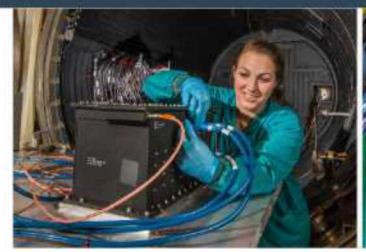
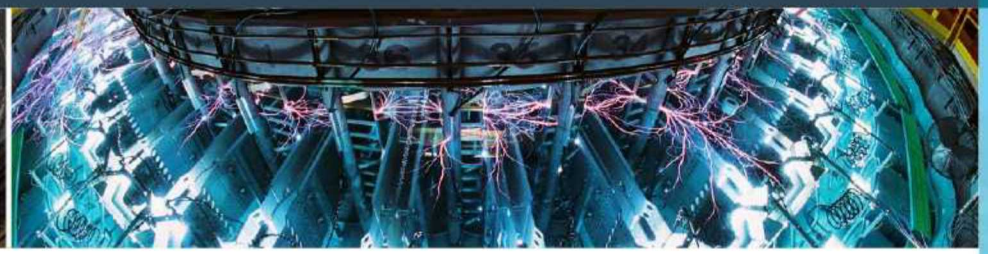
SAND2019-1715C

Sandia National Laboratories

Neutron Lifetime to National Security: Careers in the National Laboratories





PRESENTED BY

Susan Seestrom

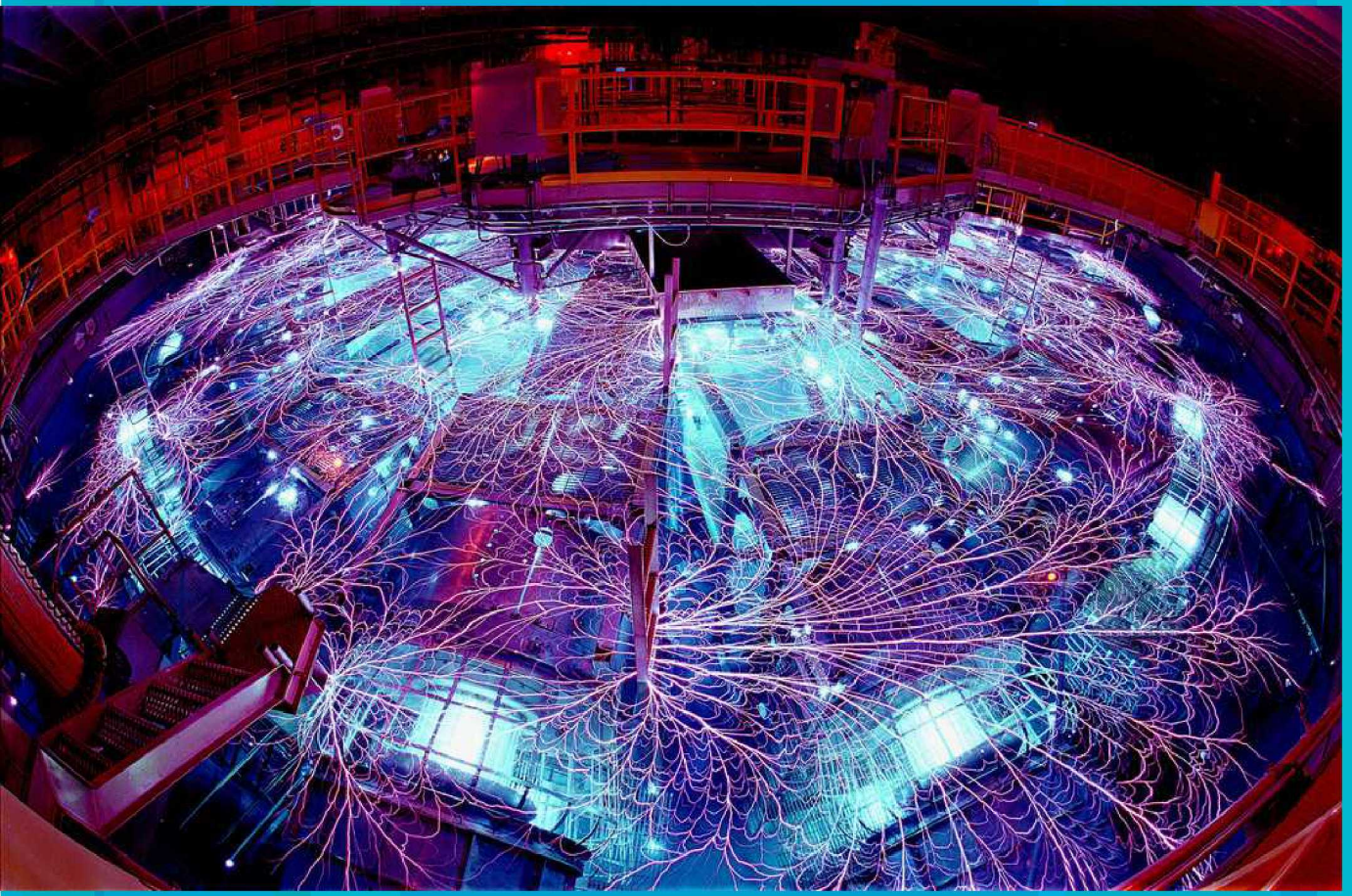
Associate Laboratories Director and Chief Research Officer, Advanced Science and Technology (Division 1000)

2019 Stockpile Stewardship Academic Programs Symposium
February 19, 2019, Albuquerque, NM

SAND REPORT NO. SAND2019-TK

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

World-Class Capability Leads to Unimagined Applications



"Ninety percent of the scientific research we do with the Z machine today is completely beyond the scope of our original designs and plans."

Sandia Develops Advanced Technologies to Ensure Global Peace

Main Sites

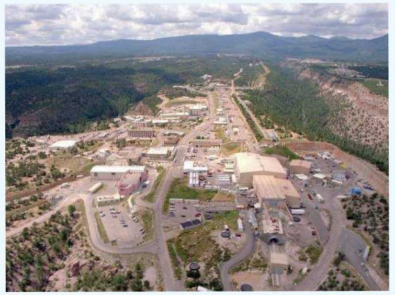
- Albuquerque, New Mexico
- Livermore, California

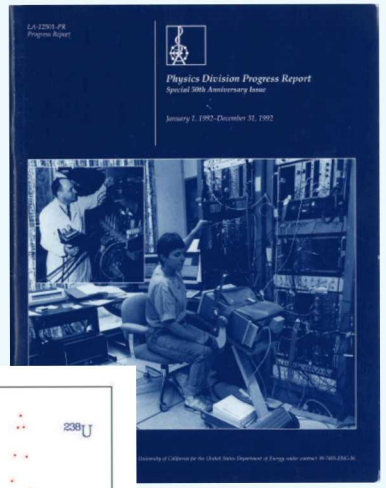
Activity Locations

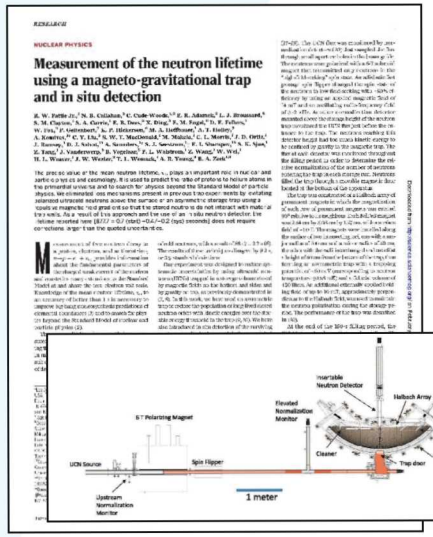
- Tonopah, Nevada
- Waste Isolation Pilot Plant, Carlsbad, New Mexico
- Pantex Plant, Amarillo, Texas
- Kauai, Hawaii

How Did I Get Here?

