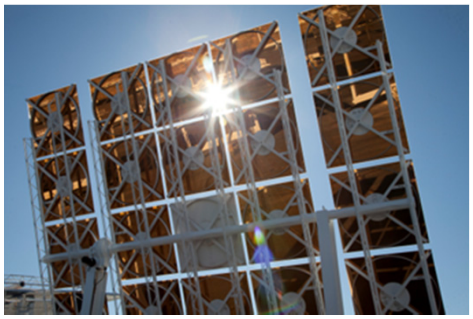
SAND2015-3034PE

Exceptional service in the national interest

Sandia National Laboratories

energy.sandia.gov



CSP Program at Sandia National Laboratories

Subhash L. Shinde, Manager
Concentrating Solar Technologies

April 21, 2015

SunShot U.S. Department of Energy

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

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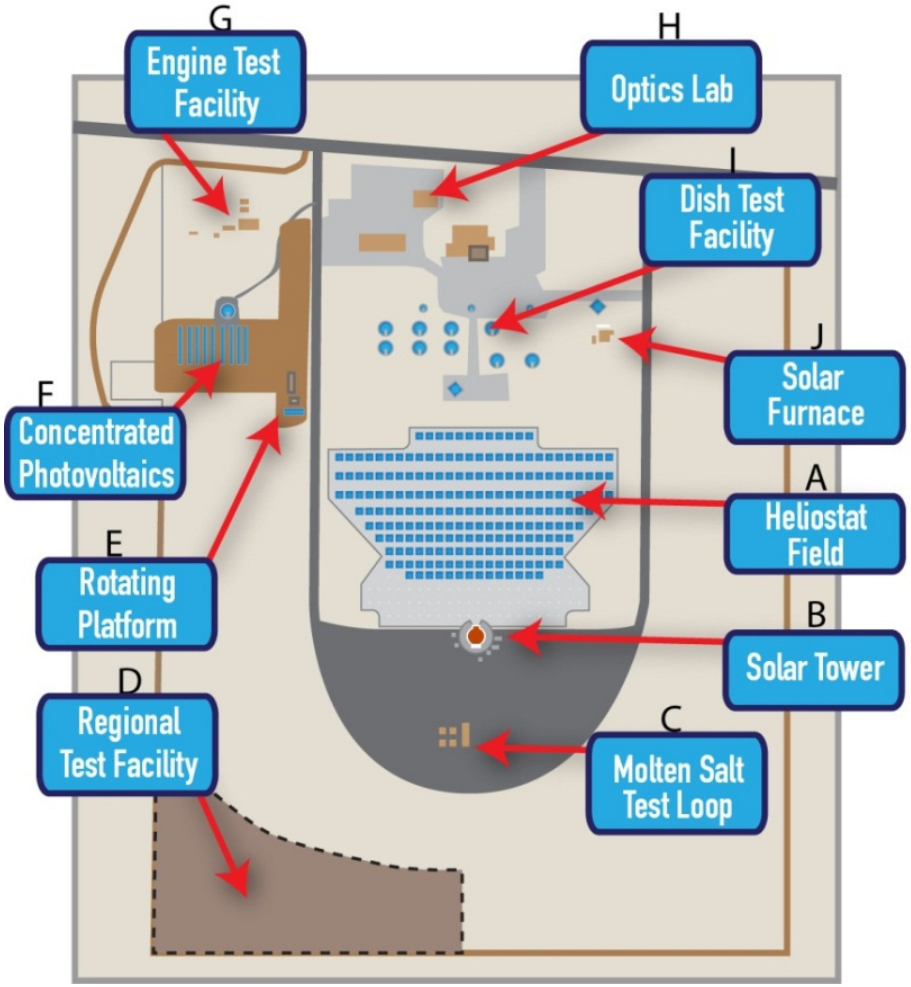
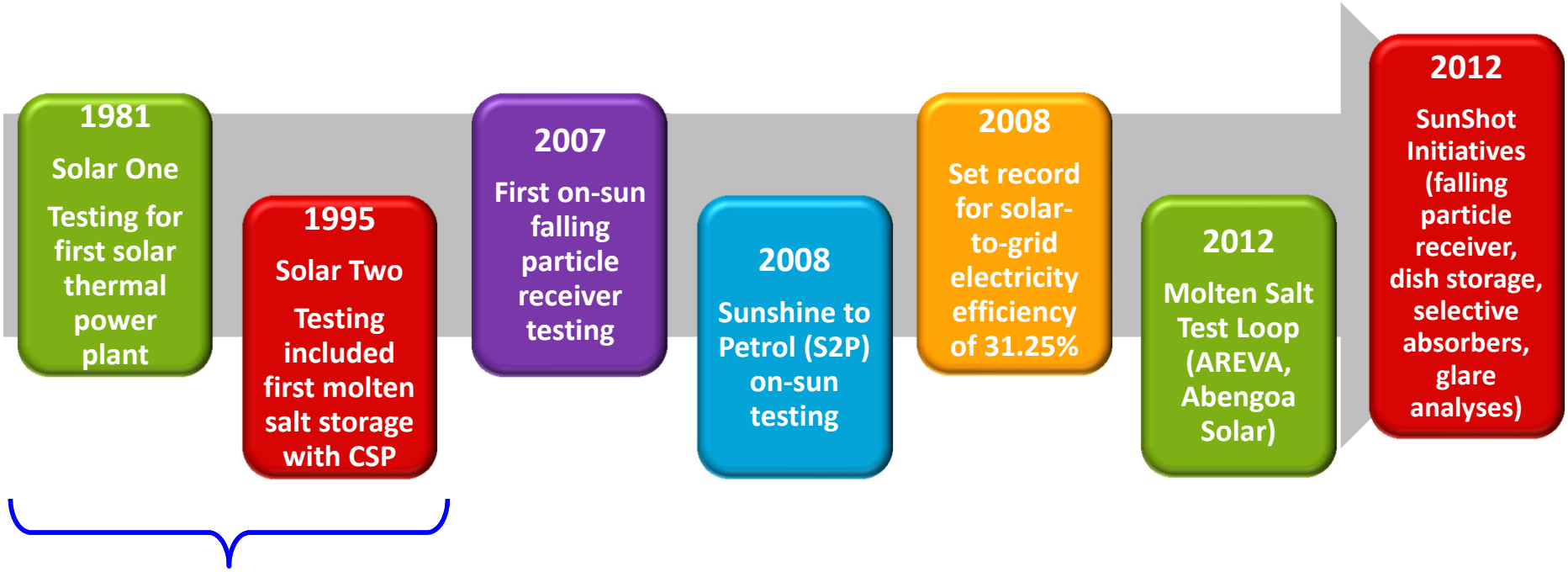
The National Solar Thermal Test Facility

