



U.S. Department of Energy
**Energy Efficiency
and Renewable Energy**

Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable

DOE Solar Energy Technologies Program Peer Review

Technical Track: Concentrating Solar Power

Project Name: Power Tower R&D

Principal Investigator: Greg Kolb (Sandia)

Denver, Colorado

March 9-10, 2009



R&D performed from 10/07 through 2/09

1. Long-distance heliostat test
2. Steam receiver plant model upgrade
3. Power tower software training
4. Solid-Particle receiver test and analysis

Budget from DOE in FY08

- \$233 K for power tower R&D (CSP program)
- \$400 K for particle receiver R&D (H2 program)
 - \$350K for test
 - \$50K for analysis (see Cliff Ho presentation)



- Sandia R&D Team
 - Greg Kolb
 - Cheryl Ghanbari
 - Cliff Ho
 - Nathan Siegel
- Special Recognition
 - 2008 ASME Solar Conference Best Paper Award -- “Design and On-Sun Testing of a Particle Receiver Prototype”
 - Sandia Patent (pending) – “Suction-Recirculation Device for Stabilizing Particle Flows Within a Solar Powered Solid Particle Receiver”



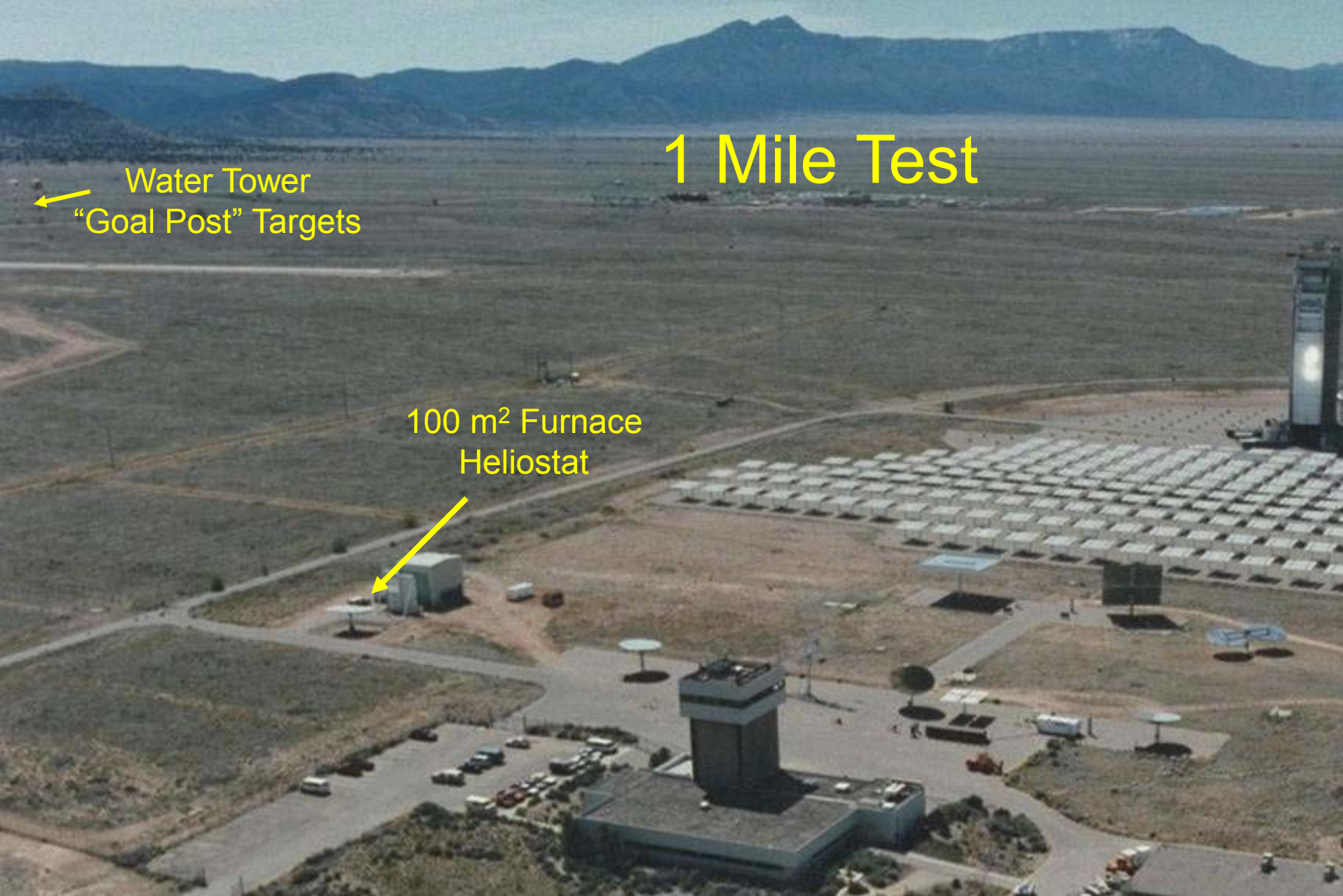
1. Long-distance heliostat test

- Solar Reserve & Rocketdyne are commercializing Solar Two technology
 - 50 to 100 MWe, 540 MWt molten salt receiver, >10X scaleup
 - Rocketdyne is also developing their own heliostat
 - Sandia sent heliostat components to Rocketdyne
 - More than 10,000 heliostats will be used in a commercial project
- Sandia is helping Rocketdyne address technology risk issues
 - Will test new heliostat in 2009
 - Will test new receiver panel in 2010
- Furthest heliostat at Solar Two was 0.25 mile
- Furthest heliostat in commercial plant is 1 mile
- In 2008, we performed an initial test of a Sandia heliostat at 1 mile

1 Mile Test

Water Tower
"Goal Post" Targets

100 m² Furnace
Heliostat





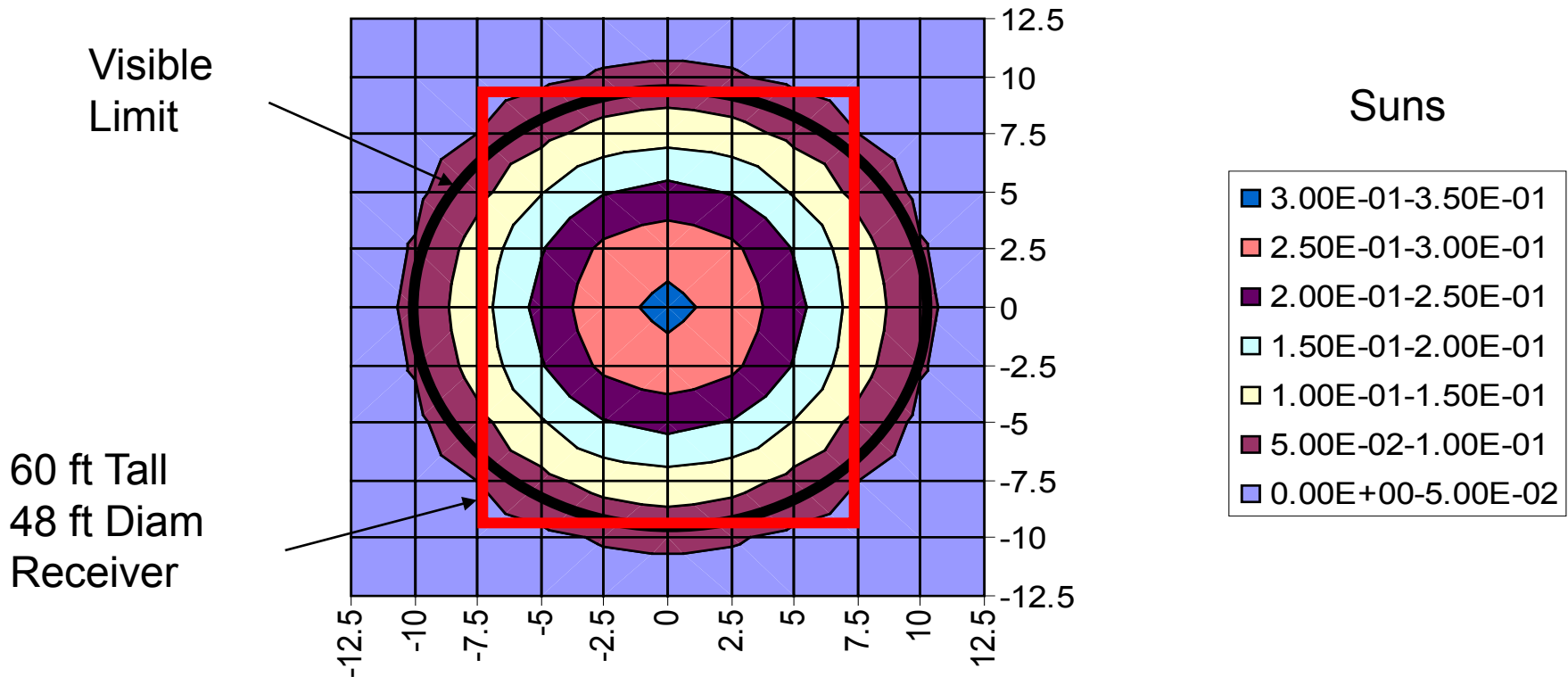
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Approximate Edge of Visible Light from Furnace Heliostat Test vs. DELSOL Prediction



