SAND2013-10432P

Overview of Sandia National Laboratories and the National Solar Thermal Test Facility (NSTTF)

Exceptional service in the national interest

Sandia National Laboratories

Clifford K. Ho
Sandia National Laboratories
Concentrating Solar Technologies Dept.
Albuquerque, New Mexico
ckho@sandia.gov, (505) 844-2384

SAND2013-XXXXP

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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.

Overview

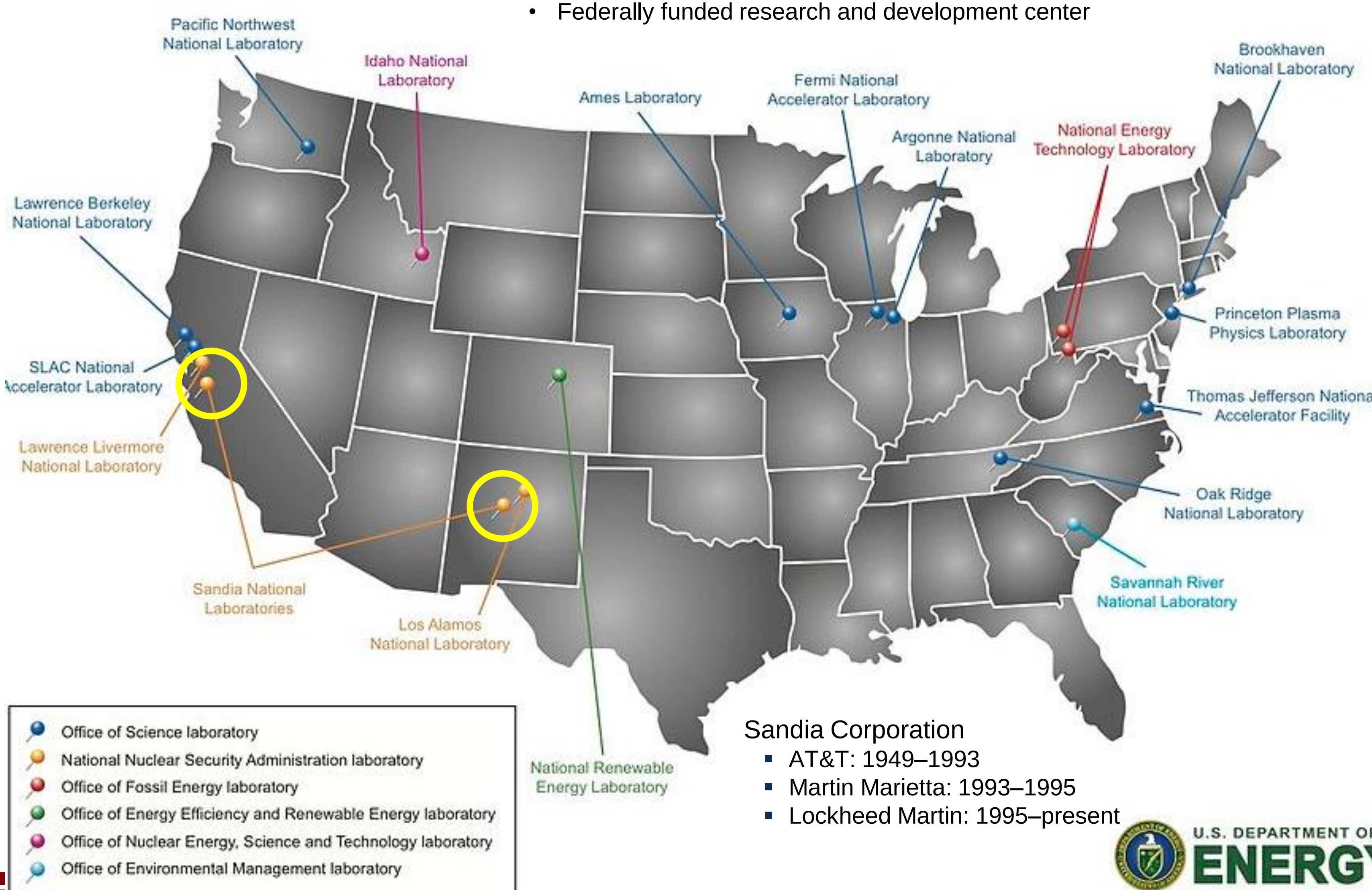
- Overview of Sandia National Laboratories
- National Solar Thermal Test Facility & CSP Activities
- Bi-National (Sandia/DLR) Proposal for CSP
  - Value proposition
  - Why Sandia and DLR?
  - Funding mechanisms

Overview of Sandia

Sandia National Laboratories

One of 16 national laboratories operated by United States Department of Energy

- Government owned, contractor operated
- Federally funded research and development center



Sandia Corporation

- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–present

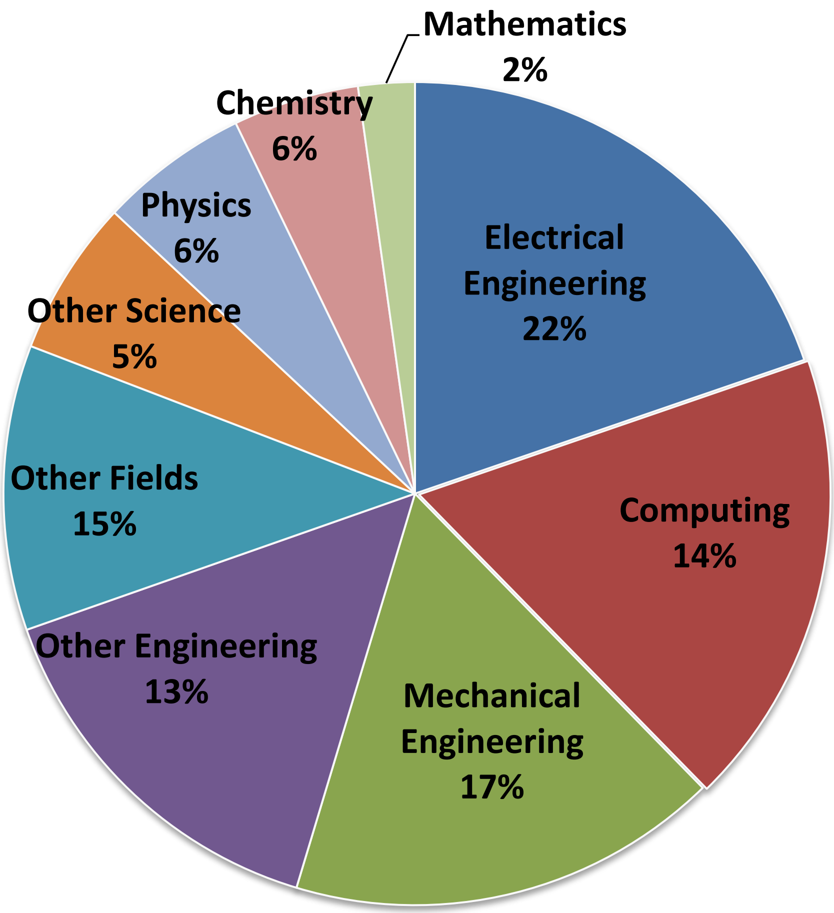
U.S. DEPARTMENT OF ENERGY

Our Workforce

- On-site workforce: 11,711
- Regular employees: 9,494
- Gross payroll: ~$1.046 billion

