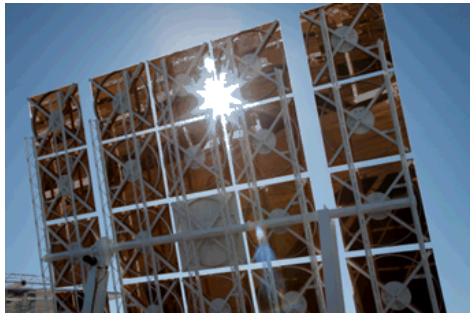
SAND2013-7762C

Exceptional service in the national interest

Sandia National Laboratories

September 17, 2013



The Concentrated Solar Power Renaissance: A Personal View from a National Security Laboratory

Jill Hruby

Vice President for Energy, Nonproliferation, & High-Consequence Security

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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Sandia's Origins – Nuclear Weapons

Sandia National Laboratories

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.

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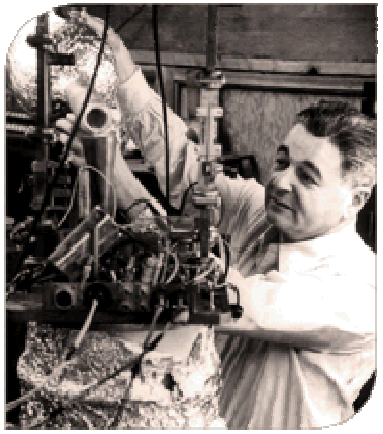


Sandia - One of 40 FFRDCs in the U.S.

Sandia National Laboratories

Federally Funded Research and Development Centers (FFRDCs) are chartered to:

- Meet a special long-term research or development need which cannot be met as effectively by federal or regular contract employees
- Access government information beyond which is common to the normal contractual relationship
- Provide objectivity and independence
- Not compete with the private sector

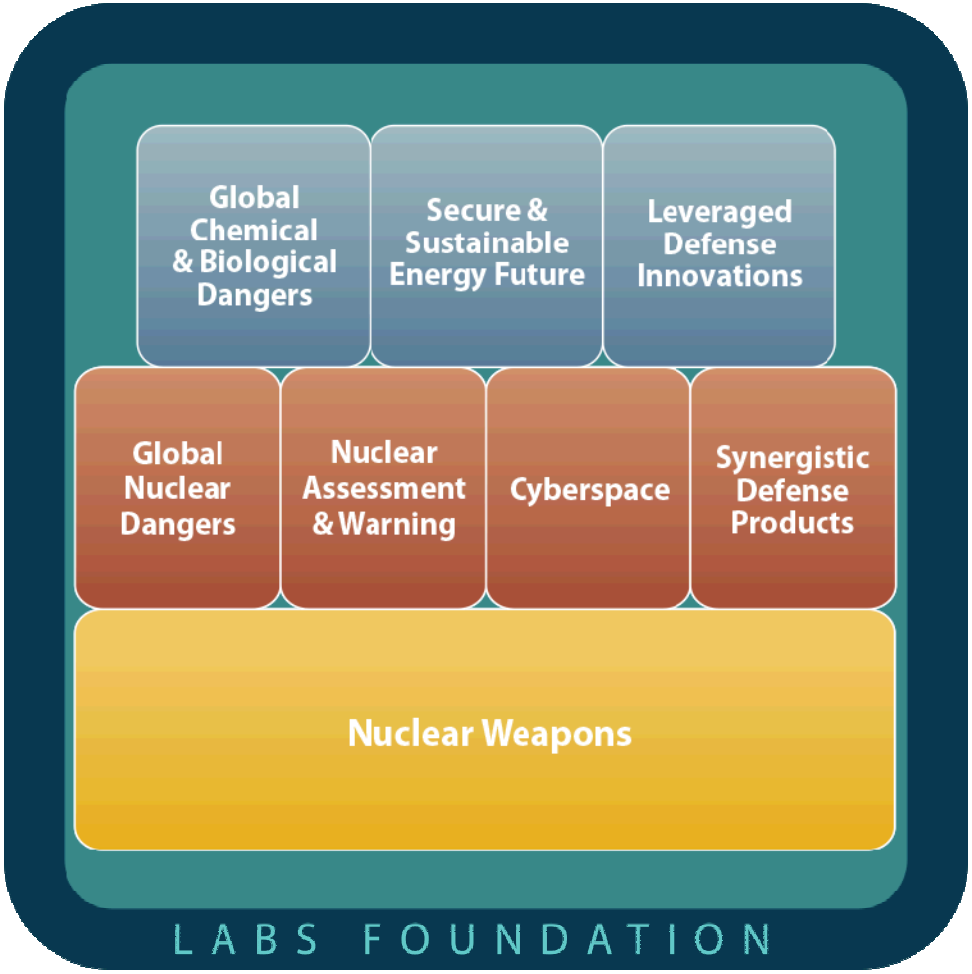
Sandia National Laboratories:

- One of 25 R&D FFRDCs
- One of 17 DOE National Laboratories
- One of three National Security Labs managed by DOE/NNSA
- Primary locations – Albuquerque, NM & Livermore, CA

Sandia's Mission – National Security

Sandia National Laboratories

- Core Purpose: to help our nation secure a peaceful and free world through technology
- Sandia's mission areas
  - Develop and evolve in response to world conditions
  - Represent the most complex issues that require interdisciplinary ST&E to address
  - Outside of nuclear weapons, Sandia's oldest mission area is energy (since 1970s)



Sandia's Energy Mission

Sandia National Laboratories

"We must ensure a secure and sustainable energy future..."

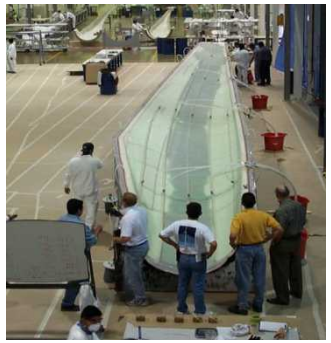
- U.S. prosperity is tightly coupled to the worldwide security and sustainability of energy.
- Shifting geopolitical dynamics of energy supply and demand create new challenges.
- The stability of the U.S. energy infrastructure and supply, and longer term pressures such as the depletion of fossil fuels, compounded by carbon emission concerns, constitute a complex national challenge.

Sandia's Energy Program Highlights

Sandia National Laboratories

Wind

- Novel vertical axis design
- Blade manufacturing
- Scaled wind farm

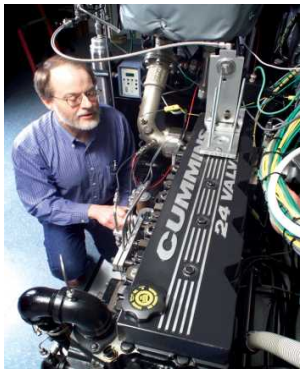


Photovoltaics

- PV System Evaluation Lab
- Advanced PV Controls & Reliability
- Microsystems Enabled PV

Transportation

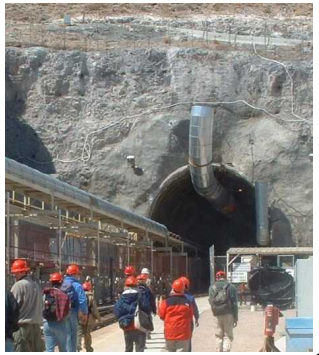
- Combustion Research Facility
- Hydrogen storage
- Bio fuels



METAL HYDRIDE CENTER OF EXCELLENCE

Nuclear

- Technical basis for NRC
- Waste disposal
- S-CO_2 Brayton Cycle



Sandia - Concentrated Solar Power

Sandia National Laboratories

Solar Power Towers

- National Solar Thermal Test Facility
- Working Fluid RDT&E: molten salt, solid particles