Sandia National Laboratories



http://energy.sandia.gov/energy/renewable-energy/solar-energy/csp-2/

NSTTF Impact on CSP Plants

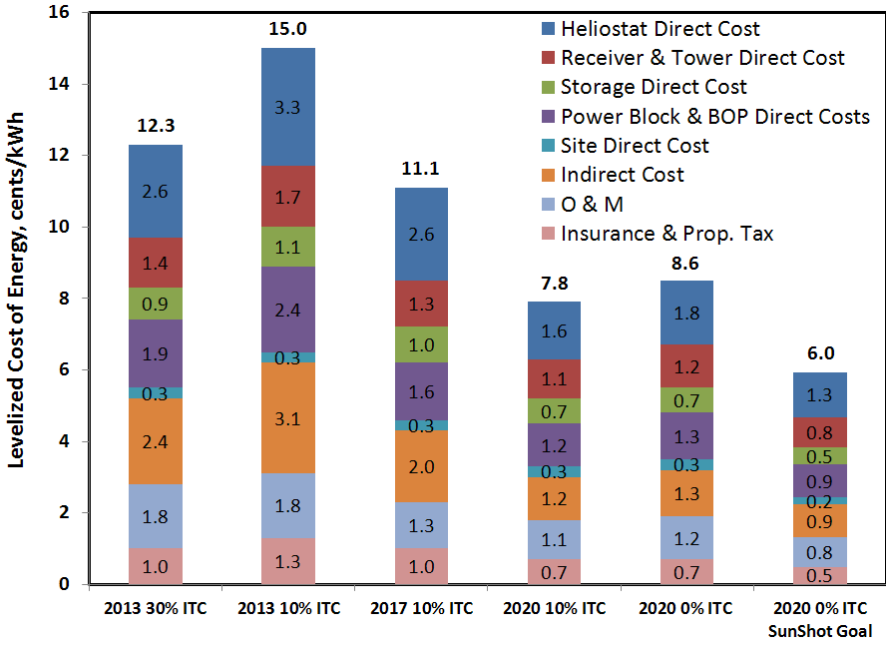


All core test & development was done at NSTTF

Virtually all of the key technologies at modern CSP towers today were either developed or tested at NSTTF

