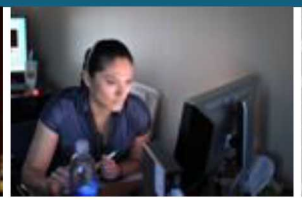
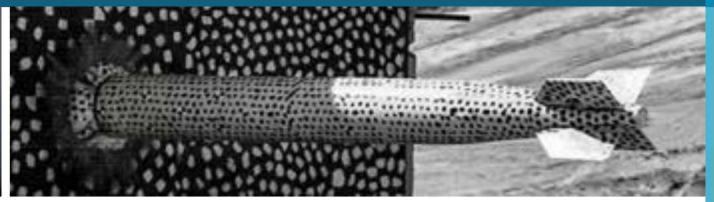
Sandia National Laboratories

SAND2019-6310PE

SANDIA NATIONAL LABORATORIES AND THE FUTURE OF ENGINEERING AND SIMULATION





PRESENTED BY

Dr. Joel Lash

Director

Engineering Sciences Center

Goodyear External Speaker Series

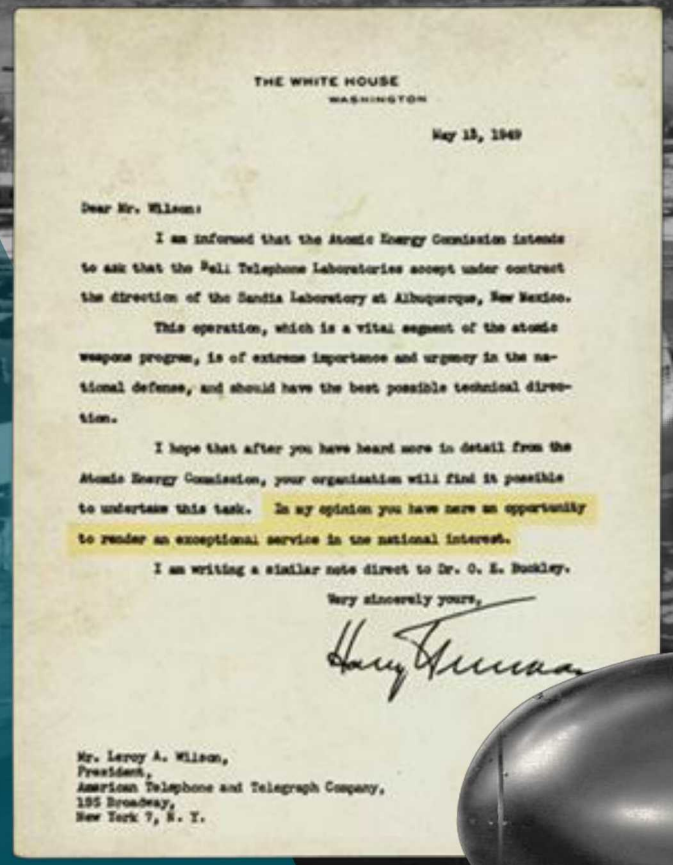
June 12, 2019

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.

SANDIA'S HISTORY IS TRACED TO THE MANHATTAN PROJECT

…In my opinion you have here an opportunity to render an exceptional service in the national interest.

- July 1945
  Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949
  Sandia Laboratory established
- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–2017
- Honeywell: 2017–present



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

SANDIA HAS FACILITIES ACROSS THE NATION

Activity locations

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

Main sites

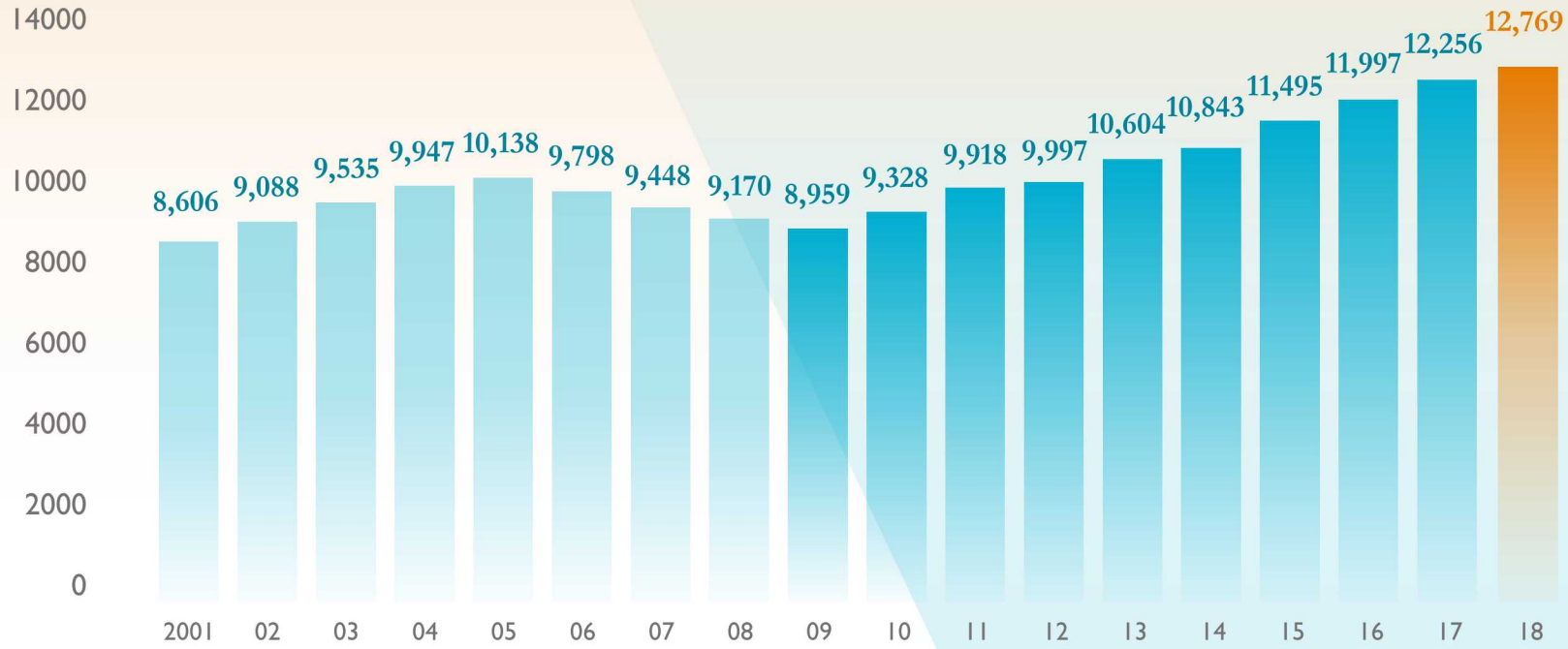
- Albuquerque, New Mexico
- Livermore, California

SANDIA'S WORKFORCE IS GROWING

Staff has grown by over 3,800 since 2009 to meet all mission needs

11,341 New Mexico

1,428 California



Final FY18 funding: $3.6B

PURPOSE STATEMENT DEFINES WHAT WE DO

Sandia develops advanced technologies to ensure global peace

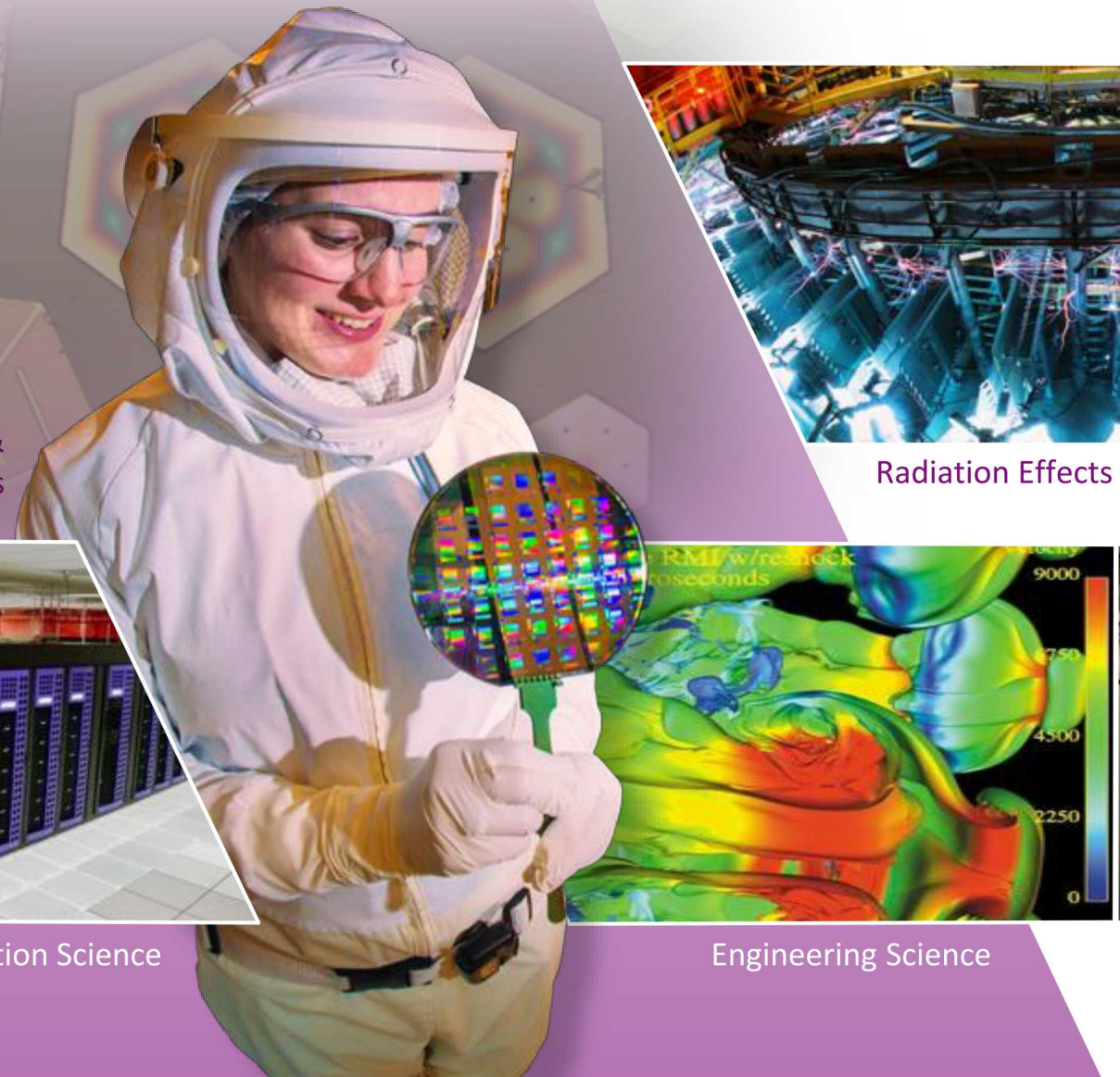
OUR PRIORITIES CREATE A VISION FOR THE FUTURE

- Deliver **quality engineering, science, and technology** in the most efficient way possible
- **Safety and security** are top of mind
- **Collaboration** is vital – inside and outside the Labs
- Sustain a **diverse and inclusive** Laboratories culture
- **Think strategically:** What might the world look like in 20 to 30 years?