Data as of April 12, 2013

R&D staff (4,799) by discipline

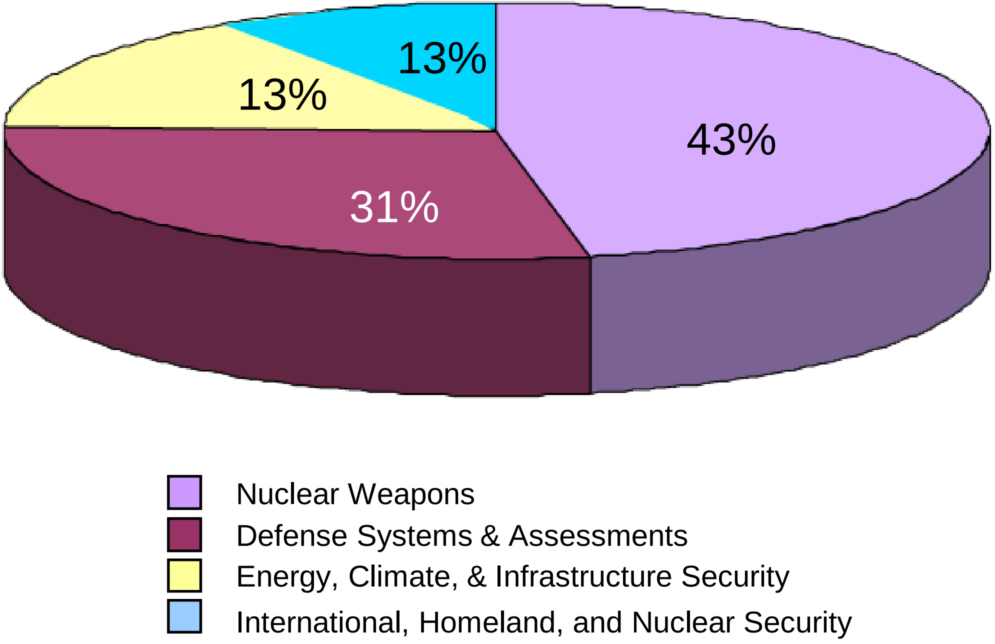


Our Budget

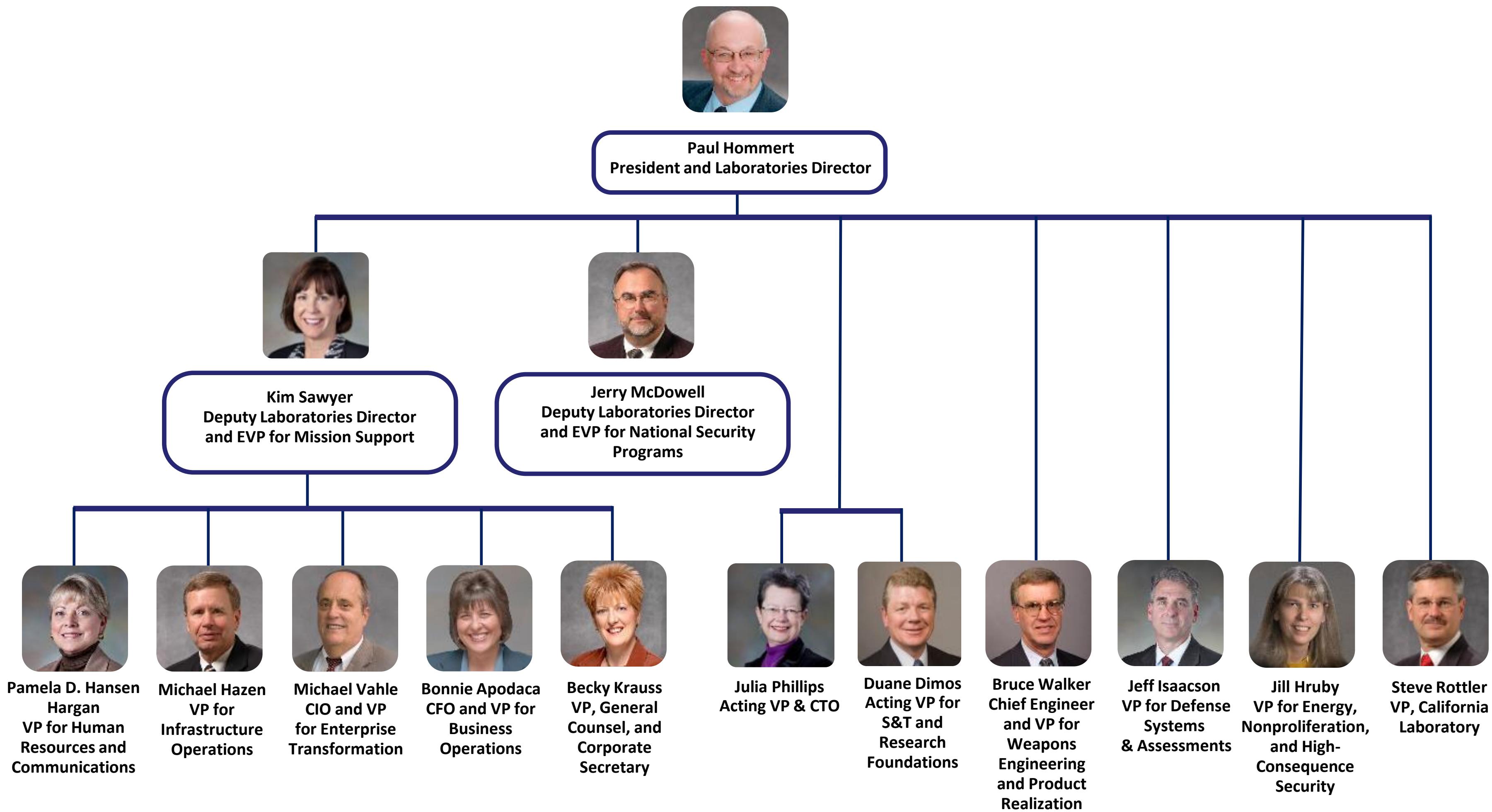
- On-site workforce: 11,711
- Regular employees: 9,494
- Gross payroll: ~$1.046 billion

Data as of April 12, 2013

FY10 operating revenue: $2.3 billion



Executive Management Structure



Overview

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NSTTF and Power Tower History

NSTTF – World's first power tower
5 MW_t

Circa 1970's

Solar One (Steam)
10 MW_e

1980-1990

Solar Two (Salt) 10 MW_e

1980-1990

PS10/PS20
11/20 MW_e 2007
1st commercial tower

eSolar Sierra 5 MW_e

2009

Gemasolar, 20 MW_e 2011
1st Salt Storage

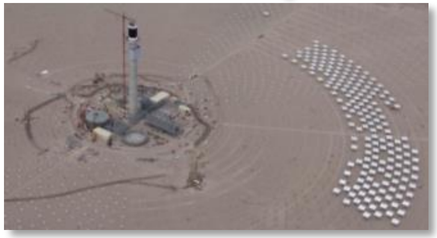
Ivanpah
2013-2014

3 Towers
377 MW_e

Direct Steam

Crescent Dunes
2014 110 MW_e

Salt storage

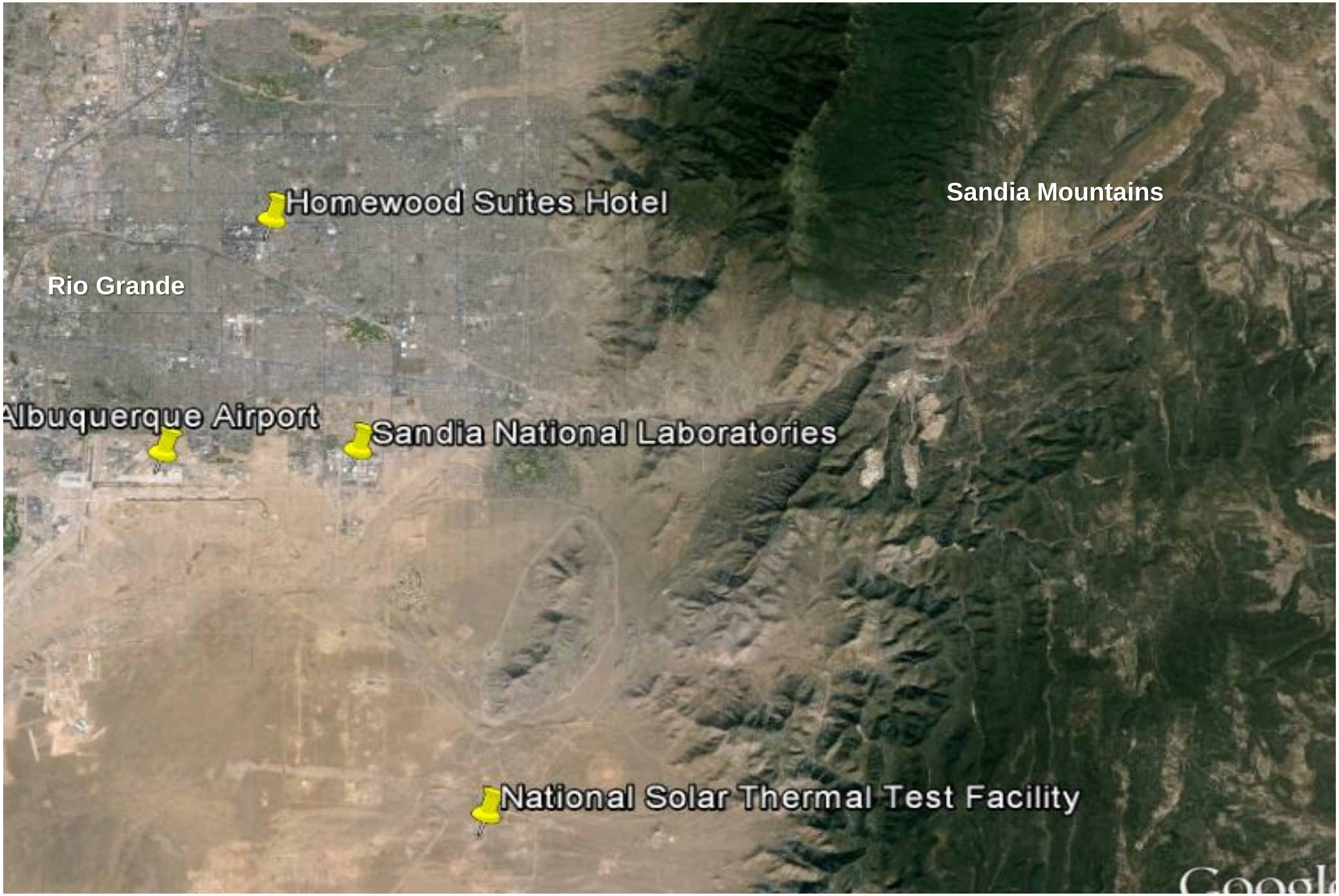


Power Tower Test Facilities:
- PSA (2)
- CSIRO (1)
- KSU (1)
- Beijing (1+1)
- Julich (1)
- Weizmann (1)

