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Engineering Science Overview and Drivers for ESRF

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&

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Presented to the

Engineering Sciences External Review Panel

Sandia National Laboratories

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Sandia is a Multiprogram Laboratory Operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy Under Contract DE-ACO4-94AL85000.

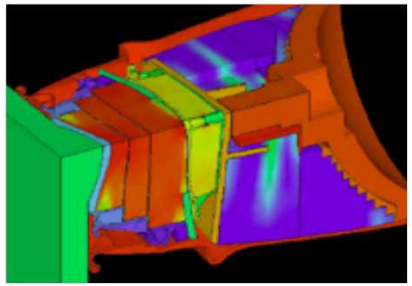
Presentation Outline

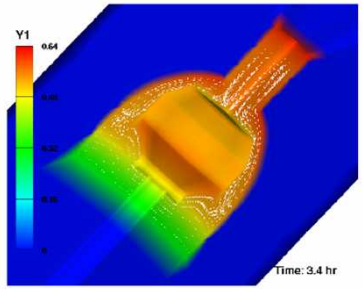
- **Overview of Engineering Sciences and ESRF**
- **Stewardship Role of ESRF**
  - Stewardship of the ES Disciplines
  - Stewardship of ES Computational and Physical Simulation
  - Driving Predictivity and QMU
- **Measuring Ourselves – Metrics**
- **Looking to future – Opportunities and Challenges**
  - Expanding the business model
  - Strategic alignments with DoD
  - A path forward for more effective relations with Academia
  - Opportunities – Strategic use of LDRD
  - Challenges
- **Closure – Setting Context**

Engineering Sciences at Sandia National Laboratories

Mission:

Provide Validated, Science-Based, <u>Engineering Solutions</u> Across The Product Life Cycle **to Meet the Mission Needs of Sandia National Laboratories.**

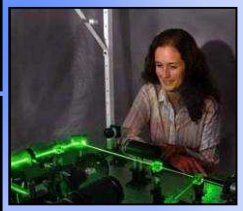




There are ~400 Engineering Sciences staff and management to meet the research, development and application needs of the Lab and its customers

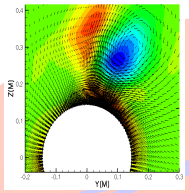
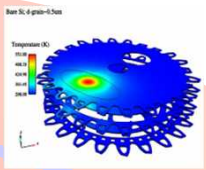
Engineering Sciences drives Simulation-enabled Engineering and predictive capability

Research
•*establishes scientific understanding* of the engineered product

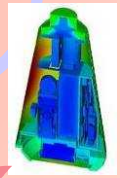
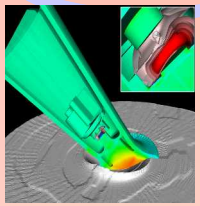



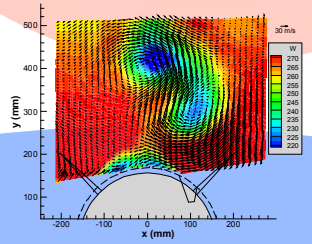

… and forms the basis for the physical models used •in numerical simulations


Advanced Computational Platforms
must provide both capacity and capability computing

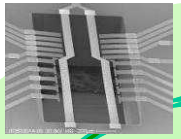



Computational Simulation



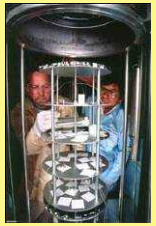
Experiments *validate the models* used in the numerical simulations




Product Engineering

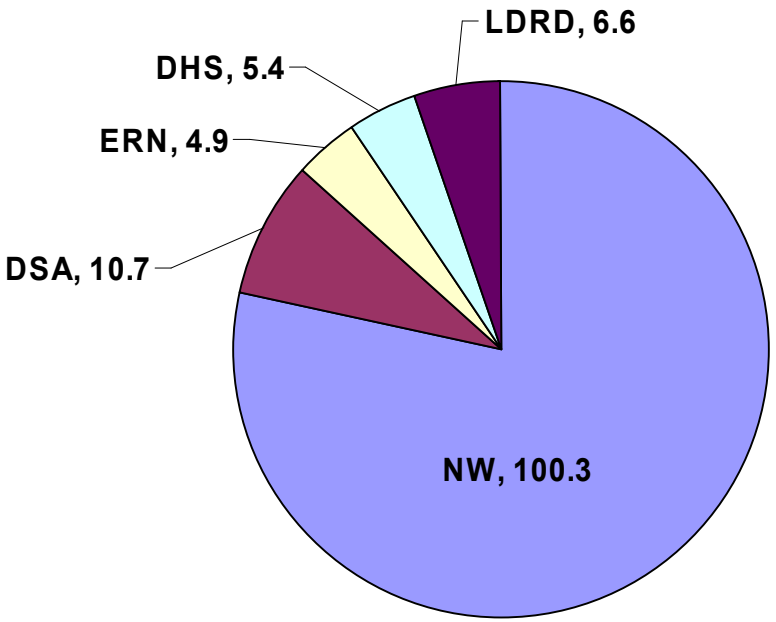
MC4627 spin motor

Physical Simulation

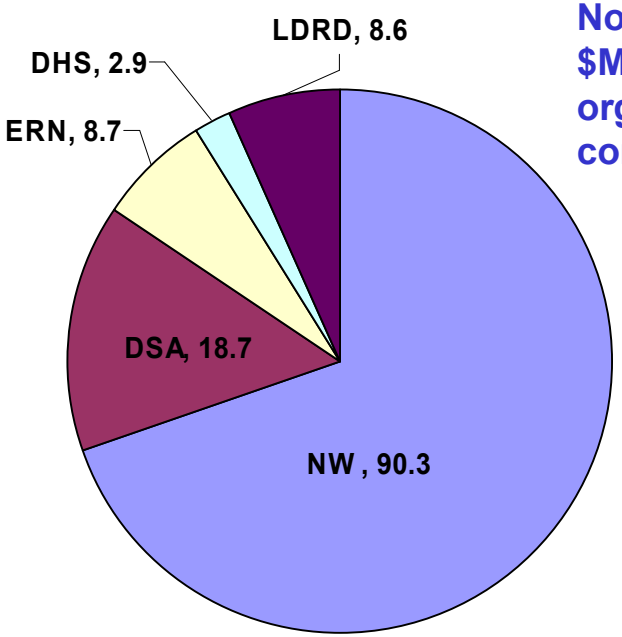


Component & system **testing** *supports* design & development process

Engineering Sciences funding is still principally derived from the Nuclear Weapons work despite reductions in that program



FY2006 Spending - $127.9M



FY2008 Spending - $129.3M (est)
(prorated based on ytd spending)

Note: Spending in $M is by the ES organizations that comprise the ESRF.

