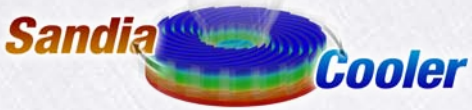
SAND2011-5305P

The Sandia Cooler

A fundamental breakthrough in heat transfer technology



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Sandia National Laboratories

Overview

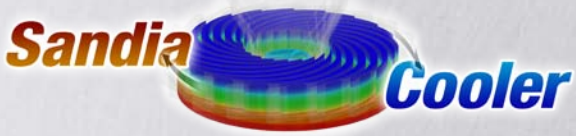
- **Federally funded R&D center managed by Lockheed Martin under contract to the U.S. Dept. of Energy**

- **Sandia's National Security Missions**
  - Nuclear Weapons
  - Nonproliferation
  - Homeland Security
  - Energy & Infrastructure Assurance
  - Defense Systems & Assessments
  - Science, Technology, & Engineering

Partnering with Sandia or Its Licensees

Potential Business Relationships

- **Sandia's primary commercialization goal:**
  - Maximize impact of the technology on U.S. jobs, economic/technical competitiveness, energy savings, etc.
- **Potential business relationships:**
  - Licensing of technology from Sandia
  - Collaborative R&D with Sandia or others
  - Investment (e.g. venture capital) for further development by thermal solution suppliers, entrepreneurial start-ups, etc.
  - [OEM customers] Validate technology and/or drive product requirements for suppliers (licensees)
  - Others?



Value Propositions for Chip Cooling

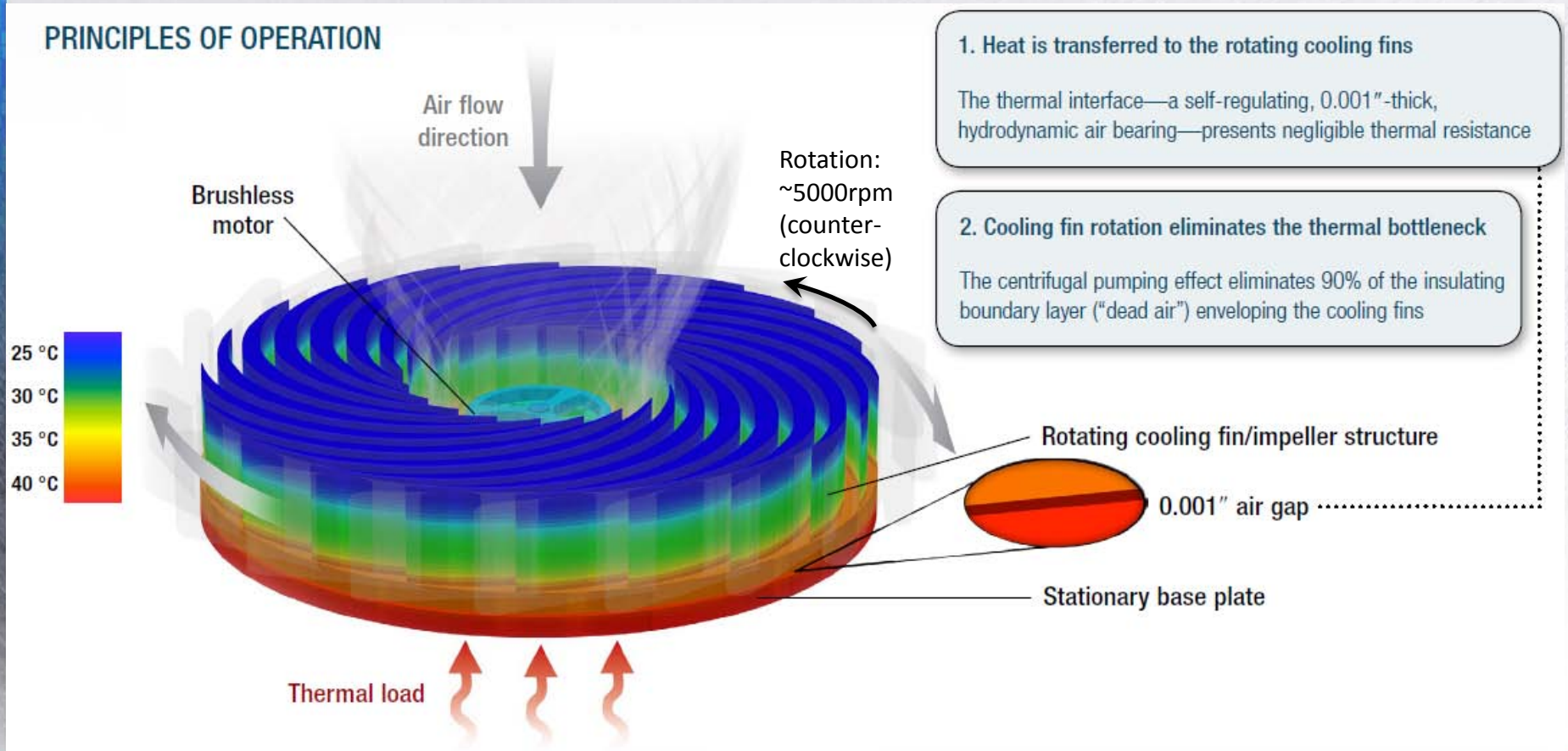
- Dramatic increase in cooling performance without resorting to exotic methods
- 10x smaller than current state-of-the-art CPU coolers
- Exceptionally quiet operation
- Virtually immune to dust fouling
- Simple, rugged, and cost-competitive design
- Energy-efficient