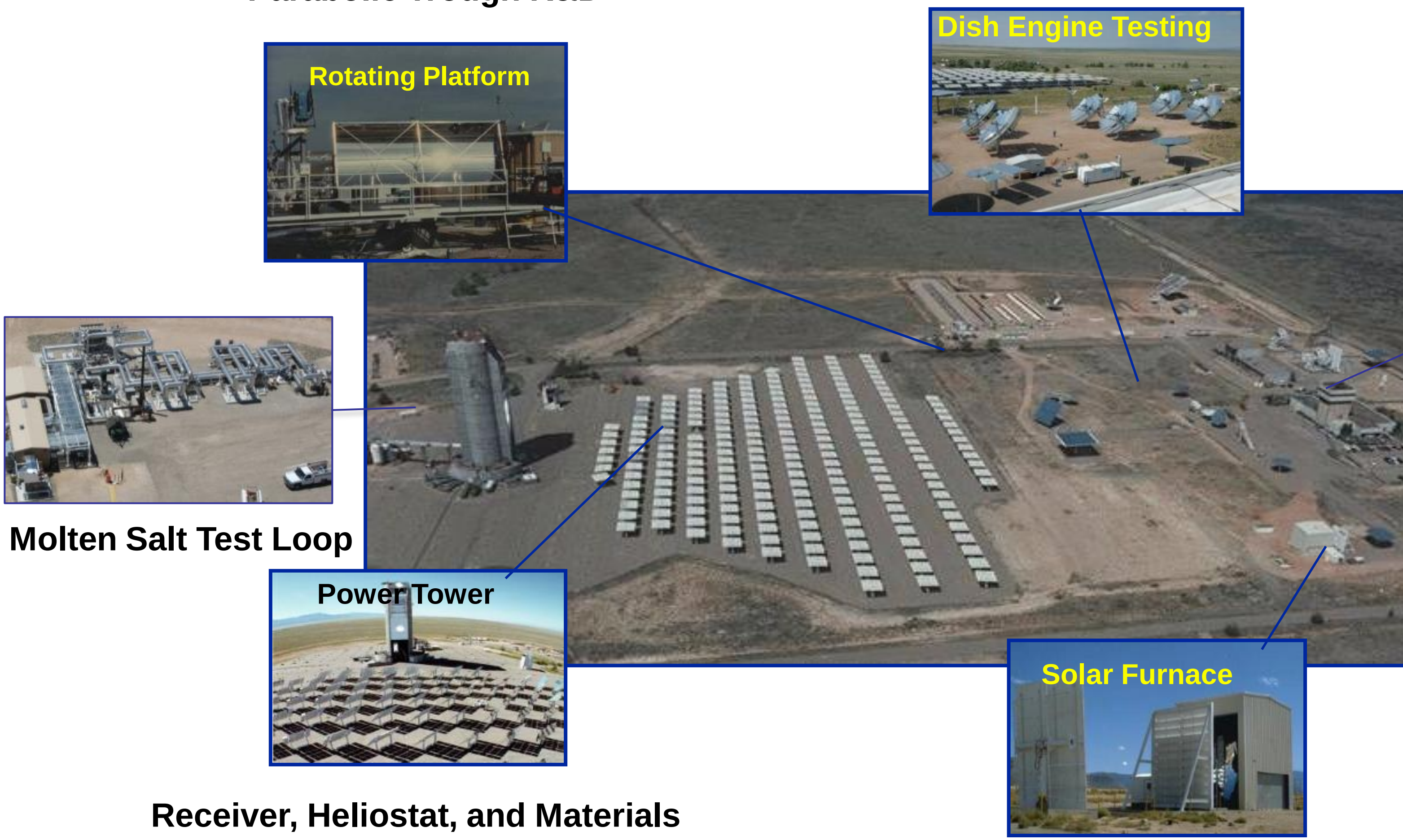
1970	1980	1990	2000	2010	2011	2013	2014

Albuquerque, NM

Population: ~600,000



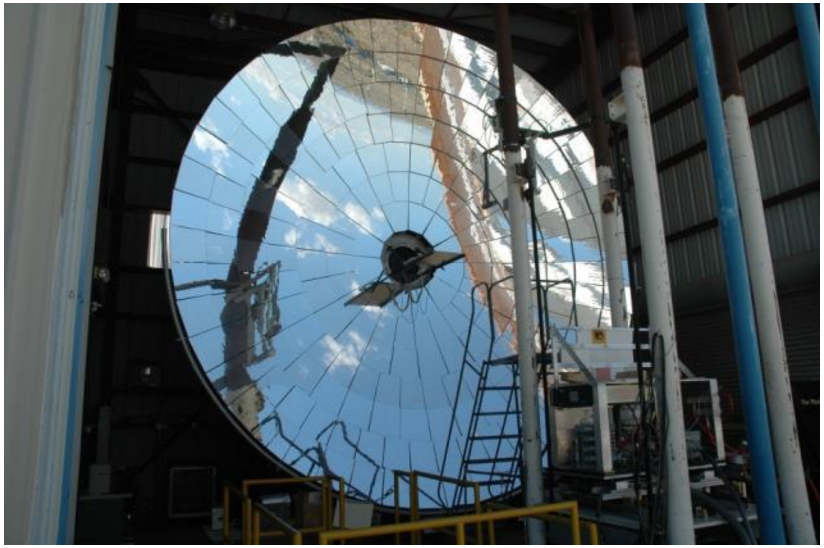
National Solar Thermal Test Facility



Tower and Heliostat Field

- Peak Flux: 350 W/cm^2
- Total Power: 6 MW$_t$
- 218 heliostats
- Tower (200 ft) 3 test bays plus top of tower
- Testing of receivers, heliostats, materials, and subsystem components

Solar Furnace



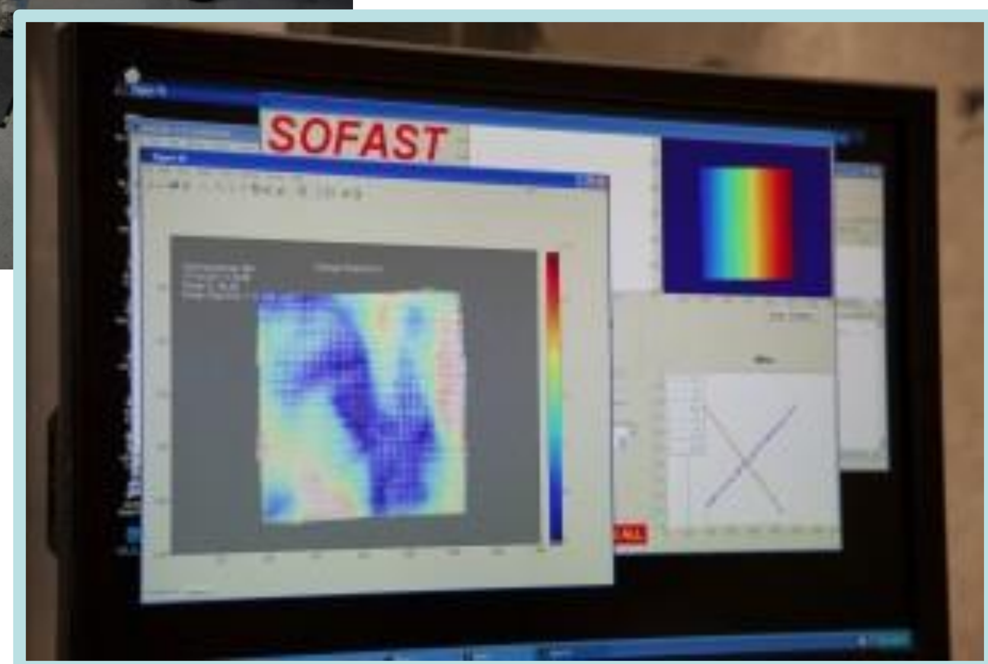
- Peak Flux: 600 W/cm^2
- Total Power: 16 kW_t
- Materials testing, solar fuels, calibration, proof of concept testing

Molten Salt Test Loop

- Operating Temp: 300 - 585 °C
- Max pressure: 40 bar (580 psi)
- Flow rates variable: 44 – 70 kg/s (up to 600 gpm)
- Three test loops
- Component and system testing
- Accelerated life-time testing

Optics Lab

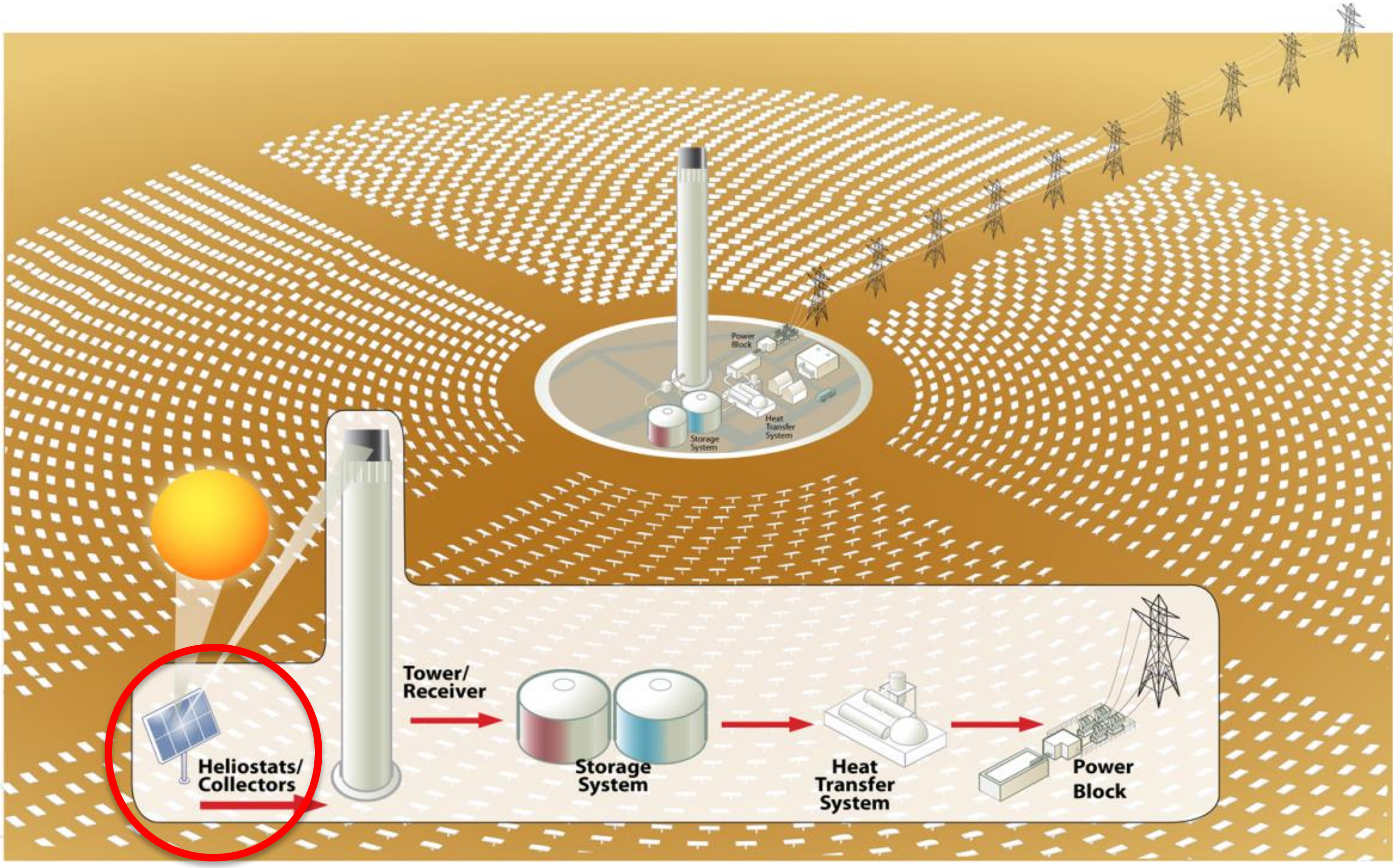
Optical characterization of collector facets, PV modules



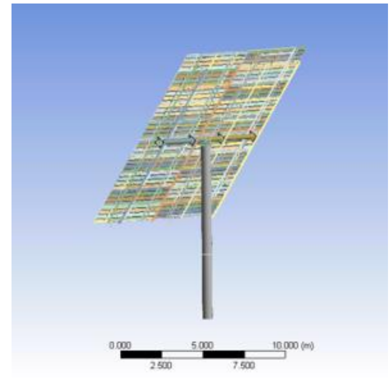
Sandia National Laboratories

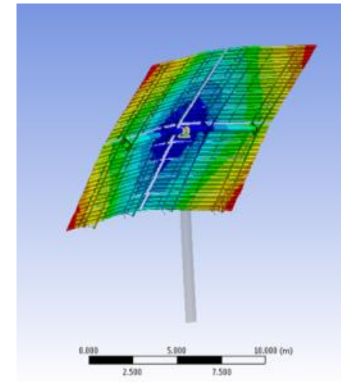
NSTTF Research Activities

CSP Research

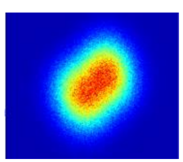
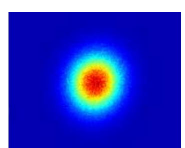
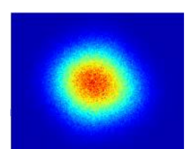
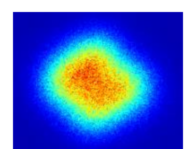
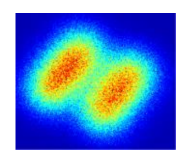