Solar Dish/Engine Technologies

- SunCatcher partnership with Stirling Energy Systems
- Sunshine-to-Petrol

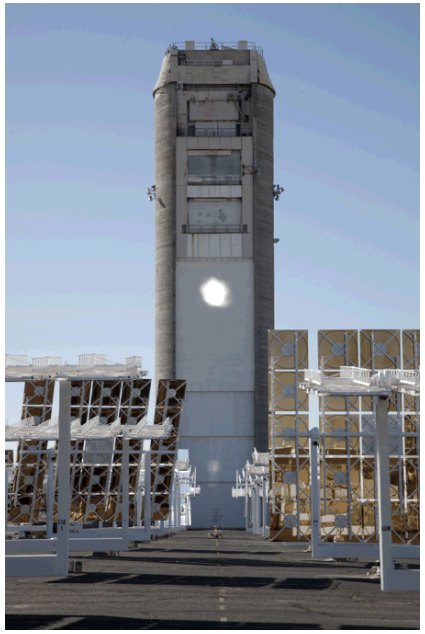
Solar Parabolic Troughs

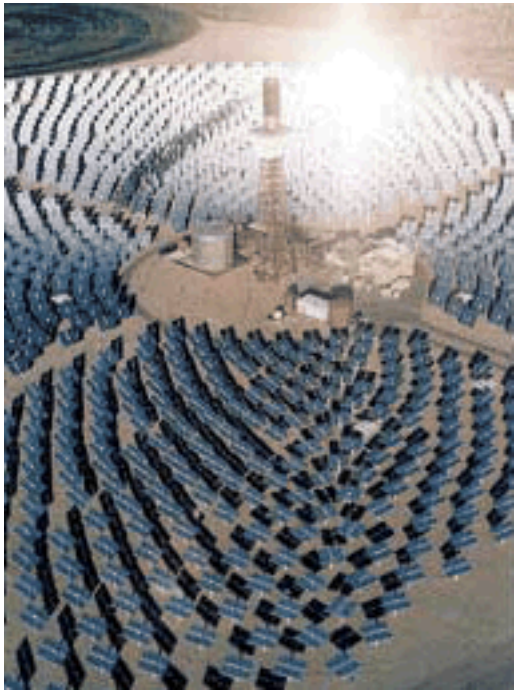
- Alignment techniques
- Working fluids

Innovation through Test

My Personal History - Solar Towers

- Oil shortage in 1970s led to DOE interest in renewable technologies
- Sandia established solar program and NSTTF built at Sandia in 1979
- Solar One Pilot Plant in Daggett, CA complete in 1981 operated from 1982-1986 as a partnership between So Cal Edison and DOE/Sandia Labs





My Personal History - Solar Towers

- I was hired at Sandia in 1983 as a mechanical engineer
- Assigned to solar tower effort
  - Liquid sodium and molten salts were being evaluated as alternative working fluids to water/steam
  - Cost goal for solar tower was $.05/kWh ($.14 today)
- Interest in high temperature concepts to improve thermal-to-electrical conversion and for chemical processing

