# Solar Energy Technologies Program Peer Review

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


## High Efficiency XR-700 Concentrator Photovoltaic System

Program Team: PV

**Mark Ventura,** Deputy Program Manager

Organization: The Boeing Company

Contact Info:

Date: May 26, 2010

# Overview



## Timeline

- Project start date: July 2007
- Project end date: Dec 2010
- Percent complete: 90%

## Budget

- Total project funding
  - DOE share: $19.6 M
  - Contractor share: $26.3 M
- FY09 Funding Received
  - DOE: $ 4.67 M
  - Contractor: $ 13.26 M
- FY10 Funding Received
  - DOE: $ 5.01 M
  - Contractor: $ $ 8.83 M

## Barriers

**Modules**

- **Material Utilization & Cost**
- **Design & Manufacturing Processes**
- **Efficiency**

**Inverters & Other BOS**

- **Inverter Reliability**
- **BOS Cost & Installation Efficiency**

## Key Partners

SPECTROLAB

A BOEING COMPANY

LPI LIGHT PRESCRIPTIONS INNOVATORS

PV Powered

**Solar Cell Design & Mfg**
**Optical Design & Mfg**
**Inverter Design & Mfg**

## Commercialization Partners

SES Stirling Energy Systems

Tessera Solar™ power from stirling energy systems

NTR Securing a Greener Future

# DOE's R&D Leveraging CPV to Achieve Grid Parity by 2015



***Develop a new concentrating photovoltaic (CPV) system incorporating high-efficiency multi-junction cells and non imaging optics for the utility-scale PV power market.***

- Advance production solar cells technology & cost reduction
  - Drive efficiency from 36% to 40% by 2010 and to 45% by 2015
  - Realize >2x reduction in cost
  - Increase production capacity to 1 GW/year by 2015.
- Implement advanced high concentration non-imaging optical system
- Advance reliability and cost of the tracker system and balance of plant
- Achieve Grid Parity - $0.15/kWh LCOE by 2010 and $0.07/$kWh by 2015

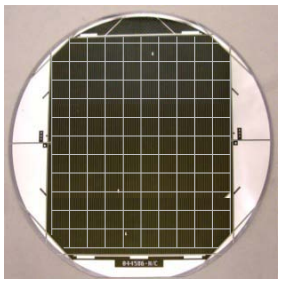
**May 09- May 10 Key Objectives**

- Demonstrate 40% production cells & cost roadmap production automation
- Partner with U.S. company to enable manufacturing scale-up & commercialization
- Demonstrate Proof of Design outdoor exposure performance stability for first year
- Improve module efficiency & demonstrate with Proof of Manufacturing production
- Demonstrate process & cost down via pilot production using robotic assembly line
- Demonstrate BOS installation and cost via 100 kW power plant deployment

# SETP Develops Key Technologies Enabling Scale-up & Low Cost



### Solar Cells and Receivers
- ✓ Efficiency improvements
- ✓ Production scale-up and automation



### Solar Array Assemblies
- ✓ Design for automated robotic manufacturing
- ✓ Single piece array assembly eliminates field alignment, reduces field installation cost


### Optics
- ✓ Advanced design reduces pointing accuracy requirements
- ✓ Lower cost of all associated system components required for accurate tracking

### Inverter
- ✓ Deployed 260kW product to PV market
- ✓ Improved reliability reduces O&M costs

### Tracker
- ✓ Design integration/ parts reduction lowers cost
- ✓ Automatic calibration to cancel sun pointing errors

# Boeing & DOE Developing Utility Class Solar Based on Concentrated Photovoltaic Technology (CPV)

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## Boeing & DOE High Efficiency Concentrated Photovoltaic Array

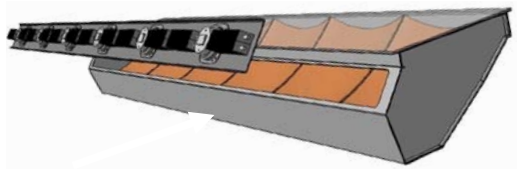

- **Power: 3.4 kW (Net-AC)/array**
- **Power: 158.4 W (DC)/module**
- **24 modules per array**
- **Factory aligned panel lowers field installation costs**
- **Low cost dual axis tracker system**