DOE SunShot Goals

- Reduce the cost of solar-generated electricity to be competitive with fossil fuels (6 cents/kWh) by 2020 without subsidies.
- All major systems in a CSP plant must have improved performance and reduced costs
  - Collector Systems: $75/m^2$
  - Receivers: > 650°C operating temperatures, > 90% efficiency, < $150/kW_t$
  - Thermal Storage: < $15/kWh, > 95% energy efficiency
  - Power Cycles: > 50% gross-cycl efficiency with dry cooling, > 650°C operating temperatures < $1200/kW_e$



Sandia Partnership with Industry

Sandia Partnership with Industry

- Solar Reserve
  - Continued partnership with SNL to improve performance and reduce costs of their heliostat designs.
  - Testing of novel heliostats prototypes featuring innovative controls and drive systems
- Abengoa
  - Molten Salt flow behavior
  - Molten Salt high temp degradation
- SQM
  - Molten Salt interactions with containment
- Alstom
  - Molten Salt Freeze Thaw issues
- Projects of General Interest to all CSP Industry
  - Work that will benefit Avian impact, and Tower Glare
  - Data-Driven Plant Performance Modeling
  - Solar Selective Coatings, and Protective Coatings for heliostats

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Projects of Current & Future Interest

Solar Glare Hazard Analysis Tool (SGHAT)

Sandia National Laboratories

2013 R&D 100

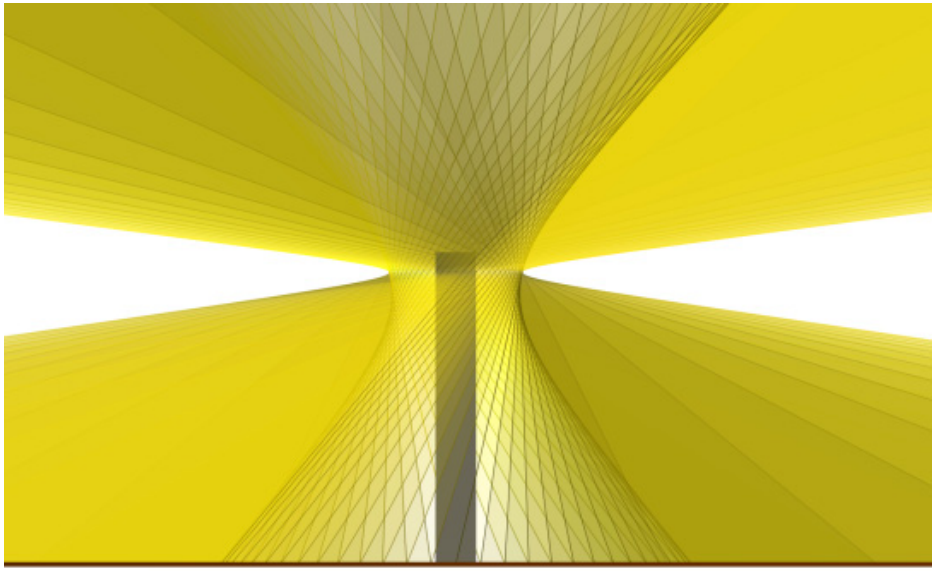
Need tools to quantify glare and potential ocular impacts to safely site solar energy systems

PV Installation Near a Boston Airport Control Tower

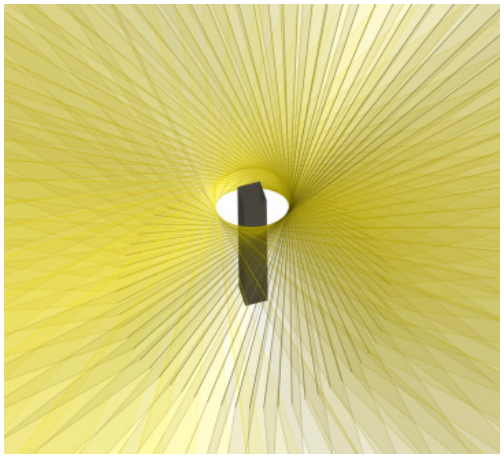
Glare from Ivanhpah

Glare from Heliostats in Standby Mode (Tower Illuminance Model - TIM)

