# DOE Solar Energy Technologies Program Peer Review

**Technical Track: CSP**

**Project Name: Trough Solar Field**

**Principal Investigator: Chuck Kutscher**

## Denver, Colorado

## March 9-10, 2009

**This presentation does not contain any proprietary or confidential information.**

# Objectives and Funding

- Support the development of parabolic trough technology for central station power generation by improving the performance and reducing the costs of solar field components

FY08 Funding: $1,139K

# Team Members

- Frank Burkholder –Ph.D. graduate student, heat transfer and optics (2 student research awards--ASES, ASME)
- Dr. Keith Gawlik – heat transfer and CFD expert (2006 NREL Staff Award)
- Dr. Greg Glatzmaier – chemical engineer
- Allison Gray – mechanical engineer, heat transfer, CPV, 2-axis trackers, UNLV Center for Energy Research
- Gary Jorgensen – optical and materials expert, Reflectech patent
- Cheryl Kennedy – completing Ph.D., materials expert (1989 NREL Staff Award)
- Dr. Chuck Kutscher – heat transfer, solar collectors (ASES 2006 Abbot Award, 2007 NREL Chairman's Award, 2008 Governor's Renewable Energy Individual Award)
- Kathleen Stynes – Ph.D. graduate student, heat transfer, data acquisition
- Tim Wendelin – optical and collector expert (2008 NREL Staff Award)

# Activities

- Optical measurement techniques
  - Mirrors
  - Overall collector
  - Overall field
- Optical model development
- Advanced absorber coating
- Receiver heat loss measurement
- Hydrogen mitigation

# Optical Measurement Techniques

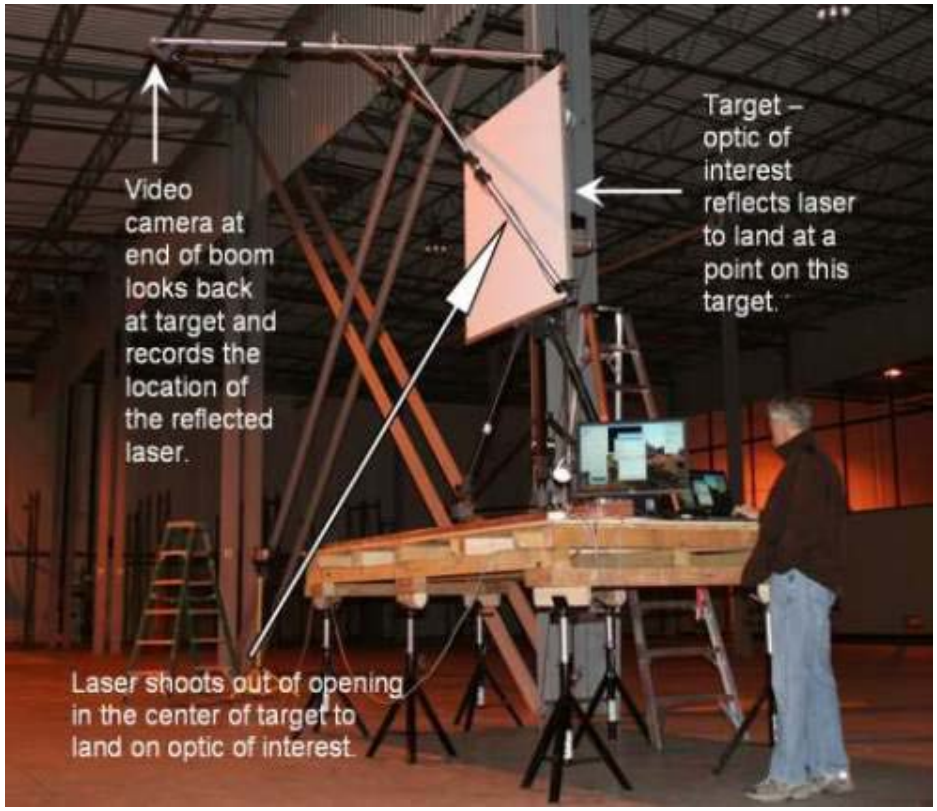
# Optical Testing Research Facilities

**Optical efficiency testing on 2-axis tracker**

**VSHOT testing of concentrators**

# VSHOT

Rapid, high-accuracy measurements of reflector shape in laboratory and field environments ensure high quality of new mirror designs