In 2009, we will measure the intensity of the beam



2. Steam Receiver Plant Model

Upgrade

- eSolar and Brightsource are commercializing steam-receiver technology
 - PPAs in place, 2200 MW Brightsource, 245 MW eSolar
- Sandia wrote many reports on the Solar One steam-receiver project
- eSolar wants to fully understand the lessons learned at Solar One
 - For example, MTBF of receiver steam valves is 1.5 yrs, not the 50 yr value that was used to predict the reliability of Solar One before it was built
- eSolar wants help from Sandia to analyze annual plant performance
- Sandia's SOLERGY model was validated with Solar One data in 1987
 - Old version of code not used in 20 years
- In 2008, SOLERGY model of Solar One was recreated and improved
 - Much better prediction on partly cloudy days
 - Storage model removed

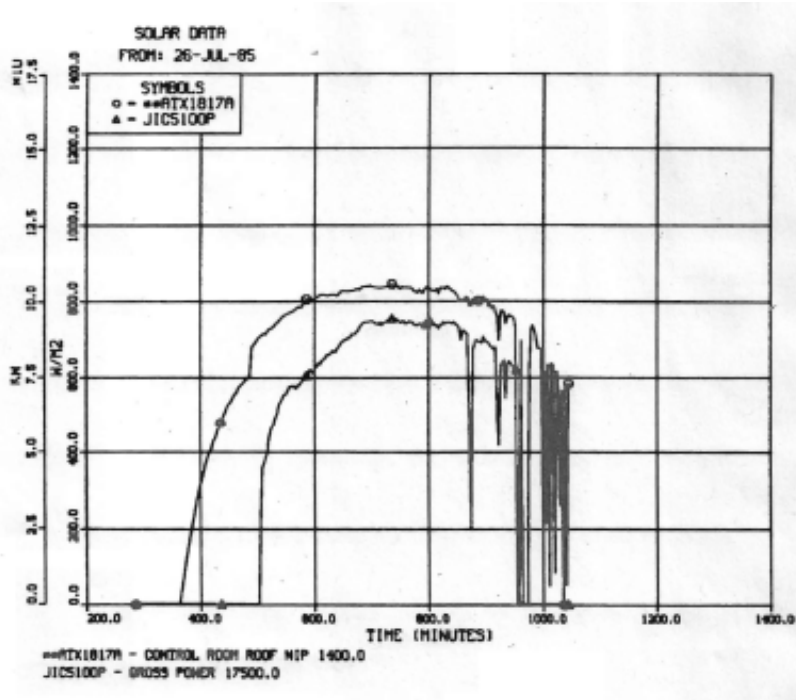


SOLERGY

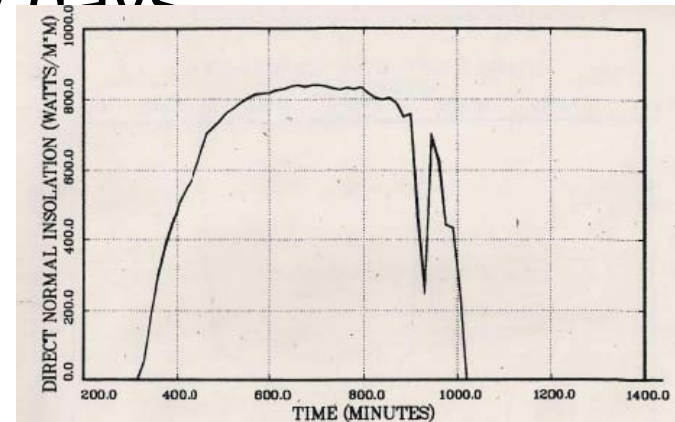
- Reads 8760 hr weather file, 15 minute time step
- Predicts annual kWhrs and subsystem efficiencies
- 1st-Law model, no detailed heat transfer
- Must input experimental-determined performance curves for each subsystem