Ivanpah Tower Glare

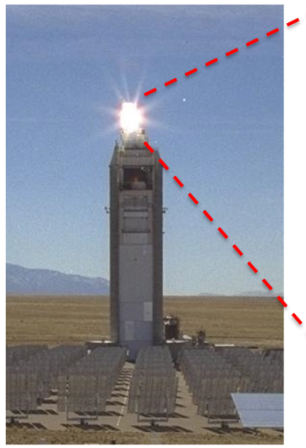


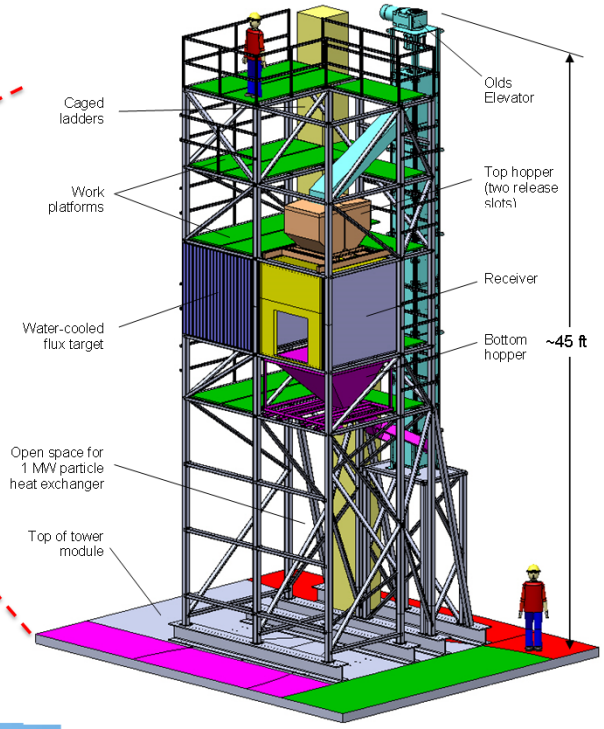
Simulated Intensity Distribution Around the Tower

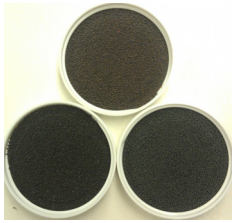


High-Temperature Falling Particle Receiver

- SunShot Award FY13 – FY15
  - Falling particle receiver designs
  - Particle properties and durability
  - Balance of plant
- On-sun demonstrations
  - Goal: continuously operating particle receiver achieving > 700 C with 90% efficiency







Fractal-Like Receiver Designs

Internal Sandia-funded LDRD project to develop exploratory receiver concepts

Goal: develop fractal-like designs and structures across multiple scales to increase solar absorptance and thermal efficiency