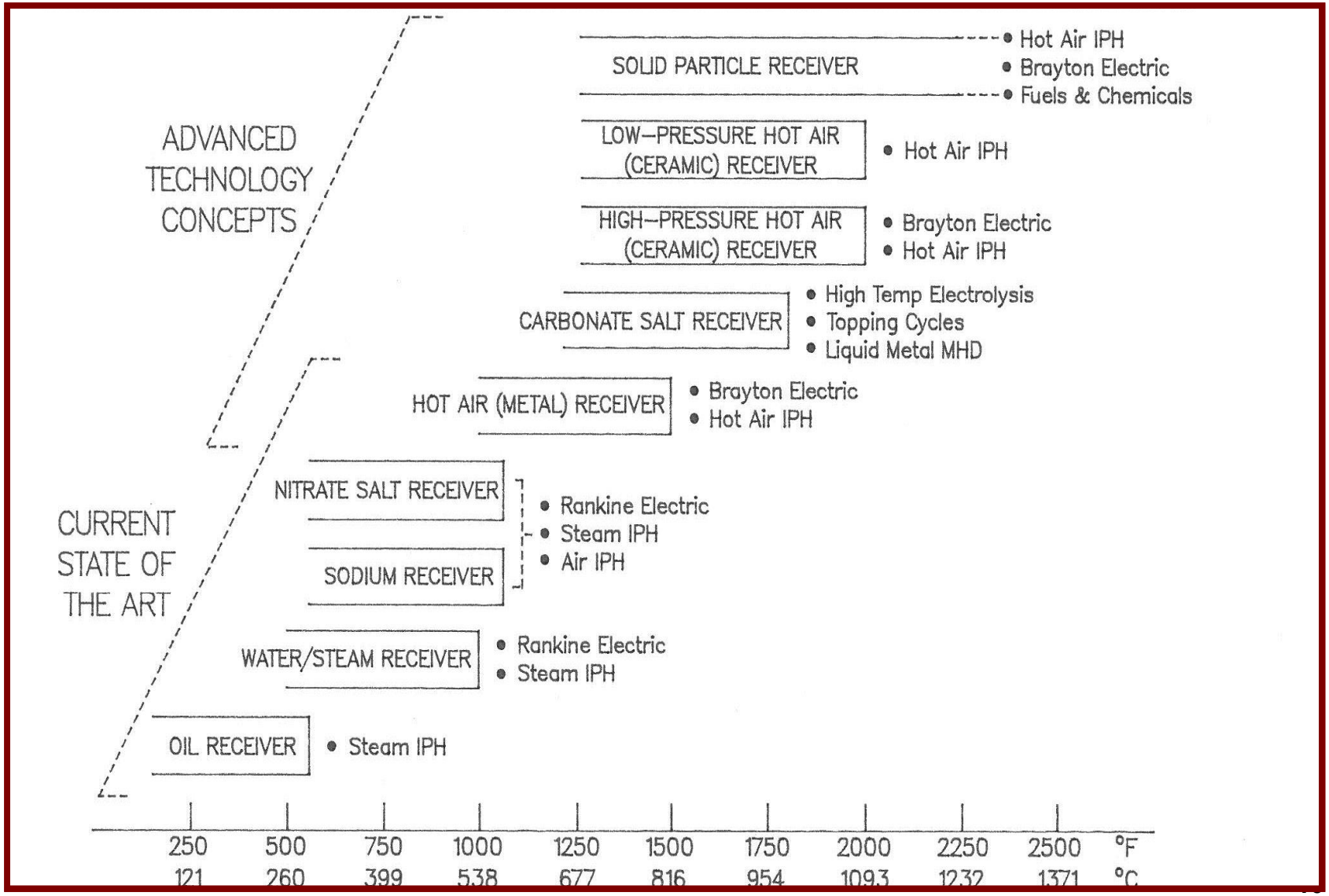
INNOVATOR:
Thomas Brumleve

1997 Discover Award: Southern California Edison et al.'s Solar Two Power Plant

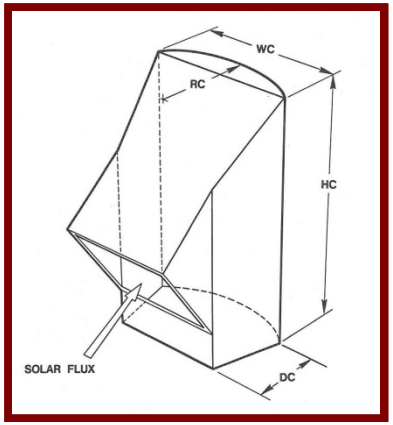
"It took nearly 25 years for Thomas Brumleve to see his invention come to life. In June 1996, in California's Mojave Desert, the Solar Two power plant began sending 10 megawatts of power--enough for 10,000 homes-- into Southern California Edison's electric grid. And Brumleve, who took early retirement from Sandia National Laboratories in Livermore, California, in 1984, was invited to the dedication as an honored guest."