Target specifications for radial-flow air bearing heat exchanger under development:

Thermal resistance (CPU/GPU to ambient air): 0.05 C/W
Dimensions: 10 cm diameter x 3 cm height
Noise level: < 30 dBa
Per-unit manufacturing cost: <$10
Electrical power consumption: 5 W

Technology - *Summary* Description

Heat is efficiently transferred across a narrow air gap from a stationary base to a rotating structure that combines the functionality of cooling fins with a centrifugal impeller.



Technology - *Detailed* Description

The hard problems faced by conventional CPU coolers

The Problem:

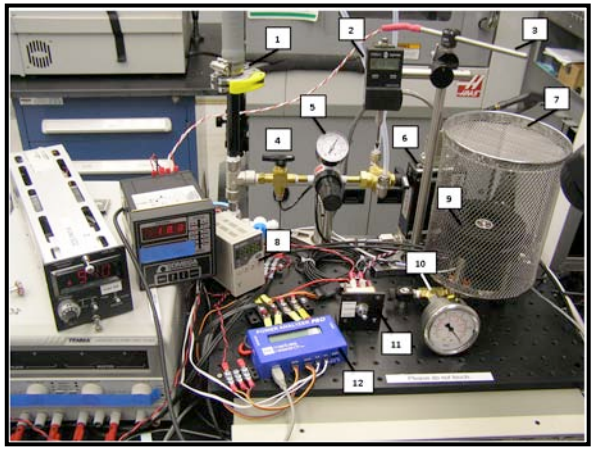
- The heat transfer bottleneck is the boundary layer of "dead air" that clings to the cooling fins
- Noise levels are a limiting factor in many applications
- Dust fouling degrades cooling performance

The Sandia Solution:

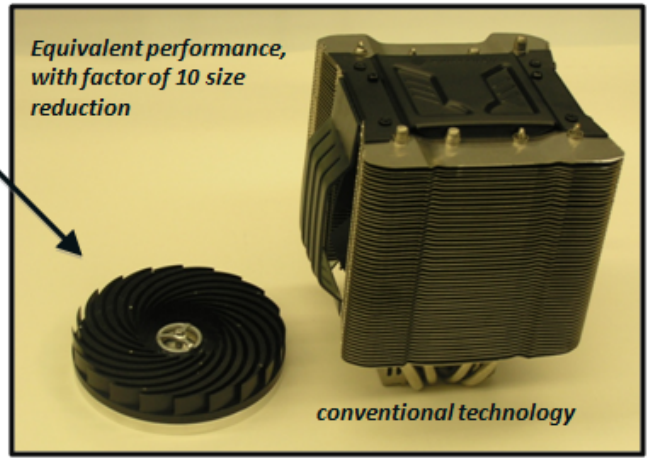
- The dead air is subjected to a powerful centrifugal pumping effect, providing a ~10X reduction in boundary layer thickness
- Relative motion between the cooling fins and ambient air is highly aerodynamic and thus very quiet
- High speed rotation virtually eliminates dust fouling