Optical Accuracy – Gravity Sag





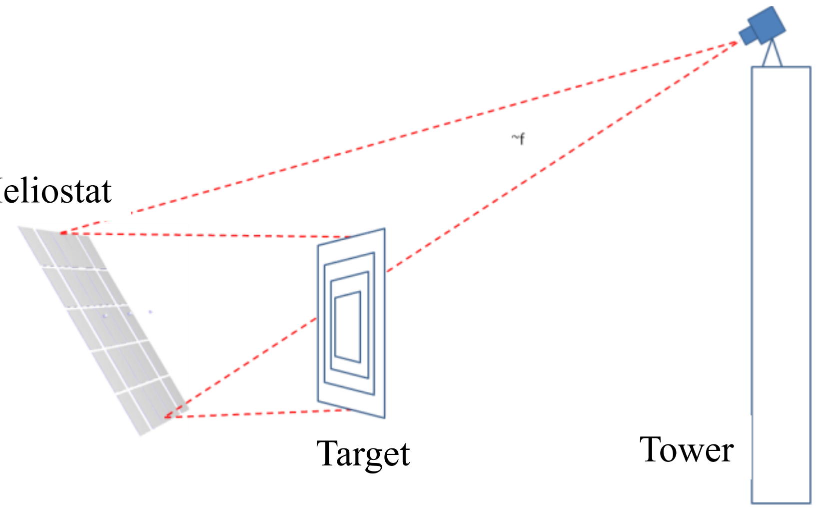
Mirror canting and gravity sag can affect optics (J.Yuan)

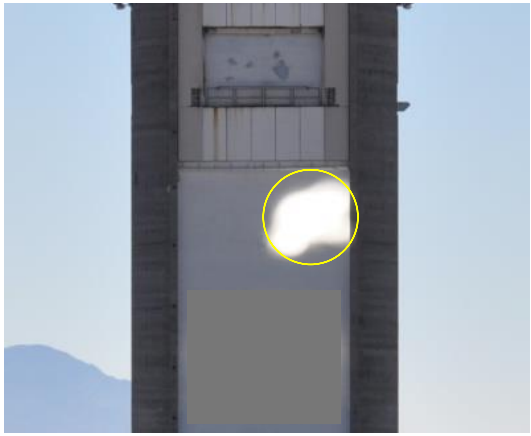
Time	10:03 AM	12:30 PM	3:12 PM	4:12 PM	5:45 PM
Actual BCS Contour Plots					
Simulation					

August 23

Optical Accuracy – Characterization, Alignment, and Tracking

(C. Andraka, J. Yellowhair, E. Smith, C. Ho)

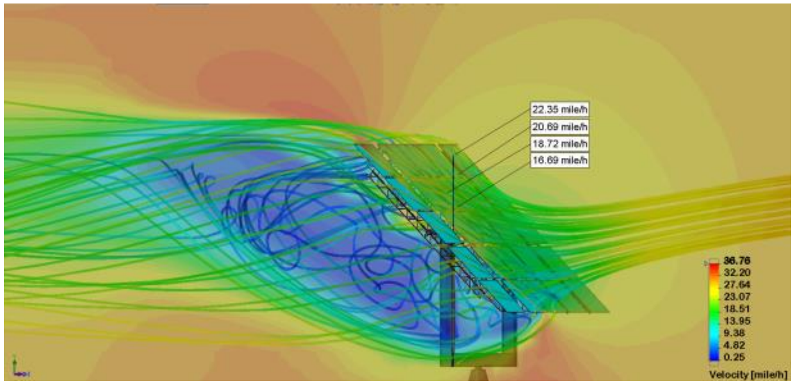




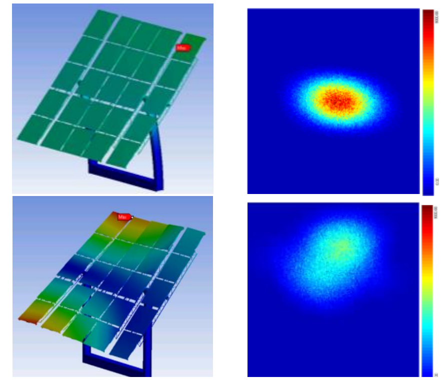
Before

After

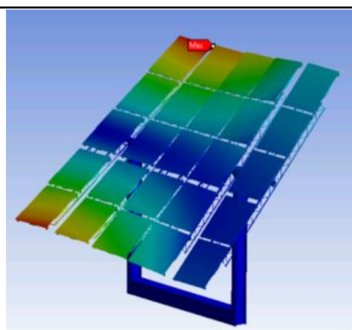
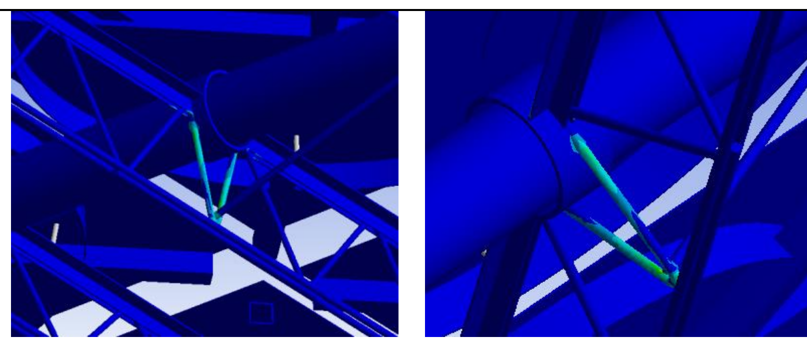
Wind Impacts – Optics and Fatigue

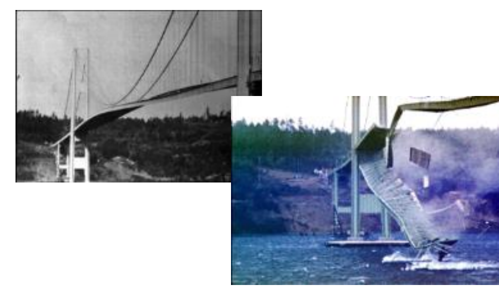


J. Sment, J. Christian, J. Yuan, T. Griffith, C. Ho



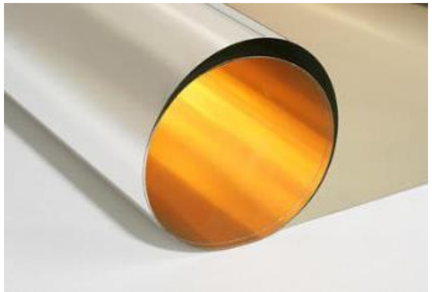
Optics impacted by “sway” or out-of-plane bending

Mode shape	Fatigue Affected Areas
 Mode 2	 Truss Cross Members at Torque Tube

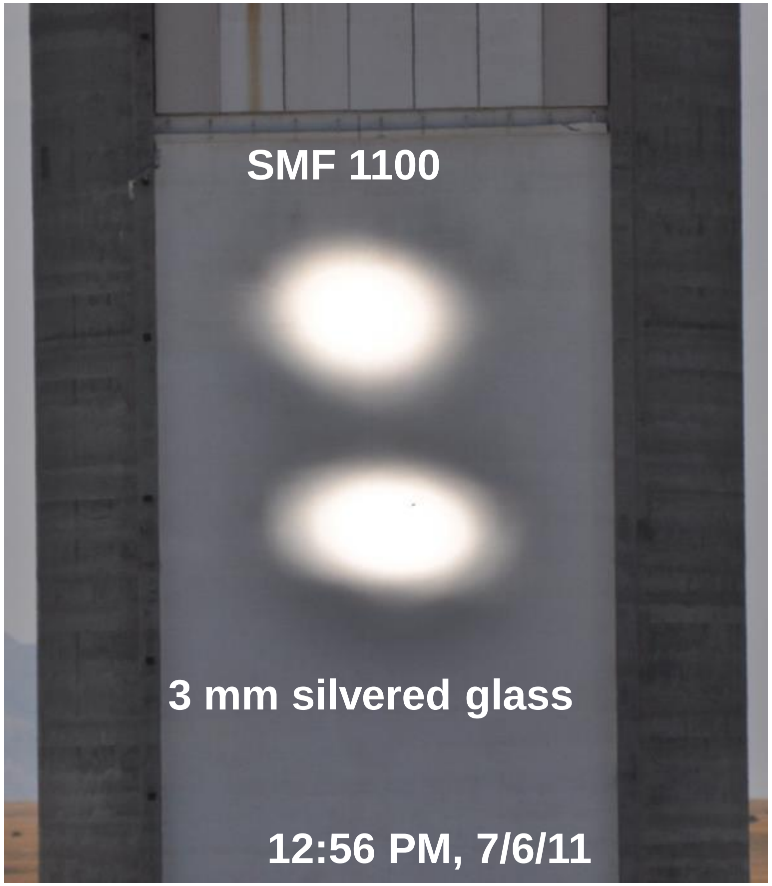


Tacoma Narrows Bridge collapsing under 40 mph winds (1940)