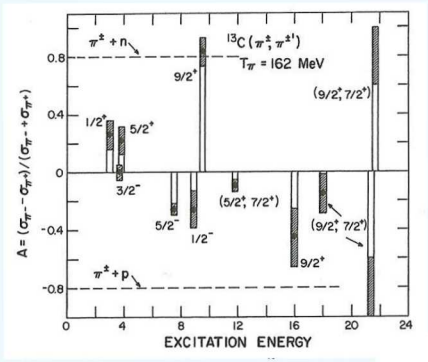
UNIVERSITY OF MINNESOTA

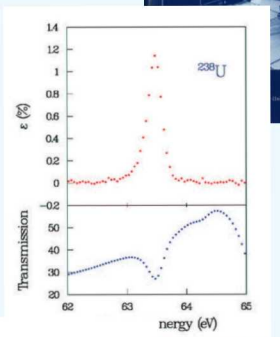






Sandia National Laboratories





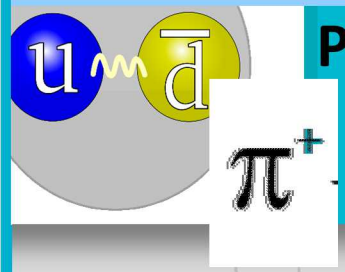
Los Alamos NATIONAL LABORATORY EST. 1943

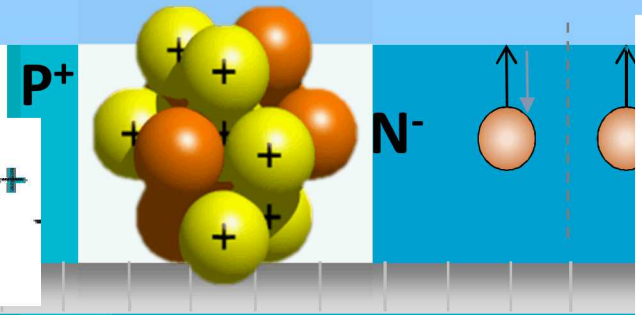
Pattie et al., *Science* **360**, 627-632 (2018)

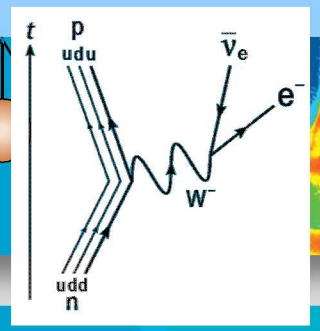
A Career in Science and Management

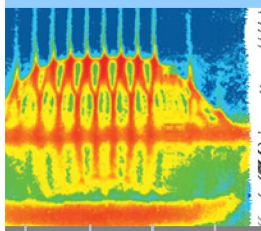
1980 — 1990 — 2000 — 2010

- *Grad Student*
- *Postdoc*
- *Staff Scientist*
- *Deputy Group Leader*
- Physics *Division Leader*
- Weapons Physics *Associate Director*
- Experimental Physical Sciences *Associate Director*
- Advanced Science & Technology *Associate Laboratories Director*

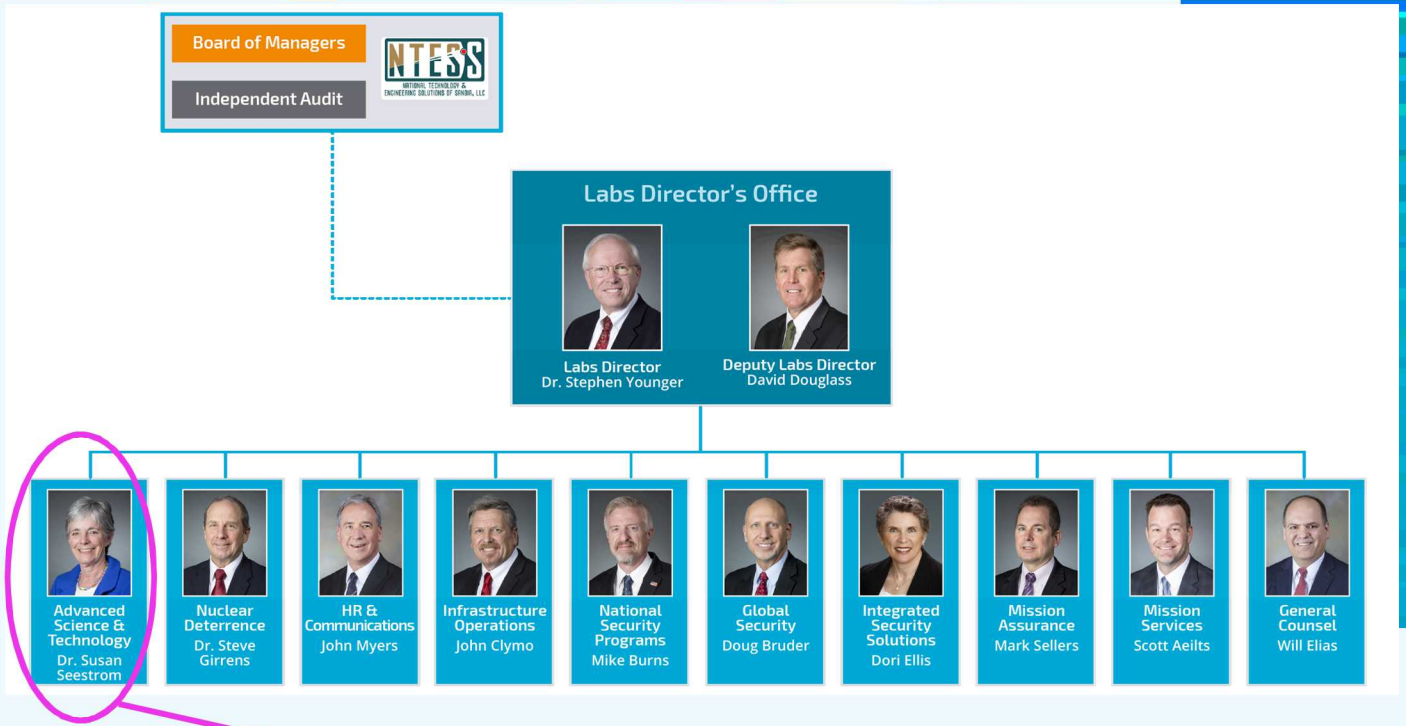








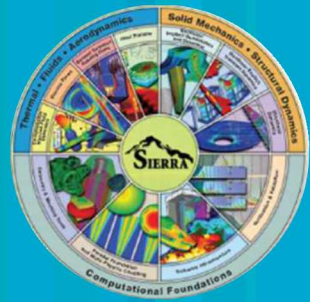
Today, Associate Laboratories Director at Sandia



The responsibilities of the ALD for Advanced Science & Technology

Science-Based Engineering Key to Mission Success

Integrating multidisciplinary efforts to advance the science of the possible for Sandia's missions

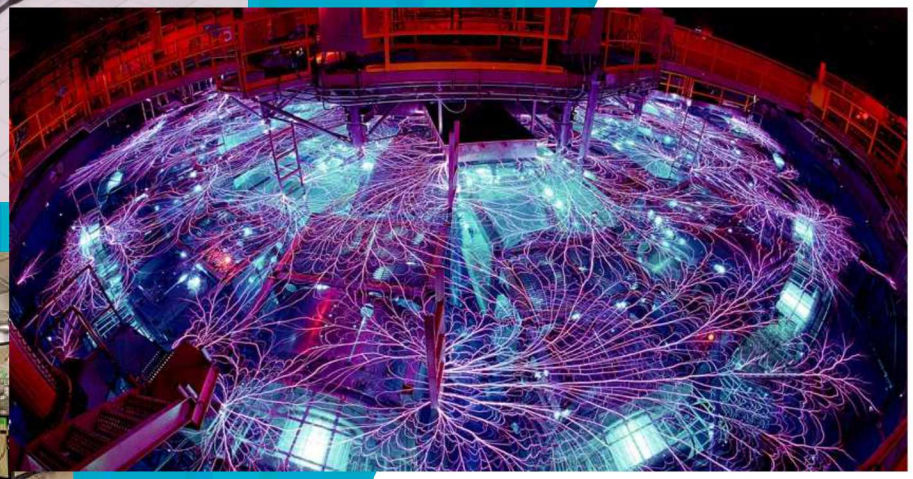


LAMMPS

DAKOTA
Explore and predict with confidence.

Modeling and Simulation

- High Performance Computing
- Software tools
- Uncertainty Quantification (UQ)

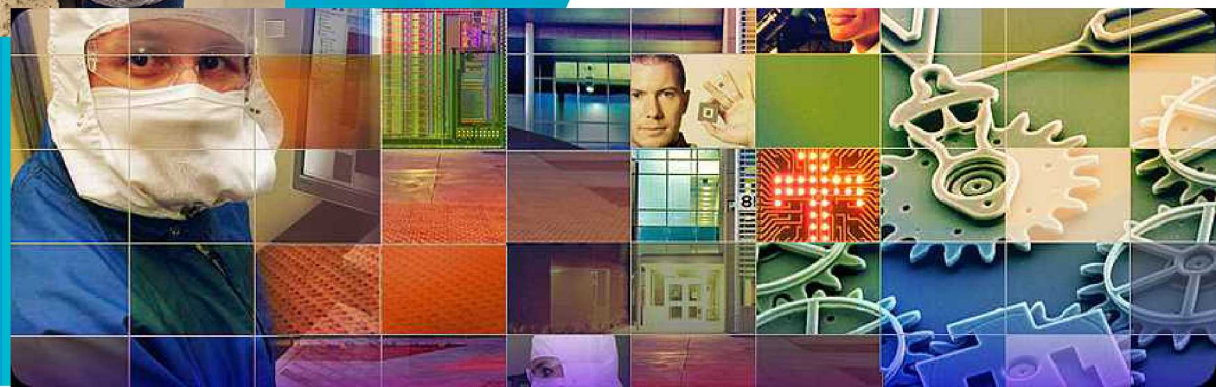


Advanced Experimental Capabilities

- Radiation effects
- Engineering environments
- Materials characterization and production

Microelectronics

- Microsystems & Engineering Sciences Applications (MESA) Fab
- Development of advanced semiconductor materials