## CPV Solar Module

- Off-axis non imaging optics design

6 High Efficiency Solar Cells

6 Thermal Control heat pipes



6 Primary Mirror & Secondary Optic Pairs

- **Features;**
  - **> 750 Suns Concentration**
  - **High Efficiency - > 40% Cell; >30% Module**
  - **Negligible O&M**
  - **Air cooled (No Water required)**

# Spectrolab Cell Production Efficiency

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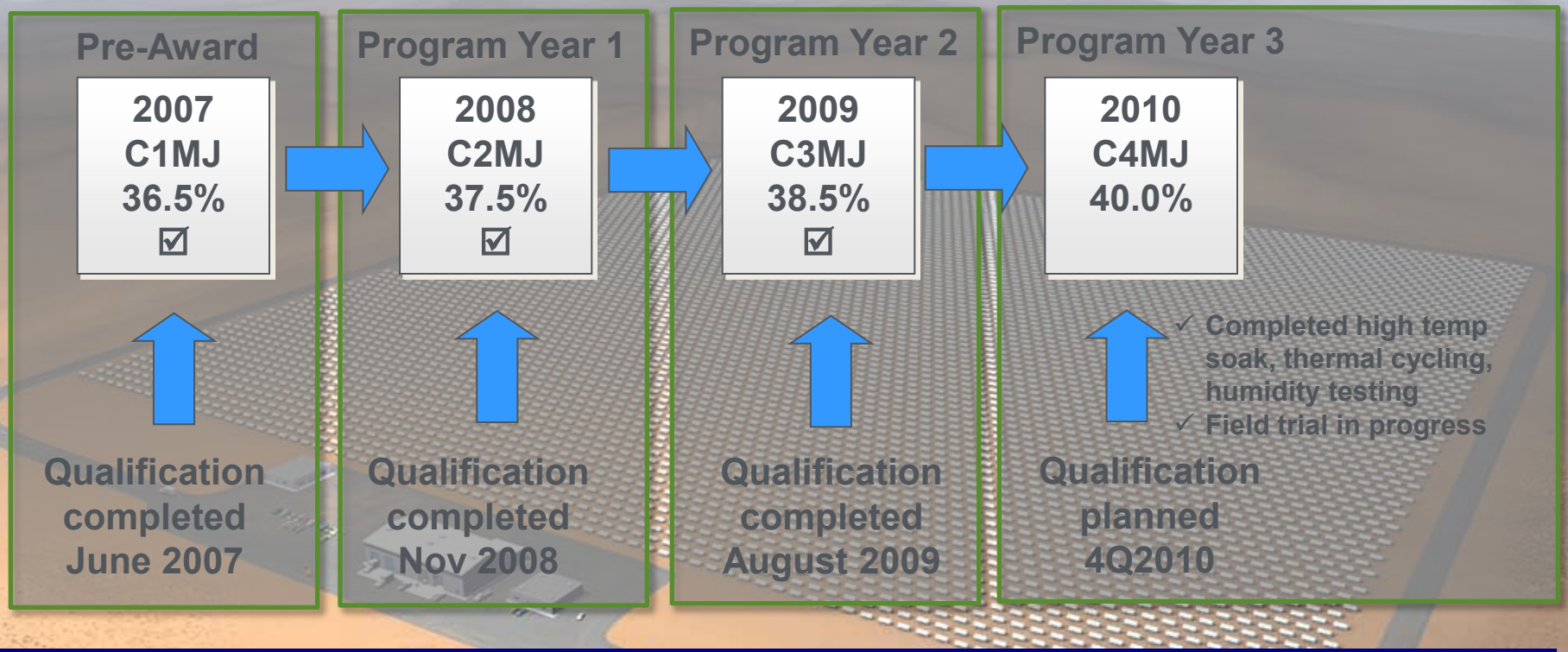
## Program Goals and Achievements

- Improve average production cell efficiency from 36.5% to 40%
- Reduce cost by >50%
- Demonstrate reliability through qualification tests and field trials




***The Spectrolab Technology Pathway Partnership program delivers lower cost, higher efficiency and proven reliability to the CPV industry***

