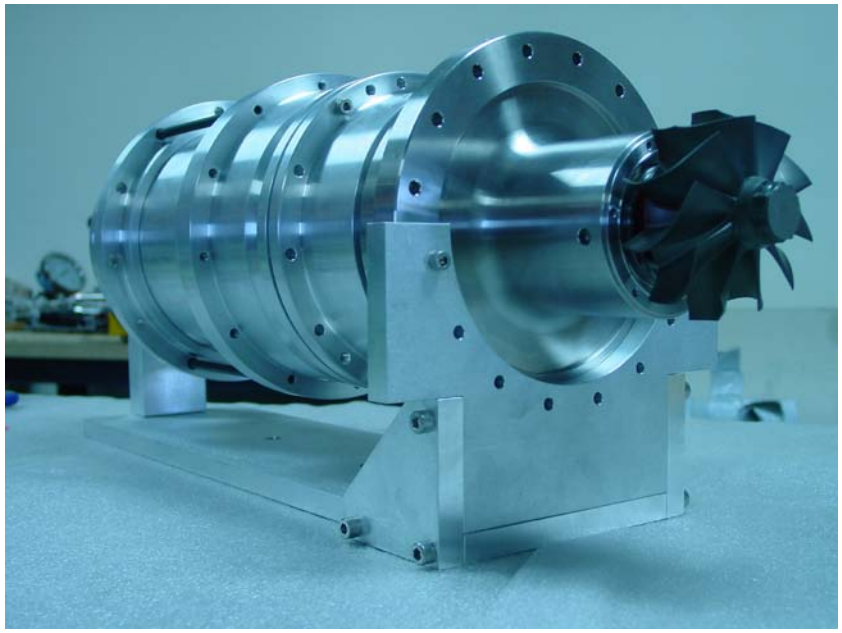

Brayton Solar Power Conversion System

CSP TEAM

Brayton Energy, LLC
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May 23, 2010

Overview

Timeline

- Project start date: Jan 1, 2008
- Project end date: Dec 31, 2010
- Percent complete: 58% by spending

Barriers

- The dish, not part of the program, has delayed the testing of the prime contract deliverables: receiver and complete PCU
- Funding

Budget

- Total project funding allocation
  - DOE share = **$2,230,435**
  - Contractor share = **$1,969,426**
- Funding received in FY08: $ 271,613
- Funding received in FY09: $ 843,384
- Funding received in FY10: $ 176,262

Partners

- Project lead:
  Brayton Energy, LLC
- Interactions/collaborations:
  - SolarCAT Inc.
  - ORNL, NREL, SNLA

Challenges, Barriers or Problems

MARKET BARRIERS

- Product capital cost
  - Overcome by this project:
    - Technical demonstration of critical technology subassemblies of a PCU (engine and receiver) – working towards a capital cost ~$1000/kWe-peak
  - Not addressed on this project:
    - Energy storage does not receive the ITC
    - Solar with energy storage system subject to ambiguous treatment of Renewable Energy Credits (RECs)

SUPPORT OF DOE'S MISSION OF WIDESPREAD ADOPTION

- Sustained joint participation with DOE is critical element of this project. DOE funds are highly leveraged by private sponsors in the following areas:

  1) Advanced CSP research
  2) CSP Dish
  3) SolarCAT manufacturing plan
  4) Future pilot-plant site and infrastructure

Relevance

SolarCAT provides two energy solutions:

1. Solar plant with compressed energy storage
2. Stand-alone Dish-Brayton module

➢ Both show potential of producing power competitive with today's fossil-fuel power plants