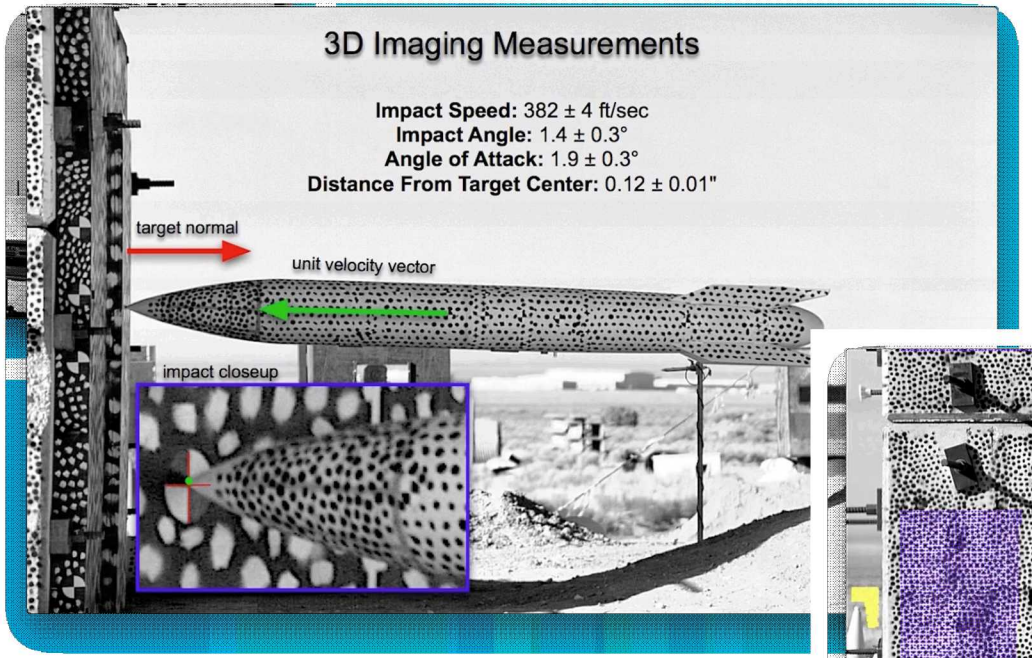
Sandia's Nuclear Weapons Mission

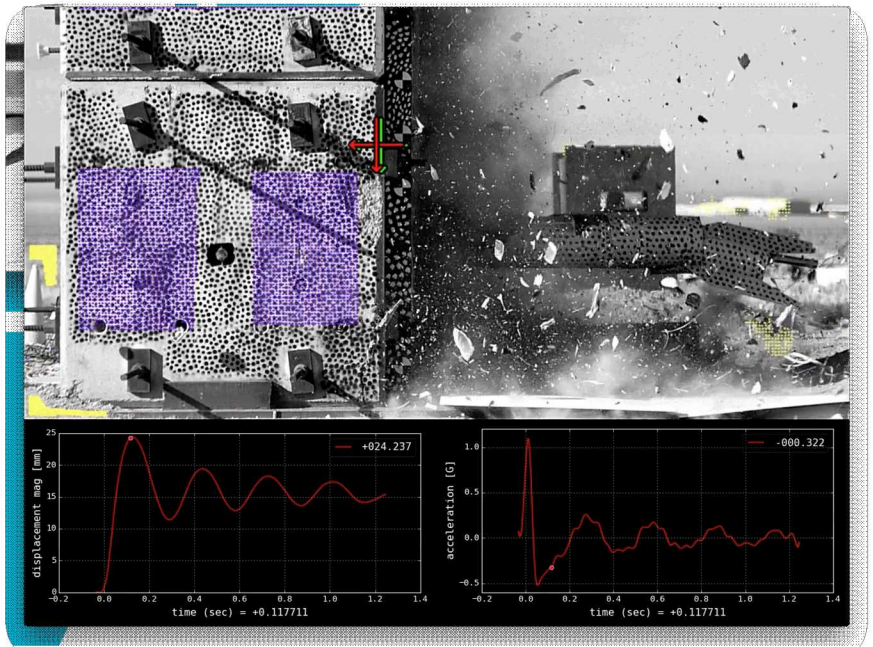
Sandia designs all non-nuclear components

- Warhead system integration
- Production
- Non-nuclear component design and qualification

Fundamental science, computer models, and unique experimental facilities are used to understand, predict, and verify weapon systems performance.

Nuclear Deterrent Experiments

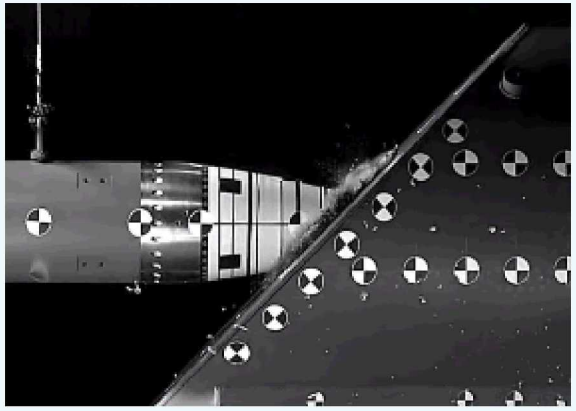


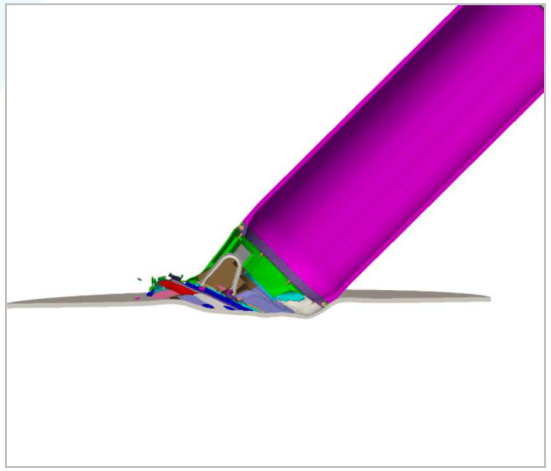


Mission Requires Increasing System Fidelity

Experiments and simulation work together

- Optimize performance of impact fuze in various environments
- Use of ‘virtual builds‘ to explore design trade space
- Simulations used to optimize tests
- Simulations provide insight into damage that is not experimentally accessible

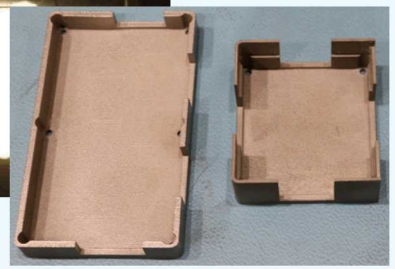


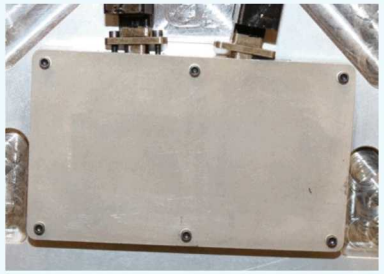


100s of virtual builds
1000s of virtual tests
Millions of CPU hours

Accelerating Design to Production

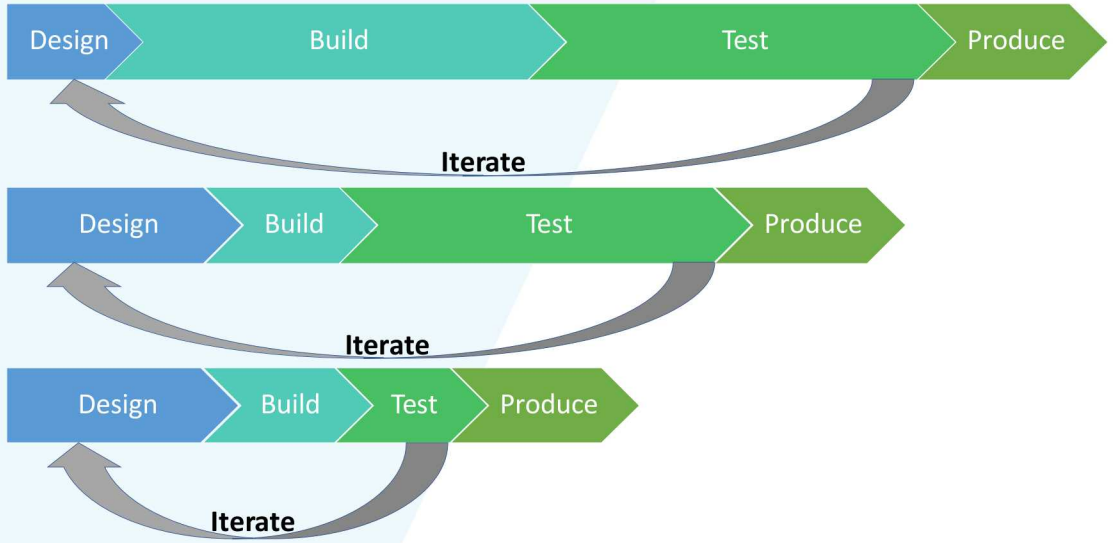
Modeling/simulation and additive manufacturing can reduce the number and speed of design-build-test iterations





316L SS ESD faraday cage covers for sounding rocket telemetry circuit boards. Printed parts (above, right); assembled (bottom right).