Advanced Reflective Materials

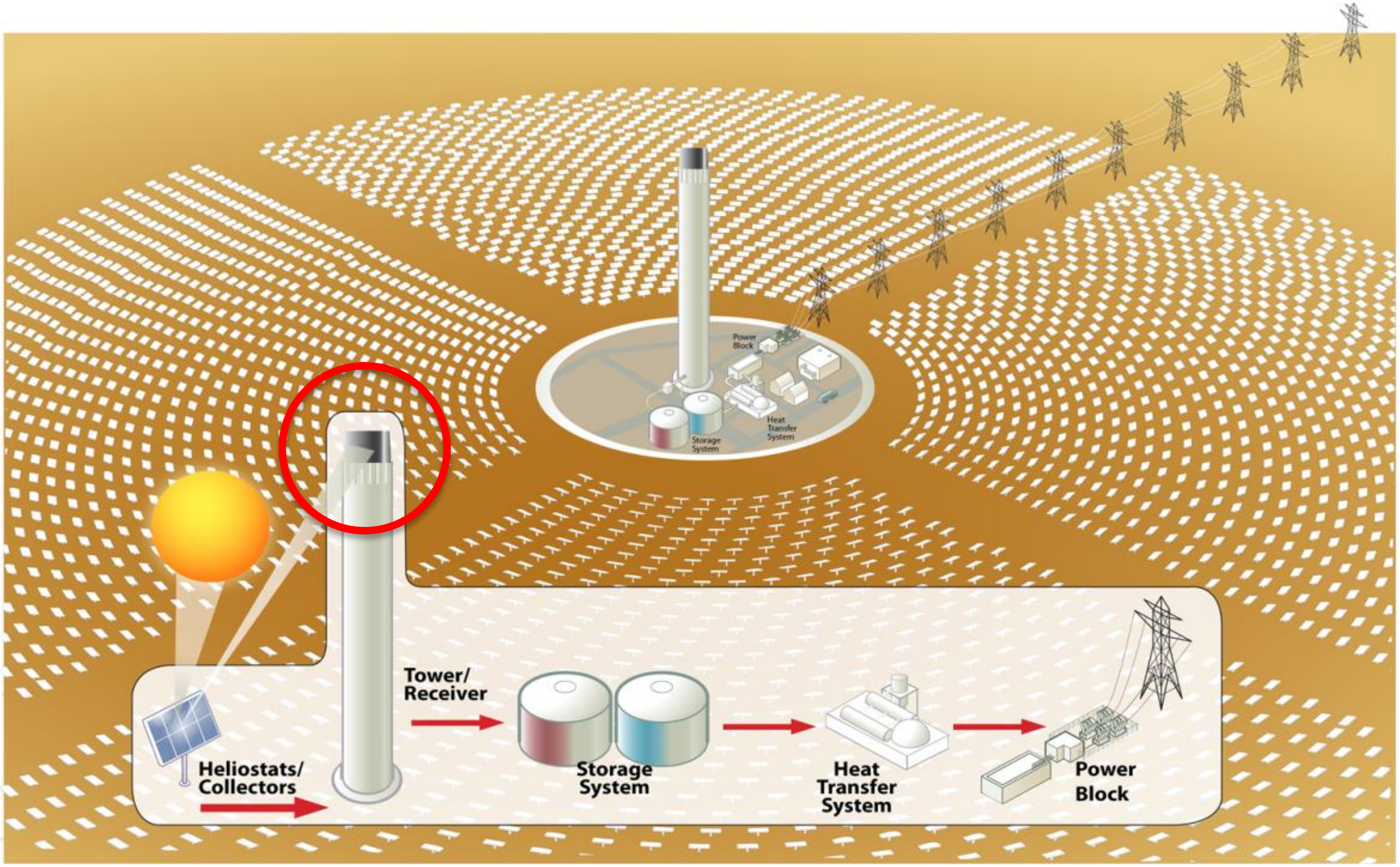


Heliostat with 3M™ Solar Mirror Film 1100



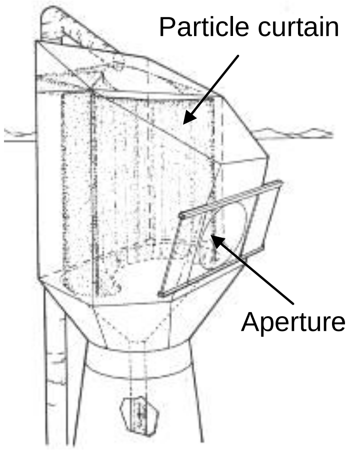
Ho et al. (*Solar Energy, 2013)*

CSP Research



High-Temperature Receivers

National Solar Thermal Test Facility, Sandia National Laboratories, Albuquerque, NM

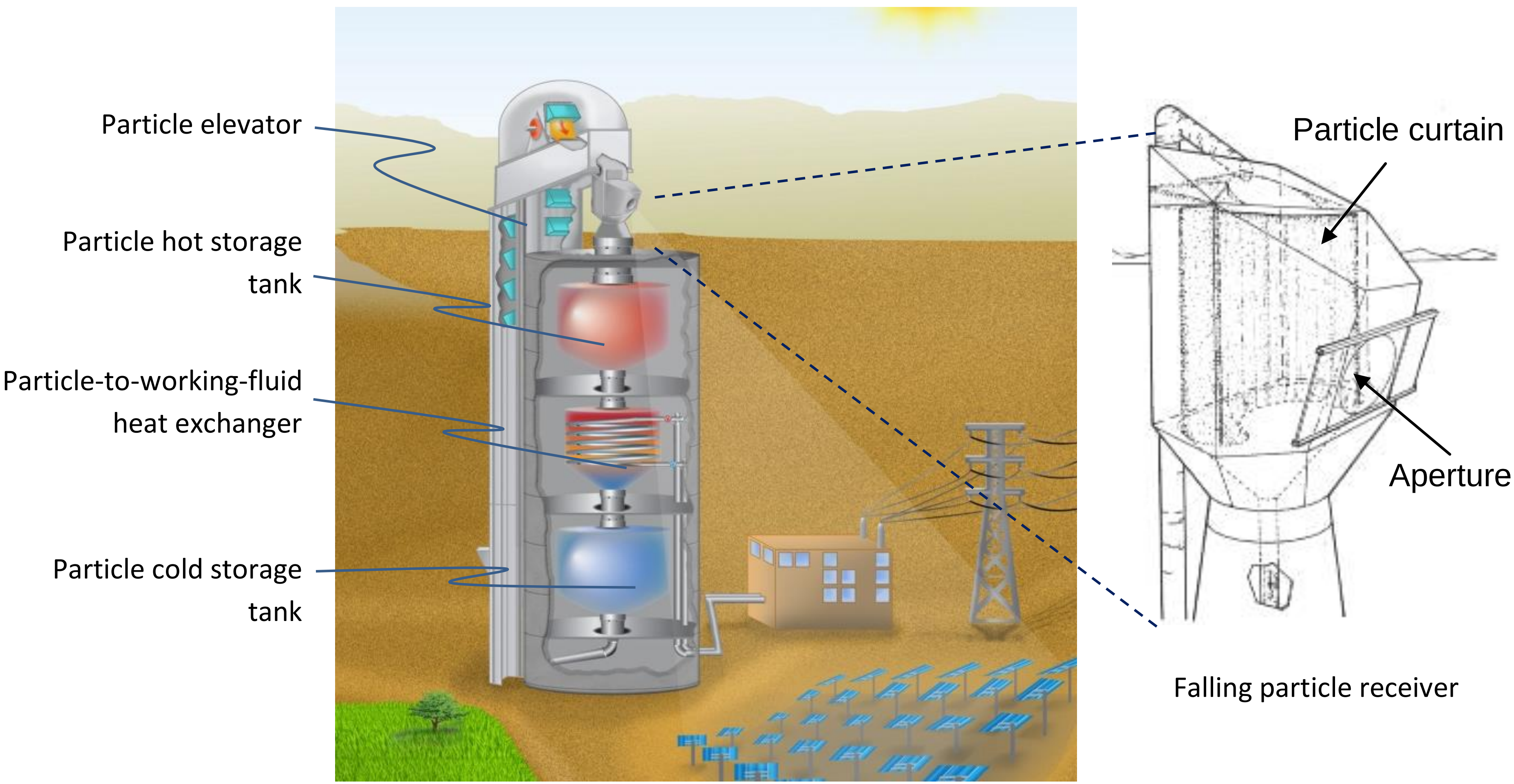


Falling particle receiver

- Maximize solar absorptance and minimize heat loss (selective absorber coatings, new geometry, high concentration ratio)
- Need materials that operate at high temperature (>650 °C) and are durable in air

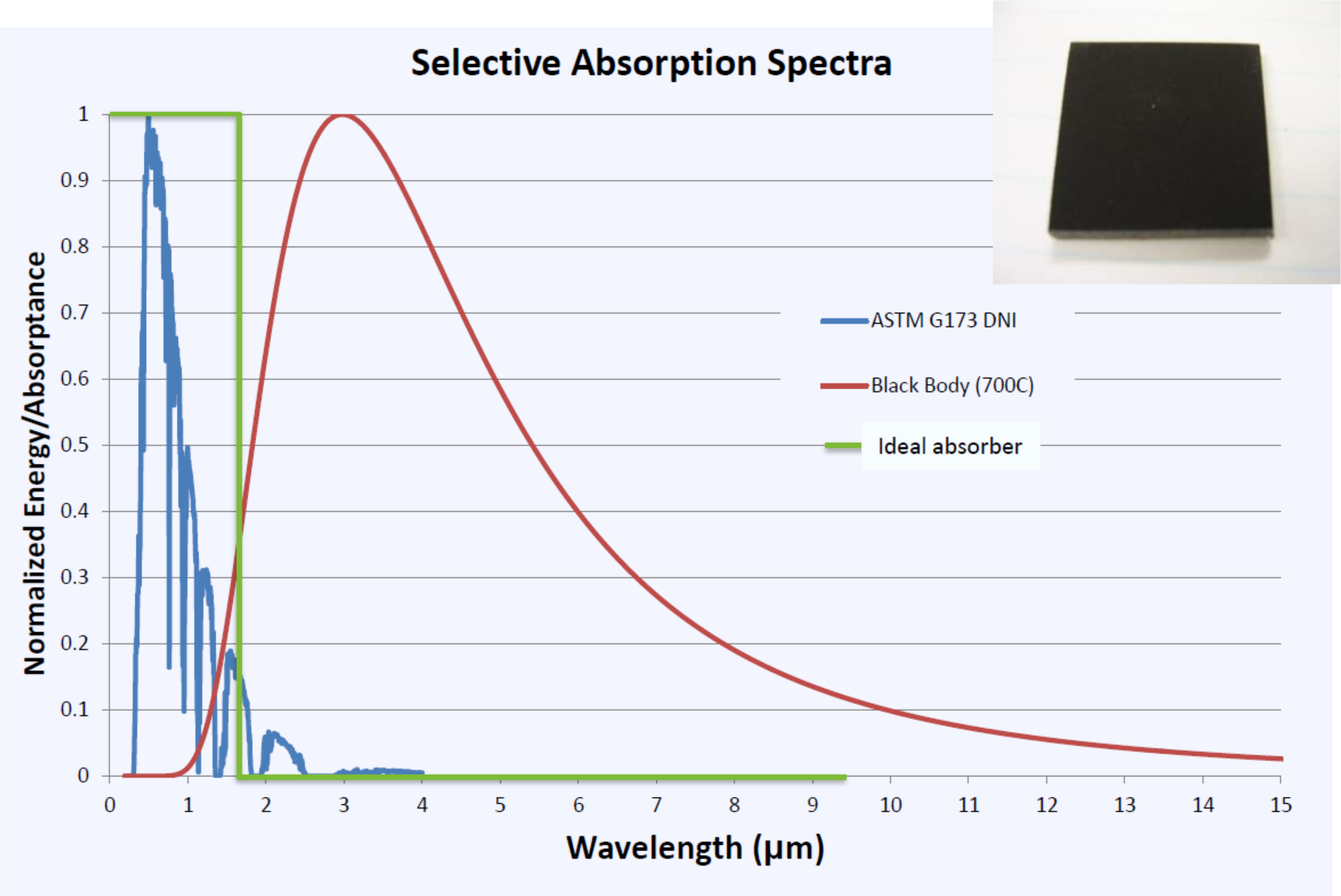
External tubular receiver

High Temperature Falling Particle Receiver (DOE SunShot Award FY13 – FY15)