Indoor test

Field test

# VSHOT Improvements

All-in-one test jig capable of supporting a large variety of reflector panels

VSHOT to go – target extended to characterize troughs with apertures to 6m

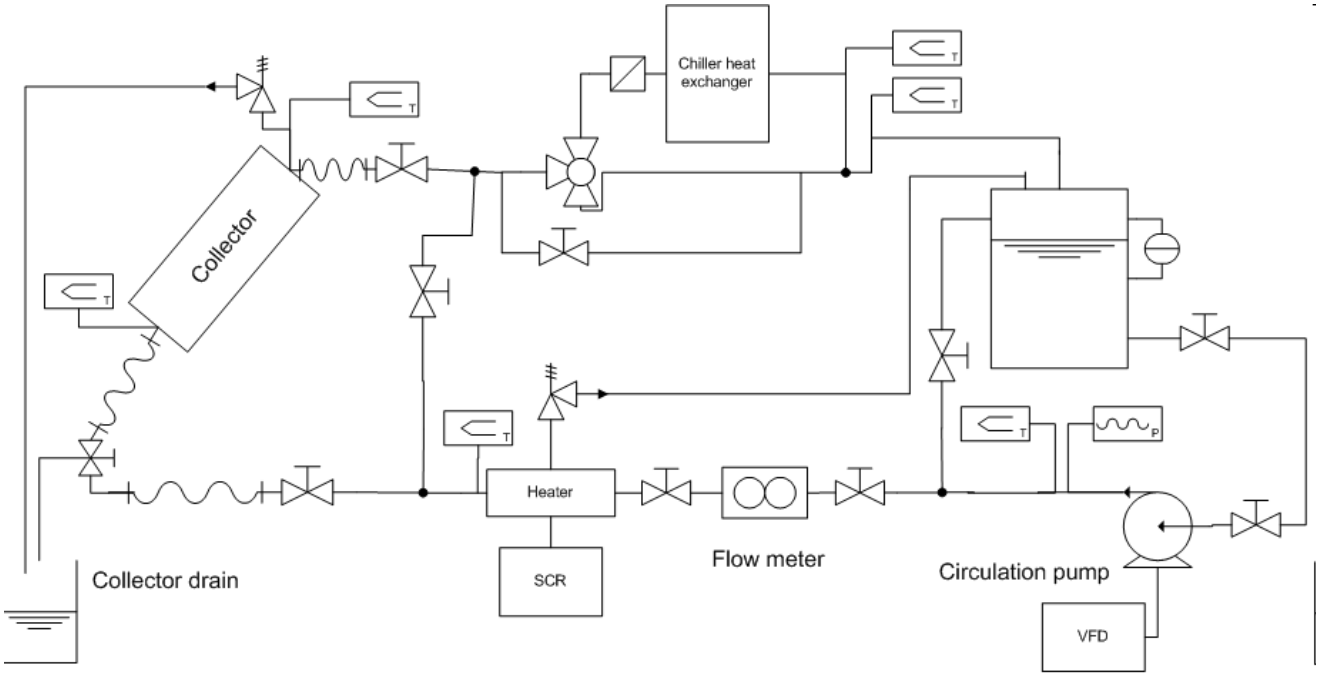
# VSHOT

- Supporting mirror, glass, and concentrator companies for both linear- and point-focus systems
  - Abengoa, SkyFuel, Reflectech, GlassTech, Solar Systems, etc.

- Surface contour data is provided with a <0.25 milliradian accuracy
- Improvements of over 4.0 milliradians obtained in SkyTrough
- Extending to larger reflectors

# Optical Efficiency Test Loop

- High-accuracy measurement of overall collector optical efficiency to ensure high overall collector optical performance
- Acciona trough tested: 79% optical efficiency
- SkyFuel collector mounted for testing