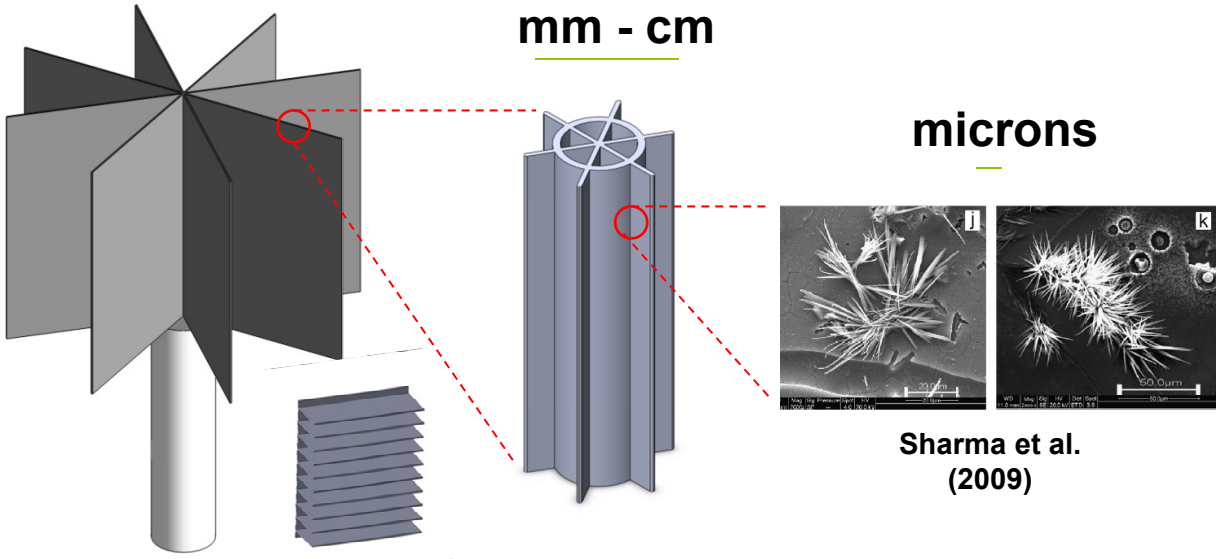
~10 m

Conventional cylindrical solar receiver

meters

mm - cm

microns



Sharma et al. (2009)

New fractal-like designs with light-trapping and low-emittance features at multiple scales

(US Patent Applications: 61/901628, 62/015052)

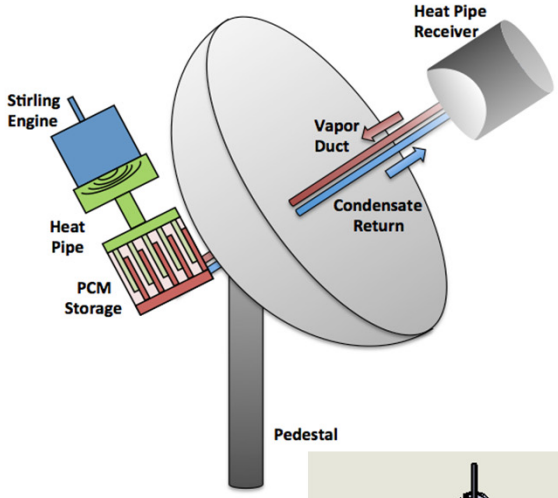
Dish Stirling High Performance Thermal Storage

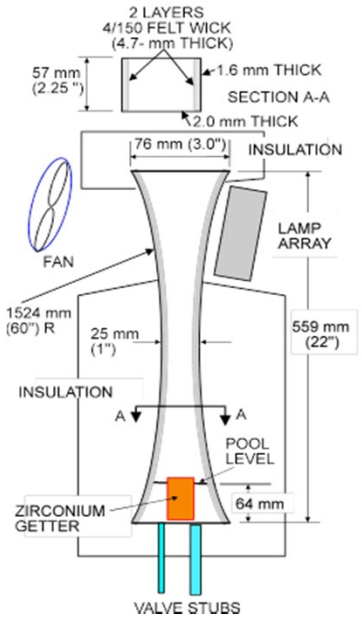
Goal:

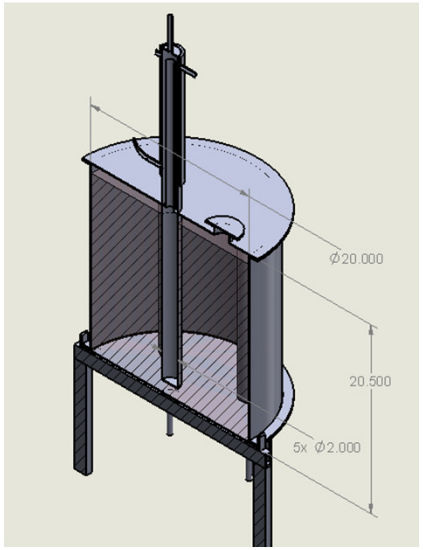
- Demonstrate the feasibility of thermal storage for dish Stirling systems
- Demonstrate key components of a latent storage and transport system
- Provide a technology path to a 25kW$_e$ system with 6 hours of storage at reduced costs

Innovation:

- Develop and validate high temperature, high performance PCM storage
- High performance heat pipes for latent transport
- Latent storage *and* transport matching Stirling cycle isothermal input







