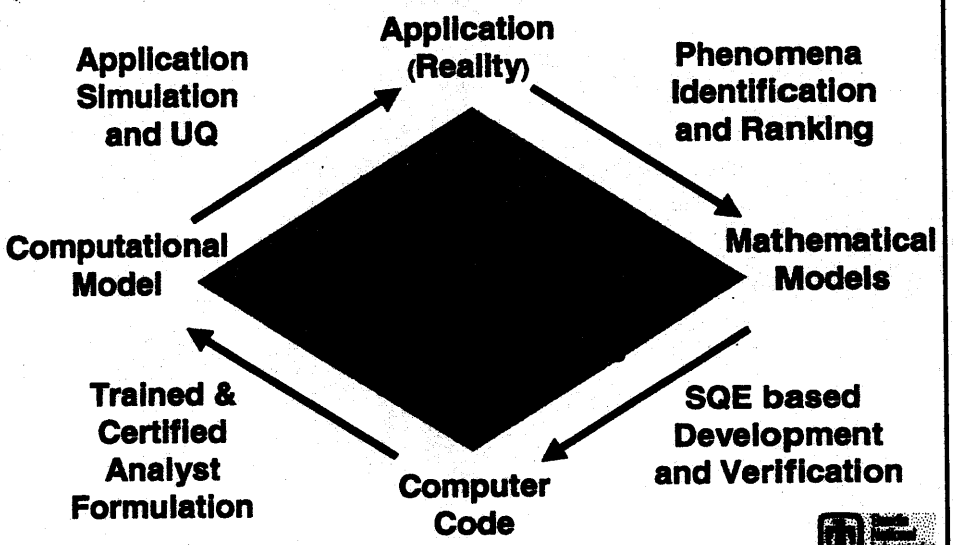
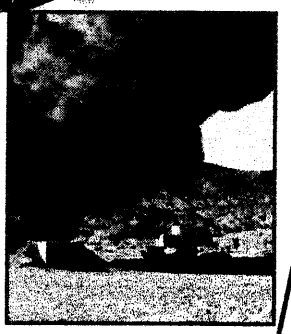
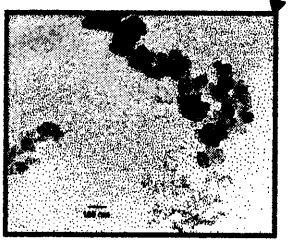
V&V Process Overview



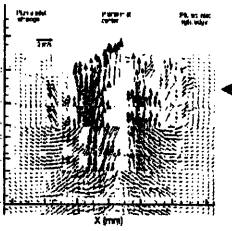
Phenomenological Identification and Ranking Table



Fire Simulations	Importance to Flux	Model Adequacy
Radiation Heat Transfer	High	Fair
• Transport	High	Good
• Radiative-Property/Turbulent-Mixing Interactions	High	Fair
• Radiation Properties	High	Poor
• Soot	High	Poor
- Temperature	High	Poor
- Mass Fraction	Medium	Poor
- Optical Properties	Medium	Fair
• Gas	Low	Fair
Convection Heat Transfer	Medium	Fair
• Boundary Layer Treatment	Medium	Poor
• Transport	Medium	Fair
• Source Terms	Medium	Fair
• Advective Closures	Medium	Fair