- Needed quick turnaround production of metal parts
- Used metal laser powder bed fusion
- Printed additional material test coupons
- Produced an estimated 60% time and cost savings

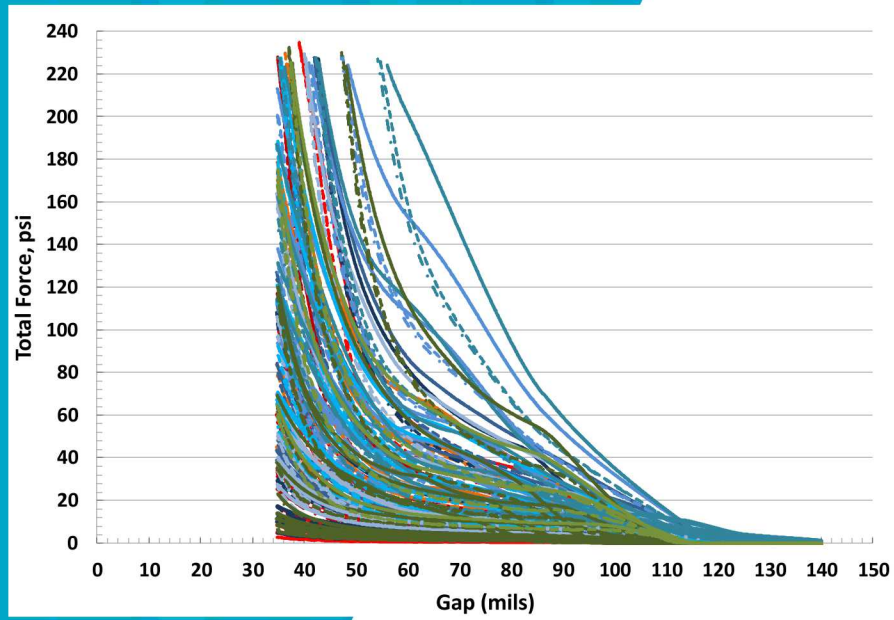


Transitioning Designs into Mission Solutions

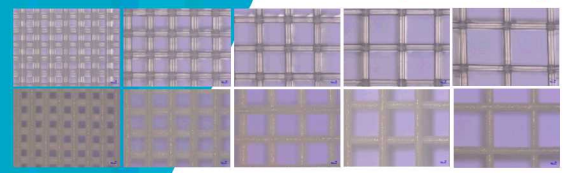
Ensuring repeatability and reliability

- Design parts for extreme mechanical conditions
- Make parts for high-consequence applications
- Validate part performance
- Perform R&D to improve understanding

Mechanically tunable compression pads



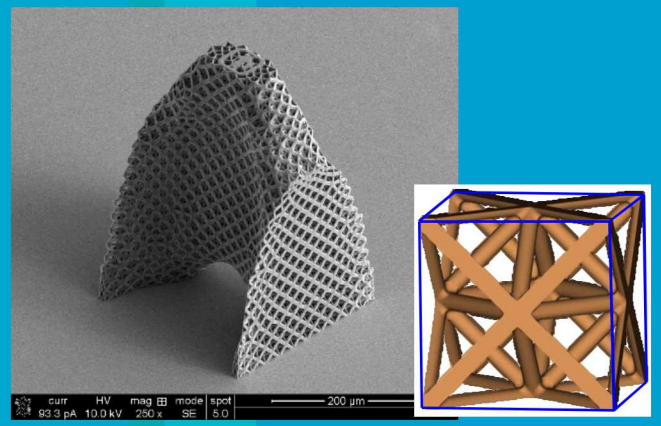
Process tunable to specific performance

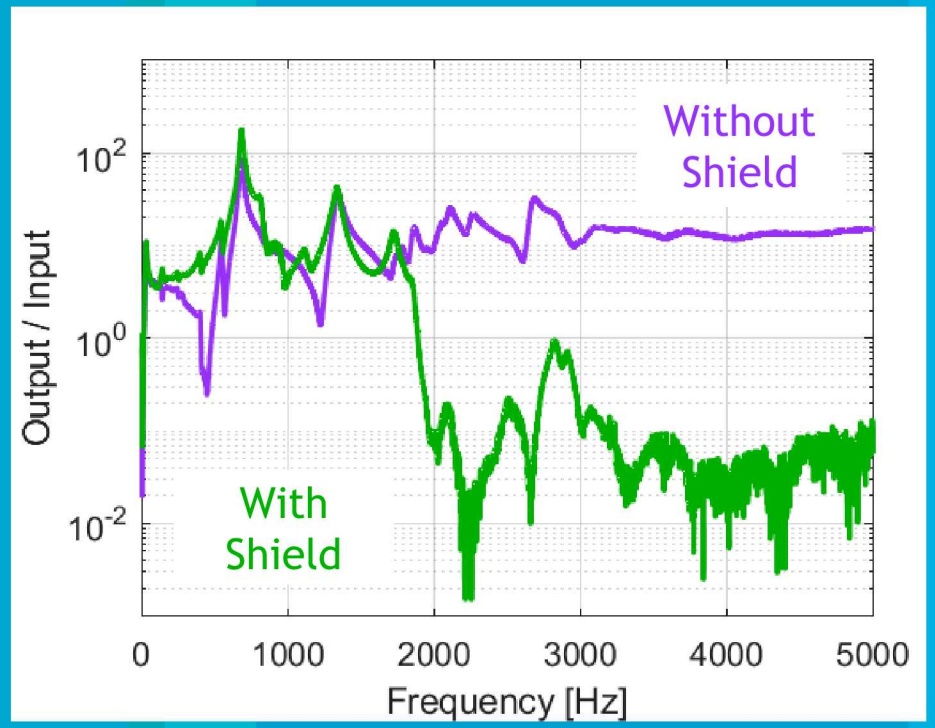


Printed compression pad cross section

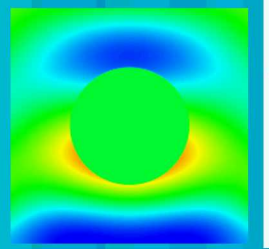
Extraordinary Control of Shape and Functionality

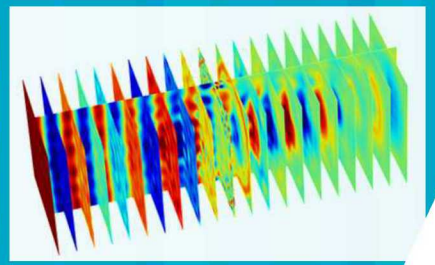
Example: acoustic metamaterials



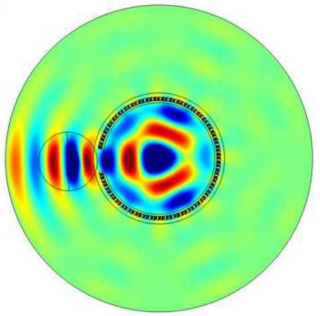


Multiphase composite materials designed to produce dynamic material properties not found in nature