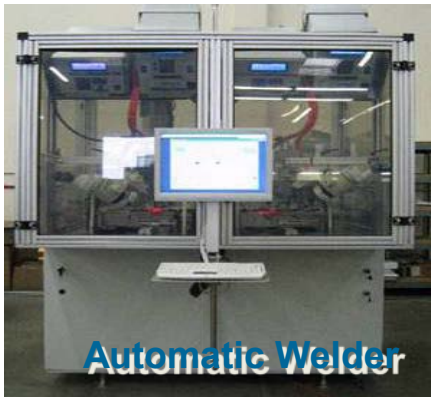
# Improvements in Factory Automation






*Spectrolab steady progress in cost reduction through automation*

- New MOVPE reactors offering larger capacity per run, more automated operation, finer control of process variables, shorter cycle time, and reduced material usage
- Fully automated wafer-level test offering flexible test capability for cells of any size
  - Cells sorted into matched performance bins via an electronic map delivered with the wafer.
- Automated dicing saws
- Automated pick & place for parts removal from saw dice tape
  - Capable of sorting into bins from wafer test map
- Automated bare cell tester capable of dark IV, light IV and FBIR testing and sorting of cells
  - Automated welding of cell interconnects





# CPV Technology Licensed to SES for Commercial Deployment



## *Boeing CPV Technology Licensed to Stirling Energy Systems*

- SES & Boeing commercialization plan
  - 2010 Cost reductions in 2010
  - 2011 Low volume production (1-2MWp)
  - 2012 High volume production

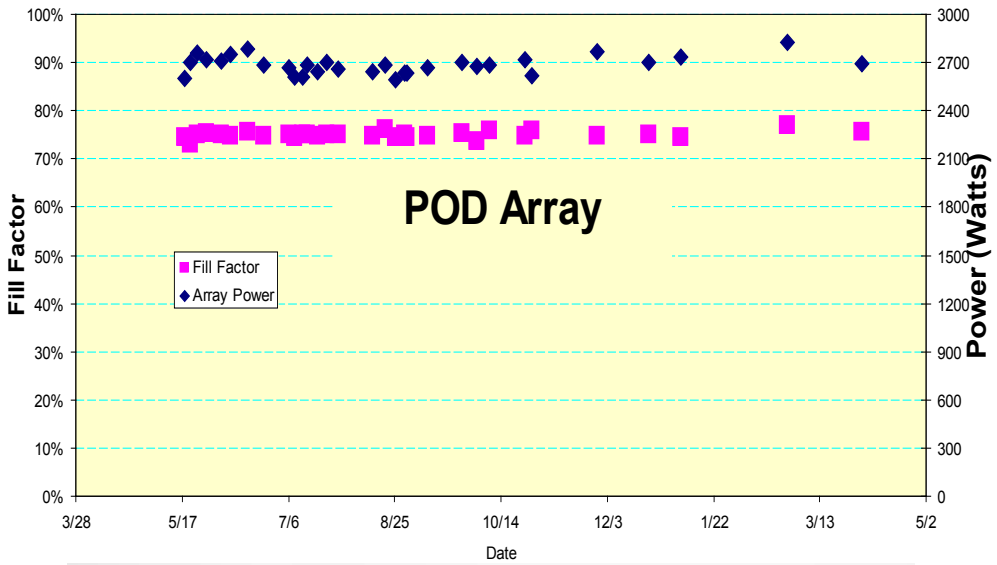
- Boeing drive product & technology evolution
- SES / Tessera drive commercialization
  - Provide demand pipeline for CPV
  - Provide high volume supply chain expertise
  - Exploit synergies with SunCatcher

"This venture with Boeing represents an ideal opportunity for SES to extend our reach into the solar market for future technology deployments with a product that shares many of the SunCatcher's key differentiating features – scalability, low water use and high efficiency," said SES CEO Steve Cowman…

# Module Design & Efficiency Improvements



- Panel Performance Stability Good
  - 5/2009 – 5/2010
  - <0.1% degradation in power
- Module Design Improvements
  - Performance and Cost
  - Production cell efficiency 38.5%
  - Optics manufacturing and coatings improvements yield higher efficiency
  - Pilot line robotic assembly yields highly repeatable alignment
  - 3500 W average Array power predicted for 100 KW demo