<u>Objectives & Accomplishments (March 2009 - May 2010)</u>

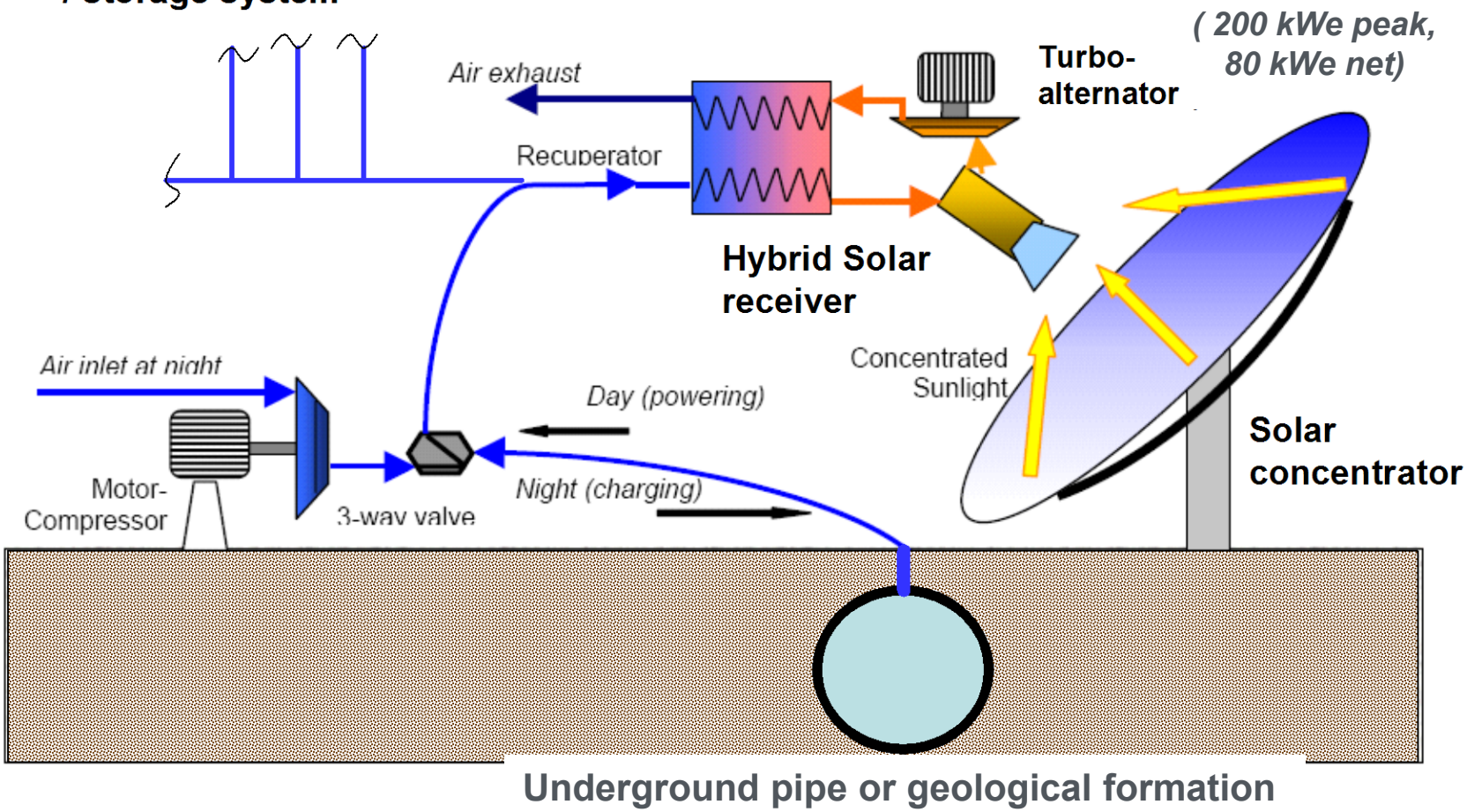
Built and tested the common subassemblies

- 320 square meter dish
  - Testing the boundaries of scale in attempt to lower cost
- Built & delivered an advanced solar receiver
  - Capable of long life
- Built and tested a high speed turbo-alternator
  - Air-bearing mechanical system
  - No wear while eliminating ancillary lube and cooling systems
  - Utilizes low cost turbocharger components

Approach (CAES)

5 to 50 Dish-modules fed by the central compressor / storage system

Brayton is building and testing the complete PCU on a dish supplied by SolarCAT Inc.