Technology - *Detailed* Description

Initial laboratory demonstration



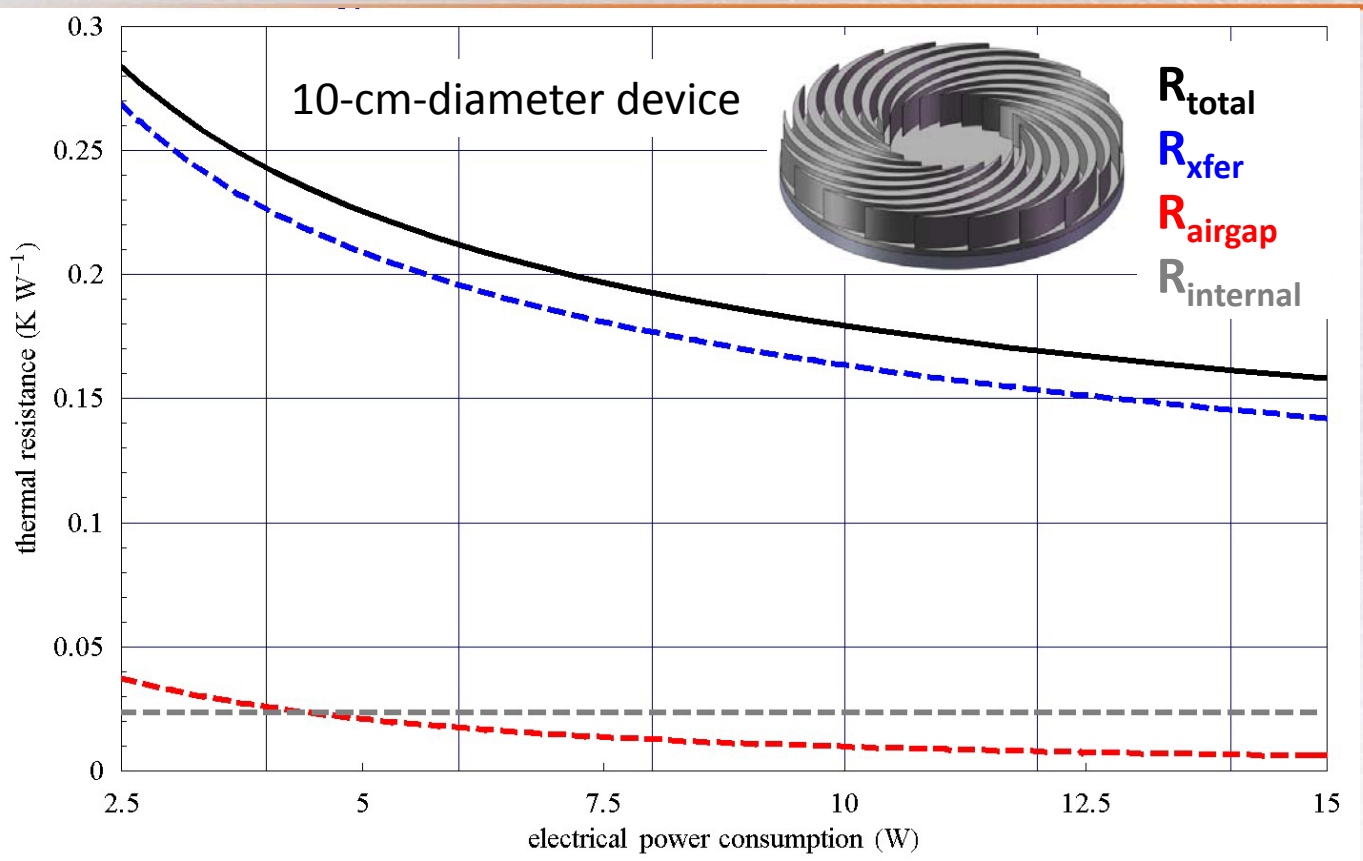
- Initial proof-of-concept device
- Factor of 30 improvement in heat transfer per unit heat exchanger area demonstrated
- Thermal resistance of air gap is only 0.02 C/W