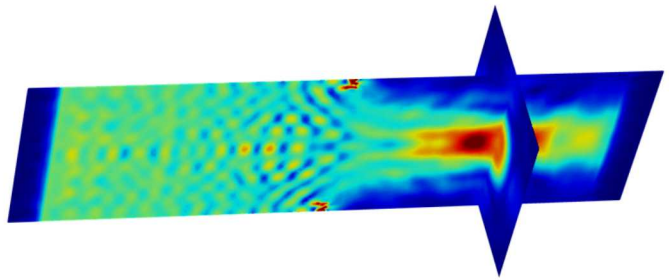




Wave Bending



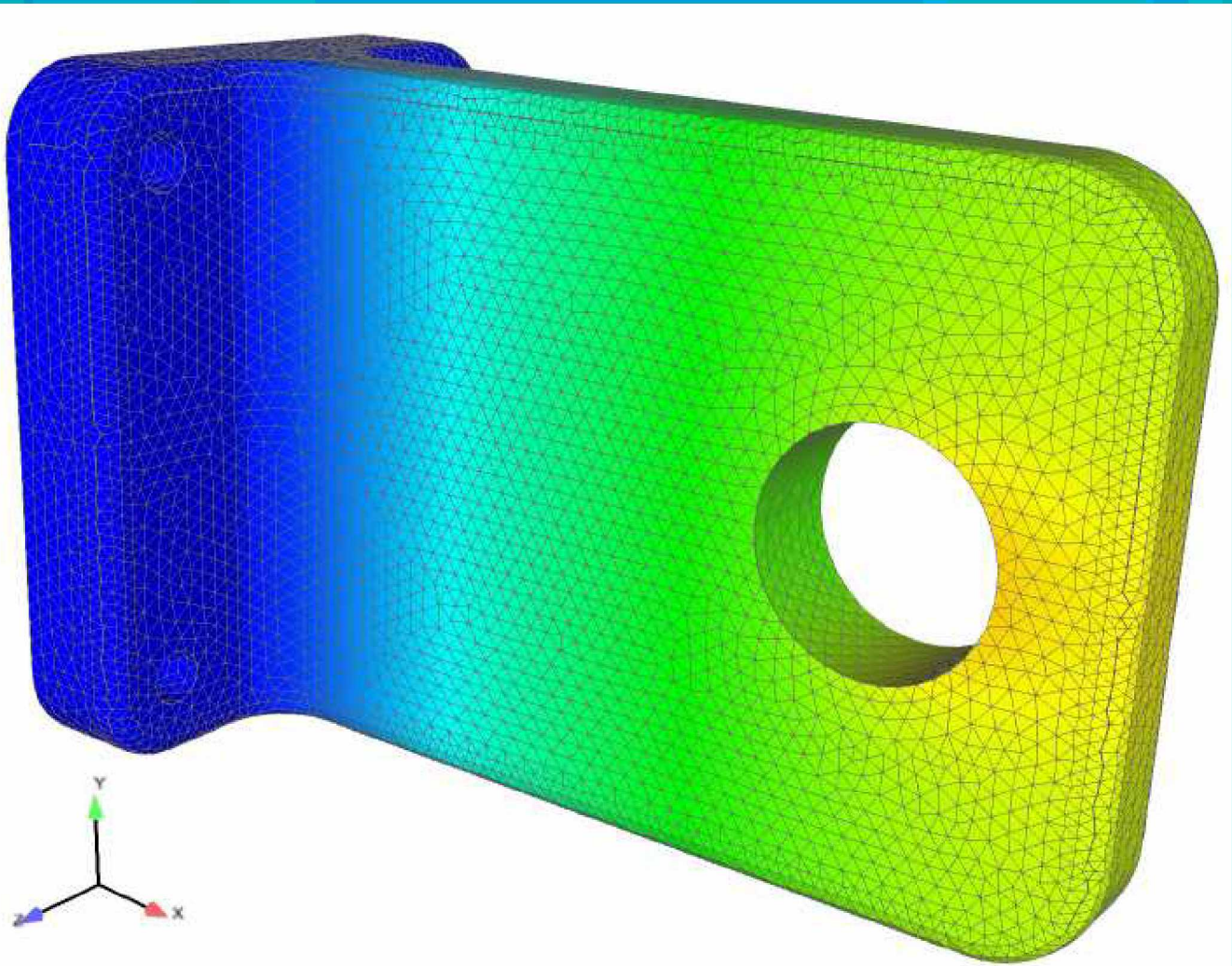
Wave Steering



Wave Focusing

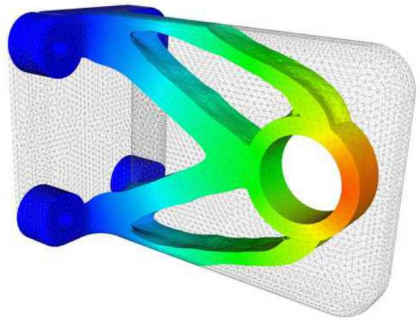
Real-Time Multi-Physics Designs Are Possible

Incorporating the Right Physics Is Essential

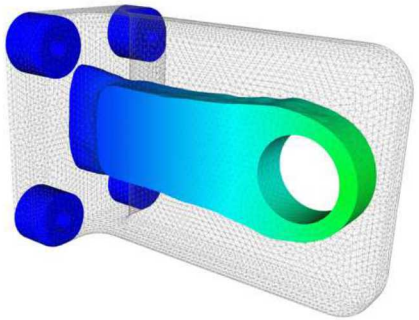


- GPU enabled solver package
- Optimized for stiffness and thermal conductivity

Mechanical Optimization Only



Thermal Optimization Only



PLATO: topology optimization

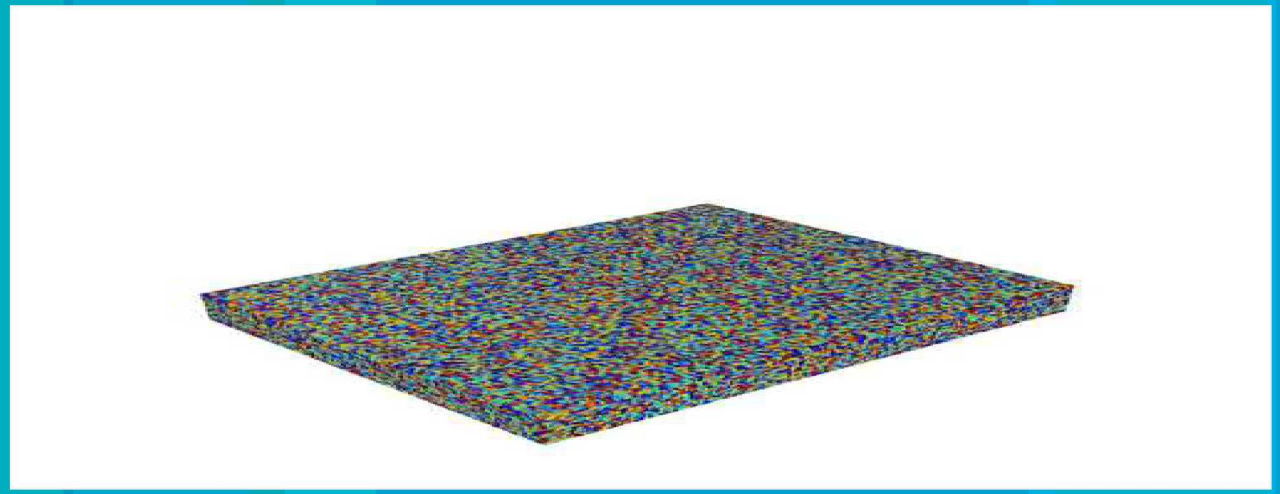
Predicting Design at the Microscale

15

SPPARKS: Stochastic Parallel PARticle Kinetic Simulator

SPPARKS

- A tool for designing AM fabrication processes
- Simulates microstructural evolution

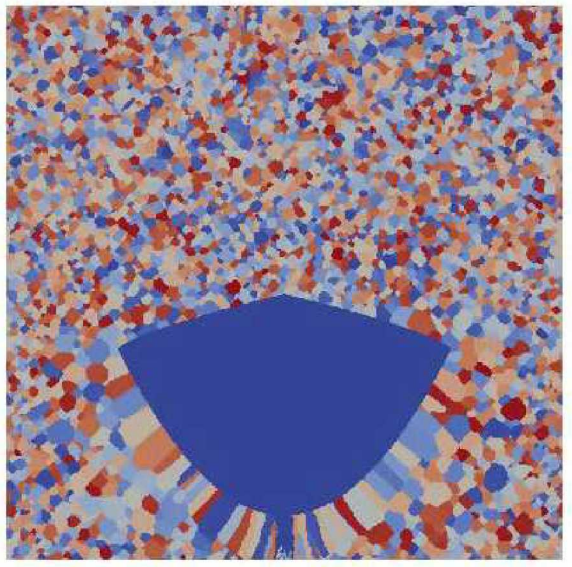


AM processes (melting, solidification, grain growth)