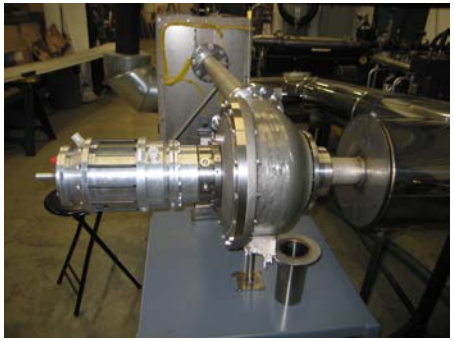
Collaborations

Brayton Energy, LLC – Hampton, NH

- Turboalternator
- Receiver
- Recuperator
- Man-made storage vessel (studies only)

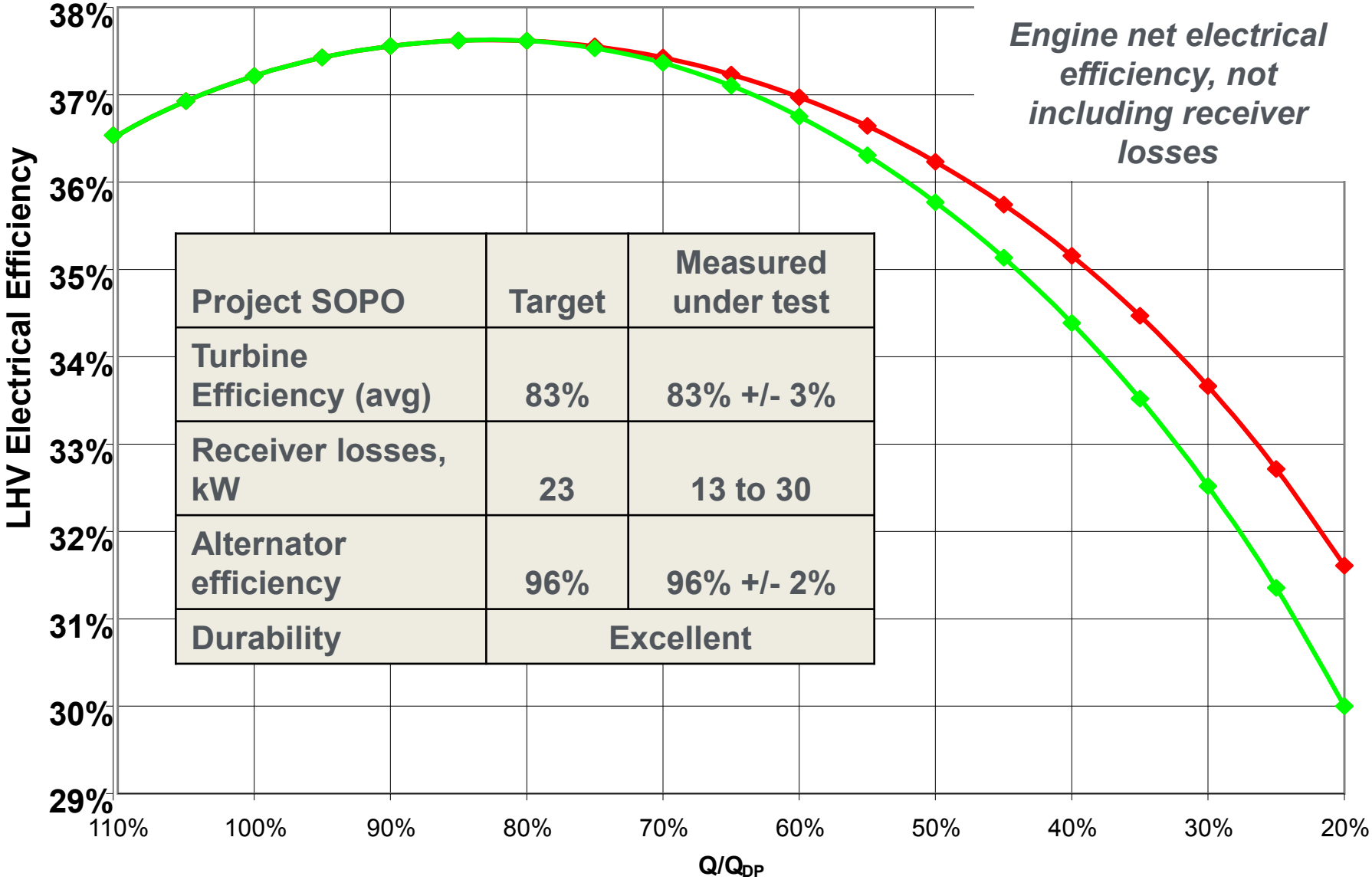
SolarCAT Inc. / Southwest Solar Corp. (John Sperling)