NW – Nuclear Weapons
DSA – Defense Systems and Assessments
ERN – Energy Resources and Nonproliferation
DHS – Department of Homeland Security
LDRD – Laboratory Directed Research and Development

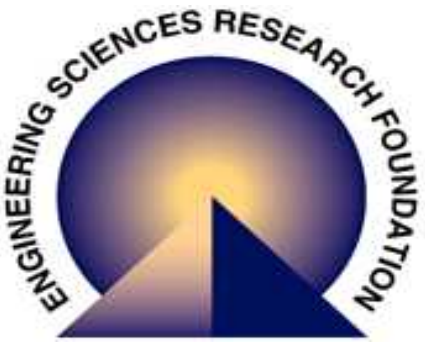
Takeaways

- Flat Engineering Sciences budget
- Decline in NW has been off-set by significant growth in ERN and DSA

Stewardship Role of ESRF

- Stewardship of the ES Disciplines
- Stewardship of ES Computational and Physical Simulation
- Driving Predictivity and QMU

Engineering Sciences Research Foundation



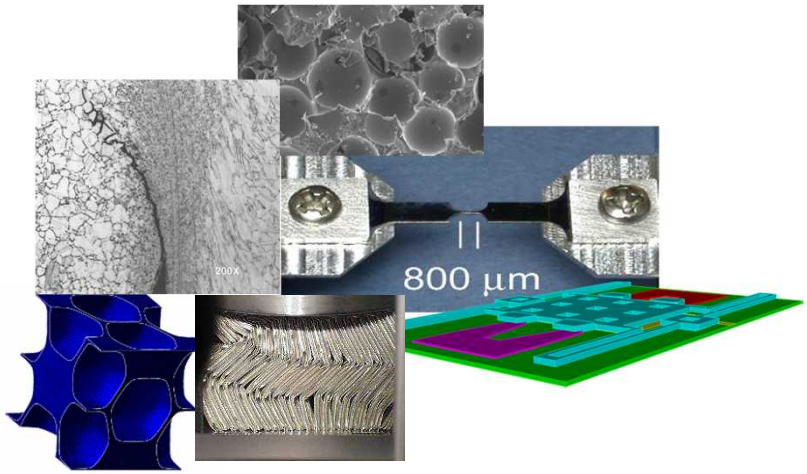
Vision:

Lead the Nation in Developing and Applying Predictive Simulation to Engineering Design and Decision Making.

ESRF Stewardship

- **Assure a sound science-base to meet Sandia's mission goals of today**
- **Develop and nurture future science and technology that Sandia will depend upon to achieve its mission goals of tomorrow.**
- **Provide significant contributions to the leadership of engineering.**

Engineering Sciences provides Sandia's stewardship of the engineering disciplines

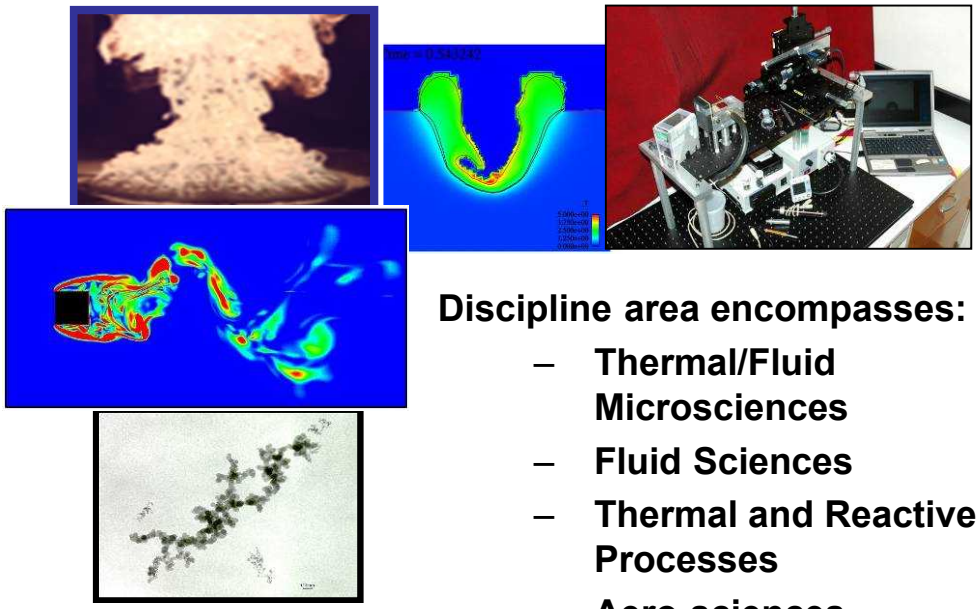


Solid/Material Mechanics & Structural Dynamics

Discipline area encompasses:

- Solid Mechanics
- Structural Dynamics
- Material Mechanics

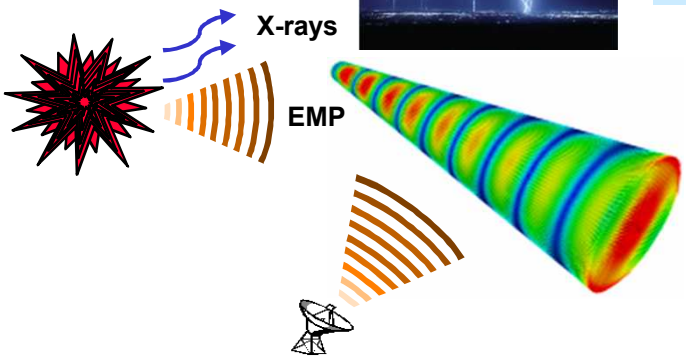
Thermal, Fluids & Aero-sciences



Discipline area encompasses:

- Thermal/Fluid Microsciences
- Fluid Sciences
- Thermal and Reactive Processes
- Aero-sciences

Electrical Sciences

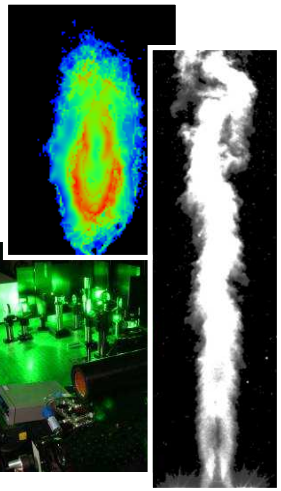


Discipline area encompasses:

- Electromagnetics, electrical effects, electrical devices, components & systems

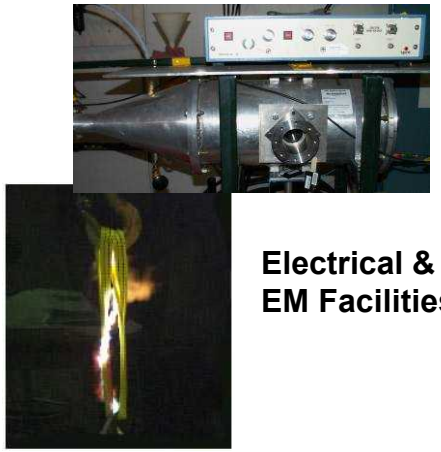
We steward significant lab-scale and large-scale testing capabilities where we perform research, development and applications work

Trisonic & hypersonic flow characterization



Noninvasive laser-based thermal/flow diagnostics

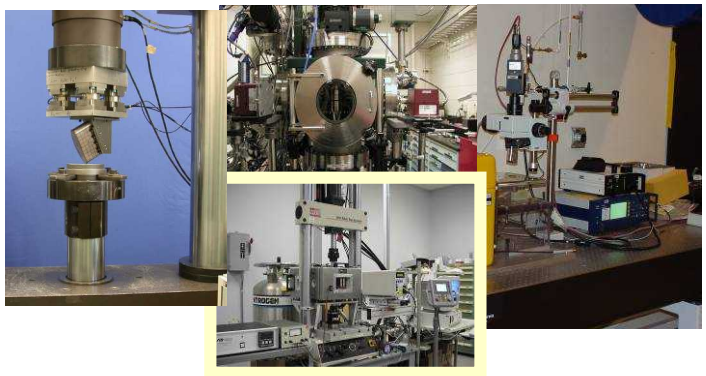
Sled Track, Blast Tube and Aerial Cable facilities



Electrical & EM Facilities

Thermal Test Complex – Radiant heat & fire testing

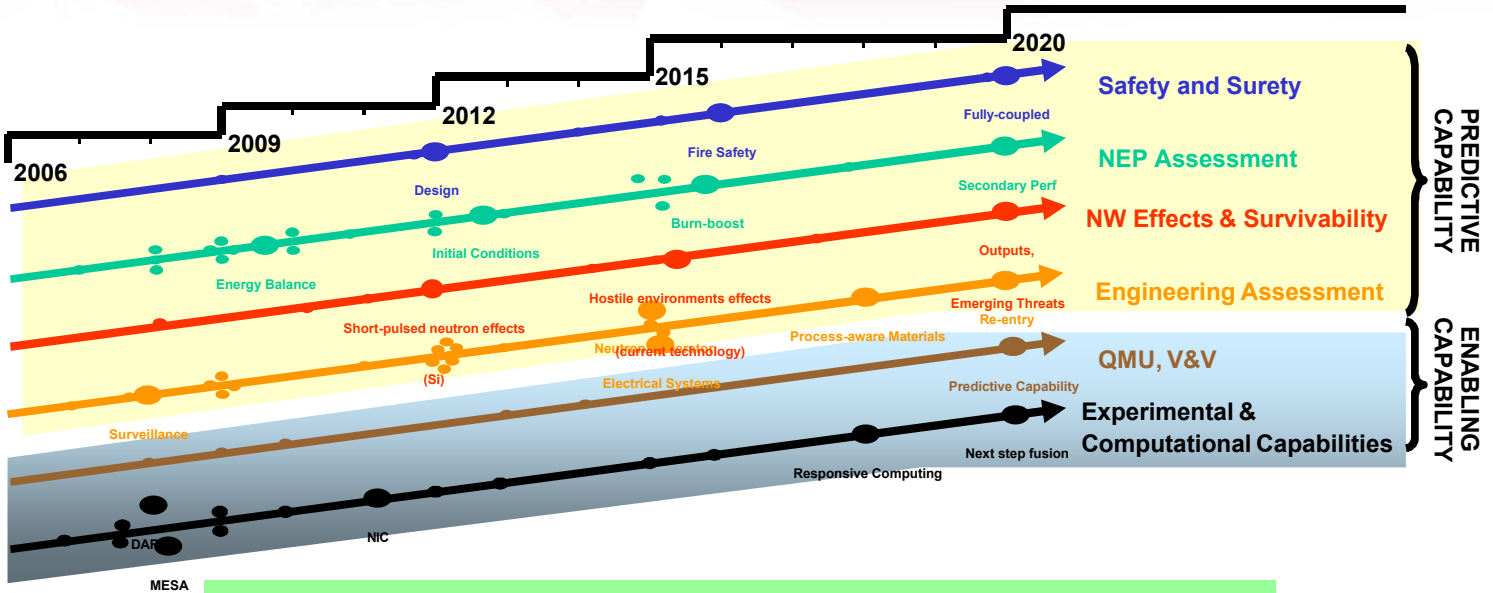
Modal, vibration, and mechanical shock & centrifuge facilities