Understanding Soot



Understanding Turbulent Mixing in Fires

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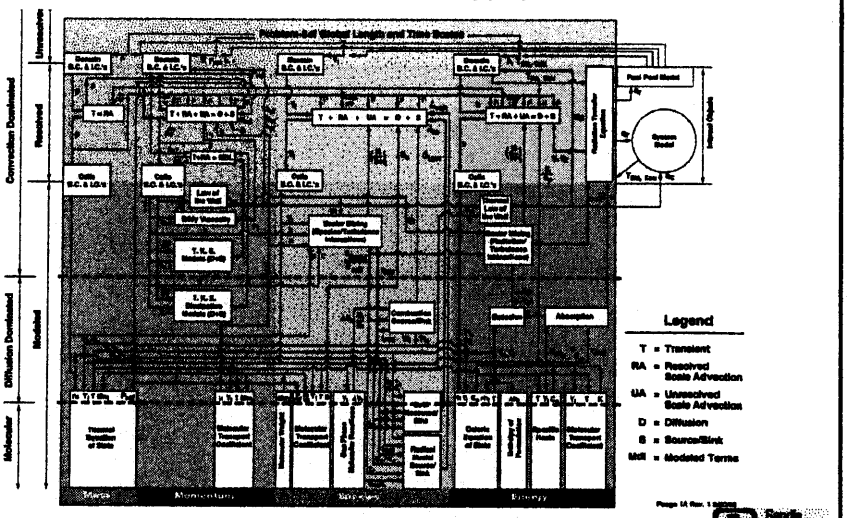
PIRT Driven Minimum Math Model Suite



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SQE and Code Verification Processes in Place

Software Quality Engineering

In use
- version control
- nightly regression testing
- requirements management
- language tools (debugger & memory checking)

Planned
- bugzilla tracking
- change management

Verification

Methodology
- Unit Testing (Subroutine level)
- Verification Problem Testing

Approaches to Verification Problem Testing
- Analytical & Semi-Analytical Solutions
- Numerical Benchmark Solutions
- Manufactured Solutions

Test Suite of 17 formal problems

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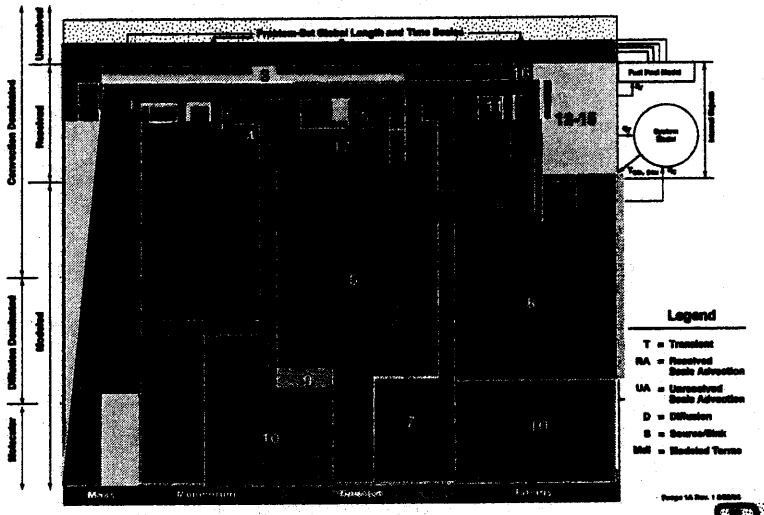
Verification Test Suite Coverage



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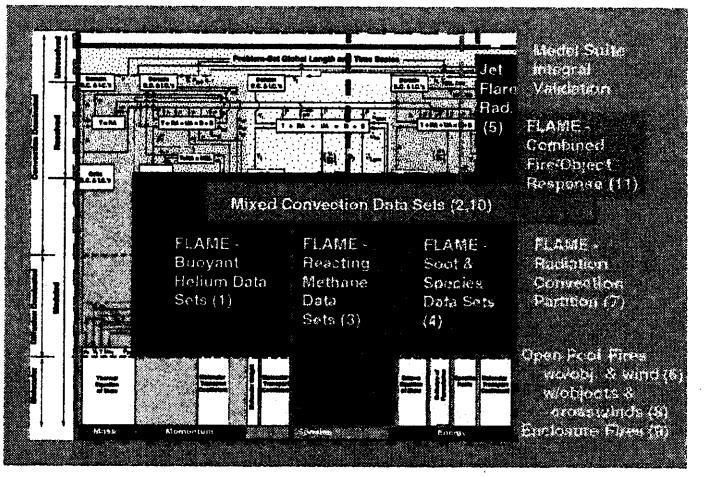
Validation Test Suite Coverage



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Questions?

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