High-Temperature Solar Selective Coatings

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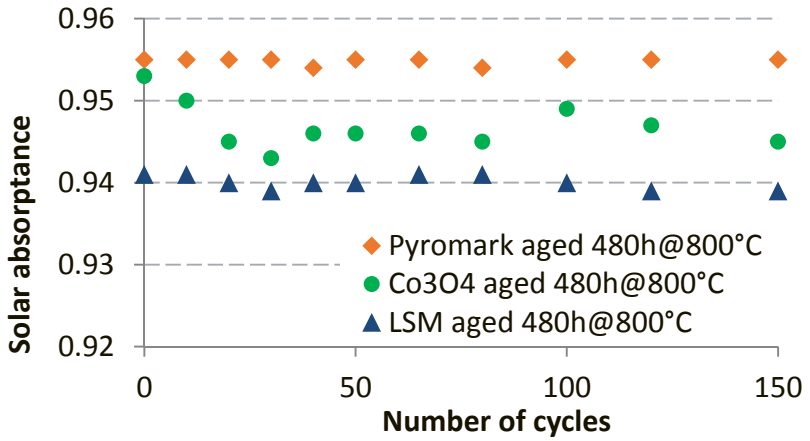
Selective absorber coatings for receivers with high absorptance in the solar spectrum & lower emittance in the infrared, stable in air, easily applied at large scale, cost effective, and survives thousands of heating and cooling cycles

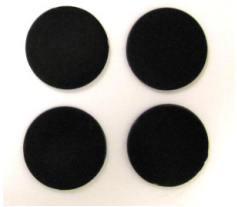
Transition Metal oxides

- –Inherently stable at high temperature and in air
- –Amenable to doping and substitution to chemically tailor their properties
- –Ease of application (thermal spray, paint, dip-coat…)

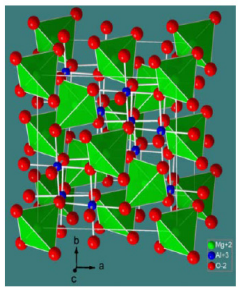
Solar furnace: 150 automatic heating/cooling cycles on already-aged samples

600 kW m^{-2} / 0 kW m^{-2}
850˚C / 100˚C
substrate: Inconel 625



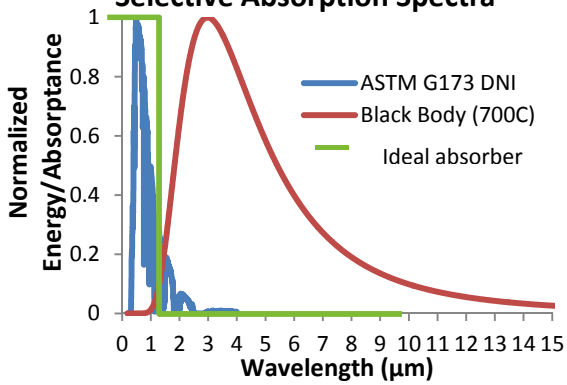


Thermal-sprayed oxide coating, aged 240 h

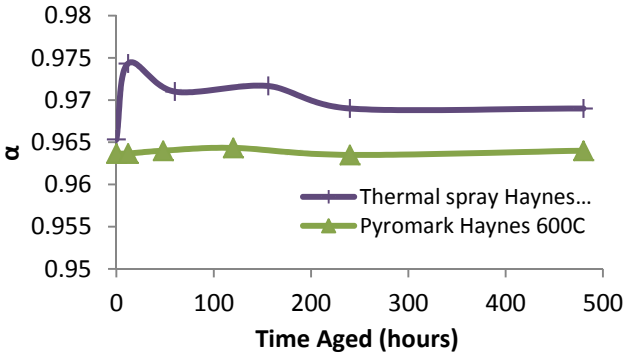


Spinel structure

Selective Absorption Spectra



Absorptance vs Temperature

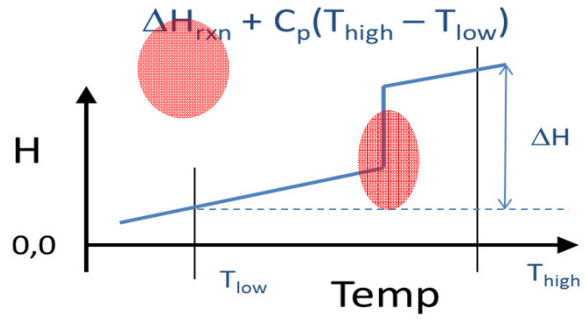


Thermal-sprayed oxide maintains > 96% absorptivity after 480 h at 600 °C (isothermal)