My Personal History - Solar Towers

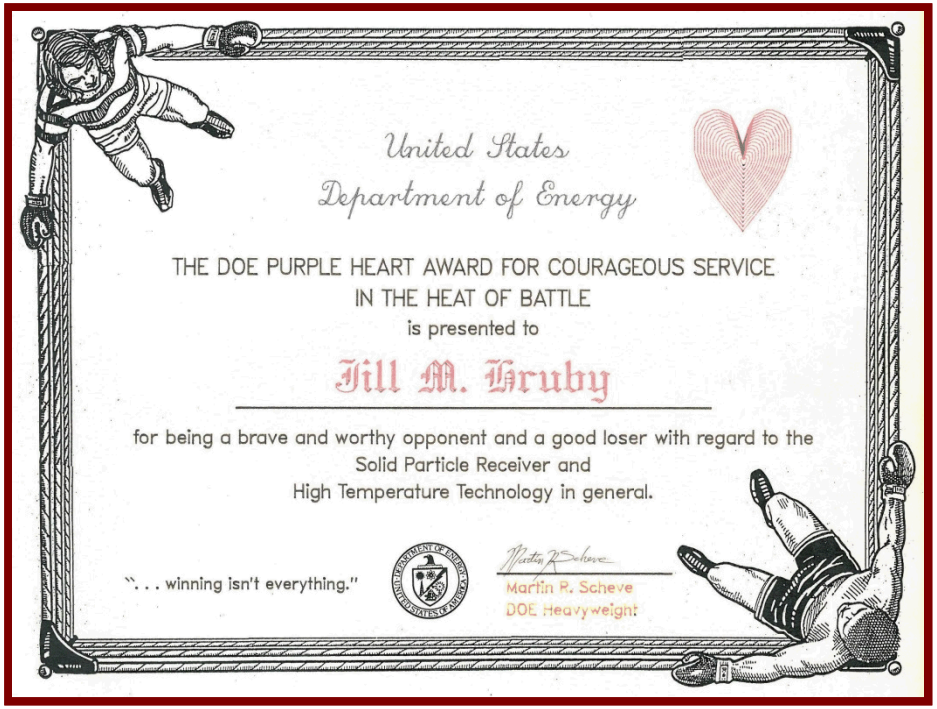
Sandia National Laboratories

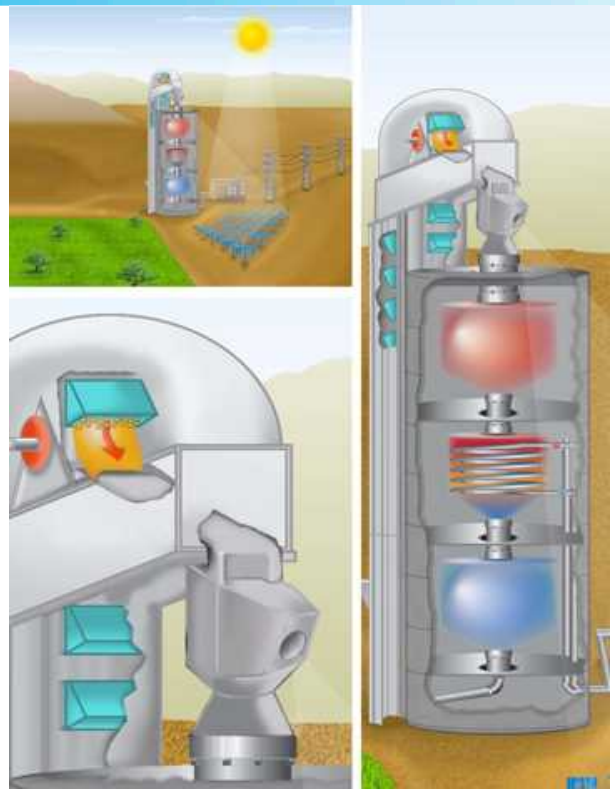


My Personal History - Solar Towers



+ 27 yrs =

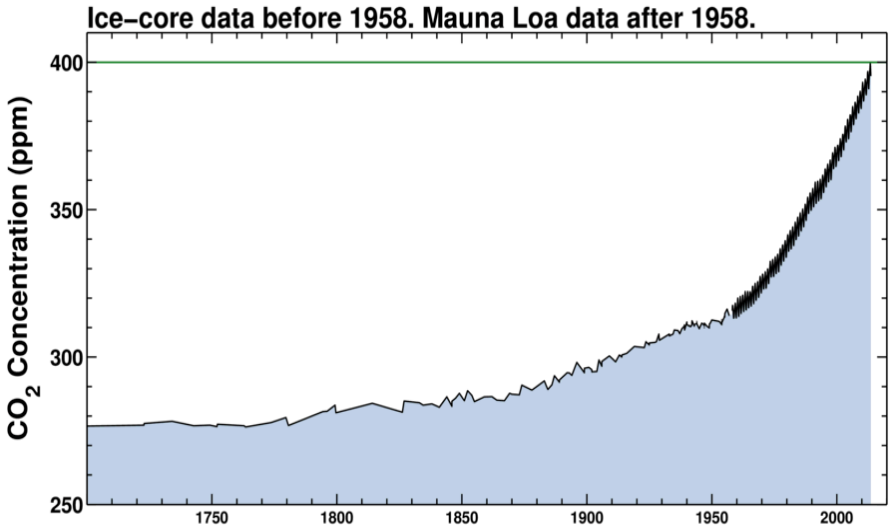




August 2012: Sandia, with partners Georgia Tech, Bucknell University, King Saud University, and DLR (the Institute of Solar Research of the German Aerospace Center), was awarded funding to develop a concentrating solar power falling-particle receiver and heat-exchanger system under the DOE SunShot Initiative.

The CSP Renaissance

- The motivation for CSP has grown
