SAND2011-3808P

Sandia's Large Scale Computation and Simulation Capabilities

Rob Leland
Director, Computing Research
Director, Climate Security Program

June 6, 2011

Sandia National Laboratories is a multi program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

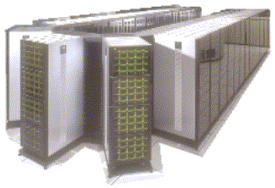
Sandia National Laboratories

Sandia has a broad and deep heritage in large-scale computational simulation

CM-2

nCUBE-2

iPSC-860



Paragon

ASCI Red

Cplant

Red Storm

1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

R&D 100 Dense Solvers

World Record Teraflops

Patent Meshing

Gordon Bell Prize

R&D 100 Storage

R&D 100 Salvo

Gordon Bell Prize

Gordon Bell Prize

R&D 100 Xyce

R&D 100 Parallel Software

SC96 Gold Medal Networking

R&D 100 Catamount

R&D 100 Signal Processing

Mannheim SuParCup

R&D 100 Allocator

Karp Challenge

World Record 281 GFlops

Patent Data Mining

Patent Partitioning

R&D 100 Trilinos

R&D 100 Meshing

World Record 143 GFlops

Fernbach Award

Patent Parallel Software

Patent Paving

R&D 100 Aztec

Sandia National Laboratories

With our new *Cielo* system, we are now operating at Petascale

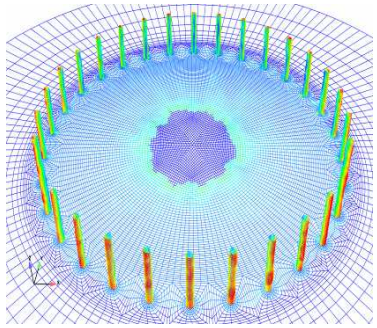
- **Background**
  - Capability computing platform
  - Partnership with LANL and Cray Inc.
  - Operated at LANL
- **Cray XE6 Architecture**
  - 3D torus w/ Gemini interconnect
  - AMD Magny-Cours 8-core processors
  - ~143,000 cores total
  - ~300TB memory
  - ~4MW power
  - 1.37 PF peak
- **Cray Linux Environment**
- **Performance to date**
  - 9.6X faster than ASC Purple
  - System MTBI > 200hrs.

cielo
NNSA New Mexico Alliance for Computing at Extreme Scale

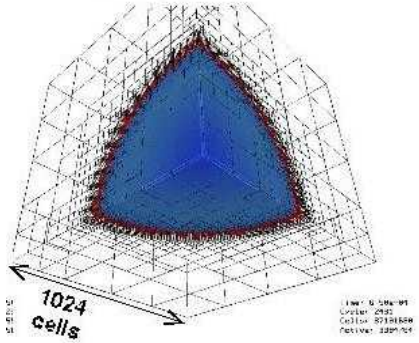
Sandia National Laboratories

Vertical integration of architectures, algorithms and applications has been critical to our success