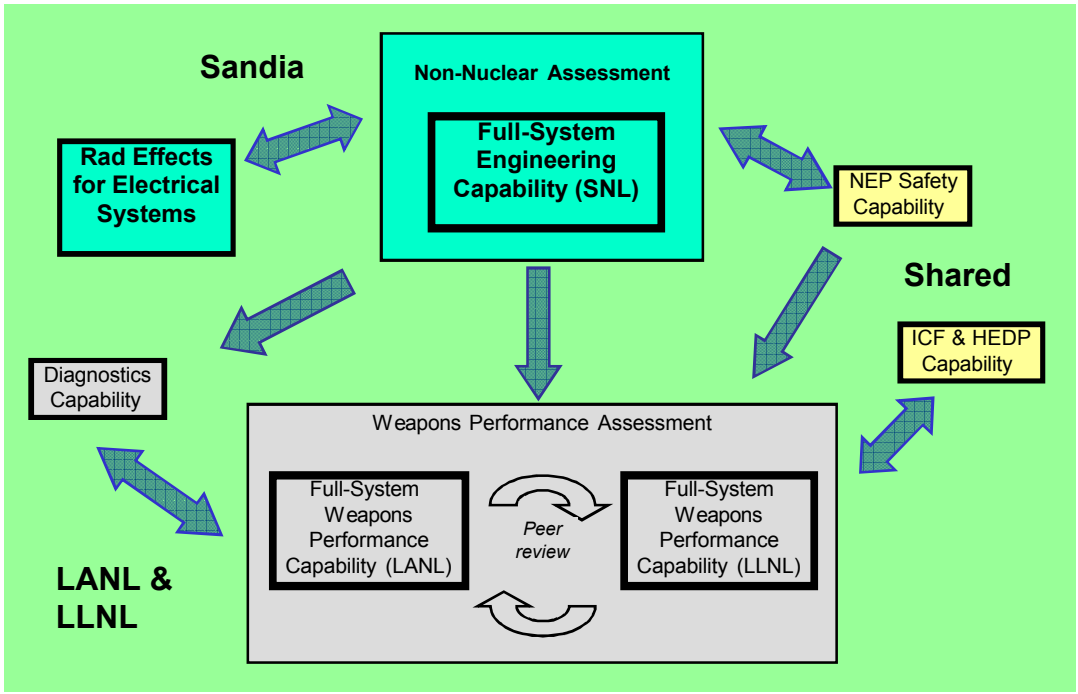
ES Laboratories

The Nuclear Weapons Program has provided the principal drivers for our S&T activities

The Predictive Capabilities Framework brings together work in ASC, ICF, Science and Engineering Campaigns



Sandia has the Engineering Stewardship role in the ASC National Simulation Portfolio for Stockpile Certification



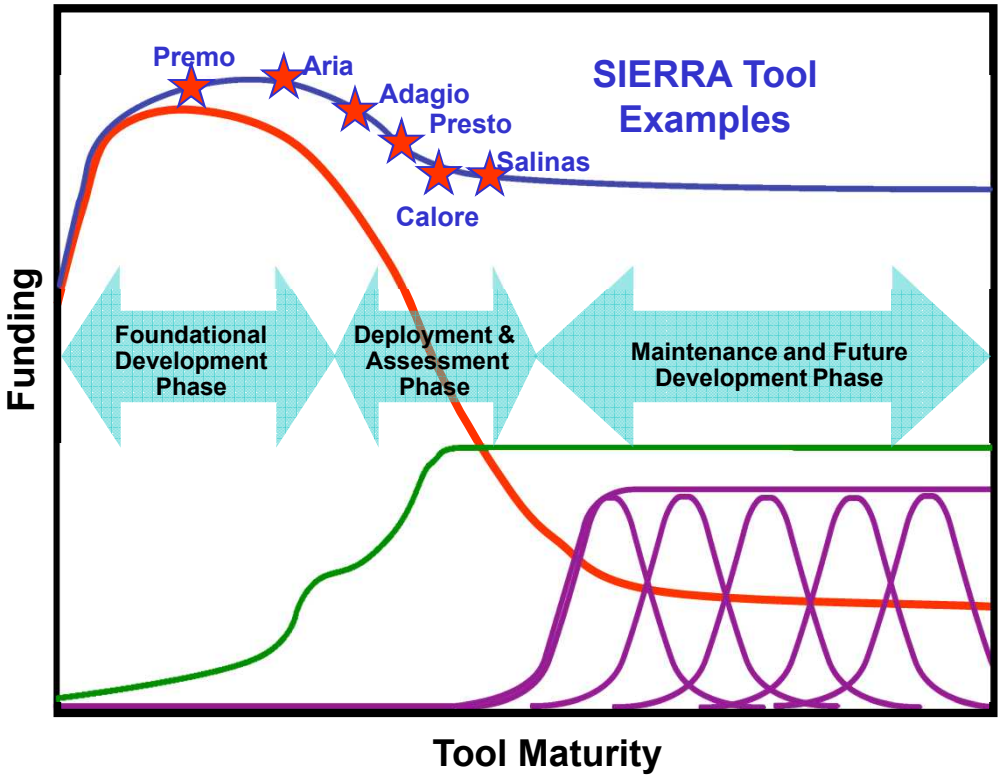
Achieving "Predictivity" is a Journey – and knowing when we are "good enough" and "can stop" is critical to success

First 10 years – what we've achieved:

- First versions of high performance computing codes and frameworks exist
- Codes developed to support W76 and W80 life extension programs

Second 10 years:

- Focus on predictivity
  - *Better physics and capability to bridge scales*
  - *Quantification of Margins and Uncertainties: performance, robustness and reliability*



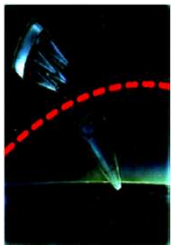
Our Immediate Goals

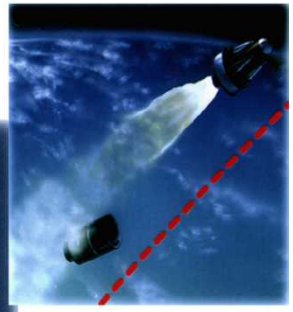
- Expand applicability of Sandia's ASC Engineering Codes for design, qualification, and stockpile evaluation with focus on increased predictivity
- Develop new computational tools for applications critical to Sandia's mission (e.g., neutron generator performance)
- Develop a more intentional (and rigorous) approach to V&V and apply QMU principles in all of our work!