Specification	Prototype v. 1.0	Dynatron G950
cooling performance (thermal resistance)	0.20 C W^{-1}	0.20 C W^{-1}
electrical power consumption	6.8 W	5.4 W
acoustical noise	"very quiet"	26.0 dBA
device size (total volume)	170 cm^3	2200 cm^3
heat exchanger fouling (e.g. dust)	inconsequential	substantial
heat exchanger surface area	400 cm^2	12000 cm^2
h (heat transfer coefficient, area-averaged value)	120 W m^{-2} K^{-1}	4.1 W m^{-2} K^{-1}

Technology - *Detailed* Description

Thermal resistance breakdown for v. 1.0 prototype

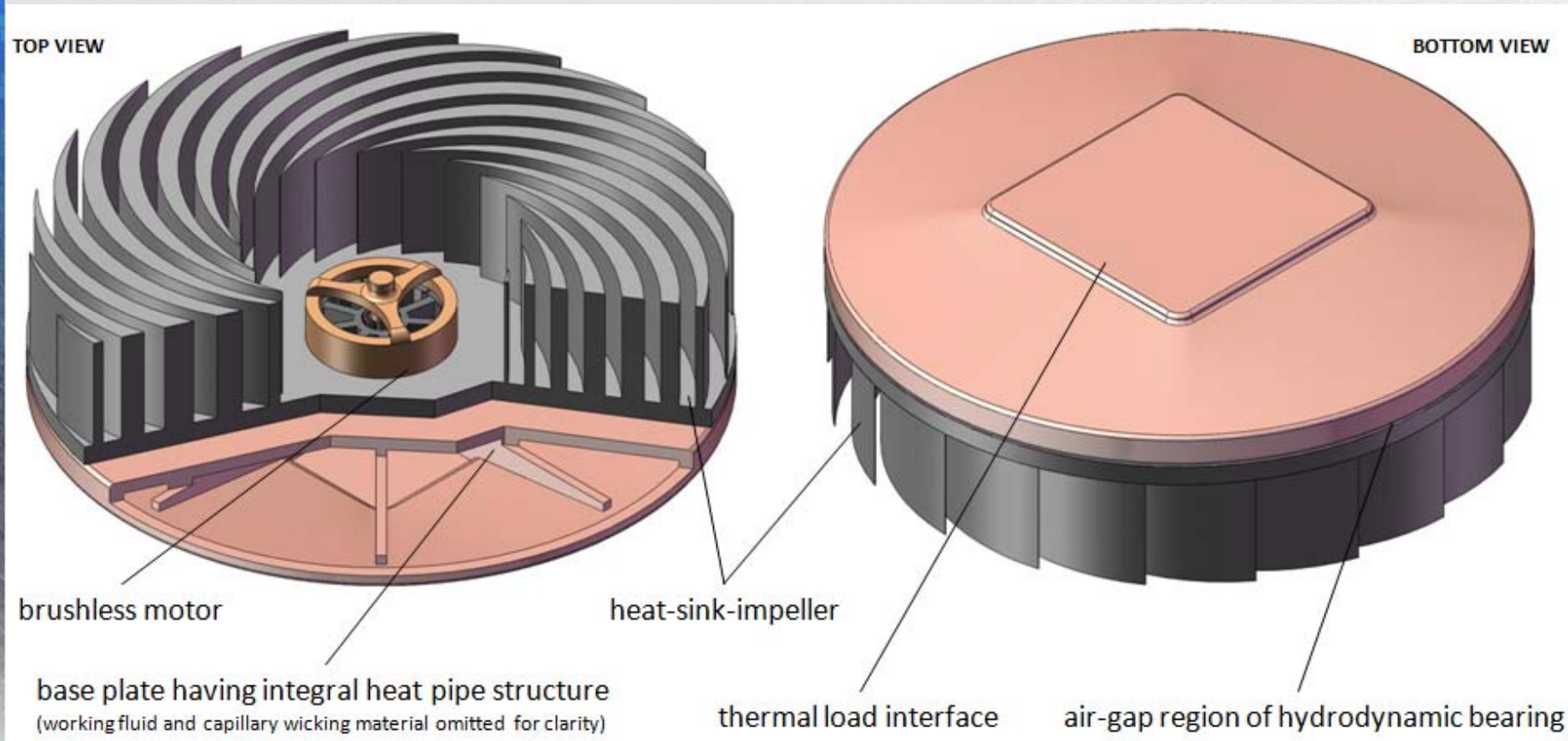


- The air bearing interface does not constitute a thermal bottleneck.
- The main limitation is heat-sink-impeller ➔ ambient air heat transfer.
- CFD modeling will be used to optimize heat-sink-impeller geometry.
- Further reductions in R_{airgap} and $R_{internal}$ will also be pursued.

Technology - *Detailed* Description

Integration

- Heat pipe incorporation shown below
- Other ideas on integration onto motherboards, LED lighting fixtures, etc. can be shared under NDA



Technology - *Detailed* Description

FAQ's

Performance

Q: Based on laboratory testing of early prototype devices, what level of performance is expected for a CPU cooler based on Sandia's air bearing heat exchanger principle?