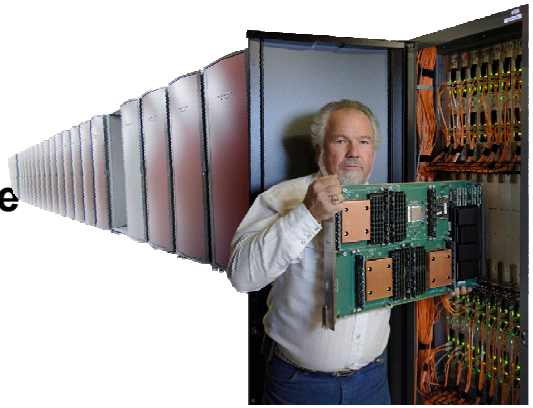
Computational simulation codes



Algorithms and enabling technologies

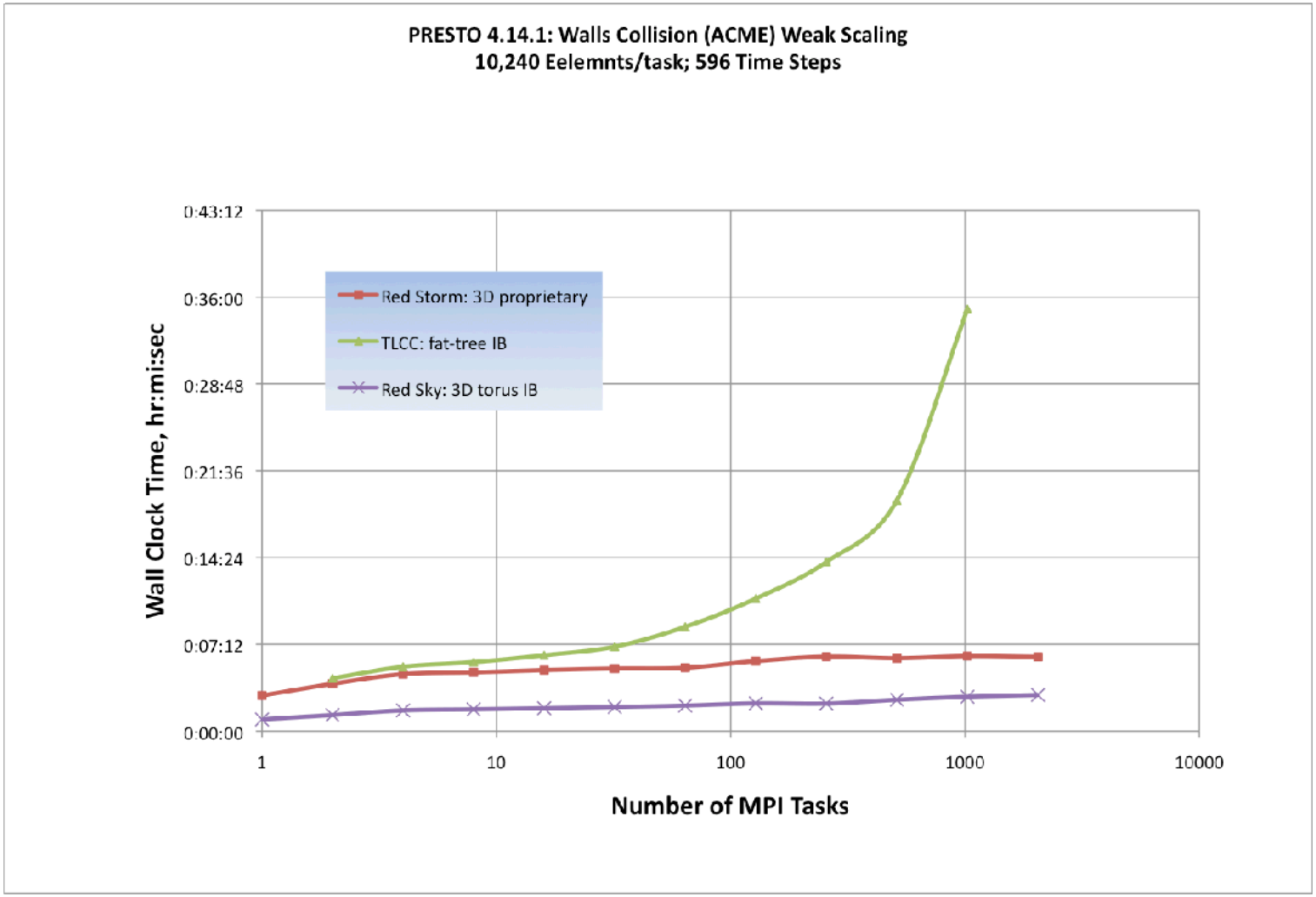


Computer architecture



Sandia National Laboratories

Striving to make things work at scale has been a great teacher

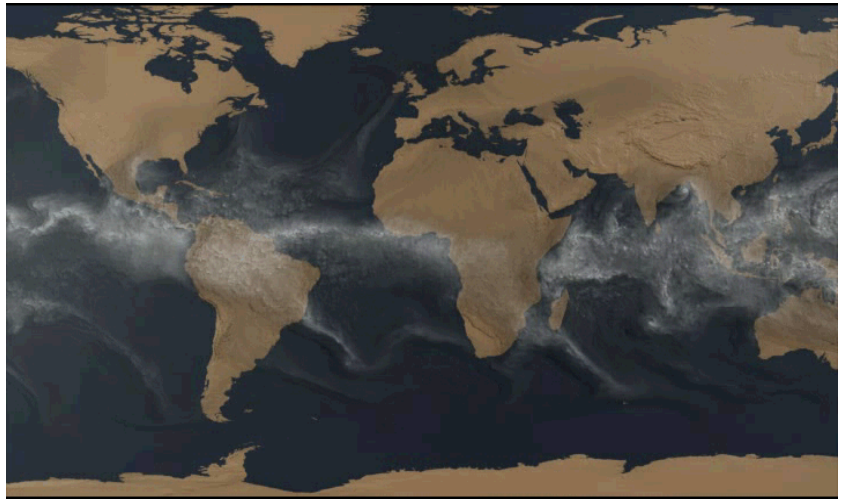


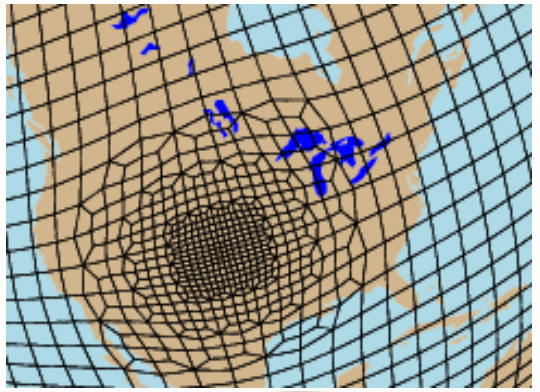
Sandia National Laboratories

We employ this capability successfully across the varied missions of the laboratory

Create a state of the art "dynamical core" for the community atmospheric model to capture high-fidelity effects.

- **Mostly highly resolved atmospheric model:** Global 1/8th degree simulation has ~13km resolution
- **Greatly improves model utility:** Captures regional effects and allows for better model validation