T. M. Rodgers, J. D. Madison, V. Tikare,
Computational Materials Science 135 (2017) 78-89

Grain Growth

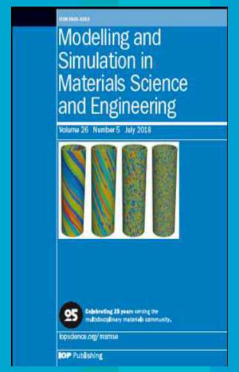
Welding



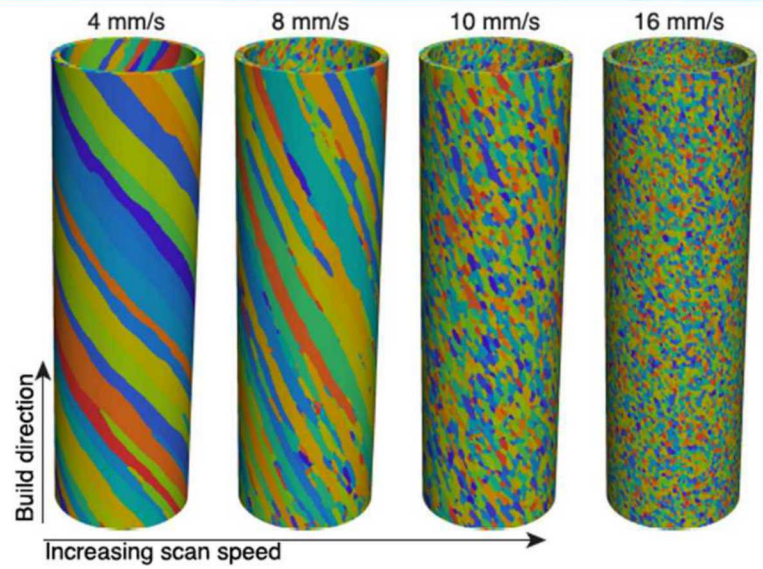
Microstructure Predicts Performance

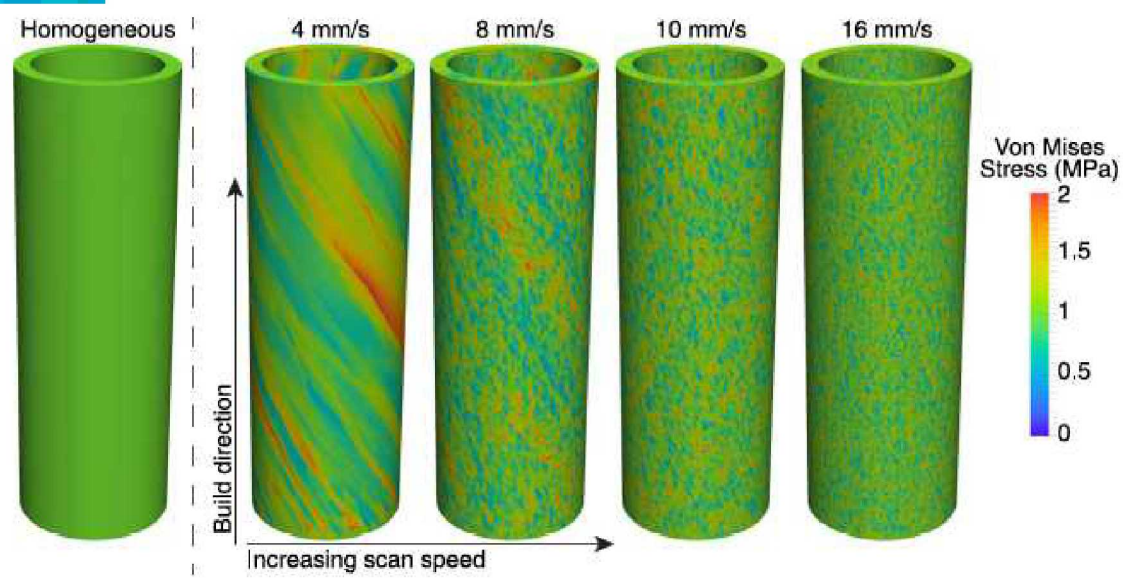
SPPARKS & SIERRA

- Processing creates microstructure
- Microstructure controls performance
- Coupling kinetic Monte Carlo (SPPARKS) with direct numerical simulation of mechanical behavior (SIERRA)



T. M. Rodgers, J. E. Bishop and J. D. Madison
Modelling Simul. Mater. Sci. Eng. 26 (2018) 055010





Requirements for Future Advances in Our Engineering Mission

New tools to make this work possible now and in the future

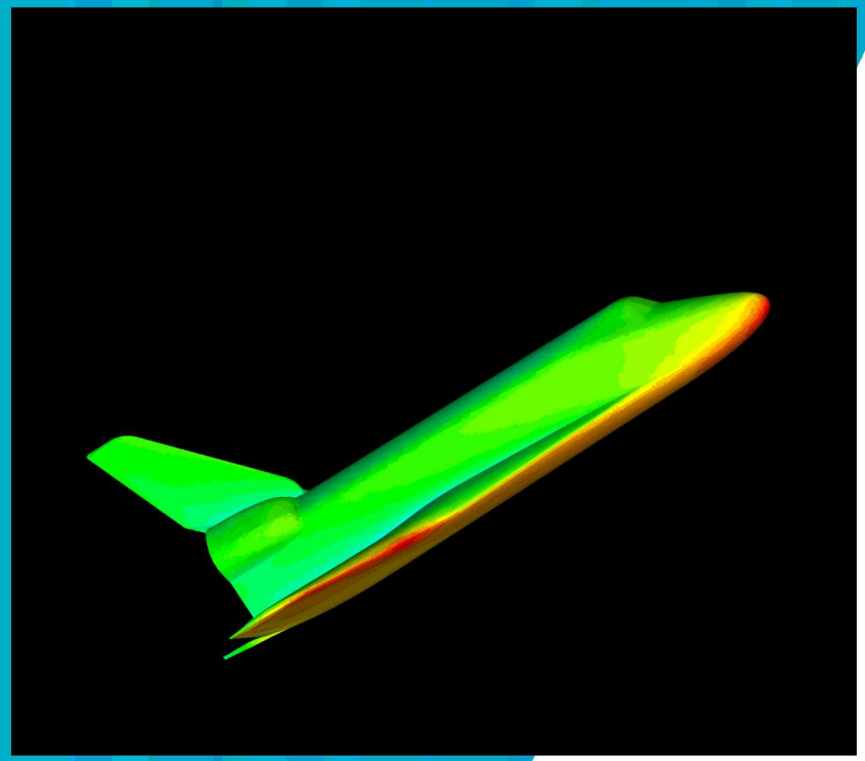
- Sandia's engineering missions are pushing us in new directions
  - Complex full-system engineering models that span a system's lifecycle
  - Explicit focus on how humans and computers interact to enable critical decisions
  - Adding automation, data analytics, and intelligence throughout computational simulation
    - See WCCM mini symposia on data-driven modeling
- But advances in computing overall are also important:
  - Exascale Computing Project—enabling 50x improvement in capability by 2021 – 2023
  - Sandia's new **Astra** ARM-based supercomputer prototype helps open the door for future custom hardware options
  - Neuromorphic and quantum efforts also moving forward
- Diverse partnerships and diverse staff will help achieve both

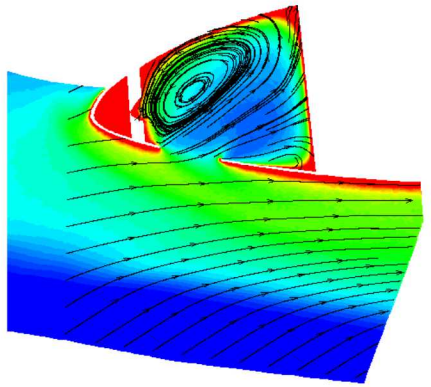
High-Impact Decisions Require High-Fidelity Analysis

The Space Shuttle Columbia accident

- Accident attributed to insulating foam impact on the wing leading edge during launch
- Sandia provided NASA aerodynamic, aerothermal, fluid dynamic and foam impact analysis
- Numerical simulations of fluid flow suggested a shock-shock interaction increased heating rates in the area of the impact
- Flow inside the wing accentuated the problem

The right physics and right model, at the right scale, might have identified a real-time solution to avoid the accident.





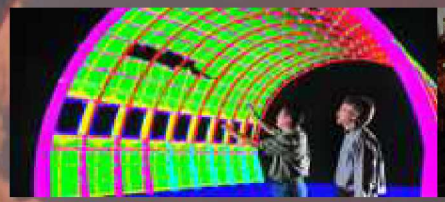
NNSA National Laboratories Offer Rich Careers – Join Us!

Challenging technical problems and amazing tools

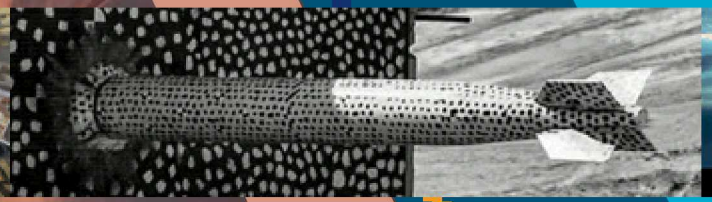
Important and unique missions

Many different op technical work to and management

Exceptional service in the national interest





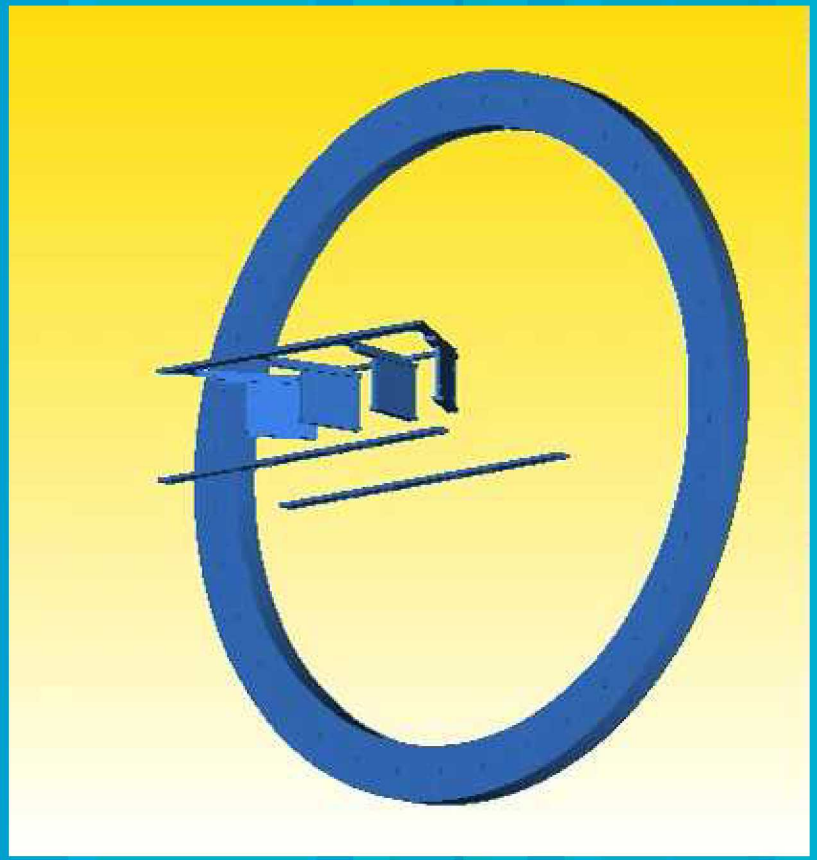



Enabling Novel Designs

Topology optimization using PLATO

Impact on Design:

- Topology optimization explodes design space
- Take advantage of new materials with unique properties
- Enabled by HPC & high fidelity mod/sim
- Use additive manufacturing to realize organic designs