A: We expect to achieve 0.05 °C/W in package that is considerably smaller and quieter than conventional high-performance CPU coolers. Because low-thermal-resistance CPU coolers are particularly susceptible to performance degradation due to cooling-fin fouling (a thin layer of dust can easily increase thermal resistance by a factor of two), the added benefit of immunity to fouling is also a crucial performance specification. Further reductions in thermal resistance would likely involve engineering trade-offs against device size and dBa rating.

Manufacturability

Q: Does the 0.001" air gap require tight manufacturing tolerances?

A: No—the hydrodynamic air bearing gap distance is passively self-regulating.

Q: Is the surface quality/flatness spec of a conventional heat sink mating surface adequate?

A: Yes—For example, conventional fabrication processes such as cold forging can be used.

Technology - *Detailed* Description

FAQ's

Real-World Practicality

Q: Can the device be mounted in any orientation?

A: Yes—the air bearing assembly is held together by magnetic attraction (between the stator and permanent-magnet rotor).

Q: Is a an air bearing suspension mechanically stiff and rugged?

A: Yes—because as with other air bearings, the rate of change of the pressure lifting force with respect to gap distance is extremely large.

Q: What other types of equipment use air bearings?

A: Devices range from hard disk read–write heads to large CNC milling machine spindles.

Q: What if small (< 0.001") particulates are somehow introduced into the air gap region?

A: They are swept outward and ejected by centrifugal force.