- **Enabled by scalable HPC:** Run on 170,000 cores of ORNL's Jaguar system (which is based on Red Storm) and achieved 4.6 simulation years per day

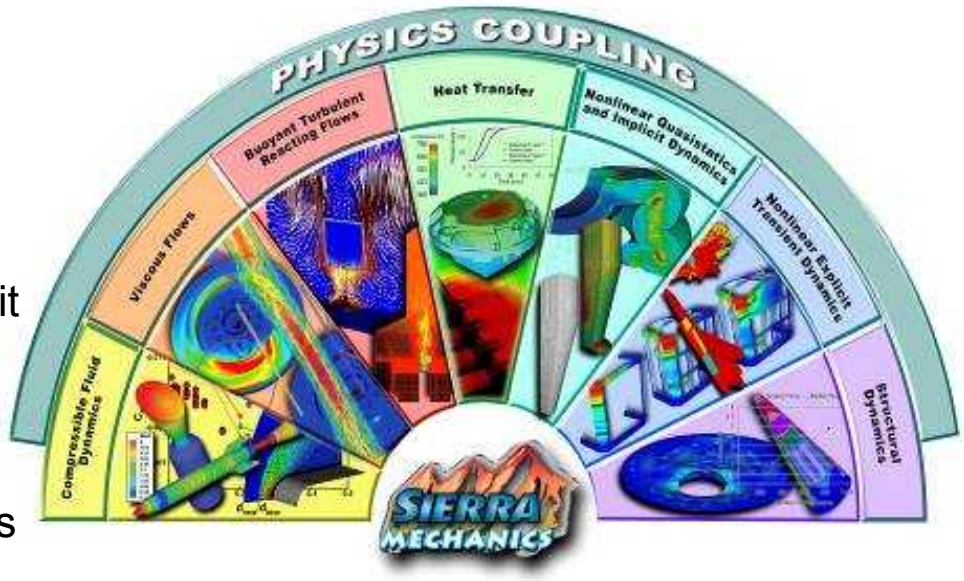




Sandia National Laboratories

We deliver these capabilities in large, integrated software packages

- **SIERRA has a wide range of capabilities**
- **Thermal/fluids/aerodynamics**
  - Compressible fluid mechanics with transonic flows
  - Non-newtonian reacting flow with free surfaces
  - Low mach number turbulent reacting flow
  - Heat transfer with convection, chemistry, and enclosure radiation
- **Solid mechanics/structural dynamics**
  - Nonlinear solid mechanics, quasistatics, implicit dynamics, failure and tearing
  - Nonlinear solid dynamics with explicit time integration, remeshing, particle methods, contact and failure
  - Linear structural dynamics and modal analysis of complex structures