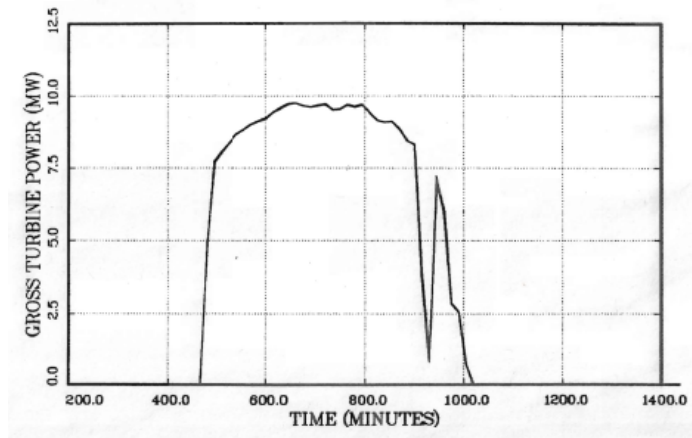
Original SOLERGY over-predicted power production on partly cloudy days



Solar One DNI and Turbine Power Data



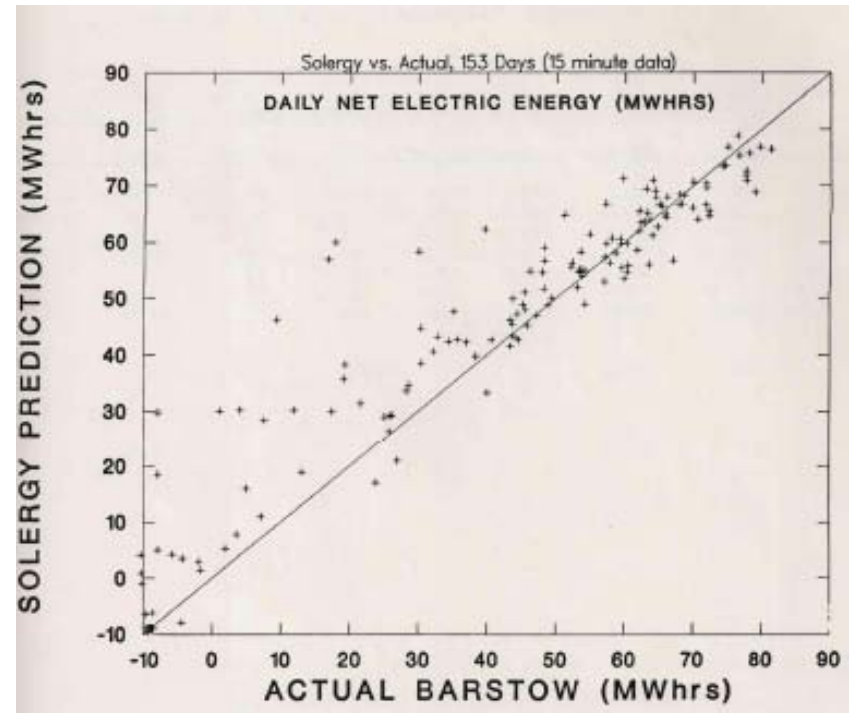
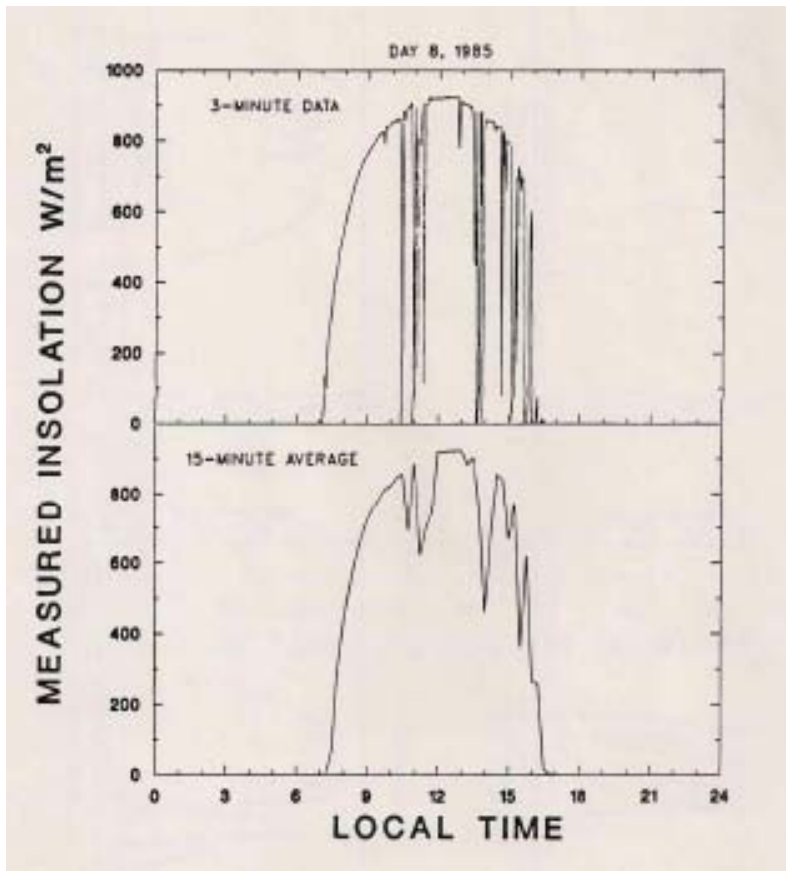
SOLERGY Input DNI