Partners: NREL, DOE SunShot, Abengoa LLC

Thermo-Chemical Energy Storage

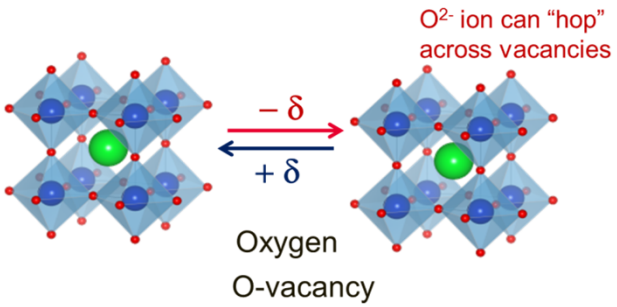
Particles Provide Reaction Enthalpy + Sensible Heat Storage for Increased Capacity, Higher Temperature Delivery

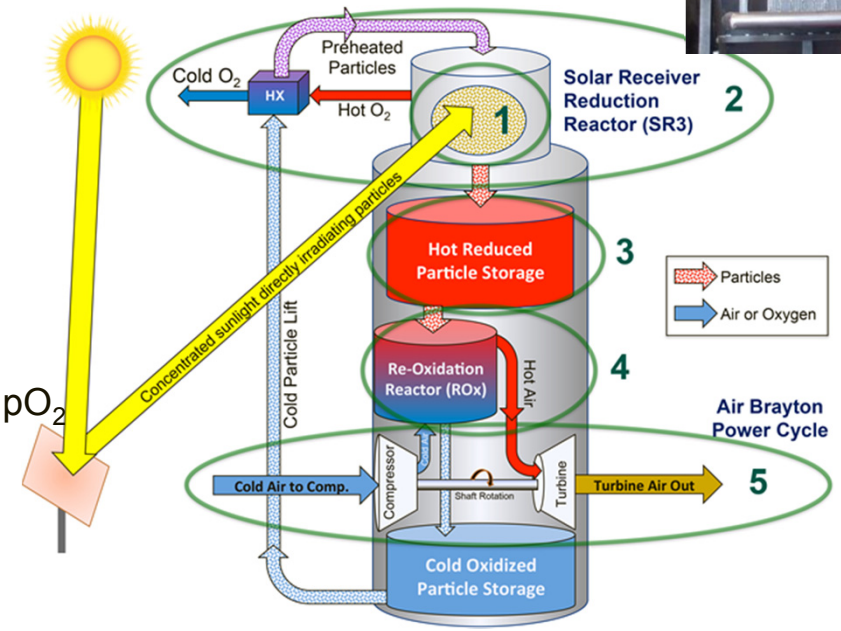


- Falling Particle Implementation
- Integration with CSP leverages previous work and midscale demonstration

Mixed Ionic Electronic Conductors

- Rapid kinetics
- No crystallographic phase change (Stability)
- Highly tunable via cation doping/substitution
- Continuum of redox states as function of T and pO_2