Sandia's Engineering Code Strategy is focused on our non-nuclear mission space

Delivery

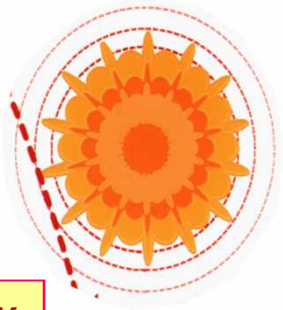
Separation shock/ Aerodynamic Heating



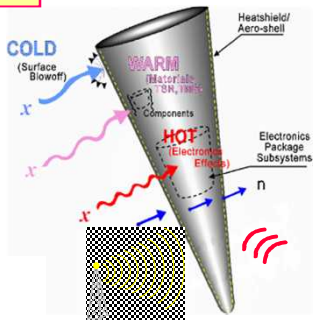


Staging shock

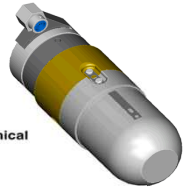
Survivability

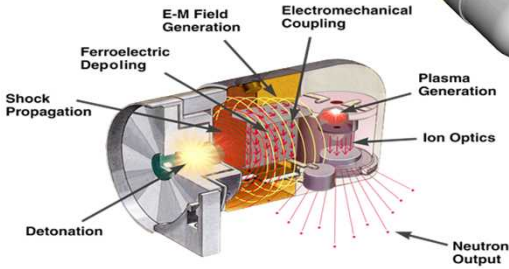


Radiation Effects



Random vibration





Assured Performance & Manufacturing

Assured Safety and Security

Mechanical Insult

Thermal Insult

Electromagnetic Insult

Security Components

Safe & Secure Transport

SNL Engineering Codes are being positioned to support engineering needs of the complex

Our S&T efforts in physical and computational simulation must sustain a healthy balance between Foundational and Targeted Activities

Sandia ASC Focus Areas

Survivability	Assured Safety & Security	Delivery	Assured Performance
QASPR*	Full System Safety*	Re-Entry*	Neutron Generators*

Foundational Elements

Codes & Frameworks	Advanced Algorithms	Physics & Materials Models	Advanced Diagnostics	Fundamental experiments	V&V & UQ Methods (QMU)

Focus of ESRF

The 4 Sandia Focus Areas (FAs) each have significant technology and phenomenology gaps that must be resolved.

*"Flagship" projects for FY08

An example of how we develop our NW S&T strategy to benefit the Assured Safety and Security Focus Area

Objective: Develop a physics-based predictive capability for weapon system response to STS abnormal environments, as required for design/requirement decisions, system design optimization, hardware qualification and QMU assessments.

Engineering Science Issues

- Pervasive material & component failure
- Multiphase reaction and transport
- Arc-over from lightning

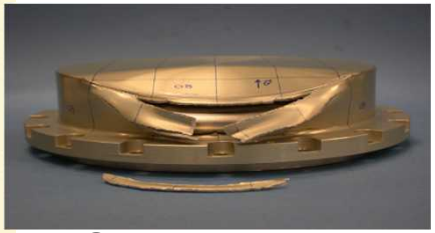
Predictive Capability Framework

Output, Effects, and Survivability

- FY09: Thermal loading from fires of various fuels of interest
- FY10: Predictive capability for Thermal/Mechanical breach of exclusion region barriers
- FY12 Electrical breakdown

Integrating NW Mission Needs and NNSA HQ Strategy

Accident Loads



System Response

NWSMU Drivers

- *FY09: Stronglink/weaklink race for all systems.*
- *FY10: Exclusion region integrity under mechanical loads for annual assessment.*

Our technology work is critical to accomplishing our ASC L-1 Milestones and in reducing our modeling uncertainties