SOLERGY Turbine Power



Original SOLERGY over-predicted power production on partly cloudy days





- New steam-receiver model allows receiver (and turbine) trip in partly-cloudy conditions
- Trip receiver if DNI within a time step is less than XX% of clear-sky value
 - Use of 60% gives a good estimate of actual Solar One

	Solar One DATA	SOLERGY in 1987	SOLERGY Today
Insolation on Heliostats (GWh)	178	178	178
<i>Hours of Turbine Operation</i>	<i>1726</i>	<i>1904</i>	<i>1707</i>
Gross Energy (MWh)	13363	14747	13227
Net Energy (MWh)	8625	10048	8873



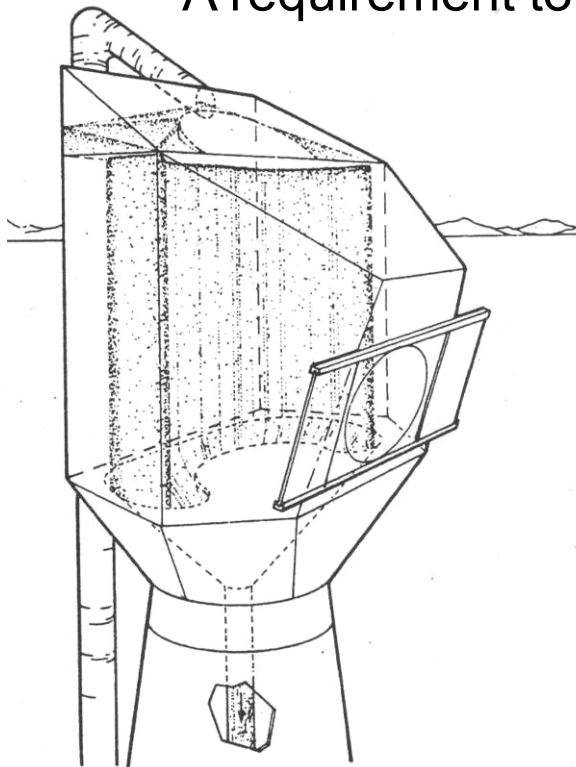
3. Power Tower Software Training

- SolarReserve/Rocketdyne optics analysis software is not user friendly and takes too long to run
 - This was greatly hindering their ability to quickly perform feasibility studies
- We compared predictions of Sandia's DELSOL software with Rocketdyne's software
- DELSOL gives similar results but is easier to use and runs much, much faster
- In 2008, Rocketdyne was trained on use of DELSOL and SOLERGY
- DELSOL and SOLERGY are now core tools at Rocketdyne