- CSP Dish
- ~20,000,000 cf salt dome (~1 GWH capacity)
- Surrounding land for 100 MWe-peak plant, Arizona



ORNL: materials analysis **NREL**: mirror analysis **SNLA**: design reviews

Accomplishments: Solar-Electric Efficiency



Project SOPO	Target	Measured under test
Turbine Efficiency (avg)	83%	83% +/- 3%
Receiver losses, kW	23	13 to 30
Alternator efficiency	96%	96% +/- 2%
Durability	Excellent	

Turbine Rotors with Air Bearings

Turbines

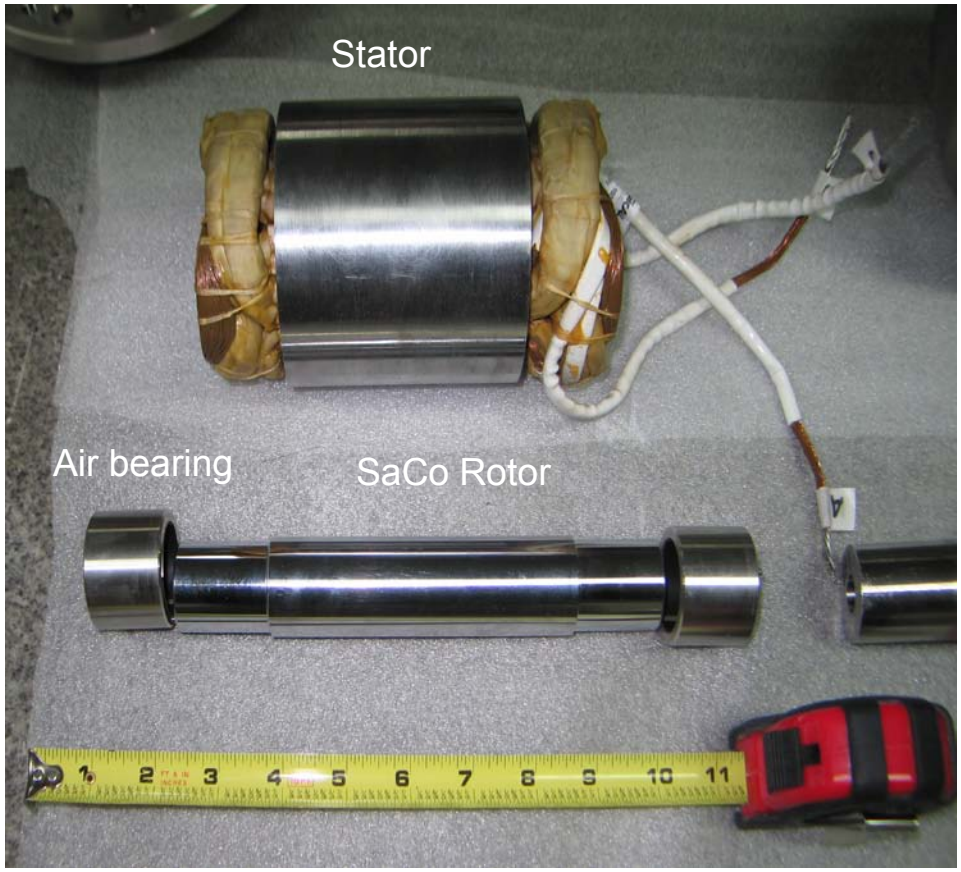
- 78 mm diameter
- 120,000 RPM
- Turbocharger turbine rotor (bottom figure) cost $80/each in small retail quantities