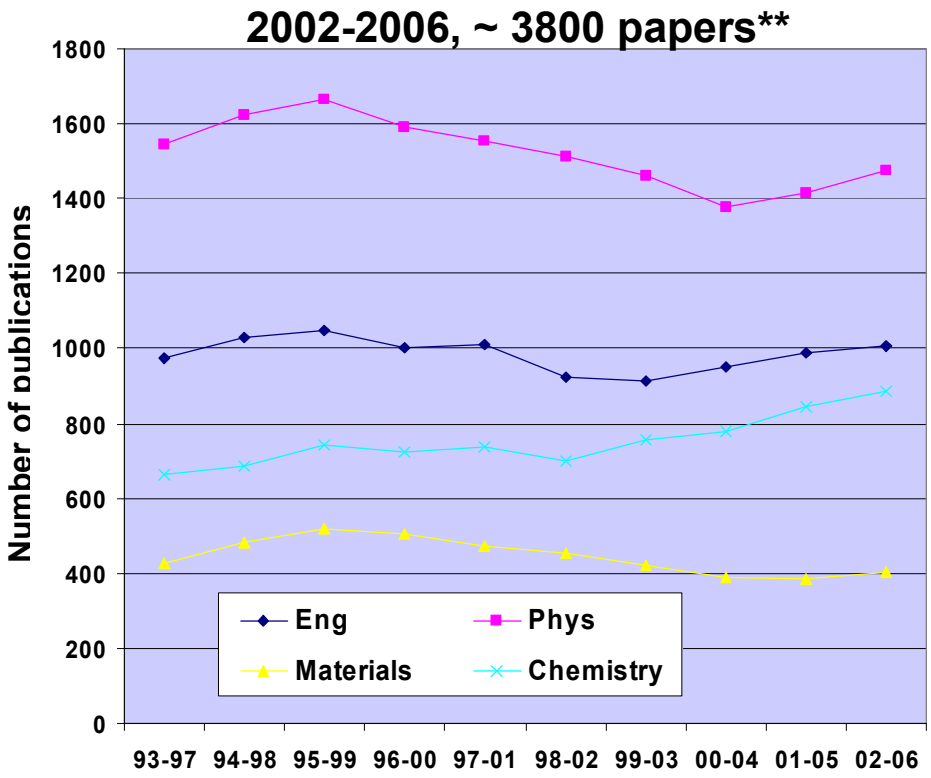
Year	Proposed Level 1 Milestone Scope	Resp. Labs	Sandia Focus Area (FA) Association and Critical Phenomenology Gaps Being Addressed under P&EM
2010	Baseline demonstration of UQ aggregation methodology for full-system weapon performance prediction	LANL, LLNL, SNL	Delivery FA – reentry physics; energy transfer across interfaces Performance FA – Neutron Generator source physics
2012	Develop, implement, and apply a suite of physics-based models and high-fidelity databases to enable predictive simulation of the initial conditions for primary boost.	LANL, LLNL, SNL	Performance FA – Neutron generator source physics and aging effects
2012*	Assessment of weapon surety status (nuclear safety and physical security) in off-normal transportation scenarios.	SNL	Assured Safety and Security FA – Fire physics; material failure/fragmentation
2013*	Demonstration of predictive capability for weapon system response to short-pulsed neutrons in hostile radiation environment.	SNL	Survivability FA - microelectronics upset phenomenology; energy dissipation across interfaces
2014*	Full-system safety assessment of damaged weapon immersed in fuel fire for transportation accident scenario.	SNL	Assured Safety and Security FA: Fire physics w/ focus on turbulence/soot formation & transport; polymeric (foams/encapsulants) and energetic material decomposition; material failure mechanisms

*** Note: Sandia has requested the FY2012-2014 L-1 milestones be added; these milestones are aligned with the Predictive Capability Framework targets**

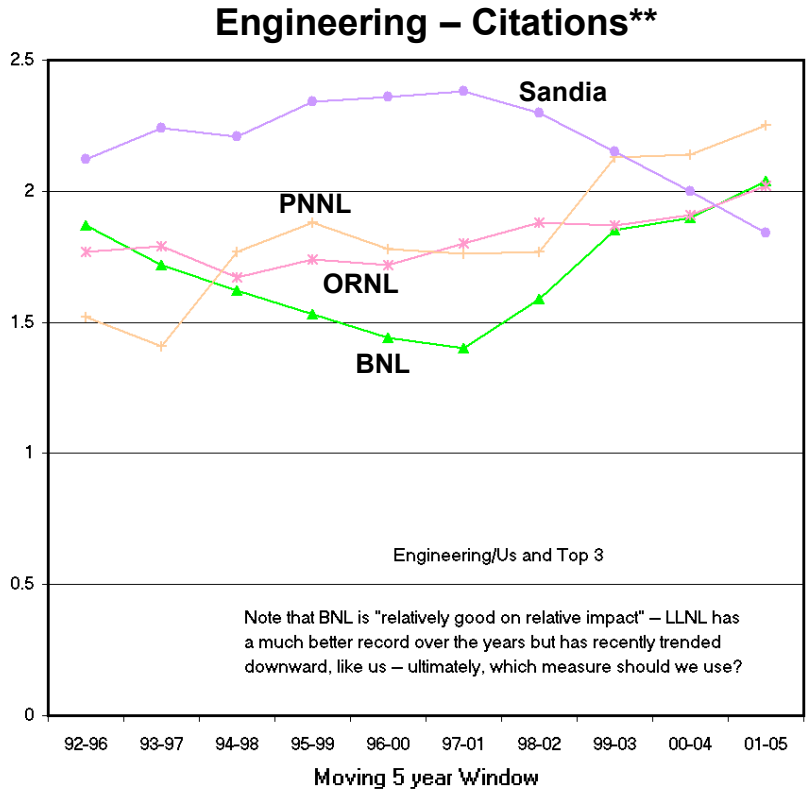
Measuring Ourselves – Metrics

Traditional Metrics of the ST&E community are focused on publication and citation counts

The ESRF is a significant contributor to the Engineering publications and citations reported for Sandia



Total number of publications for SNL by discipline (5 year moving window).



Note that this set of metrics excludes pubs from conference proceedings as well as internal SAND reports where much of our National Security work is documented

** Data provided by ST&E Council study commissioned in winter 2007

We also measure ourselves by the quality of our staff and our work

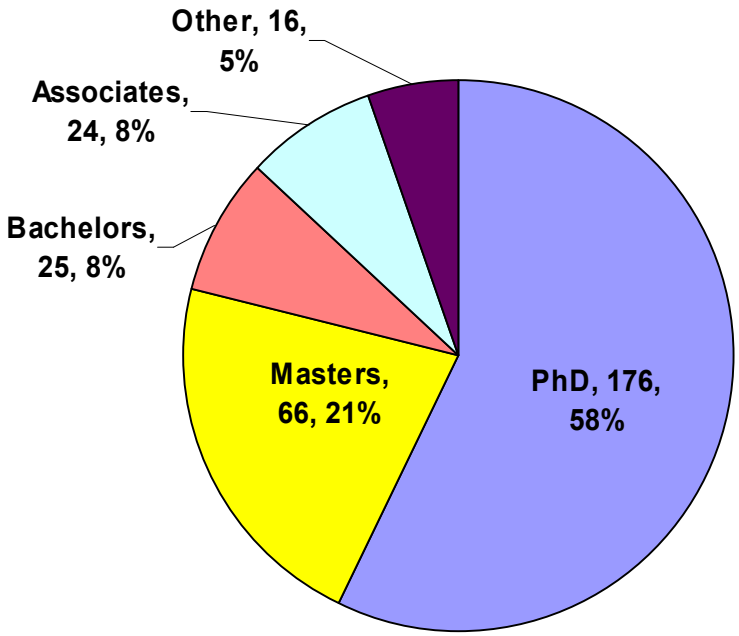
Staff Credentials include:

- **Education: degrees granted, GPAs, schools attended**
- **Honors received during and following graduate education**
- **Publications**
  - Both internal and external to Lab
  - Joint with researchers external to Lab
- **External visibility**
  - Continuing affiliations with Academia
  - Professional society membership
  - Leadership roles in Prof Societies
  - Invited papers/presentations
  - Honors (Fellows, outstanding papers, etc)

While no formal customer surveys currently we do solicit verbal inputs**

- **on staff performance for performance review**
- **to assess work progress**

** Formal customer feedback to be considered as a metric



FY2008 Data (as of 6/30/2008)

307 management and staff in Engineering Sciences groups that support ESRF – does not include students, admin support or contractors

There are other metrics we want you to know about!

External funding into ESRF orgs (from DoD and industry) is growing – expect to exceed $10M this Fiscal Year

We are again a sought after partner within the Laboratory

- We are now the competency owner for env. test, analysis and contamination for 5000 satellite programs. Asked to manage KSPIF environmental test operations
- We are being invited to team with programs across the SMUs that "avoided us" years earlier

Our support of the NW program is acknowledged – this year 1500 work was acknowledged in the NNSA Defense Programs Awards of Excellence

- Of the 7 SNL Individual Awards, 2 were given to ES staff
- Of 14 SNL Team Awards, 3 were led by ES staff
- Of 14 SNL Team Awards, ESRF staff were part of 7 teams

These metrics span the S-T-E activities of Engineering Sciences, with the bulk of work either fully supporting or complementary to our mission-related work

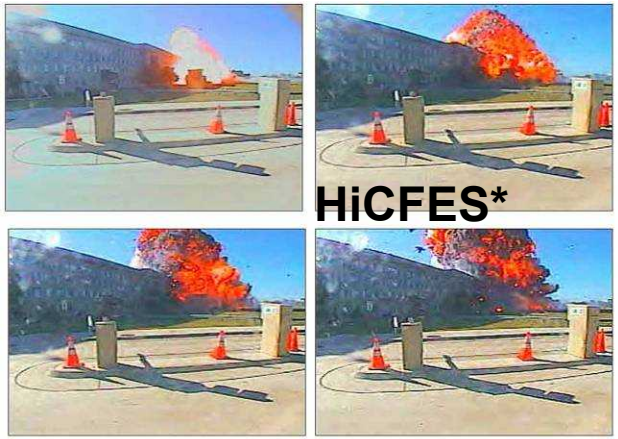
Looking to future – Challenges & Opportunities

- Establishing the business model
- Establishing more effective relations with Academia
- Opportunities – Strategic use of consortia & LDRD
- Challenges… and our path forward

We are implementing a business development strategy focused on 5 ES market thrusts

- **Market Thrusts Identified**
  - Nuclear Weapons *(sustain)*
  - Energy *(grow)*
  - Satellites and Sensing Systems (S^3) *(grow)*
  - High Consequence Failure of Engineered Systems (HiCFES) *(grow)*
  - Department of Defense *(grow)*

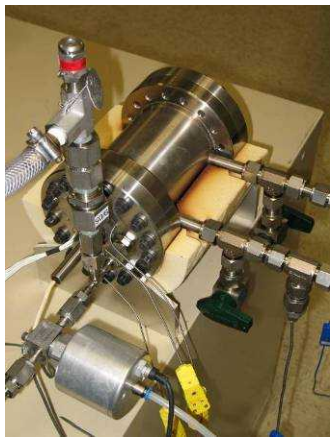
- **Why Market Thrusts?**
  - Provides organizing principle for the Center
  - Provides pursuit decision guidance
  - Leverages ES capabilities
  - Allows for key partnership opportunities
  - Rationale for identifying S&T gaps



HiCFES: Focused on Vulnerability Assessment & Consequence Mitigation

The General Motors Partnership is providing ES with opportunities to impact the nation's energy solution

- **Strategy – grow our energy program with an emphasis on transportation systems**
- **Sandia and General Motors R&D are developing fuel system technology for advanced transportation concepts through the following agreements:**
  - Hydrogen Storage Engineering Demonstration WFO
  - Hydrogen Technology Umbrella CRADA
  - Energy Systems Umbrella CRADA

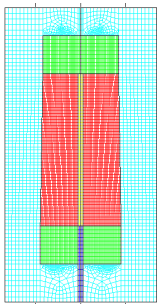


Experimental apparatus for thermal properties evaluation.

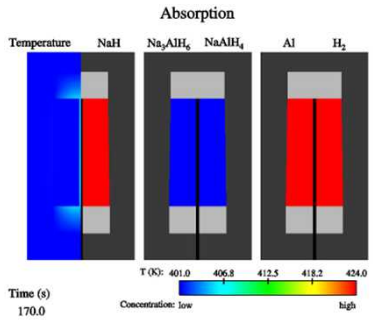
Engineers experimentally validate thermal and chemical kinetic performance of our solid-state hydrogen storage prototype designs.

Computational simulation enables design for optimal thermal performance:

- System-level simulation w/ fuel cell
- Hydride bed design and efficiency
- Compact heat exchange and rejection
- Efficient heat generation for drive cycle



Simple packed bed for effective conductivity measurement.



Hydriding simulation for hydrogen absorption.