Technology - *Detailed* Description

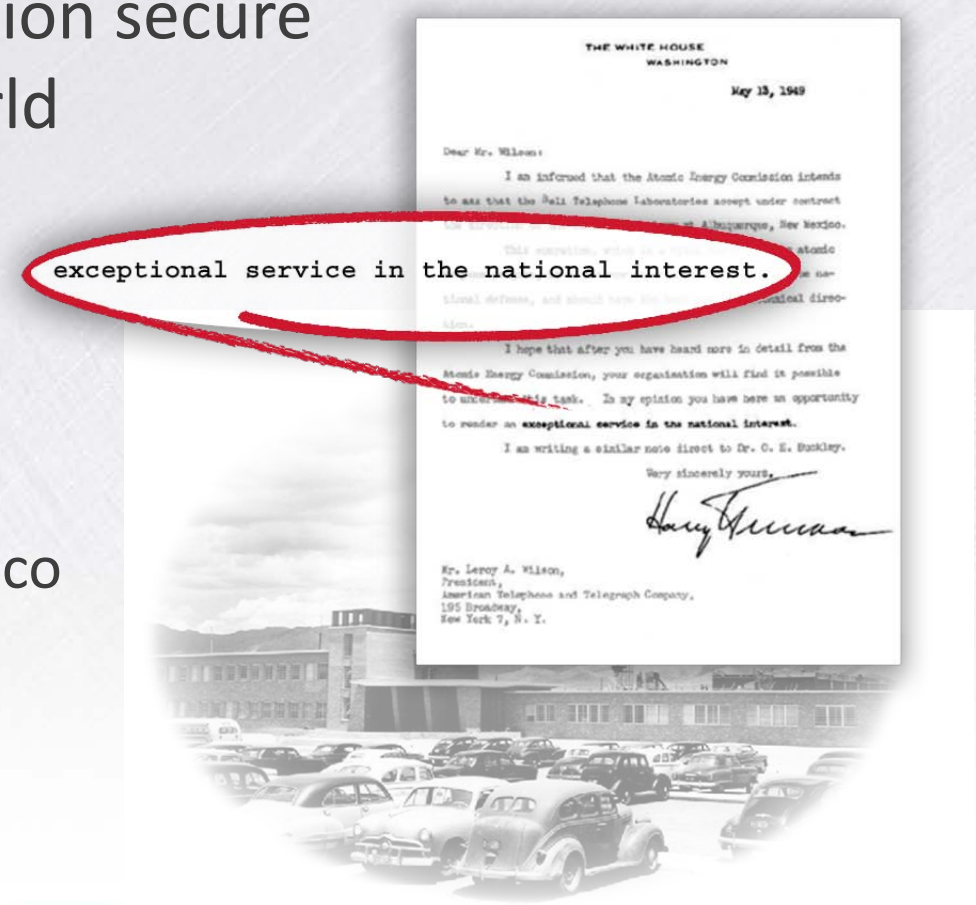
General & miscellaneous information

- **Product life cycle status:** Alpha
- **Scaling:** Sandia is initiating R&D collaboration with a "Fortune 100" company to explore scaling, cooling fin optimization, etc.
- **Patent Applications:** Multiple patent applications have been filed.

Sandia National Laboratories

General information

- **Vision:** Helping our nation secure a peaceful and free world through technology
- **Year founded:** 1949
- **Major sites:**
  - Albuquerque, New Mexico
  - Livermore, California

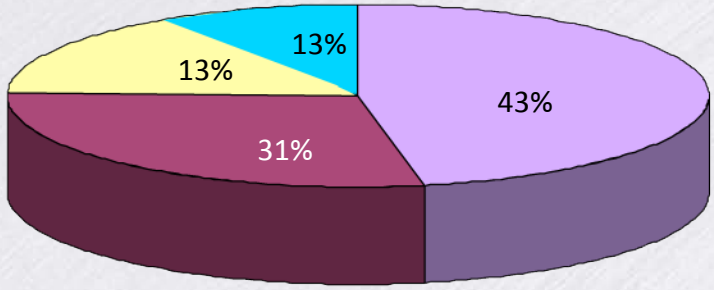


Sandia National Laboratories

People and Budget (As of October 15, 2010)