**Industry leading performance achievements and outdoor exposure stability paving cost and reliability road to commercialization**

# Low Volume Pilot Production Demonstration




- Final design, installation, and automation validation completed this year
- Full Production of 32 panels in progress (4/26 through 6/14)

**Pilot production demonstration validates design for low cost manufacturing approach**

# Power Plant Construction & System Integration Demonstration

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- **100 kW Demo Site at California State University Northridge (CSUN))**
  - Design & Infrastructure Improvements Complete 5/23/10
  - All equipment fabricated and on site
  - Panel installation underway (5/11 through 6/18)
  - Network and Field Monitoring Software and Hardware in place
  - Utility connection agreements with LADWP in place
- **Inverter Commercial Production, Certification, and CPV field Demo**
  - PVPowered 260 kW Inverter Commercial Production, UL1741 Cert, CEC listed
- **Low Cost Tracker Architecture, Development, and Design is complete and in deployment**
  - High acceptance angle optics permits elegant low cost Boeing tracker design and integration
  - Open loop architecture puts the control at the array, status reported back to central data system


100kW Proof of Manufacturing Site
Northridge, CA


Underground Utilities install


Inverter


Tracker

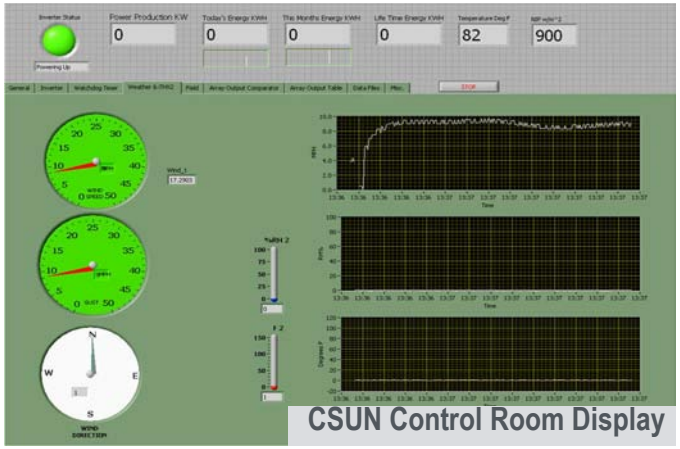
# University Collaborations



## CSUN 100KW CPV Control Room Display

Leverages CSUN unique interest in advanced alternative power

- Complements CSUN PV, fuel cells, and CO2 capture projects
- Real time control room
  - Data from each of the array
  - Site instruments (weather and wind etc.)
  - Inverter Data
  - Provides a historical data base
  - Verifies system performance



CSUN Control Room Display

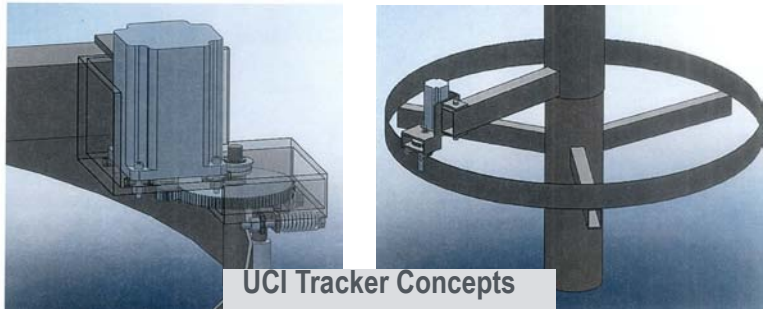
## CU roof top tracker project

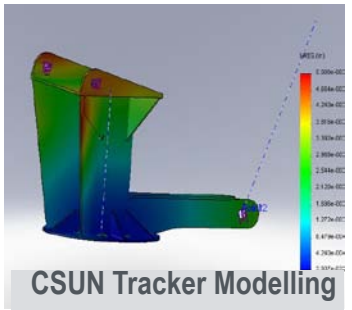
3 year collaboration with Colorado University, Boulder Professor Frank Kreith.