SANDIA HAS FIVE MAJOR PROGRAM PORTFOLIOS

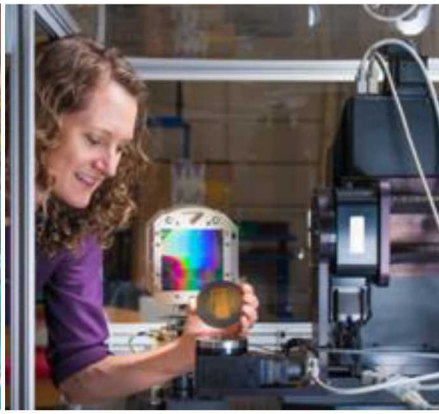
ADVANCED SCIENCE & TECHNOLOGY

Research Foundations play an integral role in stewarding our capabilities



Nanodevices & Microsystems

Radiation Effects & High Energy Density Science



Materials Science

Computing & Information Science

Engineering Science

Geoscience

Bioscience

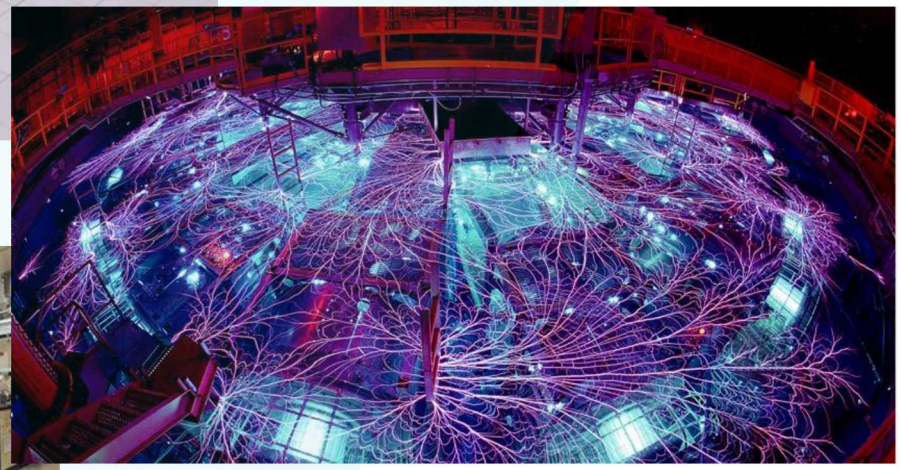
Integrating multidisciplinary efforts to advance the science of the possible for Sandia's missions

LAMMPS

DAKOTA
Explore and predict with confidence.

Modeling and Simulation

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

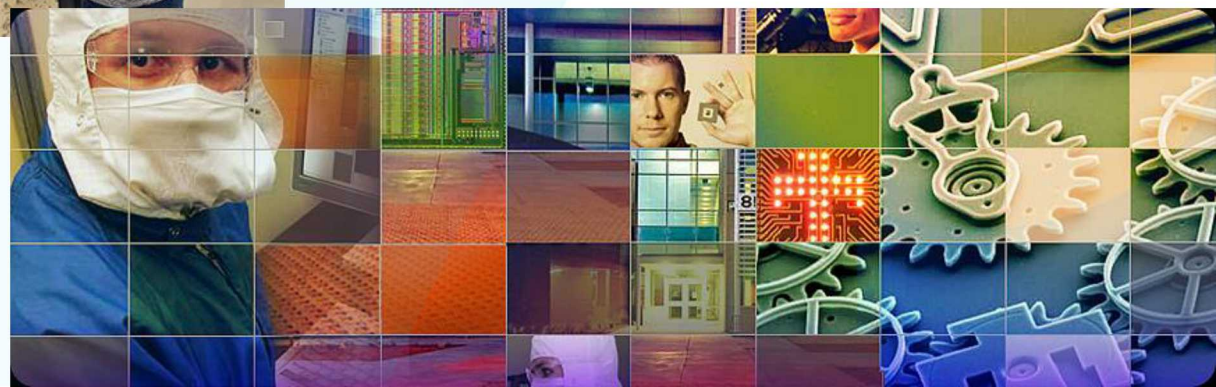


Advanced Experimental Capabilities

- Radiation effects
- Engineering environments
- Materials characterization and production

Microelectronics

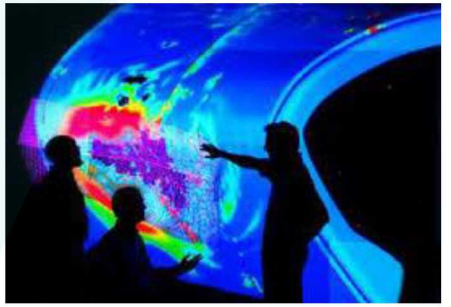
- Microsystems & Engineering Sciences Applications (MESA) Fab
- Development of advanced semiconductor materials



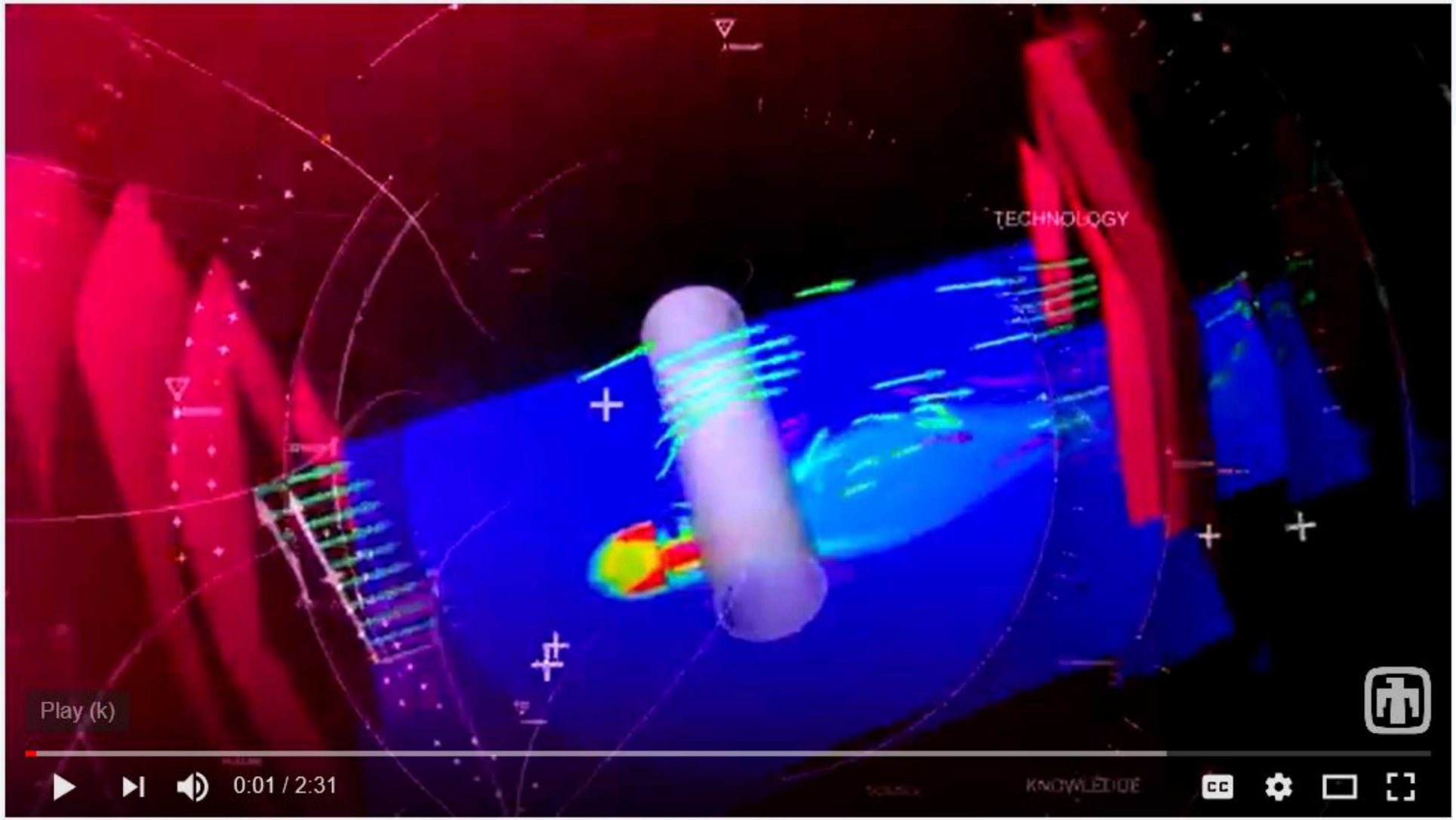
SUPPORTING THE NATION'S ENGINEERING CHALLENGES