  - Interest to diversify energy sources remains for geopolitical reasons
  - End-of-oil is considered possible, if not likely
  - Clean energy production is needed due to rising CO_2 concentrations
  - Clean, renewable energy is an international concern



Concentrated Solar Power (MWp)

Year	1984	1985	1989	1990	...	2006	2007	2008	2009	2010	2011	2012
Installed	14	60	200	80	0	1	74	55	178.50	306.50	628.5	802.5
Cumulative	14	74	274	354	354	355	429	484	662.5	969	1597.5	2553

CSP Has Come a Long Way

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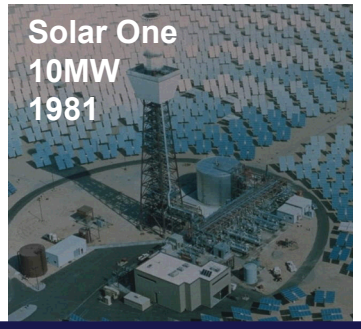
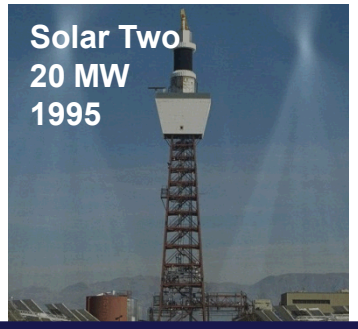