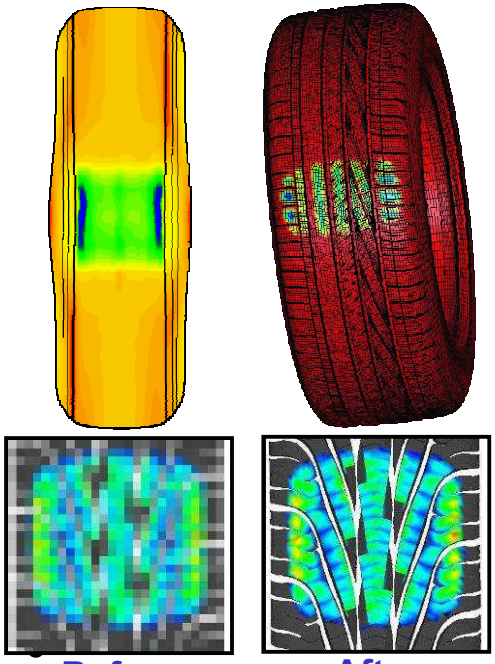
Sandia National Laboratories

We partner with industry to achieve impact beyond the Laboratory

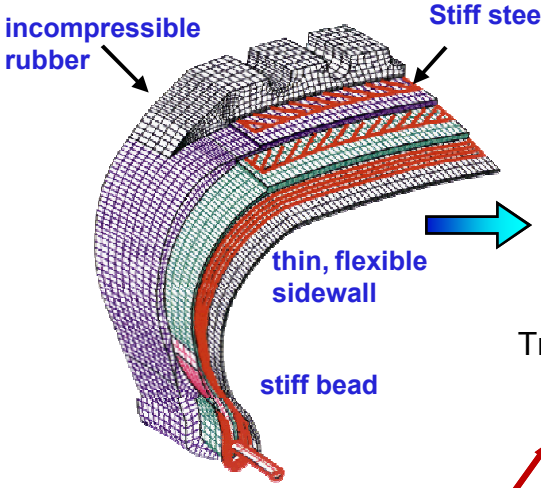
- **Goodyear partnership: validated computational mechanics tools for predicting structural, thermal, and fluid response of visco-elastic systems**

Technology Breakthrough 1994-1996

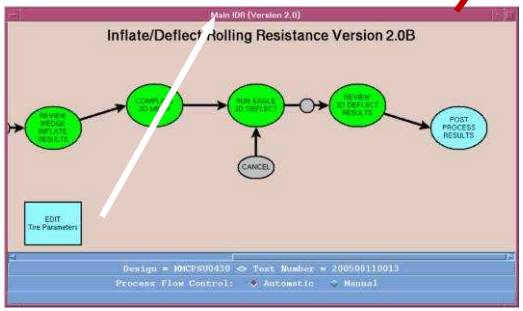
"The Pneumatic Tire Represents One of the Most Formidable Challenges in Computational Mechanics Today"
A. Noor, Journal of Computers and Structures



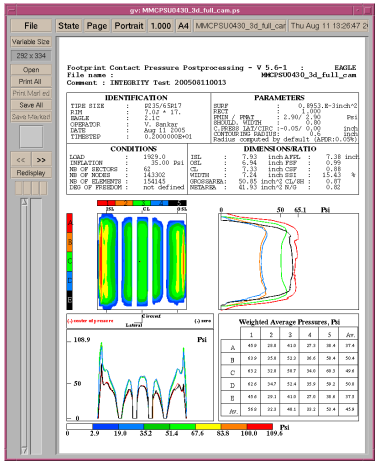
Technology Maturation 1997-2003



Automated Simulation Process



Traditional Build/Test Product Development, 2-3 Years



Product Innovation 2004 - Present

Today all tire designs at Goodyear are modeled *before* molds are ordered.

Sandia National Laboratories