Sandia's ability to leverage and integrate a breadth of capabilities and expertise has served the nation time and time again

- USS Iowa Investigation (April 19, 1989)
- TWA Flight 800 Accident Investigation (July 1997)
- Post 9/11 Vulnerability Studies (September 11, 2001)
- Columbia Space Shuttle Accident (February 4, 2003)
- I-35W bridge collapse in Minneapolis (August 1, 2007)
- BP Deepwater Horizon Oil Spill Accident (April 20, 2010)
- Aircraft Vulnerability (Jan 11, 2013)
- WIPP Accident Investigation (2014)



ENGINEERING SCIENCES OVERVIEW VIDEO



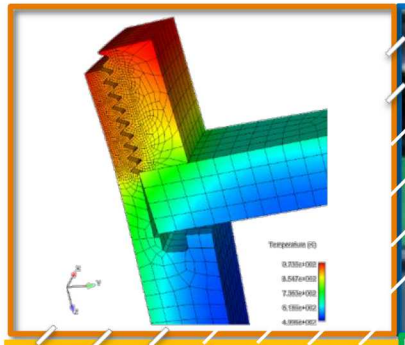
Engineering Sciences at Sandia Labs

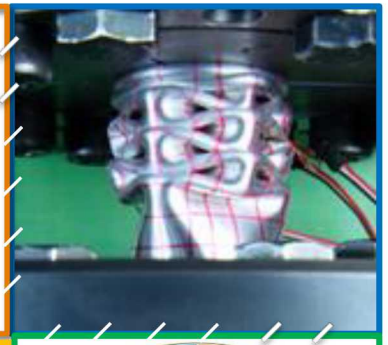
ENGINEERING SCIENCE CENTER PURPOSE

Provide validated, science-based engineering expertise, capabilities and solutions to inform critical engineering decisions.

- We integrate theory, computational simulation and experimental discovery/validation across length and time scales to develop the technical basis for complex systems.
- We steward a breadth of engineering disciplines: Aerosciences, Fire Sciences, Fluid Mechanics, Energetics, Shock Physics, Solid Mechanics, Structural Dynamics, Thermal Sciences, Computational Simulation and Engineering Analysis.