- On-site workforce: 11,677
- Regular employees: 8,607

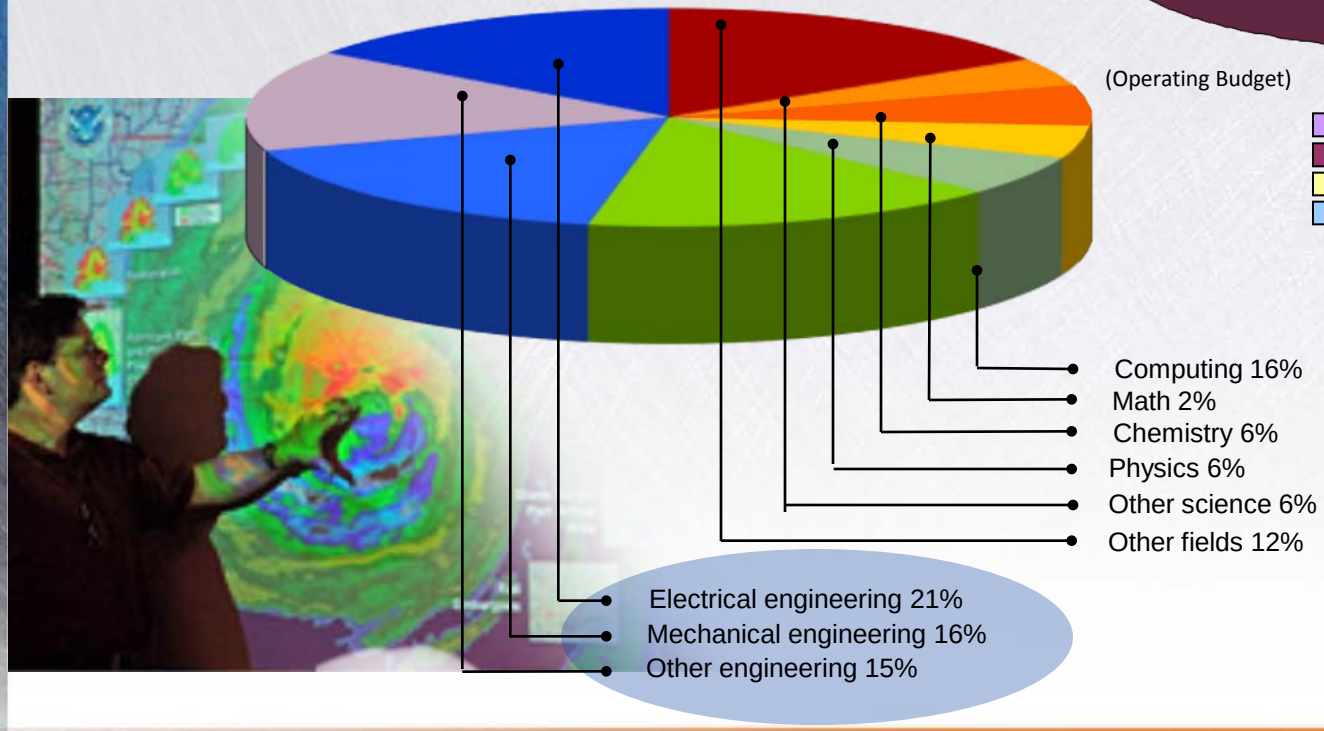
FY10 operating revenue
$2.3 billion

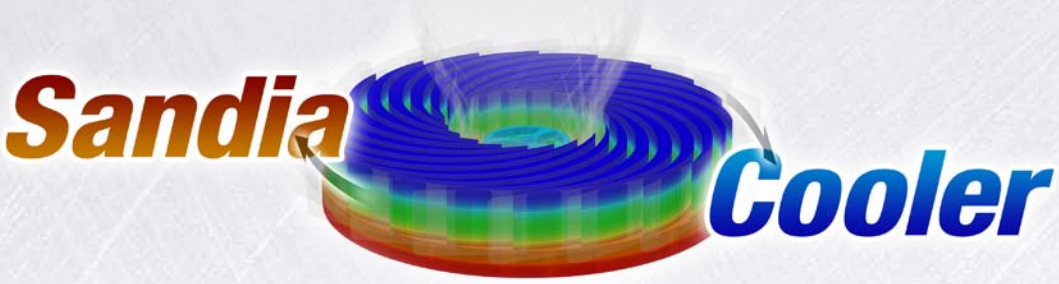


(Operating Budget)

- Nuclear Weapons
- Defense Systems & Assessments
- Energy, Climate, & Infrastructure Security
- International, Homeland, and Nuclear Security

Technical staff (4,277) by discipline:

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