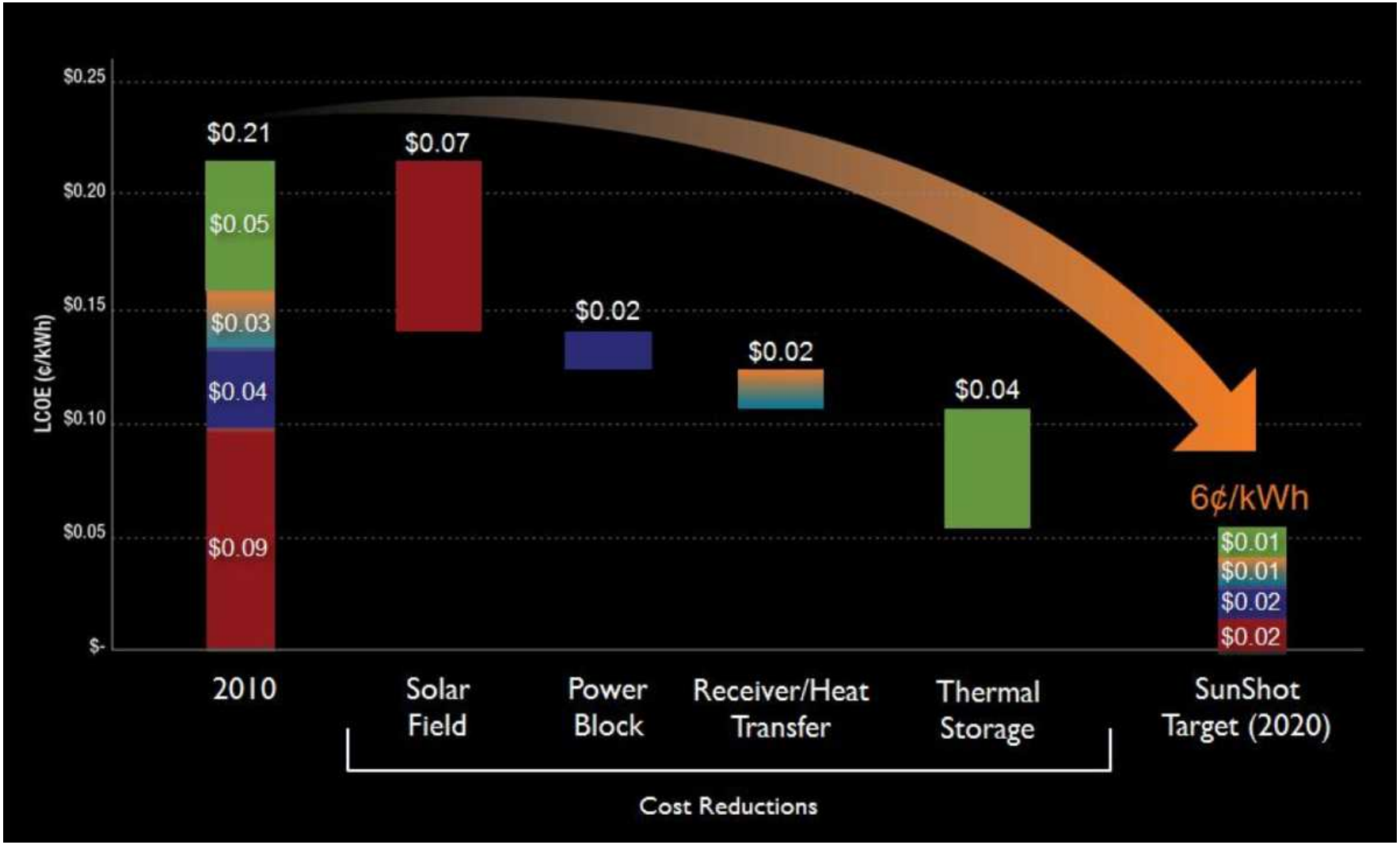
Proof of Concept and Initial U.S. Deployments