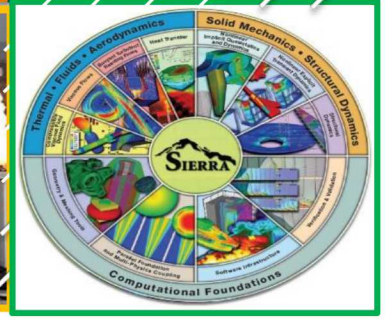
Engineering Analysis





Engineering Science Physical Phenomena

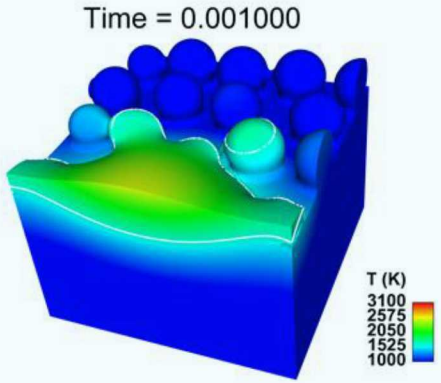
Environmental Simulation & Test

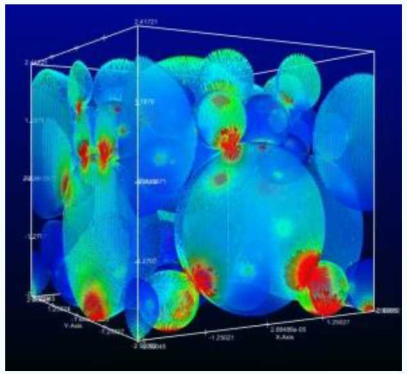


Computational Simulation Technology

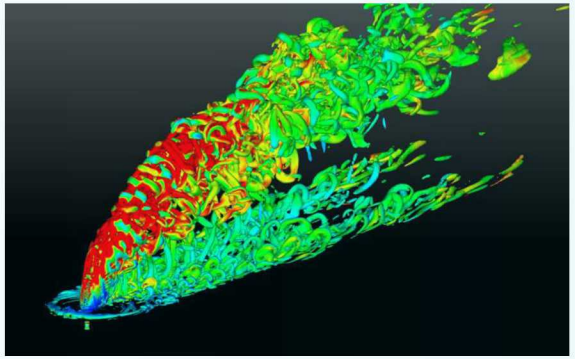
ENGINEERING ANALYSIS EXAMPLES

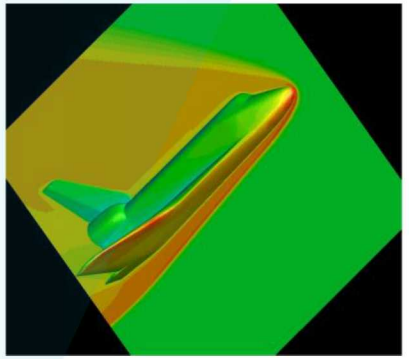
Manufacturing and Fluid Flows



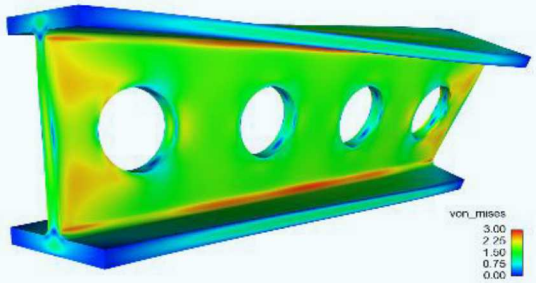


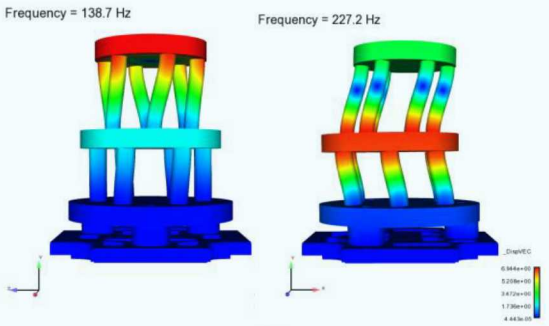
Aeroscience and Flight Phenomena



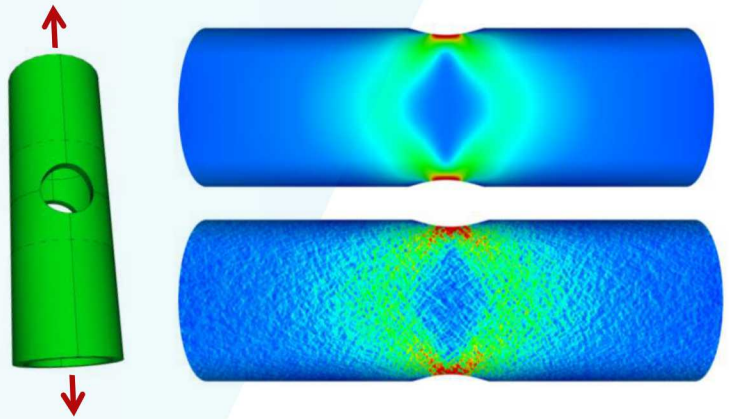


Structural Dynamics



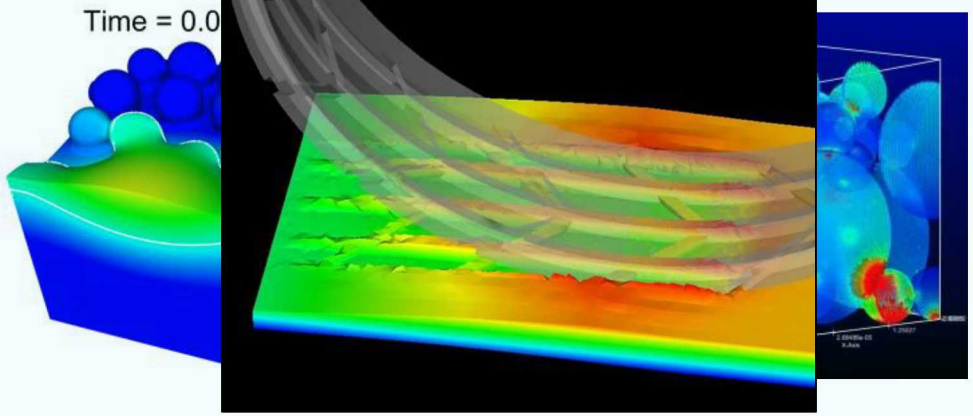


Solid Mechanics and Failure Assessment

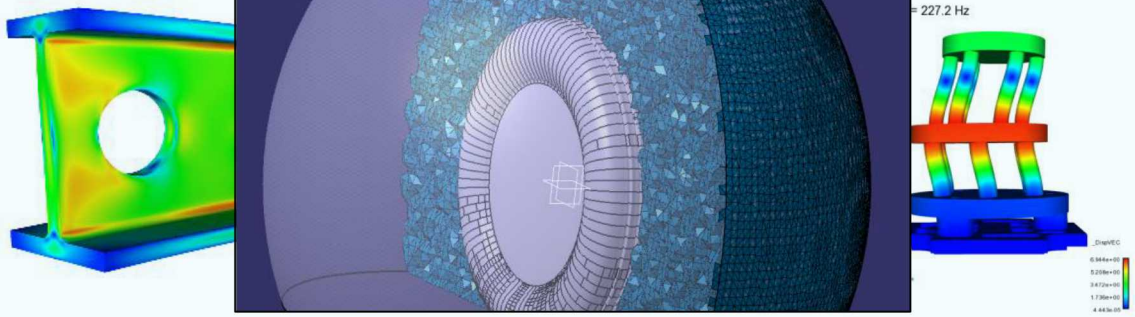


ENGINEERING ANALYSIS EXAMPLES

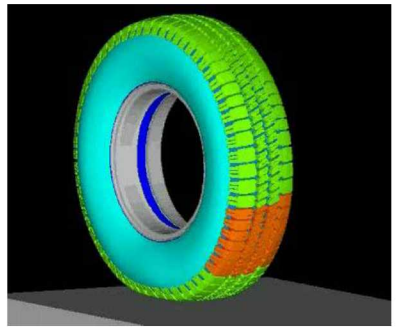
Rolling in Snow/Mud

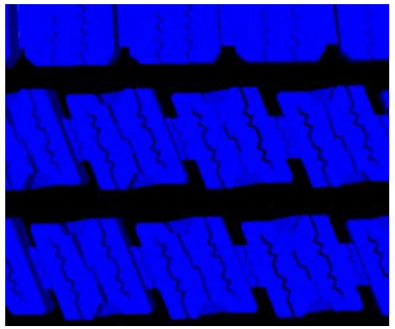


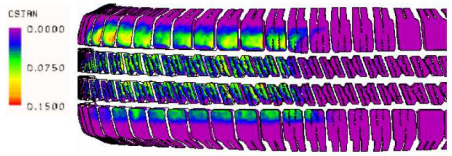
Noise prediction for rolling tire

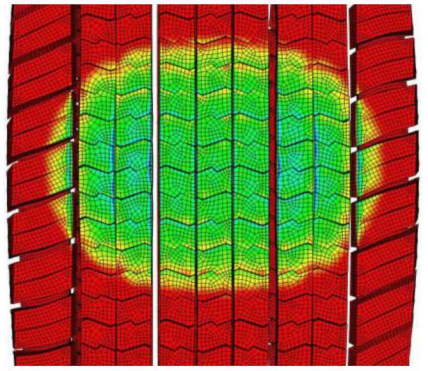


Performance Study of Different Tread Designs









Tire deflection against road showing groove closures.

Current efforts focused on production tools:

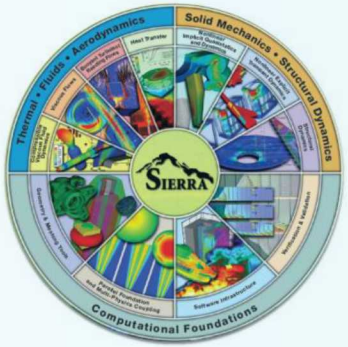
Sierra delivers computational simulation capabilities for thermal, high Mach aero, low Mach flow, reacting flow and species transport, nonlinear implicit/explicit solid mechanics, structural dynamics, acoustics and inverse problems.

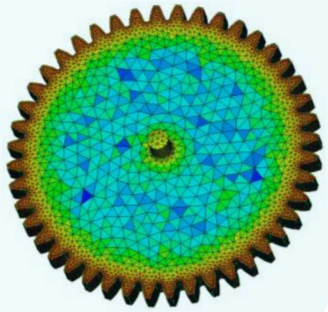
Cubit delivers a full-featured software toolkit for robust generation of finite element meshes and geometry preparation.

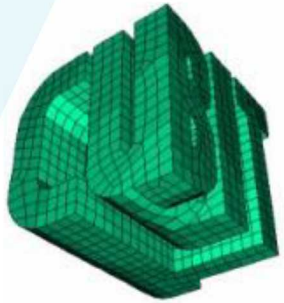
Plato delivers computational topology optimization design capability to meet engineering mechanics functional requirements.

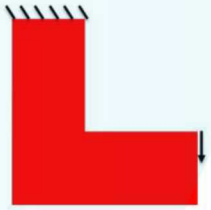
CTH delivers high-fidelity, hydrodynamics and shock physics capabilities.

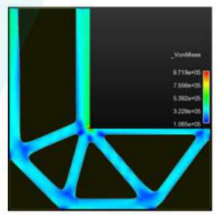
Verification & Validation (V&V) and Uncertainty Quantification (UQ) Tools deliver analysis capabilities that support the Predictive Capability Maturity Model and assessment credibility framework.

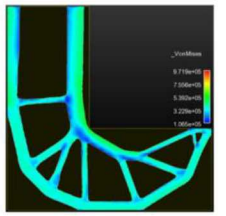


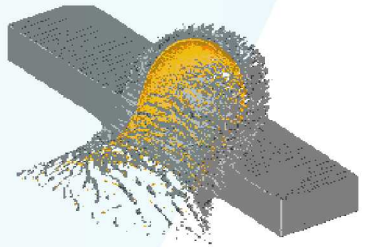


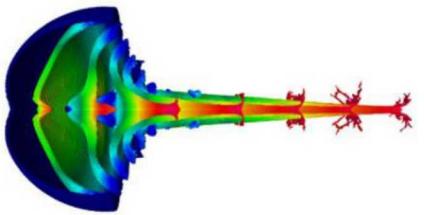






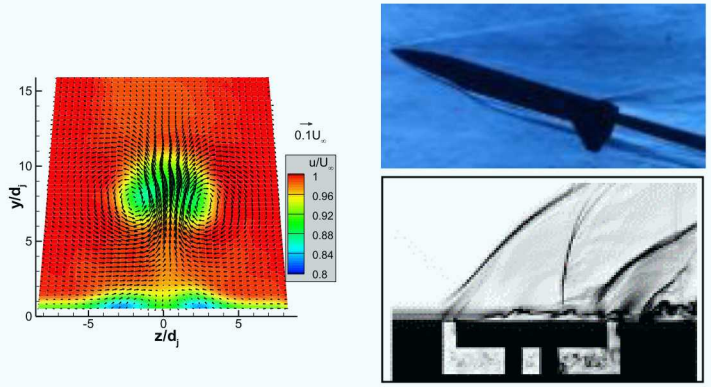




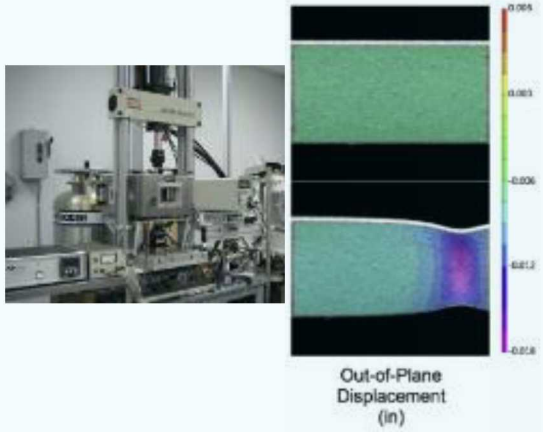


EXPERIMENTAL DIAGNOSTICS AND PHENOMENOLOGY

High Speed Compressible Flows

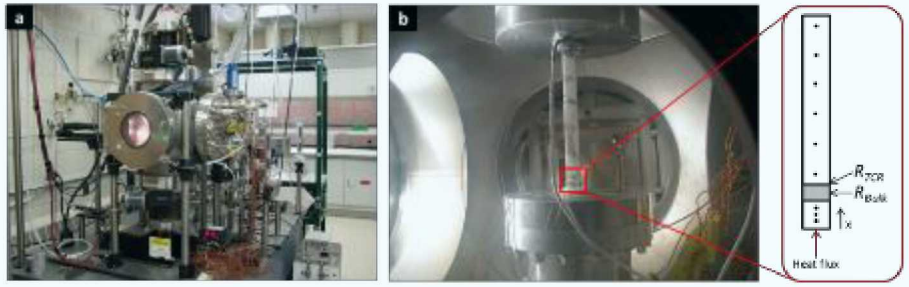


Full Field Mechanical Strain and Motion

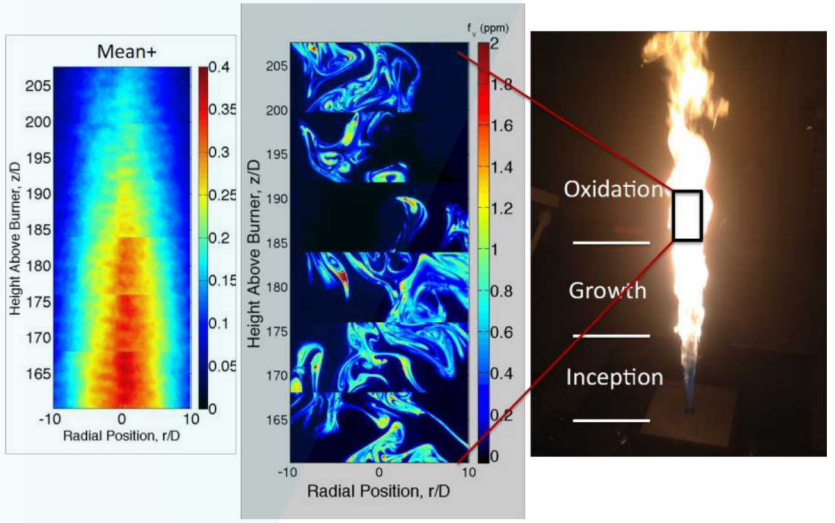


Laser-based Thermal/Flow diagnostics

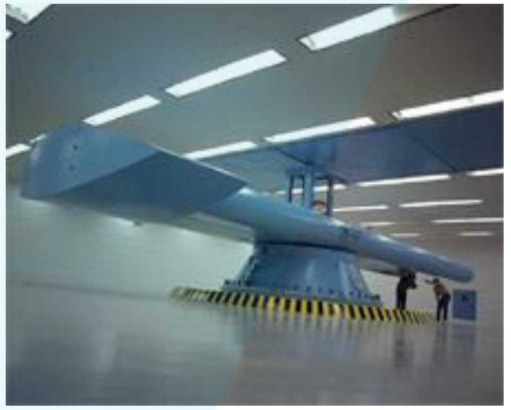
Thermal Property Measurements



Fire Imaging and Spectroscopy



LARGE SCALE ENVIRONMENTAL TESTING FACILITIES



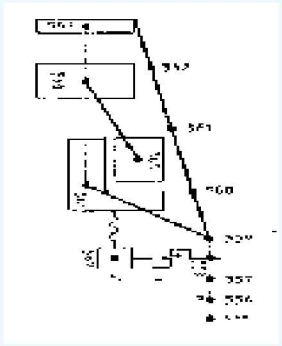
WE HAVE DELIVERED INCREASING *MODEL* FIDELITY

Enabled by platform and software advances

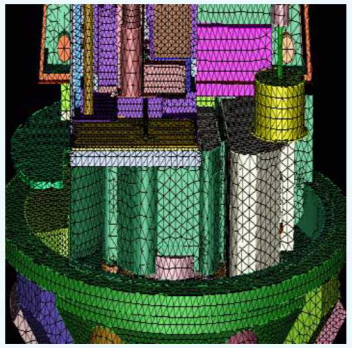
Enormous progress in computational mechanics over the past 3 decades.