- 2010 Prototype built and operated

## UCI & CSUN tracker studies

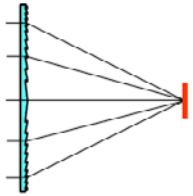
- UCI ground based 2 axis tracker
- CSUN ground based tracker

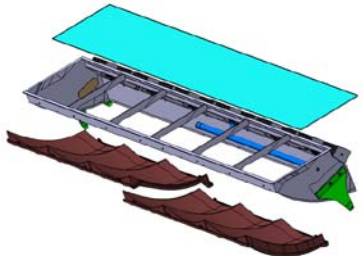

UCI Tracker Concepts


CSUN Tracker Modelling

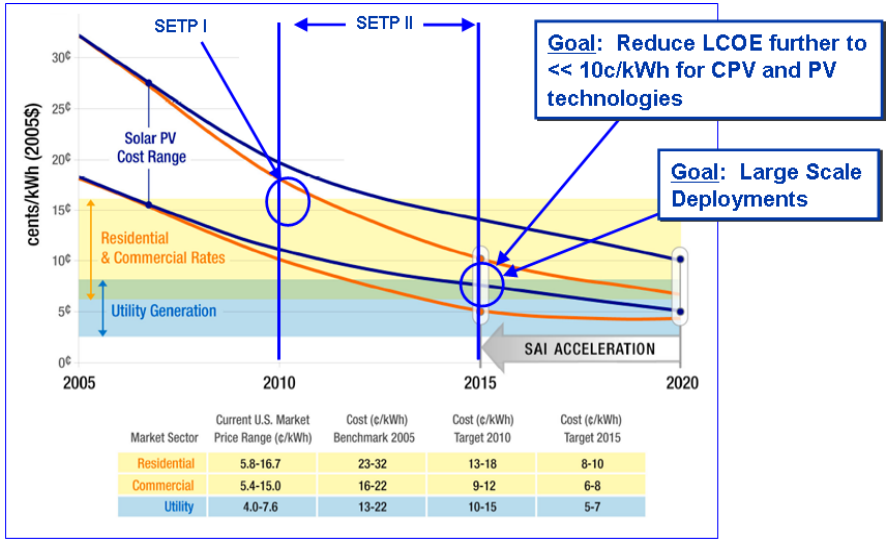
# Future Research enables roadmap to grid parity by 2015







- Solar cell efficiency- Driving towards 50%
- Manufacturing processes- mirrors, coatings, high volume assembly systems
- Next generation optical architectures
- Next generation module & tracker
- Reliability testing
- BOS optimization
- Wind tunnel testing / load reduction
- Structural code interpretation & standardization




| Market Sector | Current U.S. Market Price Range (¢/kWh) | Cost (¢/kWh) Benchmark 2005 | Cost (¢/kWh) Target 2010 | Cost (¢/kWh) Target 2015 |
|---|---|---|---|---|
| Residential | 5.8-16.7 | 23-32 | 13-18 | 8-10 |
| Commercial | 5.4-15.0 | 16-22 | 9-12 | 6-8 |
| Utility | 4.0-7.6 | 13-22 | 10-15 | 5-7 |

**Future DOE R&D enables U.S. to maintain leadership in CPV & PV Technology**

# Summary Table



| Performance Metric or property | Item | Status in FY09 | Result in FY10 | Notes |
|---|---|---|---|---|
| Production Efficiency | Solar Cell | 38.5% | 38.5% | 40% by Dec '10 |
| Output Power | Array | 2.7 kW dc<br>One POD Array | 3.5 kW dc (avg)<br>32 POM Arrays | |
| Robotic Assembly | Modules & Panels | Preliminary Design | Pilot Line Validated | |
| System Deployment | Power Plant | Site Secured, Preliminary Design | 100 kW Demo Plant Deployment | |
| Commercialization | CPV System | Soliciting Deployment Partner | SES partnership | |
| LCOE | System | Credible Cost Down Roadmap to meet 2015 $0.07/kWh objective | Partnering to execute business plan to meet 2015 $0.07/kWh objective | |

**DOE's R&D Successfully Enabling CPV Technology to Achieve Grid Parity by 2015**

# Thank You

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