International Deployment

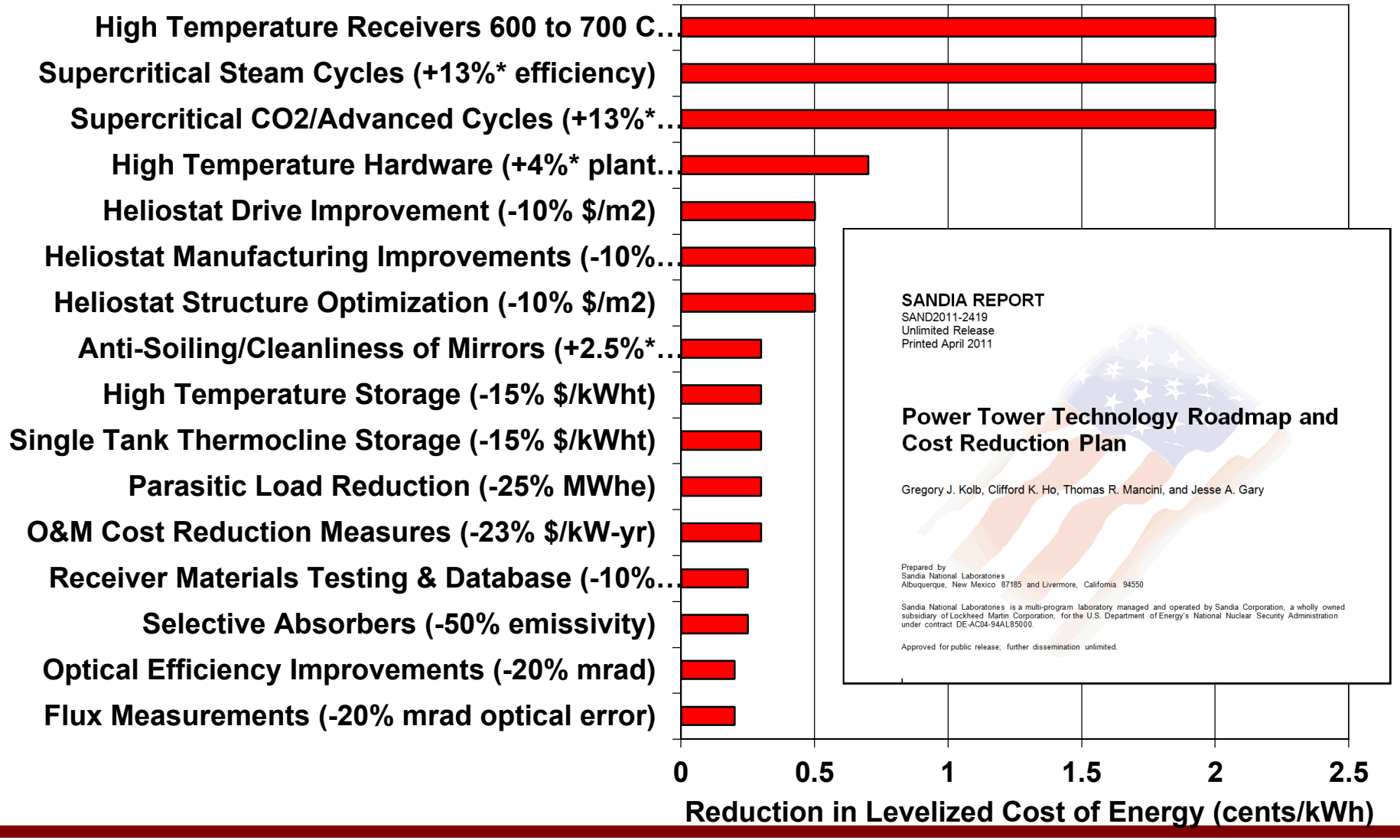
SunShot U.S. Department of Energy

Large Commercial Scale and Future Efforts

But more is needed - SunShot Goals



Technology Innovations Required at both the Component and System Level



SANDIA REPORT
SAND2011-2419
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Power Tower Technology Roadmap and Cost Reduction Plan

Gregory J. Kolb, Clifford K. Ho, Thomas R. Mancini, and Jesse A. Gary

Prepared by
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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.

Approved for public release; further dissemination unlimited.

Closing Comments

- CSP is in a renaissance as a technology and industry
  - Need is clear and is not likely to go away
  - International interest is high
  - Clear goals have been established – but are very challenging
  - ***It's up to you!***
- Innovation is needed in near- and long-term
  - "Known" technologies must be advanced and piloted
  - New innovative ideas will pave the way for future development - ideas invented today could take 25-30 years to get to "market"
- The DOE SunShot Initiative requires broad engagement
  - Governments, component and plant manufacturers, A&Es, finance/investment firms, and R&D institutions need to define/refine the roadmap to ensure SunShot is successful in the remaining 6 years

Back up

Sandia National Laboratories

Where are we today?

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- Collectors
  - Silvered glass is still the standard; az/el drives
    - ✓ Reflective polymeric films; autonomous controls
- Receivers
  - Pyromark 2500 paint on tubular receivers is still the standard
    - ✓ Durable selective absorber coatings, falling particle receivers
- Heat Transfer Fluid
  - Molten salts (<600 C) are being used (Gemasolar, Tonopah)
    - ✓ Advanced high-temperature molten salts, solid particles
- Thermal Storage
  - Two-tank sensible liquid storage is still the standard
    - ✓ Thermochemical, phase-change, solid particles
- Power cycles
  - Rankine cycle is still the standard (~40% efficiency)
    - ✓ Supercritical CO_2 closed-loop Brayton cycle (>50% efficiency)

What is still needed to accelerate adoption?