Air Bearings

- Incur no shaft wear and require no ancillary lubrication or cooling subsystems

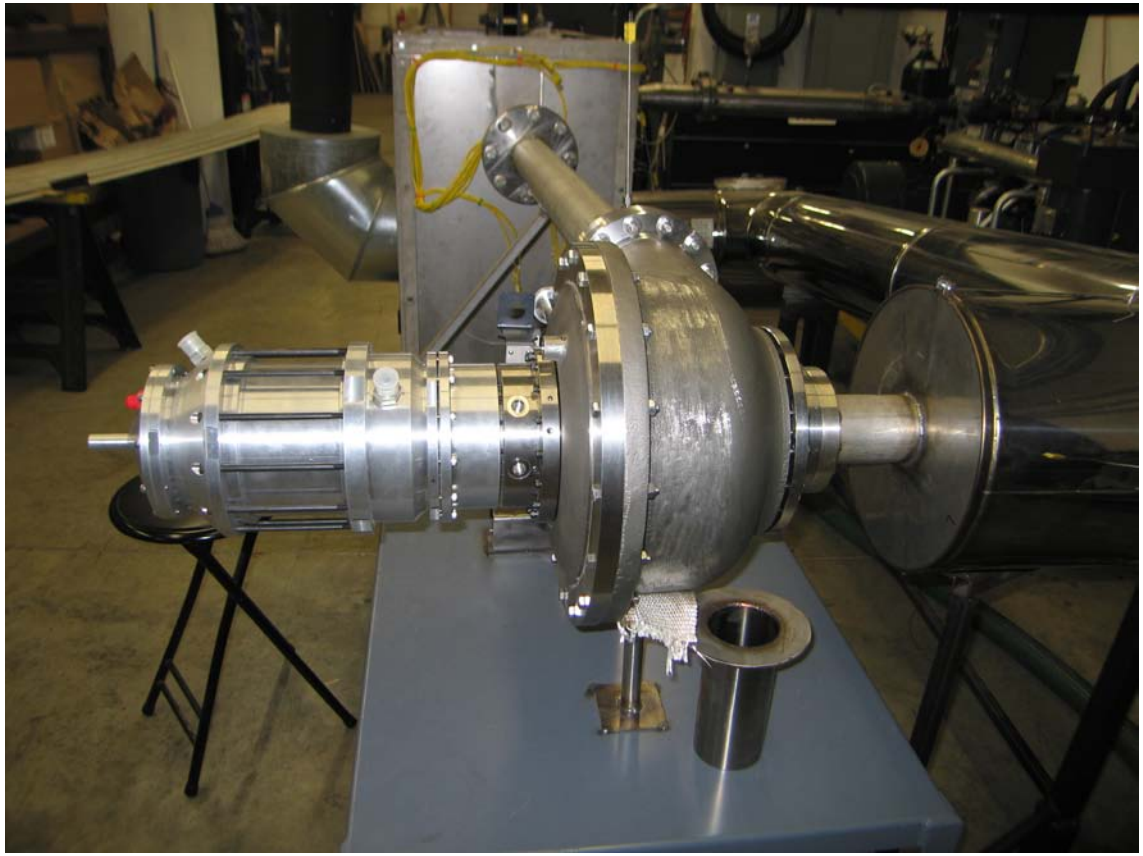
Brayton 'SolarCAT' Turboalternator

- Shaft speed alternator
  - High power density
  - 53 kWe is about 4" in length and 4" in overall stator diameter
- Mechanical & electrical systems have demonstrated exceptional durability under 60 hours of test
- Provides variable speed for excellent part-load efficiency
- Purpose built air-cooled design