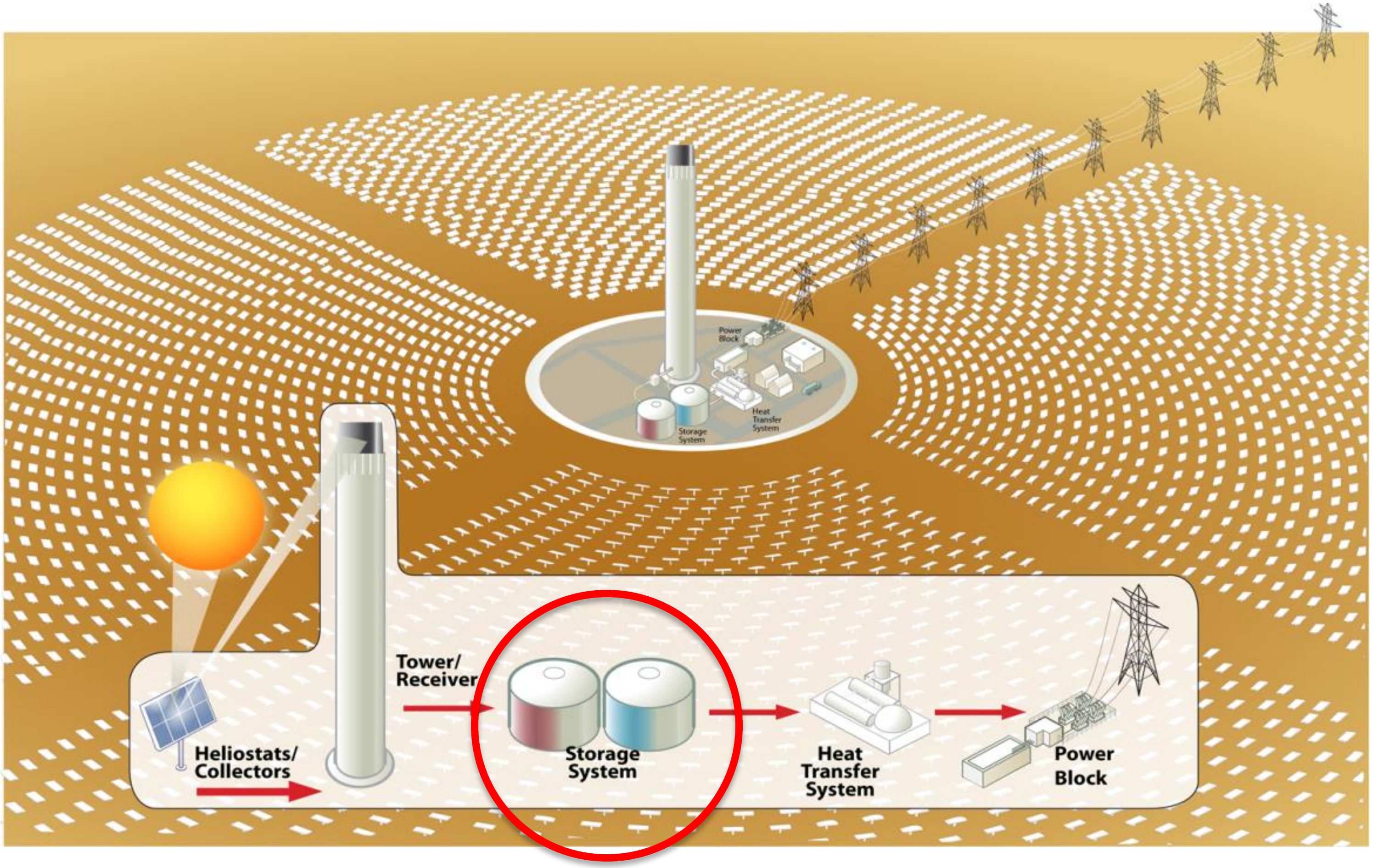


Participants: Sandia, Georgia Tech, Bucknell U., King Saud Univ., DLR

Selective Absorber Coatings



CSP Research



Molten Salt Research

- Molten Salt Test Loop – Plant-Like Conditions for On-Sun Testing of Salt Components/Collectors
- 700 C Salt Pots – Corrosion testing along with Analysis Capability
- Molten Salt Expertise for Testing
- Thermochemical experience from S2P, Fuel Cells, and Hydrogen Expertise

Salt Pot

Molten Salt Test Loop (MSTL)

AREVA Linear Fresnel and Salt Tube Test

Single Module Linear Fresnel Test Connected to MSTL

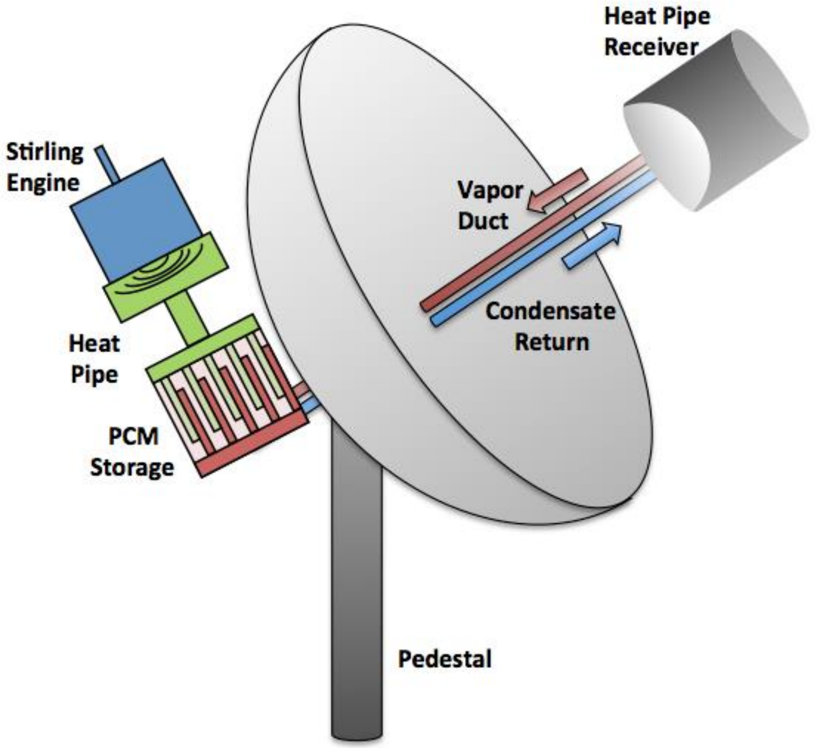
Evaluate:

- Salt performance in Linear Fresnel
- Salt components
- Filling/draining strategies
- System efficiency
- Operating strategies
- Off-normal conditions

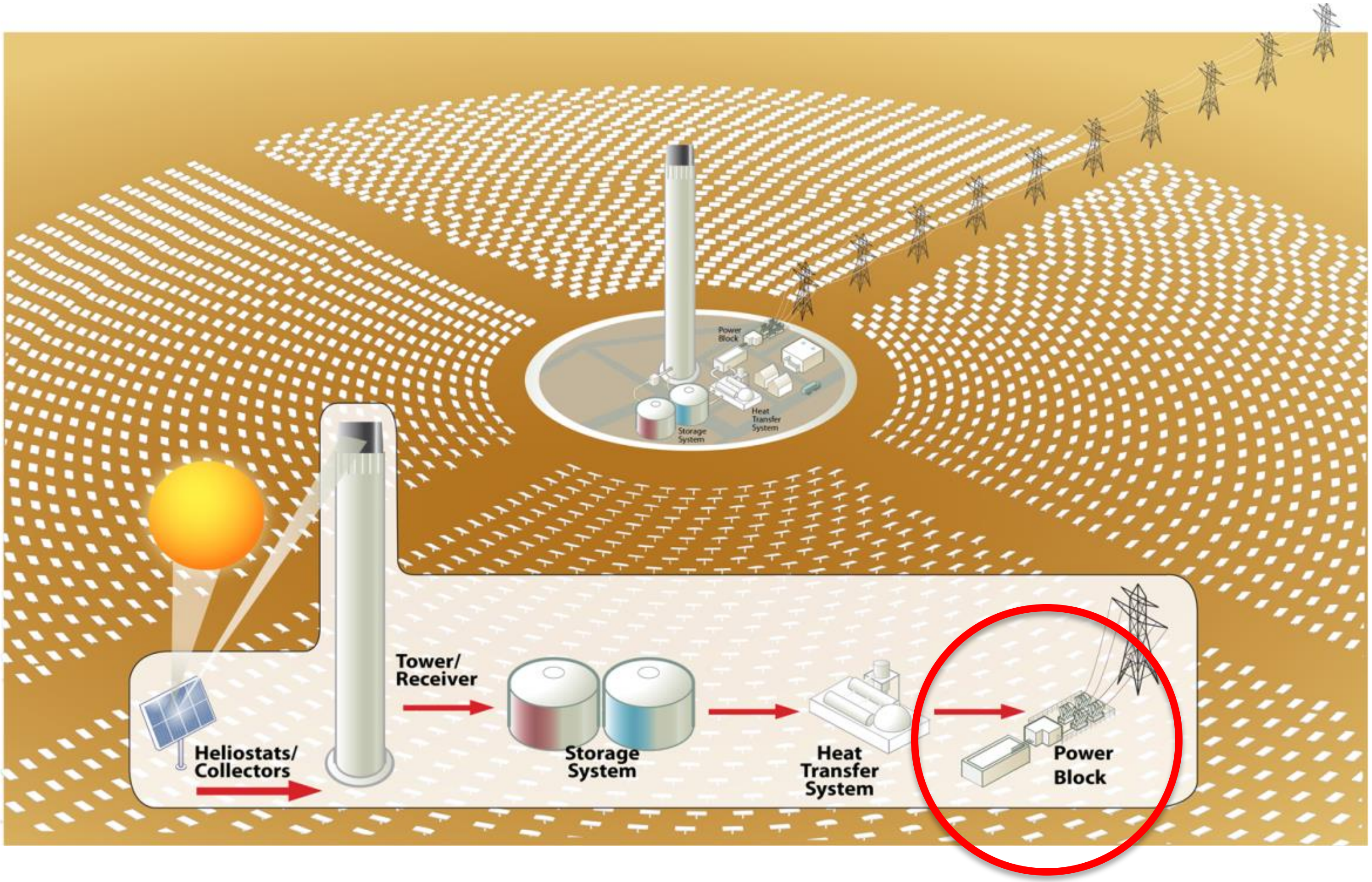
Areva's Linear Fresnel Test (middle of picture) Connected to MSTL (lower left)

Dish Storage Concept (C. Andraka)

- Phase Change Material (PCM)
  - Heat pipe transport to storage and to engine
  - Latent transport and storage ideal for Stirling input
- Rear dish mount
  - Rebalances system
  - Allows heavy storage
  - Closes pedestal gap
- Demonstrated system performance boost with latent input