- Computer architectures
- Geometric details
- Physics in computational models
- Scalable algorithms
- Multiphysics simulation codes

ASC Sequoia Supercomputer at LLNL
98,304 nodes x 16 cores; 20 petaflops



1970s:
200 DOF



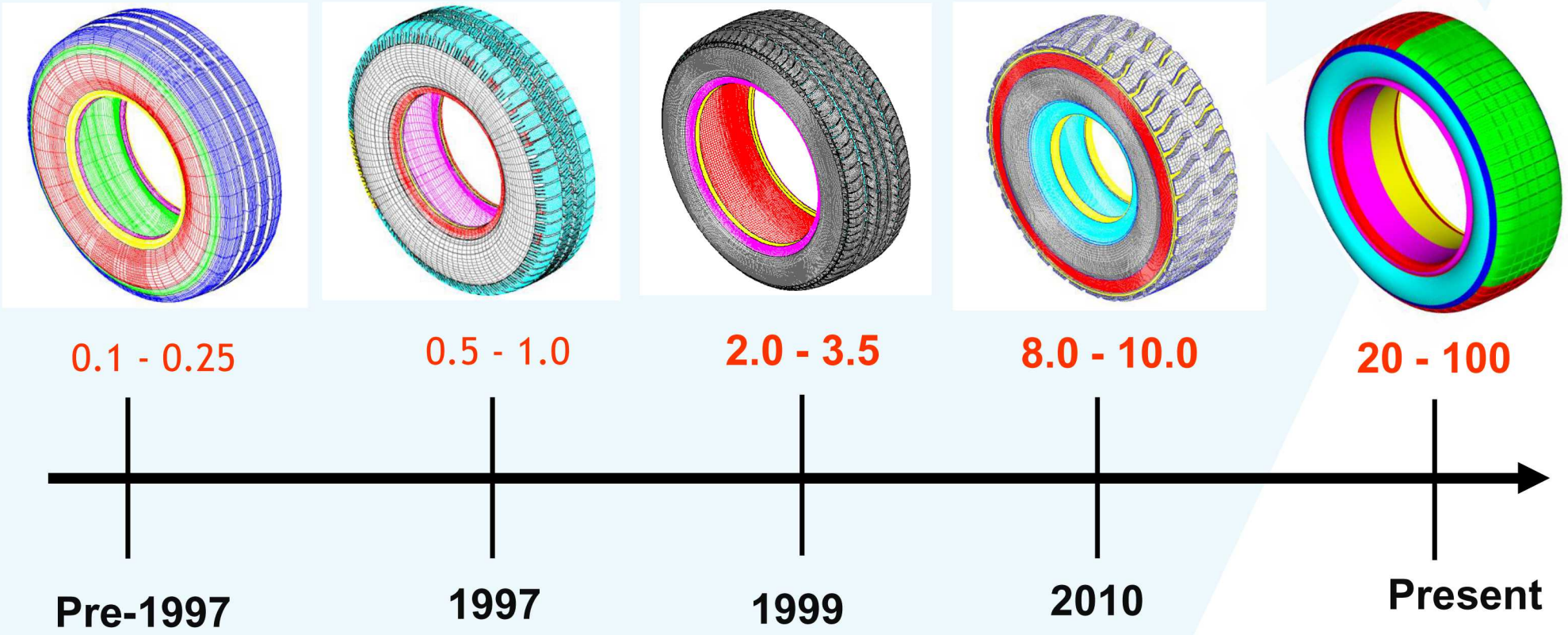
ca. 2000
8M DOF

ca. 2008
40M DOF

Solving previously
intractable problems

GOODYEAR HISTORY OF TIRE FE MODEL SIZE

MILLIONS OF DEGREES OF FREEDOM



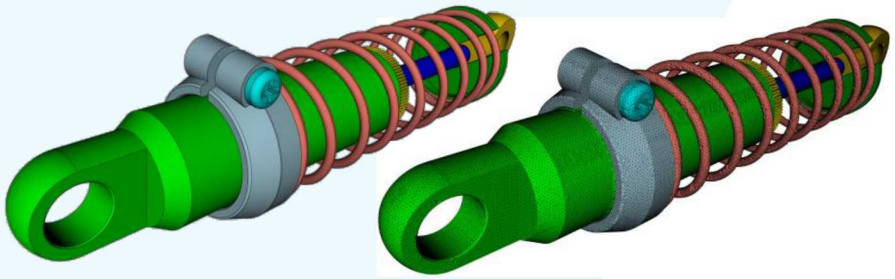
WE ARE ADDRESSING THE DESIGN TO ANALYSIS CHALLENGE

Next Generation Simulation effort will take us from "months to minutes"

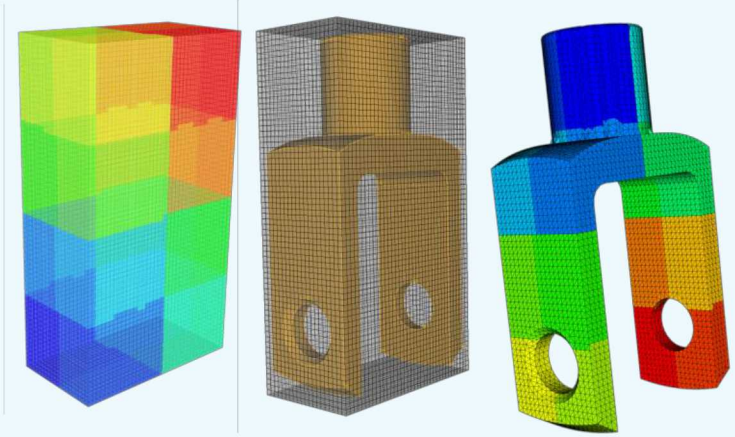
Complex parts and assemblies typically require months of analyst time addressing CAD deficiencies and building acceptable hex meshes

NGS is automated meshing that captures features larger than a specified length-scale and "gracefully ignore" smaller geometric features using tets