National Nuclear Security Administration

Sandia National Laboratories

We are re-thinking our engagement with Academia:
we need to be more intentional in our interactions

Funding reductions are requiring we re-assess our interactions

- Is the value proposition for our strategic partnership with NSF still valid or should we use the funding differently to
  - Directly fund University faculty (in strategic areas)
  - Sustain a summer graduate student outreach program

Strategic engagement models under consideration

- Be more active in Corporate efforts such as *National Initiative in Nano-Engineering (NINE)*
- Establish ties with key Universities in areas of mutual interest
  - U of Texas, *National Initiative in Modeling & Simulation (NIMS)*
  - U of Florida, investigating forming possible *Defense Science Consortia*
  - Predictive Science ASC Alliance Program (PSAAP) schools
    - Stanford – Hypersonics phenomena
    - U Texas – Re-entry physics (and V&V)
    - Purdue – MEMs technology and aging phenomena
    - Caltech – Material mechanics (and V&V methodologies)

Change the business model – encourage more teaming on proposals

- Development of LDRD & BES proposals for joint funding

Will continue to encourage one-on-one University-to-staff research interactions; want to facilitate opportunities for sharing students and exchanges (including potential sabbaticals for ES staff)

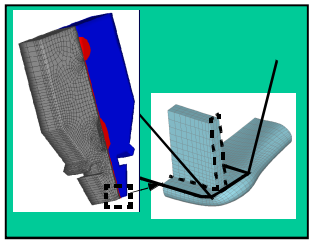
We are using Consortias and LDRDs as the "seed-corn" for growing future business lines and strategic partnerships with academia

Started "*Modeling and Simulation of Nanoparticle Dispersion Stability and Suspension Flow*" consortia in 2007 – partnership includes major industrial partners

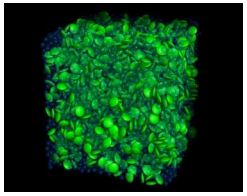
- Ties to NINE initiative led by Sandia
- Spin-off (proprietary) S&T work specific to Industrial partner needs being developed

We will initiate 2 new LDRD Thrusts starting in FY2010 that align with NIMS and NINE

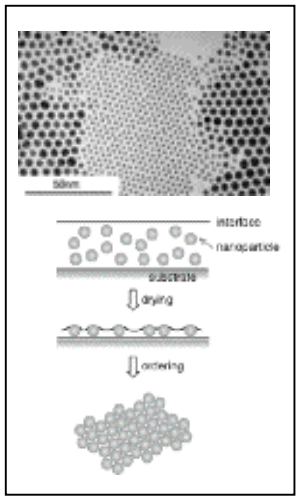
- Nanomanufacturing: Nano-Structured Materials Made Layer-by-Layer ($1M/yr for 3yrs)
  - Conceived through work with UT (NIMS) and work with UT ChE faculty supporting NINE
- Computational Mechanics for Geosystems Management to Support the Energy and Natural Resources Mission (~$1M/yr for 3 yrs)
  - Conceived through work with UT NIMS and Sandia Energy program
  - Follow-on activities include development of BES Energy Frontiers Center of Excellence in CO_2 Sequestration



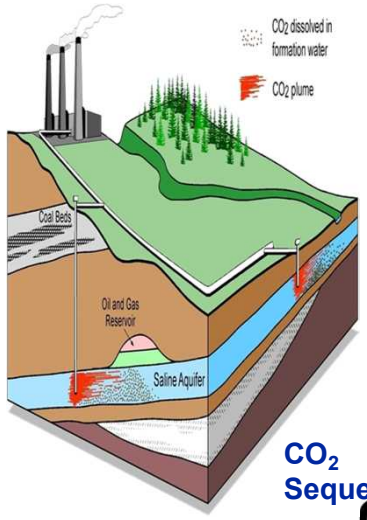
Coating/Extrusion



Dispersion rheology



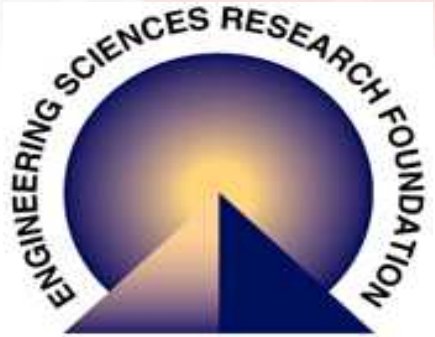
Self/directed Assembly



CO_2 Sequestration

Challenges that we are facing – and our path forward

- **Sustaining a High Performance Computing Environment**
  - SNL will have largest computing capacity in its history in FY09 w/ TLCC clusters (120 TFlops), Red Storm (280 TFlops) and Project Y (tbd TFlops)
  - SNL & LANL have formed a strategic partnership (ACES); will field ZIA petaflop machine in FY10
  - Looming issue – midrange computing after 2010 when RS becomes institutional asset
- **Sustaining the experimental infrastructure**
  - Making "difficult" decisions on RTBF disinvestment at CA site
  - On track to see TCR Phase 2 completed in FY2013
  - Leading Corporate study on health of Sandia's test facilities – how to share costs for sustaining
- **Sustaining a balance of S-T-E in period of reducing NW S&T budgets**
  - Lab leadership after 2nd "landlord" interested in long-term health of Lab (BES, etc)
  - Must develop greater advocacy of work at NNSA HQ for ES technology work
  - External business strategy must target "strategic partners" interested in S&T
- **Re-thinking what ESRF is/should be for the Lab; balancing traditional engineering mechanics stewardship & electrical sciences needs**
  - Senior Mgmt in Pulsed Power working strategy for Electrical Sciences; we are included
- **Attracting and nurturing a World-Class-Workforce in an uncertain time**
  - "Specialist" hiring has been difficult and foreign national hiring still an issue



Closing Thoughts

- **First 2 overview talks were intended to set context for our planning exercises for long-term ESRF stewardship**
  - Shared our business strategy and engagement strategy for engaging industry and academia
  - Provided metrics we will measure ourselves by
- **Our technology planning effort is "a work in progress"**
  - Still considerable angst about the changing model – built around greater intentionality – ***rather than "everything is important"***
  - Drafts of all technology plans have been completed – several still not "meeting" the expectations we have set!
  - Worked to strawman budgets - not yet finalized for FY09
- **We are soliciting your advice on our technology strategy**

Remember: This meeting is about "advising" rather than "assessing"