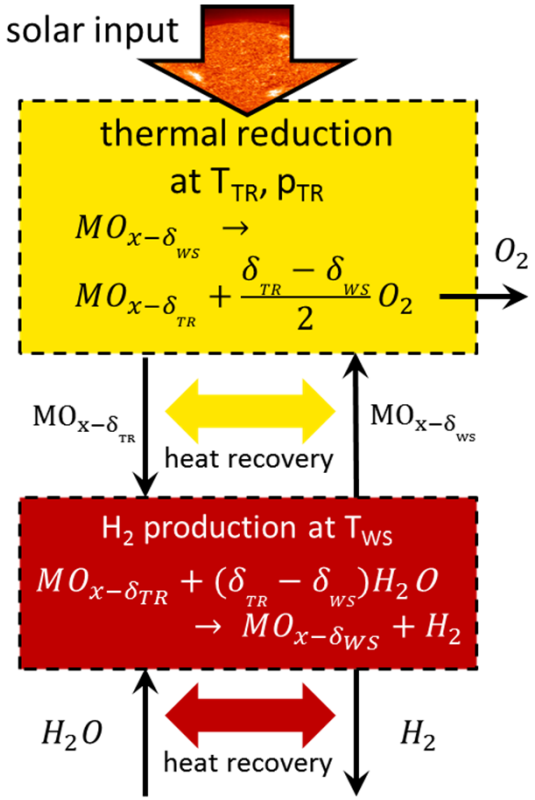


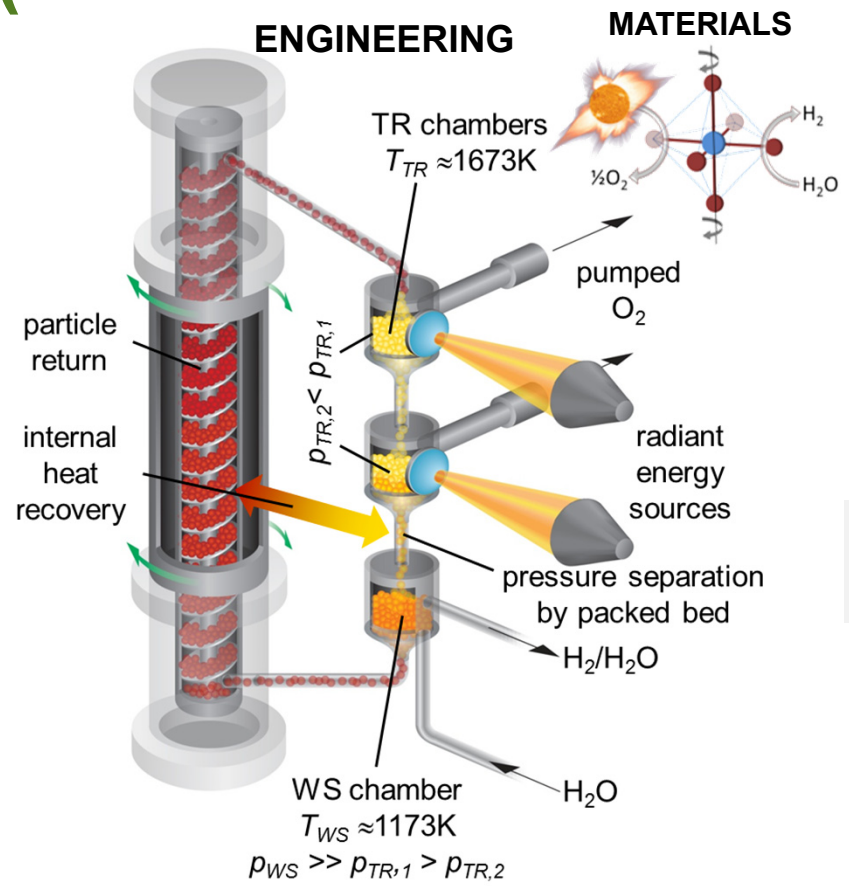
- High Temp/High Efficiency Air Brayton Power Cycle
- Air acts as reactant and heat transfer fluid

High Performance Reduction/Oxidation Metal Oxides for Thermochemical Energy Storage (PROMOTES)

Solar-Thermochemical Hydrogen Production (Fuel Cell Tech. Office)

Sandia National Laboratories





CPR2: From Concept to Device

Compatible with tower system

Process simplicity:

- **Two-step heat engine**

- **Cascading pressure reactor: CPR2**
- **Advanced redox materials**

Efficiency and economics via reactor and materials design

Our Path Forward

Sandia National Laboratories

- Create a platform for regular communication with Industry
- Work with DOE and industry to assure the NSTTF continues to provide relevant capabilities to support the CSP industry
- Work with DOE in collaboration with, Industry, NREL and other National Labs to pursue impactful CSP development projects
- Continue diversification of CSP Group portfolio
- Develop sustainable RD & D activities to support current and future CSP & Solar Thermal Industry needs

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Backup slides

FY14-15 NSTTF Partners

Sandia National Laboratories

Parabolic Trough R&D

PV System Reliability

SUNPOWER

Dish Stirling R&D

Non-CSP Testing

Schafer

EXELIS

Statoil

Thermal Energy Storage R&D

ABENGOA

AREVA

Power Tower

Receivers and Heliostats

University Partners