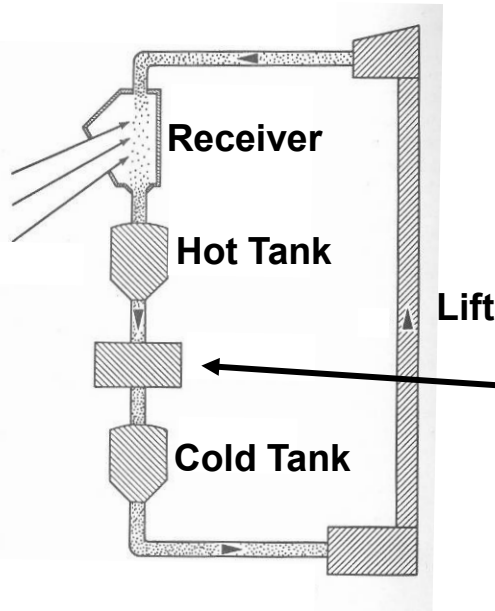


4. Solid-particle receiver

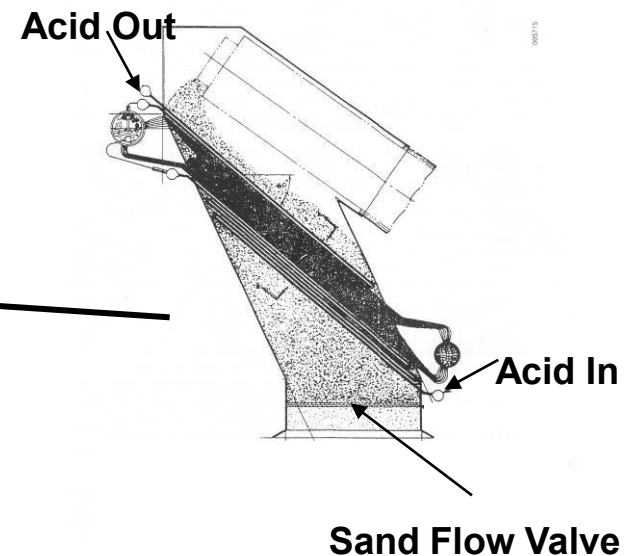
- Sandia performed early R&D in mid 1980's
- Capable of operating at 950 °C to power sulfur-hybrid and other H₂ cycles
- Falling curtain of "sand" within a windowless cavity
- Low-cost energy storage allows "around-the-clock" operation
 - A requirement to interface solar with complex thermo-chemical H₂ plant



Receiver/Storage Concept



Particle-to-Acid Heat Exchanger





A very large molten-salt power tower using a low-T electrolyzer can produce H₂ today. This is the competition the solid particle receiver must *significantly* beat.

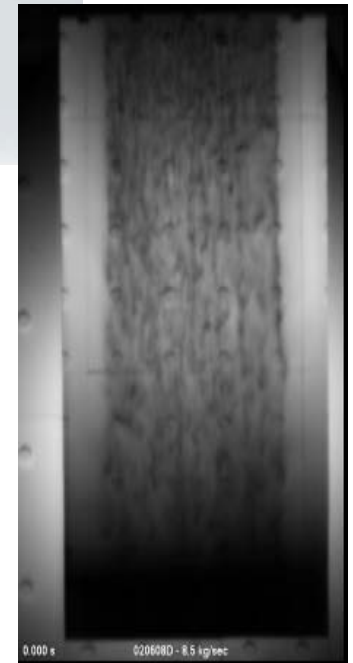
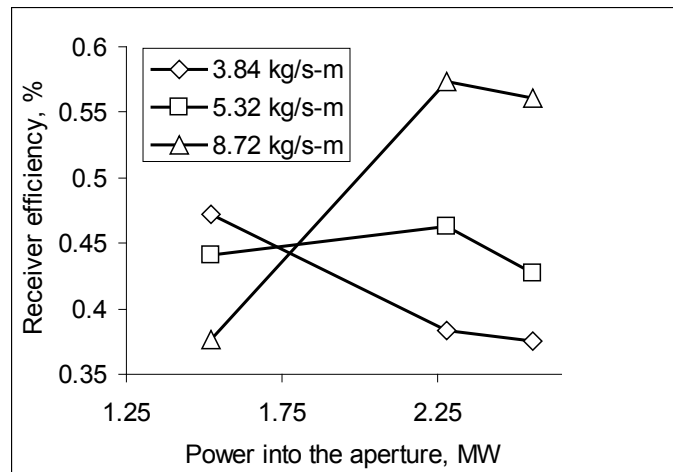
- To beat the economics of solar-electrolyzer plant, the solar-thermochemical plant must be very large to achieve the economy of scale already possible with the solar-electrolyzer plant
- Analysis using DOE's H₂A software suggest this may be possible
 - Potential showstoppers include <70% receiver efficiency and wind problems