Brayton 'SolarCAT' Turboalternator

- Part load performance mapping on Brayton's recuperated test rig
- Hybrid / supplemental fuel – compliant with utility demand for 'firm power'
- Test time >60 hours (SOPO target is 50 hours)



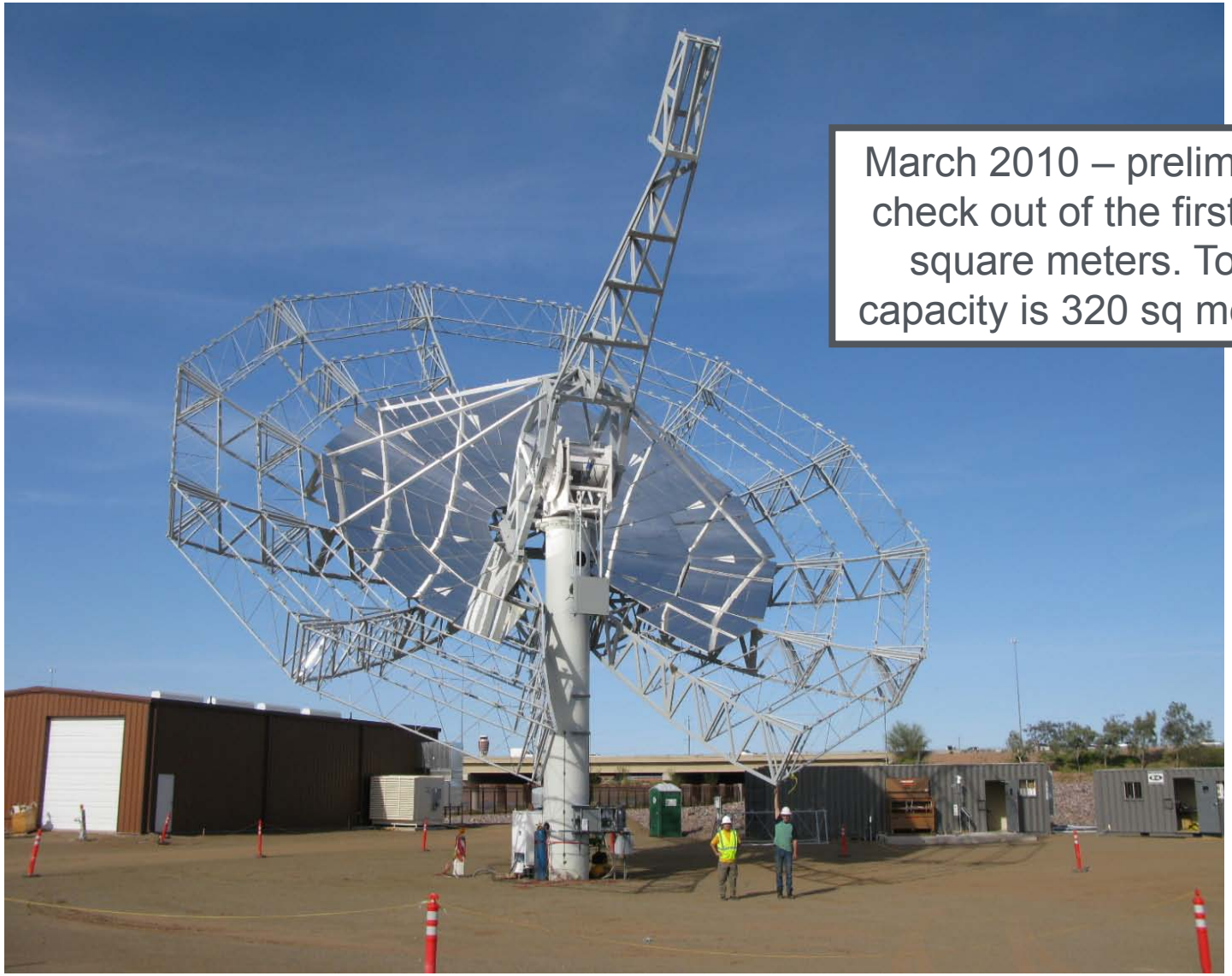
Rigorous test facilities have been built with commercial support: Arizona Public Service and Sempra Energy