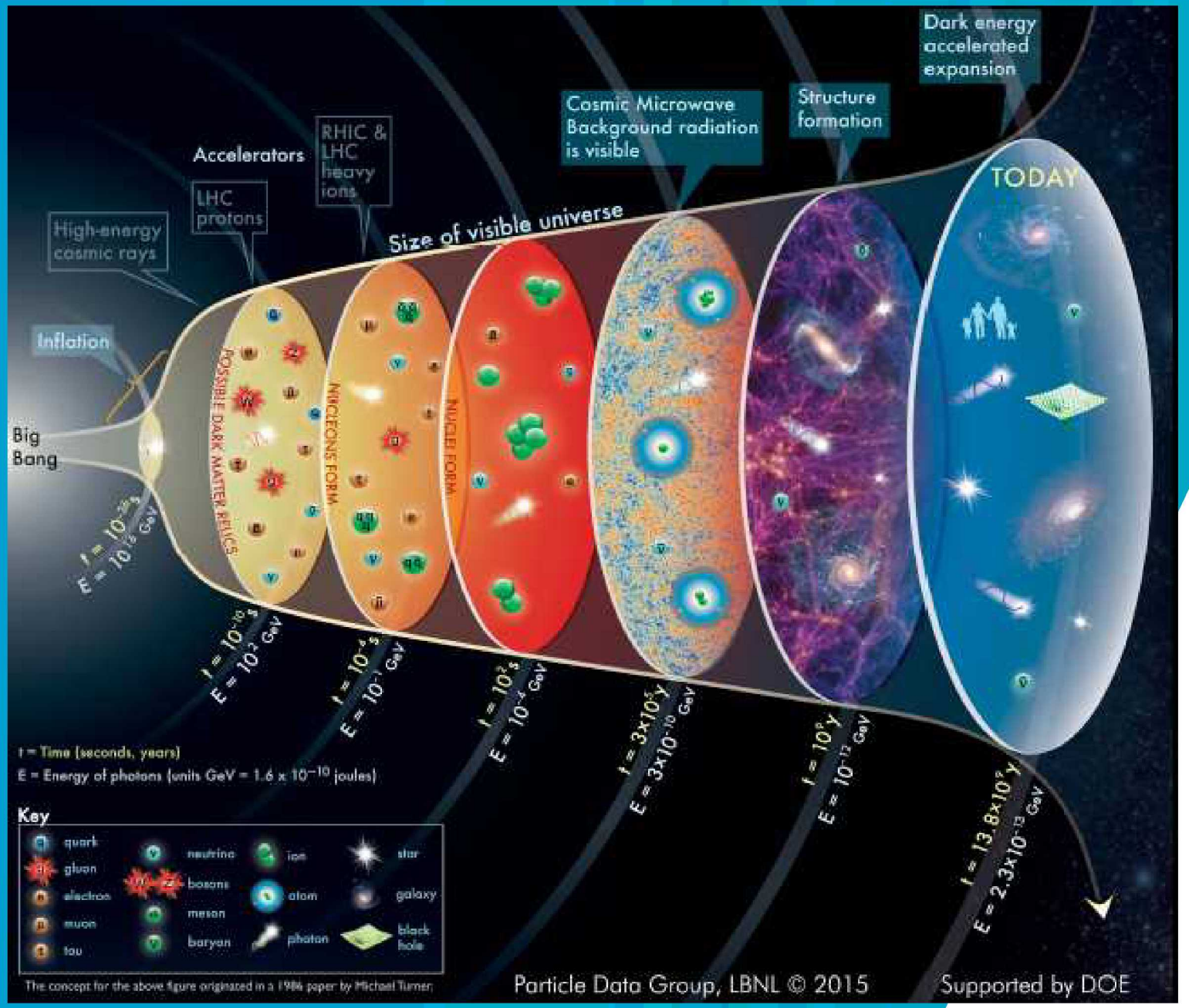


Example: satellite bracket design with increased stiffness, 40% weight reduction

PLATO Features:

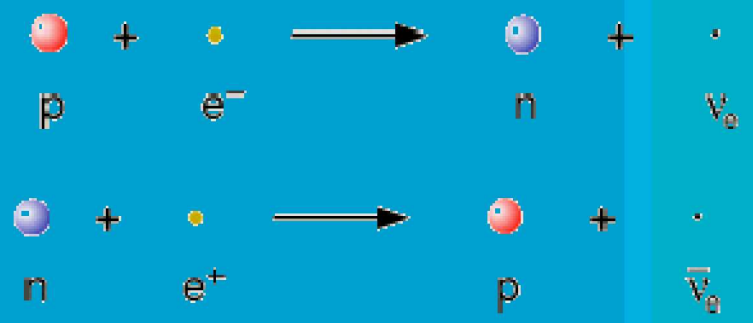
- Print ready design
- UQ-enabled designs
- Multi-material designs
- Designs with lattice metamaterials
- Automated conversion back to CAD surfaces