Levelized H ₂ Cost (\$/kg)	
Tower-Electrolyzer (700 MWt)	Tower Sulfur-Hybrid (700 MWt)
\$4.70	\$3.00

1 kg H₂ = 1 gallon of gasoline



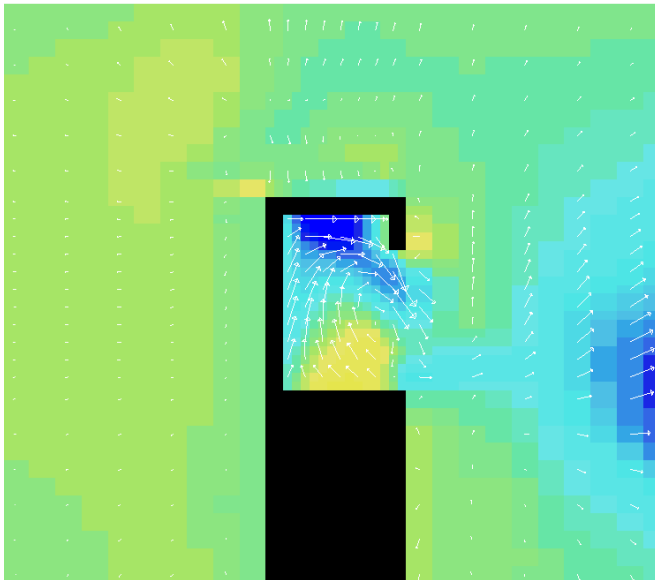
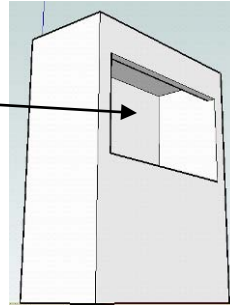
A first non-optimized 2.5 MWt test was performed at Sandia in 2008





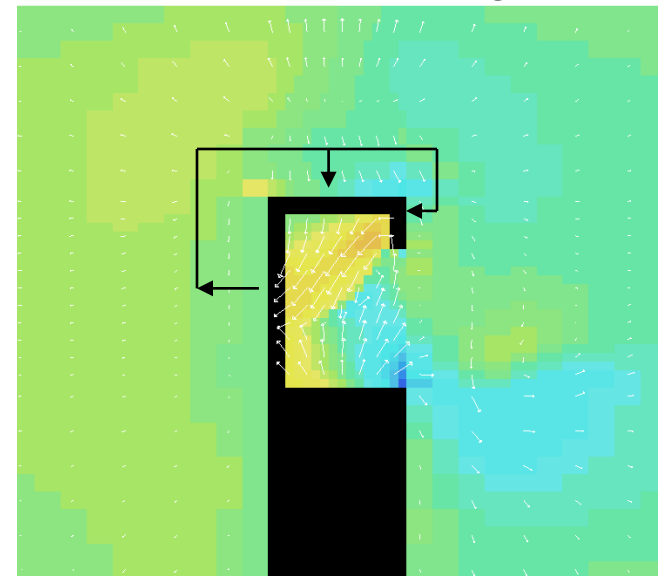
Defeat of the wind showstopper looks promising

~10m aperture in commercial receiver



10 m/s wind from an oblique angle causes particles near back wall to be expelled from open aperture

Patent Pending



With suction-recirculation device activated, particles near back wall are not expelled from aperture



Future Directions

- Rocketdyne – heliostat and receiver panel tests
- eSolar – receiver measurements and SOLERGY modeling
- All power tower developers – tech transfer
 - Power tower software training
 - Lessons learned from experimental programs
- Sandia in-house R&D
 - Development of portable power-tower testing tools
 - Heliostat CAD modeling and design optimization
 - Seek funding for particle-receiver proof-of-concept test