Accomplishments: Receiver Test Rig

- Custom receiver test rig, prepared for on-sun characterization
- Delivered to test site May 1, 2010
- Pre-delivery testing
  - Hydro pressure (leak) test
  - Thermal cavity loss test using internal electric heaters

Receiver and test equipment arrive at dish site in AZ

Accomplishments: SolarCAT Dish



March 2010 – preliminary check out of the first 100 square meters. Total capacity is 320 sq meters.

Budget Status and Potential for Expansion

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

DOE FY	DOE, $	Cost Share, $	Cost Share		SolarCAT/ Brayton $	SolarCAT Dish & NRE, $	Net cost share, $
FY2008	271,613	74,030	21.42%		793,897	1,190,846	13%
FY2009	843,384	376,855	30.88%		3,175,589	4,763,383	10%
FY2010	176,262	79,190	31.00%		1,323,162	1,984,743	5%
FY2011	939,176	1,439,350	60.51%				
TOTAL	2,230,435	1,969,426					

Status:

- Received 'Go' for Budget Period 2 (02/2009)
  - Proposal for PCU did not define dish for testing
  - Milestone added to require testing of 320 sq meter dish (not budgeted)
  - SolarCAT Inc. embarked on dish development in 2009 (private funding only)
  - BP2 funds expended in early Jan '10, yet milestones associated with the dish and dish/receiver are not complete
- Release of Budget Period 3 funds (to have started in Jan 2010) would enable us to proceed with fabrication of the complete PCU so that it will be ready when the dish is finally commissioned. (Includes $103K from DOE towards dish)

Potential for Expansion

SolarCAT Redesign	**DOE**	**Private**	**Goals**
Design to cost BETA TurboAlternator	$ 600,000	$ 600,000	Cost target, reduced complexity
Advanced solar receiver	$ 700,000	$ 700,000	50% weight reduction, 50% reduced cost
Field Testing	$ 500,000	$ 500,000	Extended durability testing and analysis
Next Generation Dish	-	$3,000,000	Target of $250/sq meter

**** Budgetary estimates prepared for this PEER review.***

More engineering development is required to achieve product maturity, and secure pilot-plant project financing.

Future Plans (FY 2011 and beyond)

- Budget Period 2: Commission and characterize dish (private funding only) through August 2010
- Install and test Brayton solar receiver test rig – September & October 2010
  - Demonstrate receiver efficiency >86%
- Complete power conversion unit (PCU) assembly and ship second unit to the dish site - Budget Period 3
  - Brayton requests partial release of Budget Period 3 funds to minimize schedule slippage
- Budget Period 3: Test complete PCU on dish
  - Projected completion before Jan 2011

Summary

- SolarCAT is an advanced solar energy conversion system that utilizes high efficiency Brayton cycle turbine engines
  - Energy storage (CAES) with exceptional efficiency and durability (optional added to Dish Brayton)
  - An advanced Power Conversion Unit with no mechanical wear and no ancillary accessories such as lube or cooling systems
  - Overall net conversion efficiency > 30%
  - Hybrid fuel option and dispatchable energy storage system

- Partners (SolarCAT Inc. and Southwest Solar Corp.) have procured a unique site with an existing salt cavern suitable for roughly 100 MWe-peak and 1 GWH compressed air energy storage capacity at a site near urban Phoenix