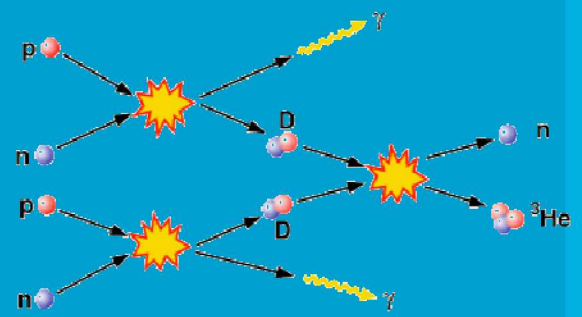
The Neutron in the Universe

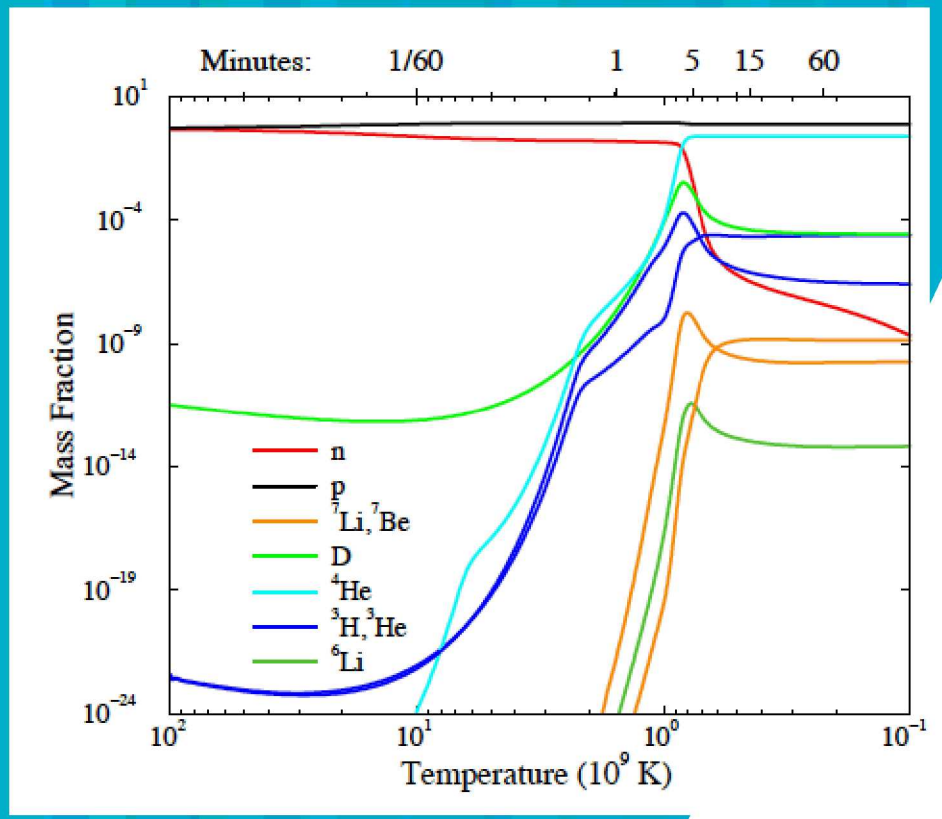


The Neutron Lifetime Determines ^{4}He Abundance

23





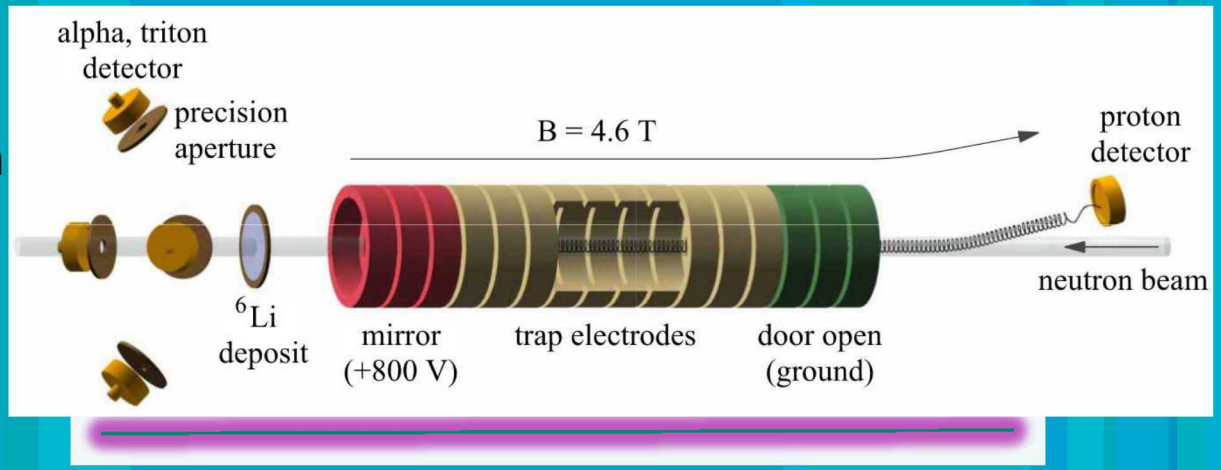


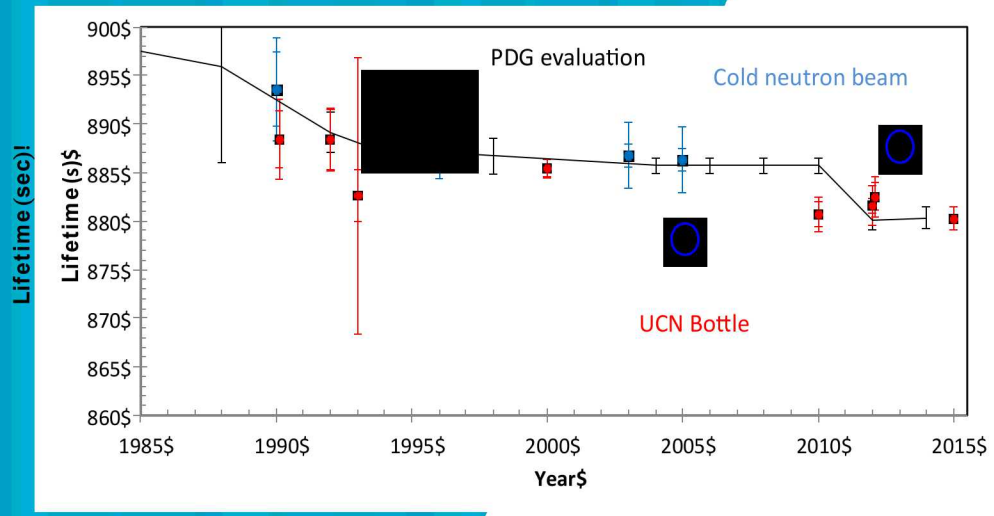
The helium abundance is predicted with a precision better than 1%, with the neutron lifetime as the limiting uncertainty [1,2]

[1] P. A. R. Ade, et al., arxiv:1303.5076 (2013).
[2] F. Iocco et al., Phys. Rep. 472 1-76 (2009).

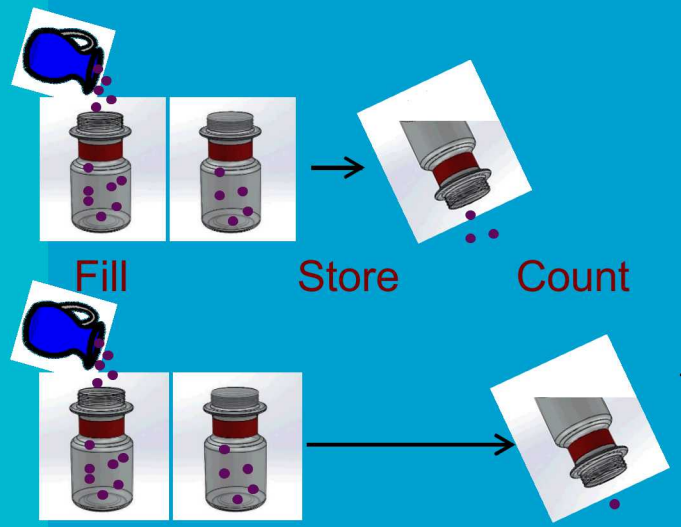
Two Techniques Are Used to Measure τ_n

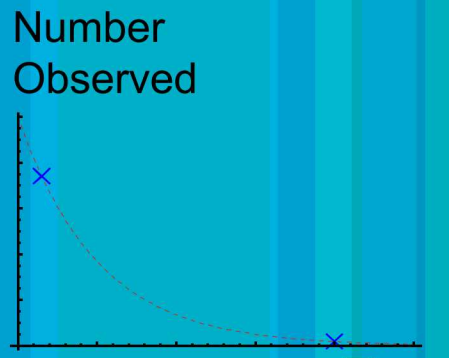
Cold Neutron Beam





Ultracold Neutron (UCN) Bottle

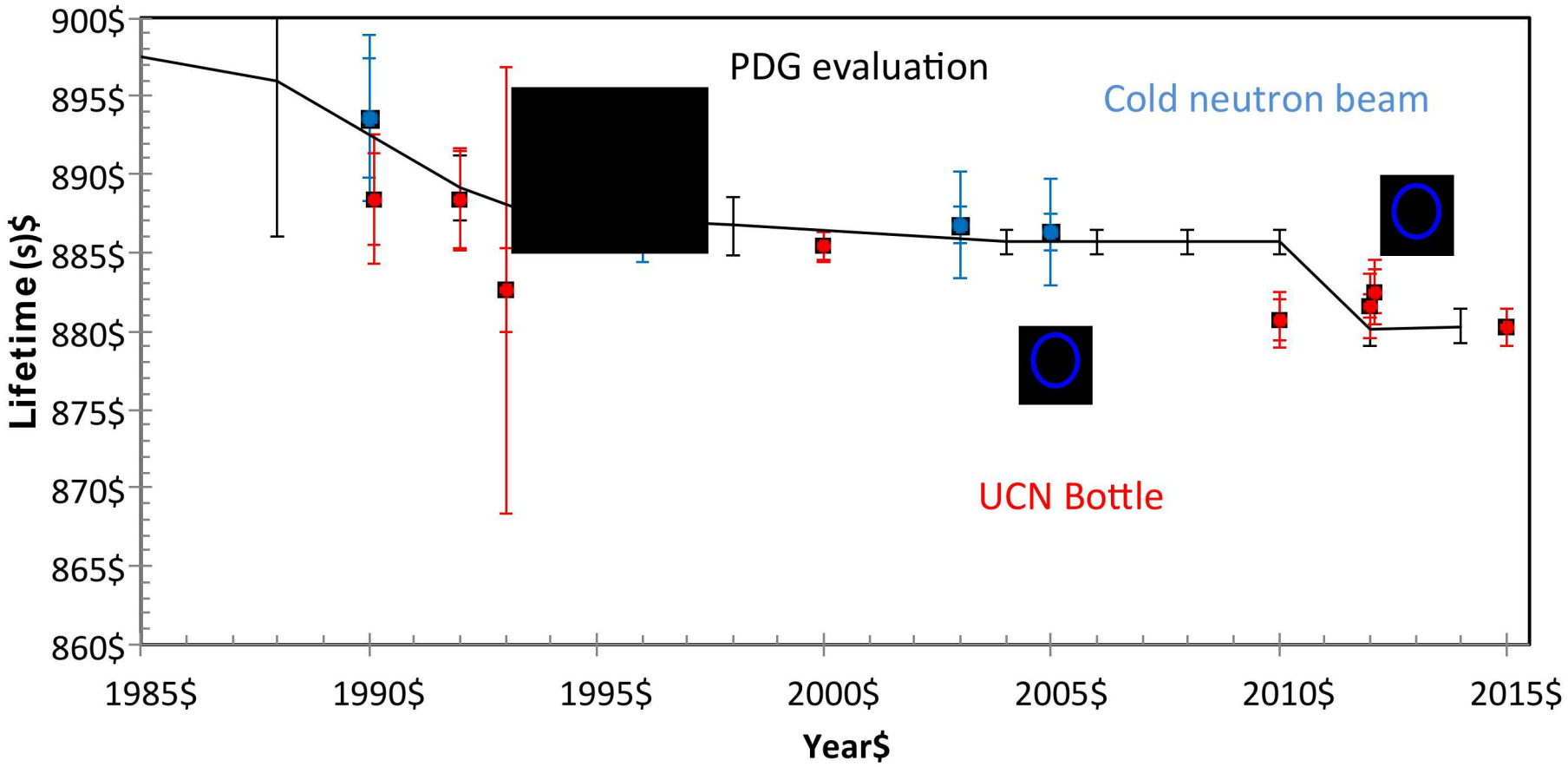




Most precise Beam:
τ_n = 887.1 ± 2.2 s

Most precise Bottle:
τ_n = 878.5 ± 0.8 s

History and Status of τ_n



Most precise Beam: τ_n = 887.1 ± 2.2 s

Most precise Bottle: τ_n = 878.5 ± 0.8 s

Sandia's Changing National Security Challenges

1950s	1960s	1970s	1980s	1990s	2000s	2010s
NW engineering and test	**NW stockpile diversity and build-up**	**NW + energy: Multiprogram laboratory**	**DOE Multiprogram + missile defense and other DOD work**	**DOE Multiprogram + DOD, economic competitiveness**	**Expanded national security role post 9/11**	**LEPs Cyber, bio, space, terrorism**
Arms race	Cuban missile crisis Vietnam conflict	Energy crisis	Cold war	Stockpile stewardship	Broader national security	Evolving national security challenges