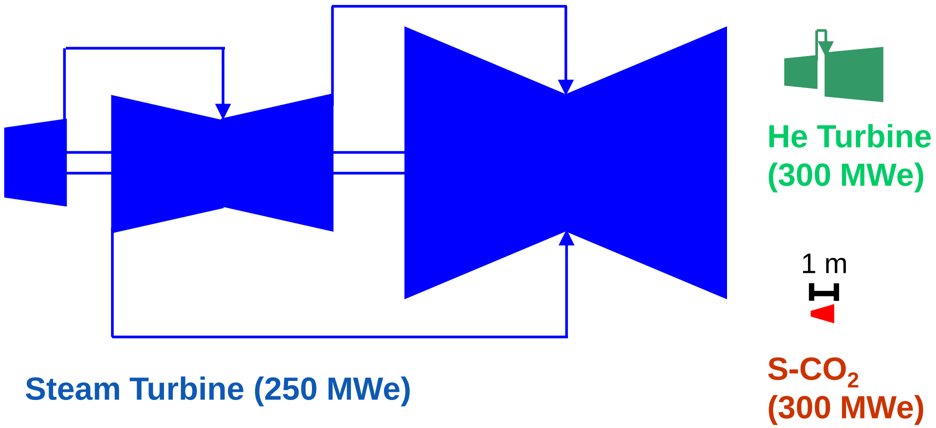
CSP Research

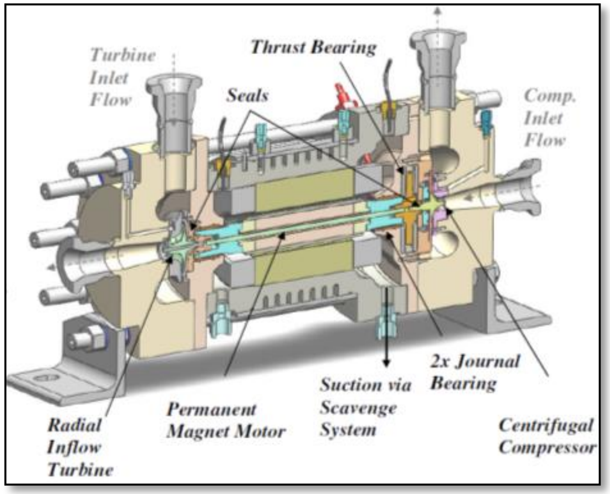


Supercritical CO_2 Brayton Cycle

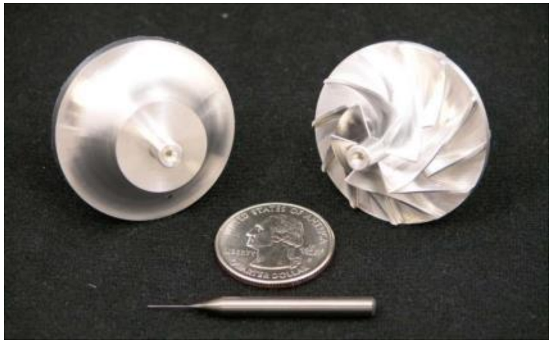
(Sandia Advanced Nuclear Concepts Group, Conboy et al.)

- High efficiency
  - 50% thermal-to-electric
- Compact power conversion
  - Liquid-like densities with CO_2



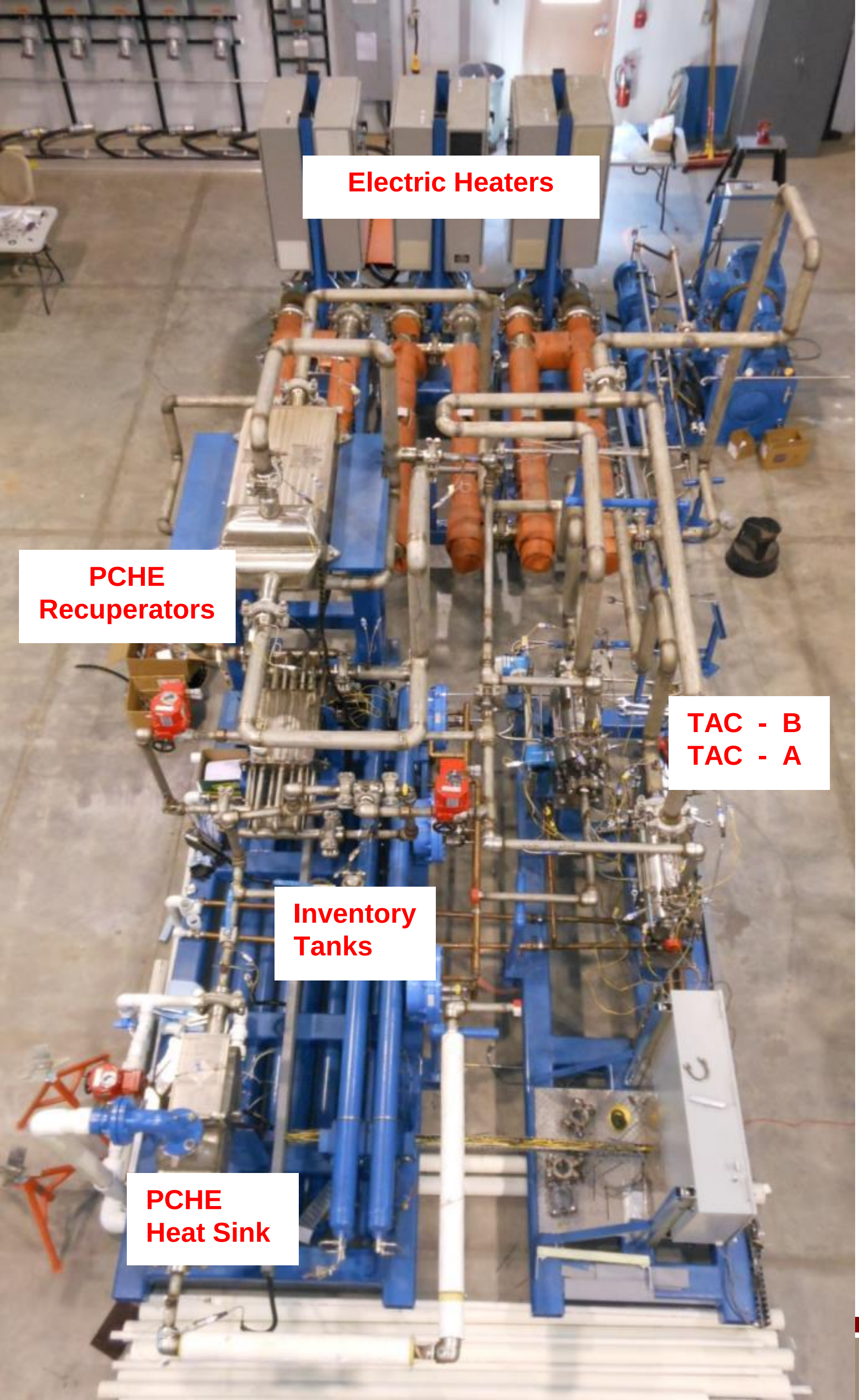


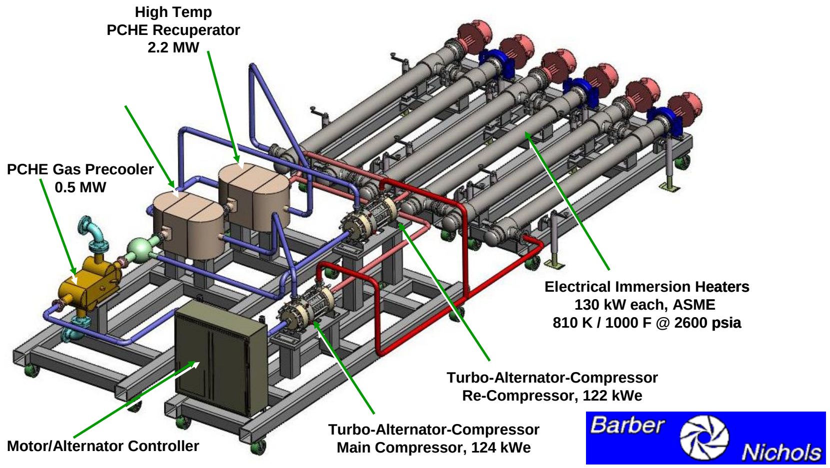
Sandia sCO_2 turbo-alternator-compressor
(Conboy et al., 2013)



Compressor wheel for 150 kW_e sCO_2 Brayton cycle
(SAND2010-0172)

Sandia's Supercritical CO_2 Brayton Cycle Loop





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Solar Particle System with Supercritical CO_2 Power Cycle Demonstration Project

Value Proposition

Technical:

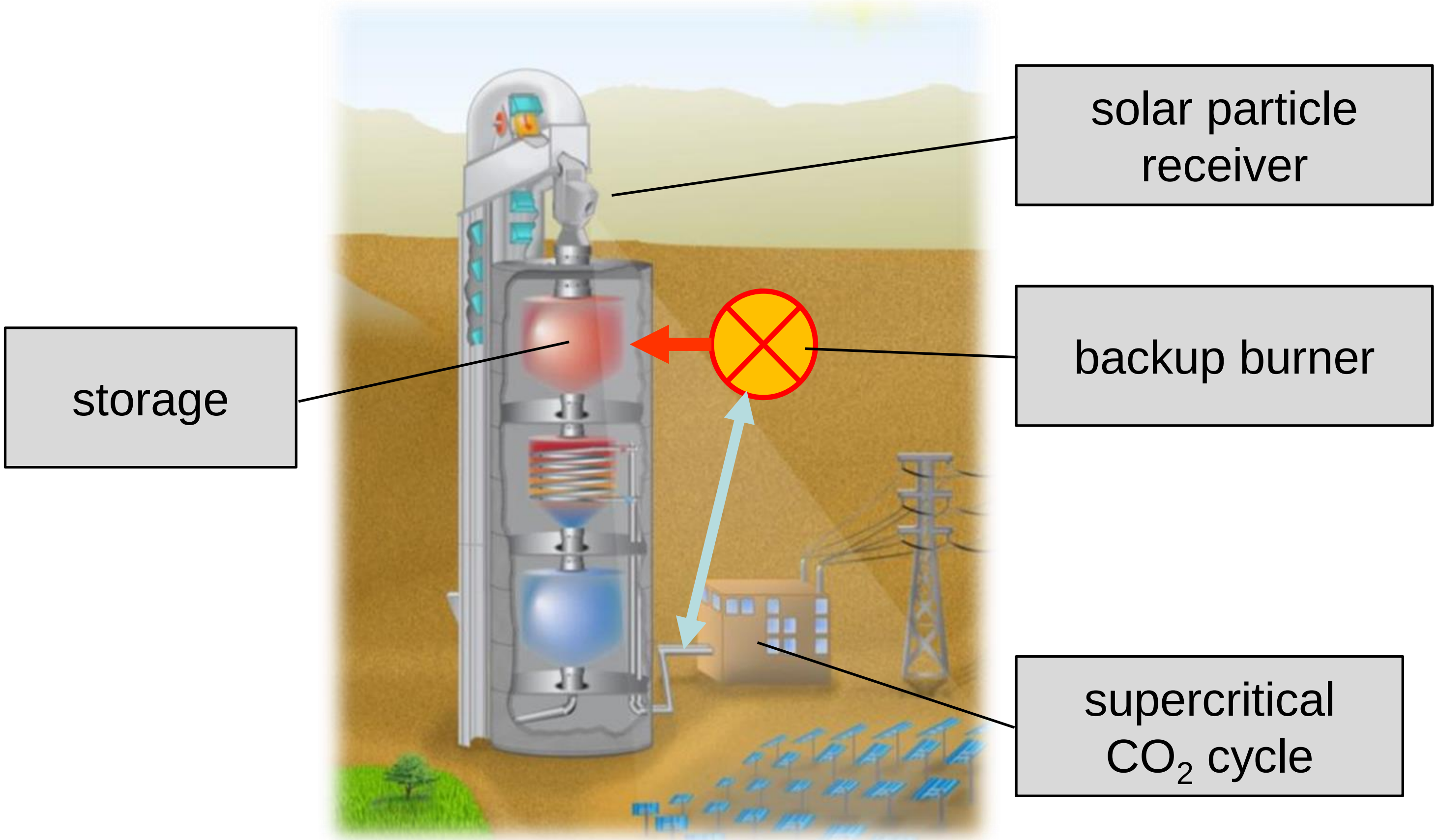
- Next generation solar system with high capacity factor and full dispatchability (storage, backup burner)
- Enables high efficiency sCO_2 power cycle
  - ~50% thermal-to-electric (higher for combined cycles)
- Reduces LCOE toward SunShot goal of 6 cents/kWh*
- Full system demonstration