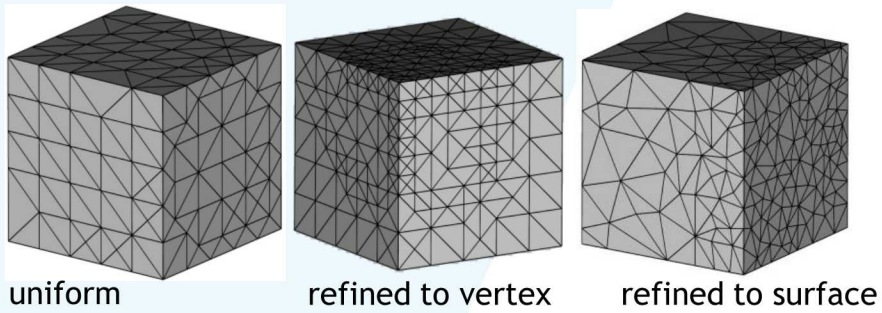
Assemblies
Interfaces, enclosures



Parallel
performance & scalability

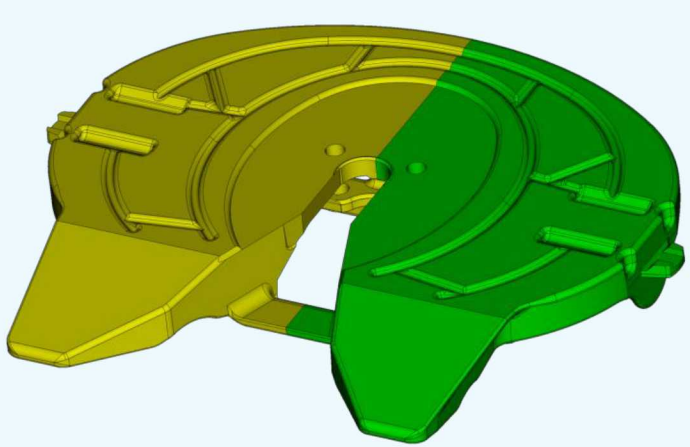


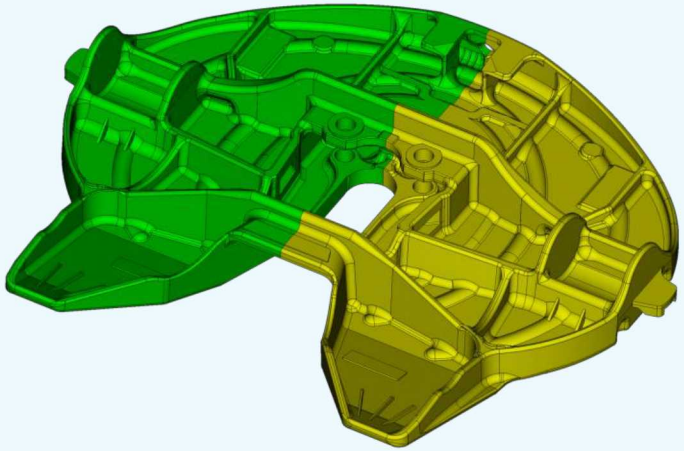
Adaptivity
arbitrary overlay grids

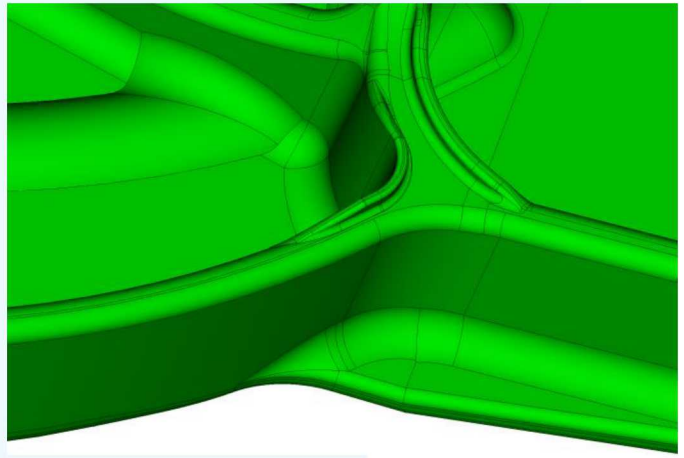


PREVIOUSLY AN 'IMPOSSIBLE PART TO MESH'

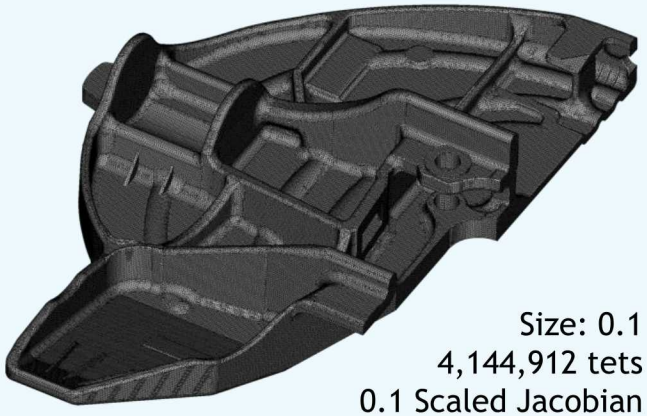
Semi tractor Fifth Wheel CAD model with multiple geometry issues



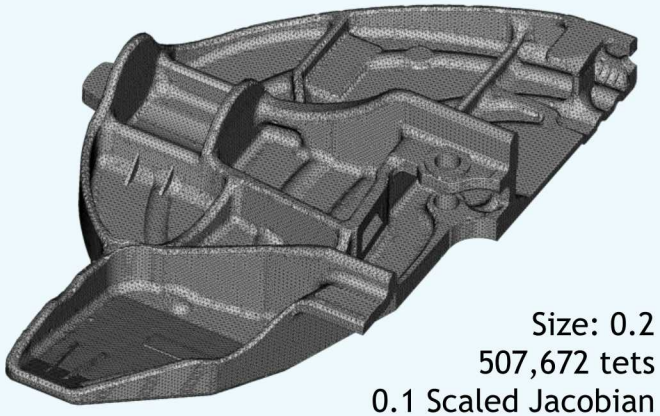




Meshing TAT: 50 minutes

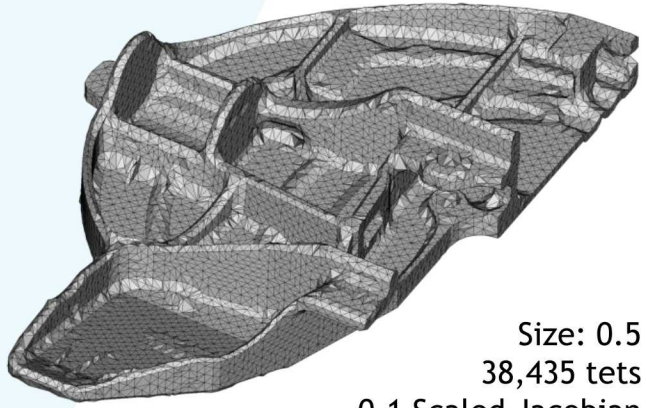


Size: 0.1
4,144,912 tets
0.1 Scaled Jacobian



Size: 0.2
507,672 tets
0.1 Scaled Jacobian

Meshing TAT: 3 minutes

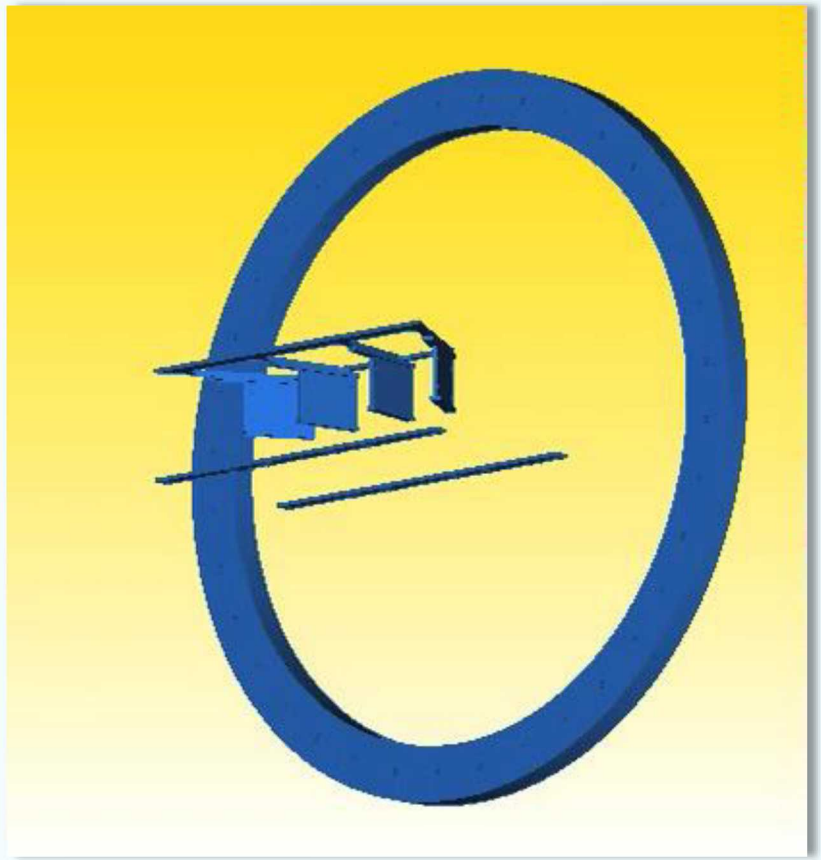


Size: 0.5
38,435 tets
0.1 Scaled Jacobian

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



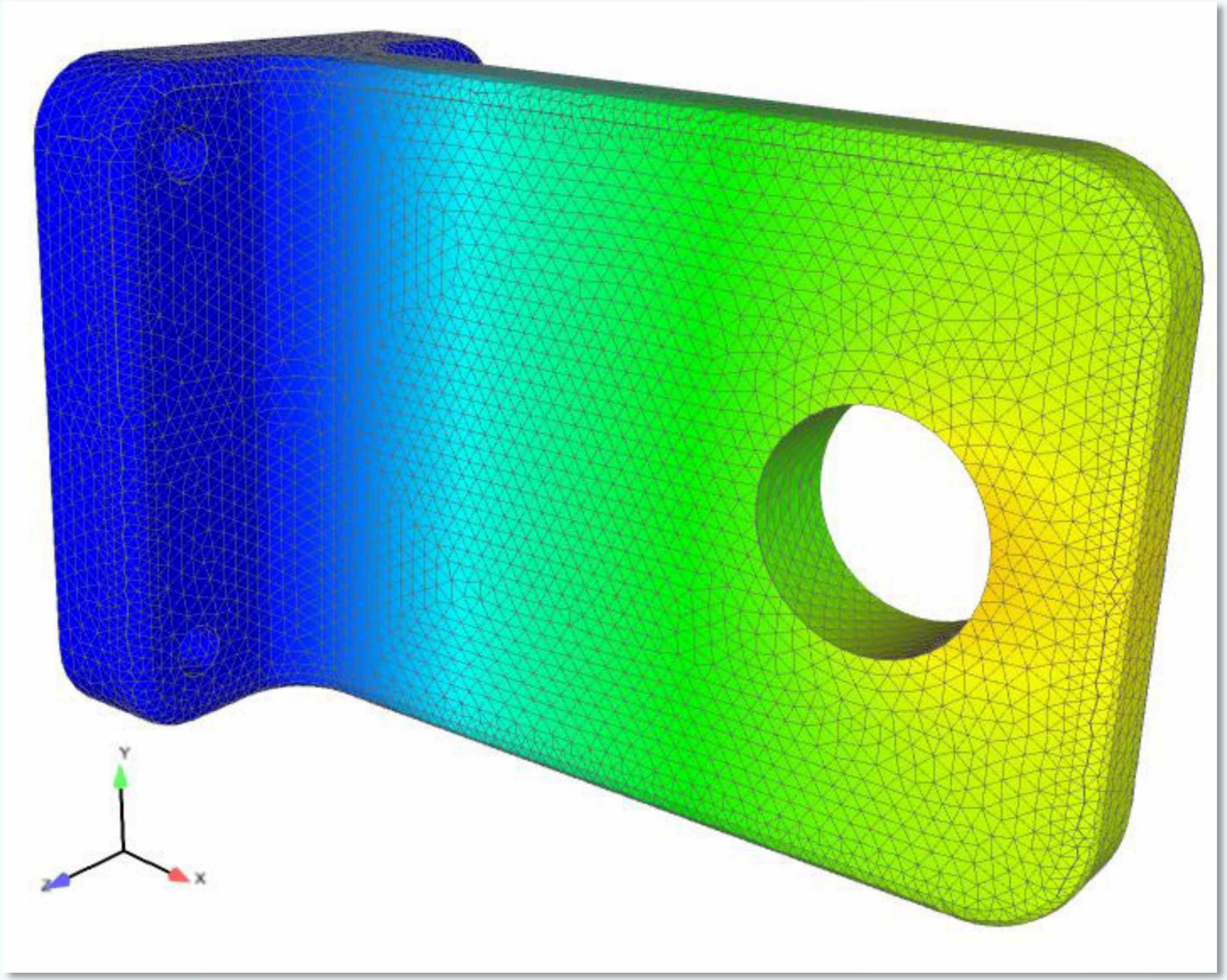
Example: satellite bracket design with increased stiffness, 40% weight reduction