Programmatic:

- Greater return on investment with bi-national funding and effort

*Power Tower Technology Roadmap and Cost Reduction Plan (SAND2011-2419)

System Scheme



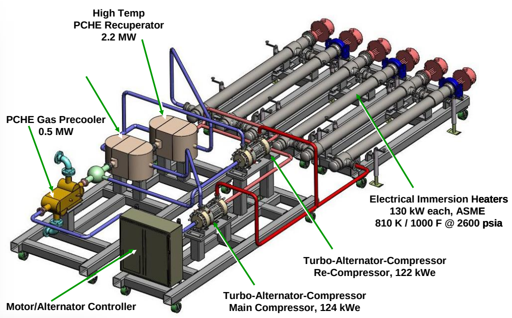
Particles serve as heat transfer and storage medium

Tasks

- Receiver: SNL, DLR
- Supercritical CO_2 cycle: SNL
- Particle-to-CO_2 heat exchanger: DLR, SNL
- Thermal energy storage: DLR, SNL
- Back-up heater: DLR
- System optimization: DLR, SNL
- Component testing and system demonstration: SNL

Why Sandia and DLR?

- Leaders in particle receiver, storage, and supercritical CO_2 technology
- Existing collaboration on particle technology
- Complementary expertise, modeling, and testing capabilities




Development and Evaluation of a Prototype Solid Particle Receiver: On-Sun Testing and Model Validation

Nathan P. Siegel
Clifford K. Ho
Siri S. Khalsa
Gregory J. Kolb

Journal of Solar Energy Engineering

SolarPACES 2009, Berlin, Germany, September 15-18, 2009

Experimental Validation of Different Modeling Approaches for Solid Particle Receivers

Clifford K. Ho[1], Marc Röger[2], Siri S. Khalsa[1], Lars Amsbeck[2], Reiner Buck[2], Nathan Siegel[1], and Greg Kolb[1]

FACE-DOWN SOLID PARTICLE RECEIVER USING RECIRCULATION

Marc Röger[1], Lars Amsbeck[2], Birgit Gobereit[2], Reiner Buck[2]

[1]German Aerospace Center (DLR), Institute of Technical Thermodynamics, Solar Research, Plataforma Solar de Almeria, 04200 Tabernas, Spain, Phone: +34-950259806, E-Mail: marc.roeger@dlr.de

Proceedings of ASME 2011 5th International Conference on Energy Sustainability & 9th Fuel Cell Science, Engineering and Technology Conference
ESFuelCell2011
August 7-10, 2011, Washington, DC, USA

ESFuelCell2011-54430

CFD SIMULATION AND PERFORMANCE ANALYSIS OF ALTERNATIVE DESIGNS FOR HIGH-TEMPERATURE SOLID PARTICLE RECEIVERS

Siri Sahib S. Khalsa[1], Joshua M. Christian[2], Gregory J. Kolb[2], Marc Röger[3], Lars Amsbeck[4], Clifford K. Ho[2], Nathan P. Siegel[2], Adam C. Moya[2]

[1]Sandia Staffing Alliance, Sandia National Laboratories, Concentrating Solar Technologies Department, Albuquerque, NM, USA
[2]Sandia National Laboratories, Concentrating Solar Technologies Department, Albuquerque, NM, USA
[3]German Aerospace Center (DLR), Solar Research, Plataforma Solar de Almeria, Spain
[4]German Aerospace Center (DLR), Solar Research, Stuttgart, Germany

ABSTRACT


DLR Centrifugal Particle Receiver Test


Sandia Falling Particle Receiver Test

Potential Industrial Partners

Sandia National Laboratories

- Abengoa
- Babcock Wilcox
- Barber Nichols
- Bechtel
- EPRI
- GE Global Research

Budget and Funding Mechanisms

- Duration: 5 years
- Budget:
  - SNL: $10M - $30M
  - DLR: 10M€ - 20M€
- Funding Mechanisms
  - Bi-National Investment
    - Germany / EU
    - U.S. DOE
  - Industry participation
  - Lockheed Martin Offset Program

Sandia National Laboratories

EERE Organization Chart

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- **Assistant Secretary** – David T. Danielson
  - **Principal Deputy Assistant Secretary** – Michael S. Carr
    - **Energy Efficiency** – Kathleen B. Hogan
      - **Building Technologies** – Roland J. Risser
      - **Federal Energy Management** – Timothy D. Unruh
      - **Advanced Manufacturing** – Kathleen B. Hogan *(Acting)*
      - **Vehicle Technology** – Patrick B. Davis
      - **Weatherization & Intergovernmental** – Anna M. Garcia
      - **Sustainability Performance** – Jennifer C. MacDonald
    - **Renewable Energy** – Steven G. Chalk
      - **Biomass Program** – Valerie Sarisky-Reed *(Acting)*
      - **Fuel Cell Technologies** – Sunita Satyapal
      - **Geothermal Technology** – Douglas W. Hollett
      - **Solar Energy Technology** – Minh Sy Le *(Acting)*
      - **Wind & Hydropower Technology** – Jose R. Zayas
    - **Business Operations** – Merle L. Sykes
      - **Business Services** – Derek Passarelli *(Acting)*
      - **Budget** – A. Avon Meacham
      - **Information & Business Management** – Douglas E. Kaempf
      - **Project Management & Evaluation** – Scott E. Hine
      - **Golden Field Office** – Carol J. Battershell
    - **Strategic Programs** – JoAnn Milliken *(Acting)*
      - **International Program** – Robert L. Sandoli
      - **Analysis & Evaluation** – *(Vacant)*
      - **Communications & Outreach** – Sarah Lynch *(Acting)*
      - **Innovation & Deployment** – JoAnn Milliken
      - **Legislative, Regulatory & Urban Affairs** – Kerry C. Duggan

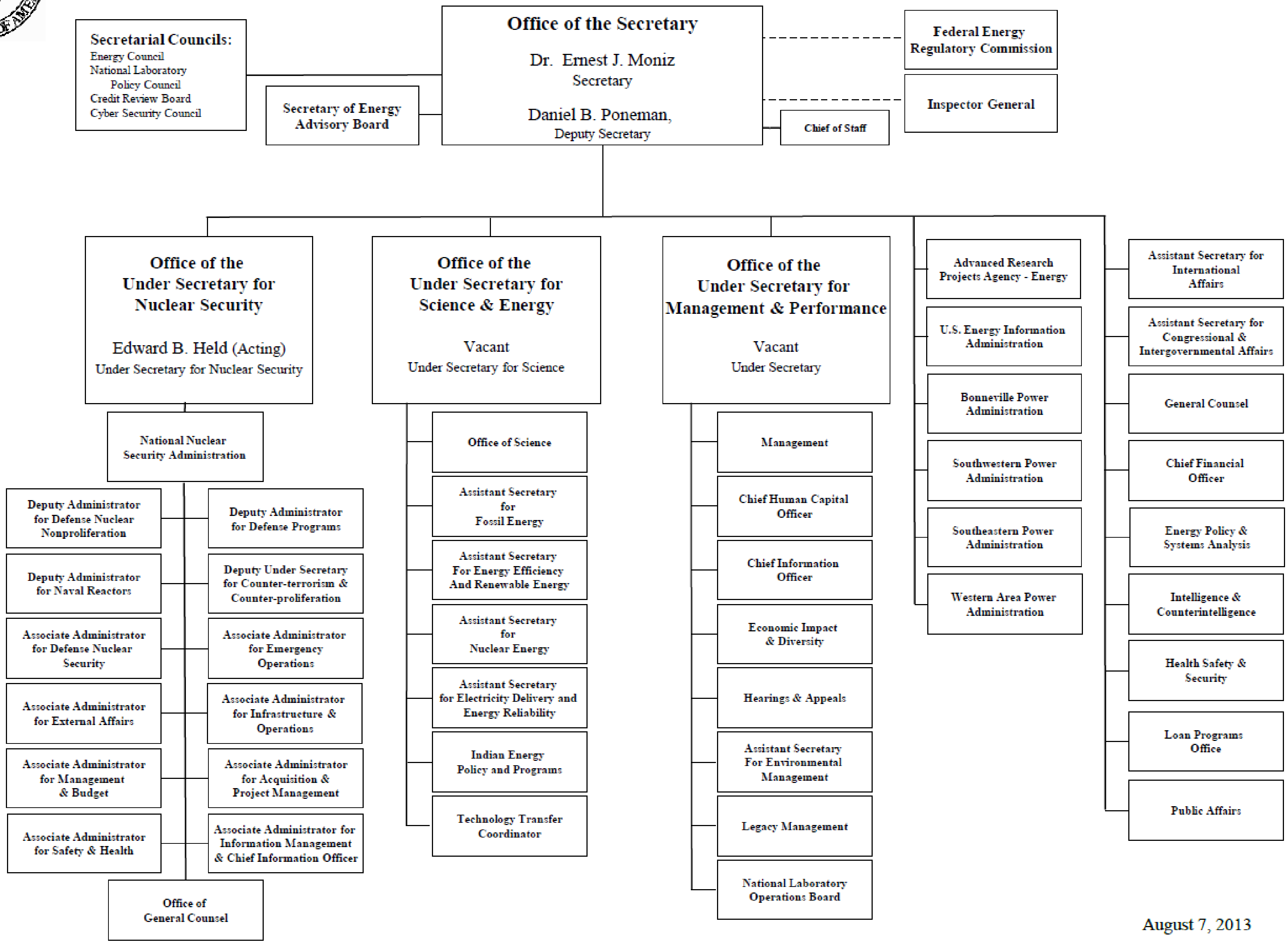
Summary

- Sandia and DLR have synergistic research and capabilities in CSP
- Seeking collaborative opportunities
  - Bi-National Proposal
    - Solar Particle System with Supercritical CO_2 Power Cycle Demonstration Project
    - Bi-national funding for greater return on investment

Questions?

Cliff Ho, (505) 844-2384, ckho@sandia.gov

DEPARTMENT OF ENERGY



August 7, 2013