PLATO Features:

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

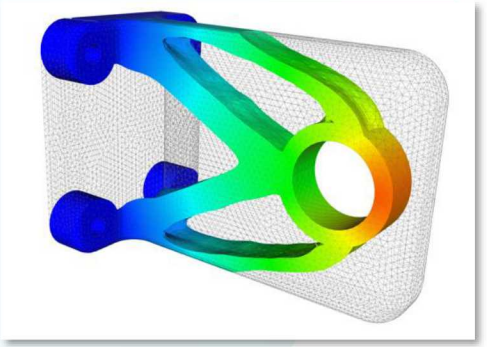
REAL TIME MULTI-PHYSICS DESIGNS ARE POSSIBLE

Incorporating the right physics is essential

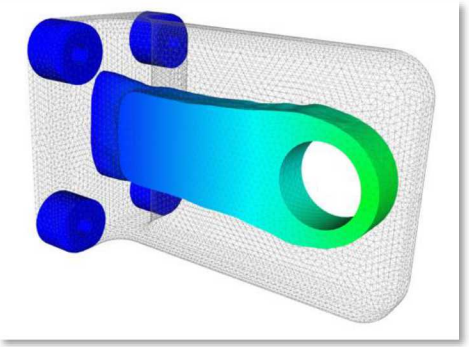


- GPU enabled solver package
- Optimized for stiffness and thermal conductivity

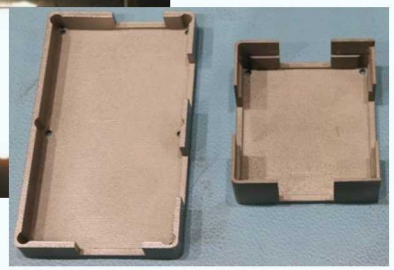
Mechanical Optimization Only

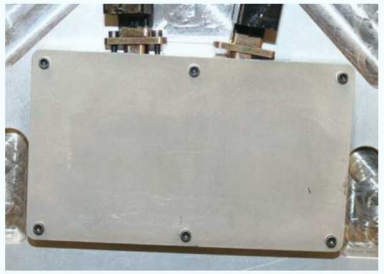


Thermal Optimization Only



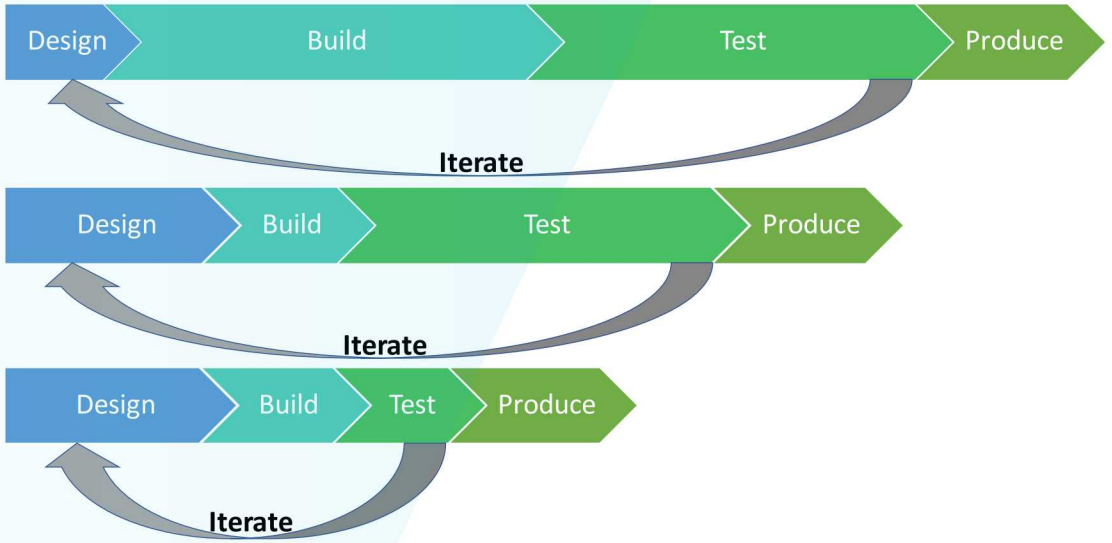
Modeling/simulation and additive manufacturing can reduce the number and speed of design-build-test iterations



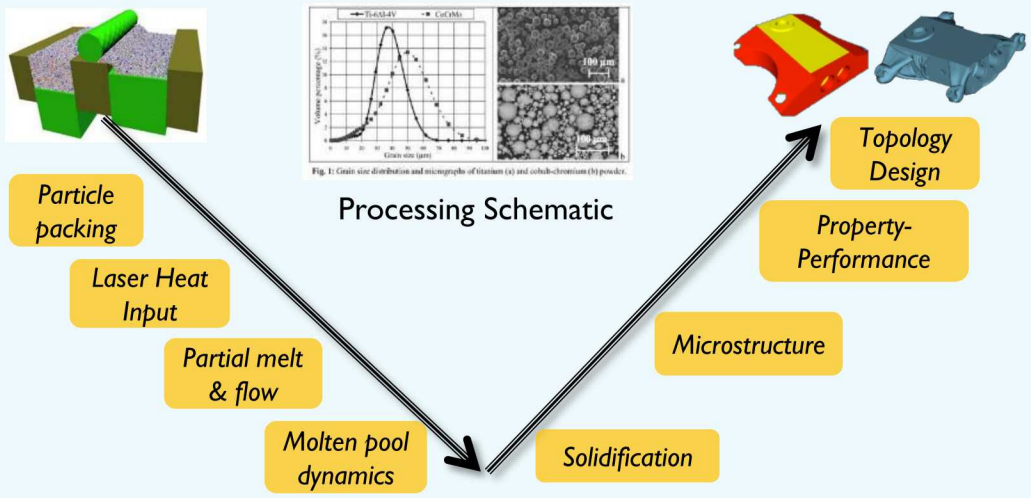


316L SS ESD faraday cage covers for sounding rocket telemetry circuit boards. Printed parts (above, right); assembled (bottom right).

- Short turn-around production of metal parts needed
- Metal laser powder bed fusion was used
- Additional material test coupons were printed
- Estimated time and cost savings of roughly 60%



Required to take full advantage of AM capabilities

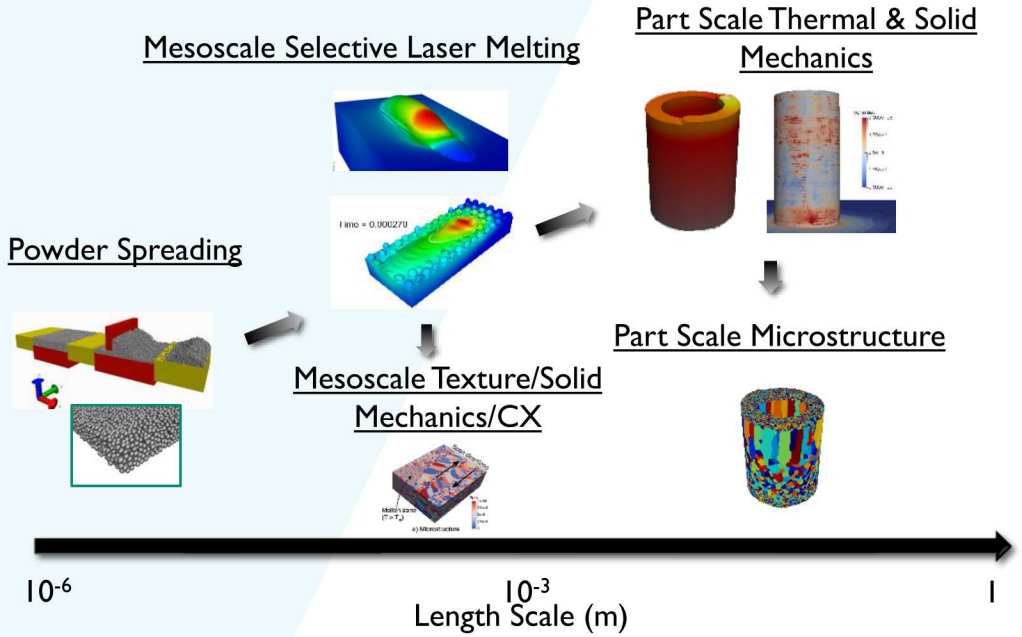


Processing Schematic

- Parallel attack on interdependent modeling areas
- Powder spreading and flowability
- Melt pool dynamics modeling
  - Robust solvers
- Grain morphology estimation based on actual build processes

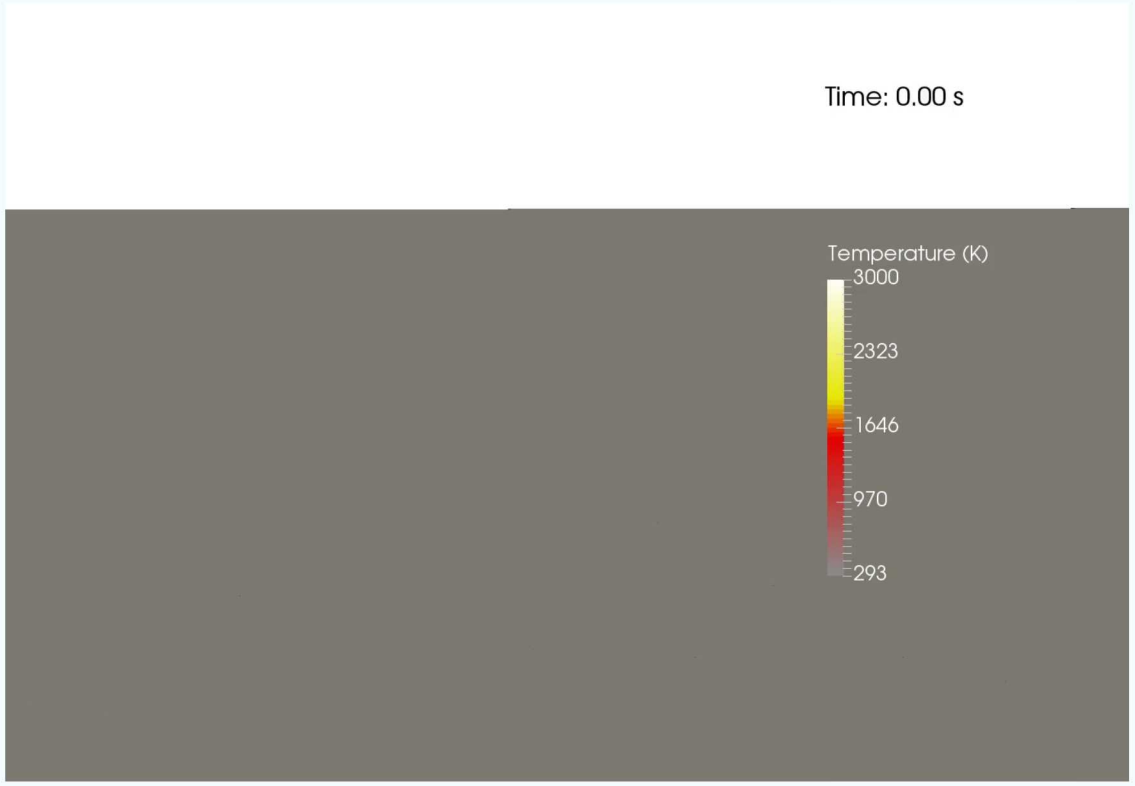
Critical modeling issues:

- Wide range of length scales
- Variability of raw materials
- Physics models are young
- Need new numeric techniques

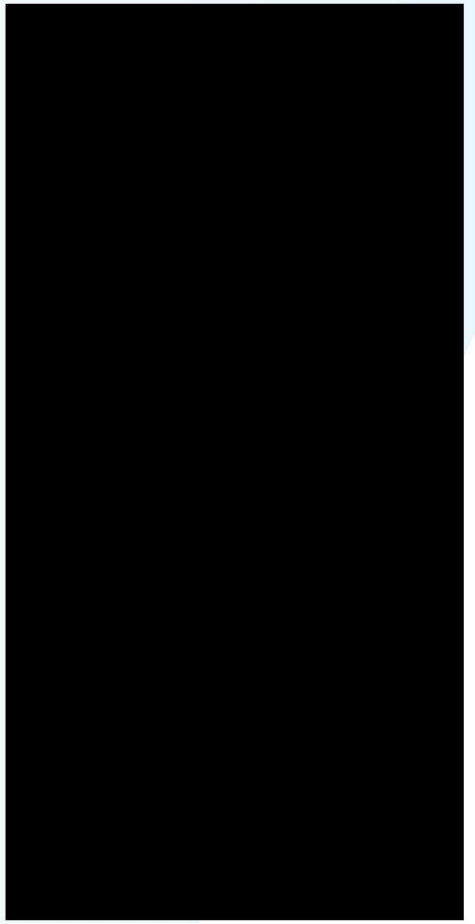


PROCESS PARAMETERS CAN AFFECT PERFORMANCE

Process determines structure which influences properties



Sierra FEA Thermal Model



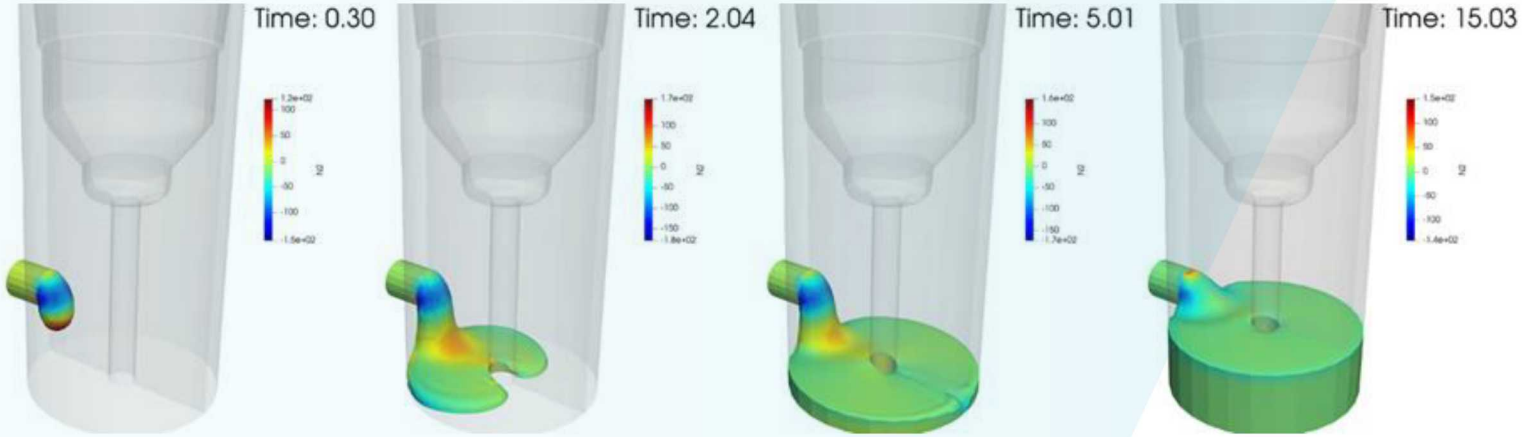
SPPARKS kMC Model

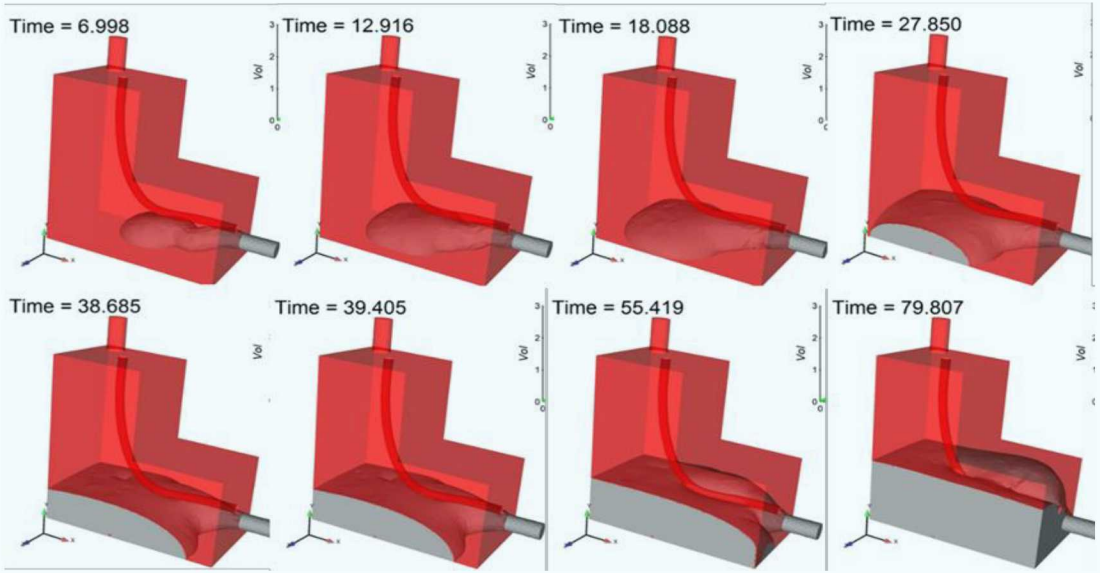
Coupling with SIERRA thermal models

K.L. Johnson, T.M. Rodgers, O.D. Underwood, J.D. Madison, K.R. Ford, S.R. Whetten, D.J. Dagel, J.E. Bishop, Comp. Mech., vol. 61, no. 5, (2018) pp. 559-574

Encapsulation of a wine-glass inclusion by a viscoelastic fluid that fills the mold, displacing the gas phase.

Minimizing voids and density variations is key for application.





Filling of a viscous fluid into an idealized cable geometry containing a single wire. The initial implementation is for the fluid flow only. In the future, we will include the stress and motion of the cable and the evolving viscosity of the fluid as it cures.

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
- But advances in computing overall are also important . . .
  - Exascale Computing Project—enabling 50x improvement in capability by 2021-23
  - Sandia's new ARM-based supercomputer prototype (Astra) helps open the door for future custom hardware options
  - Neuromorphic and quantum efforts also moving forward
- Along with novel diagnostics for elucidating phenomena and validating models.
- External partnerships and a diverse workforce are a must!

Sandia National Laboratories

Exceptional service in the national interest