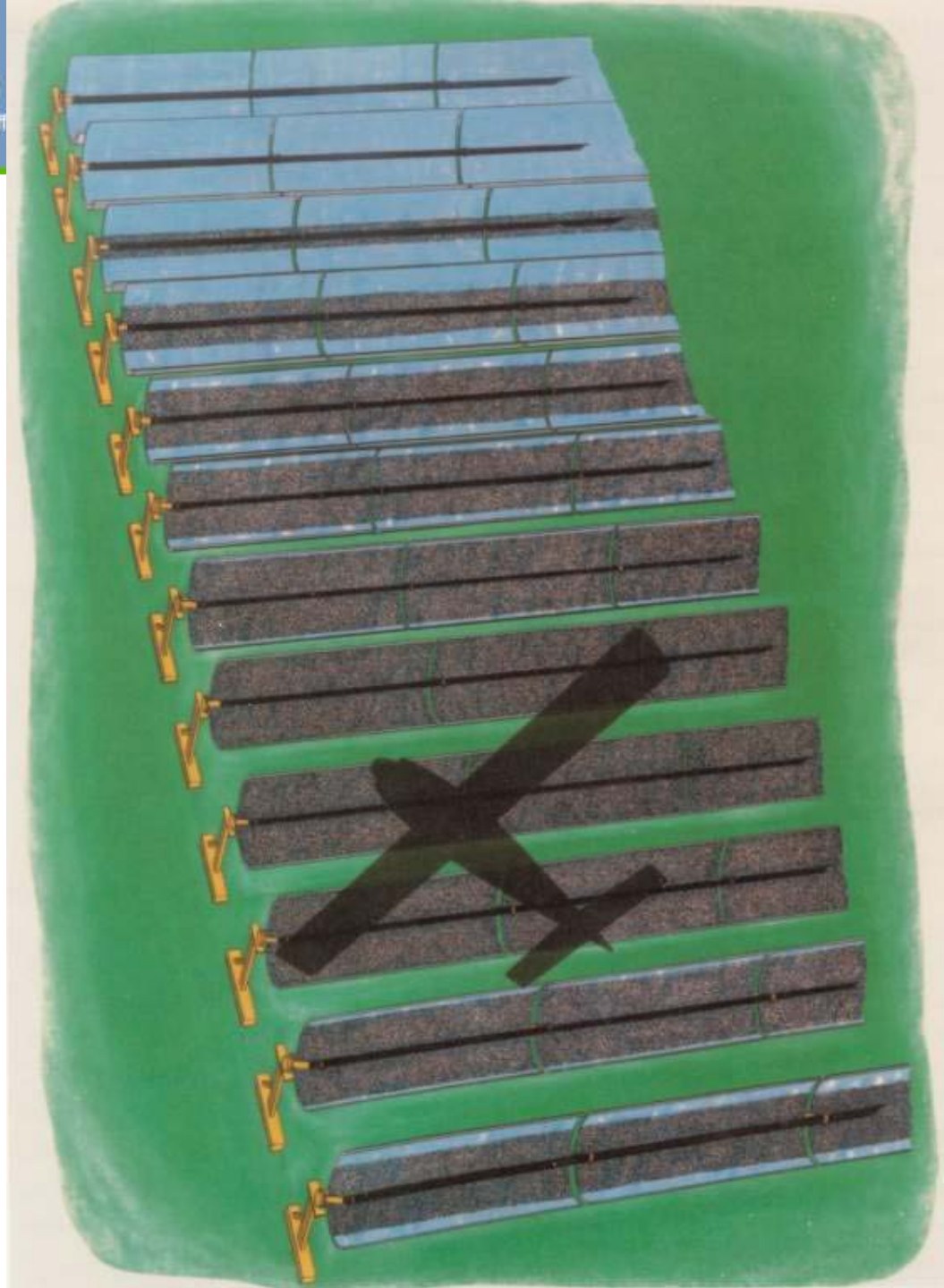
# Optical Efficiency Test Loop

8-m long trough undergoing test

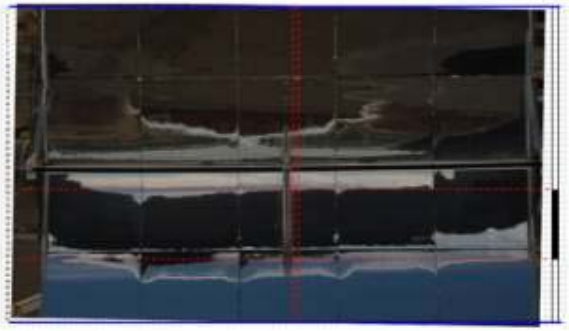
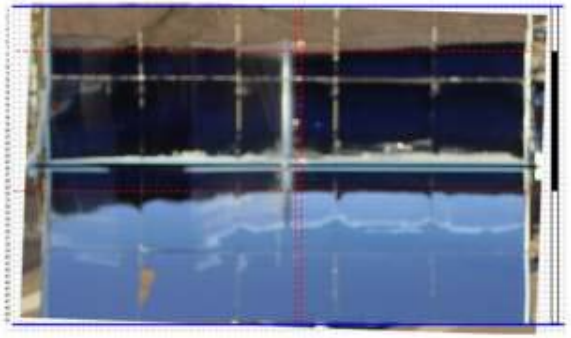
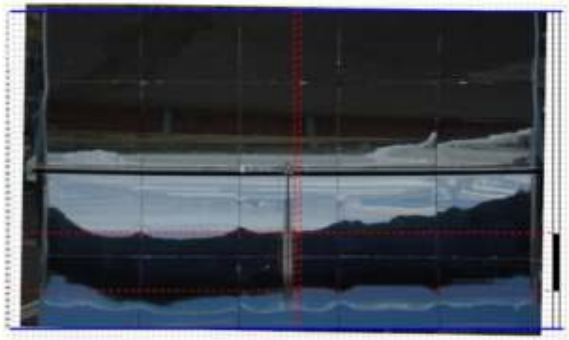
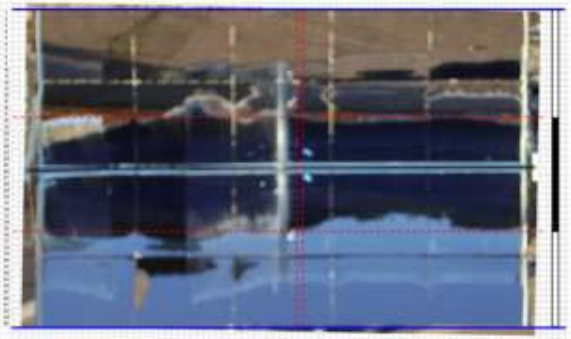
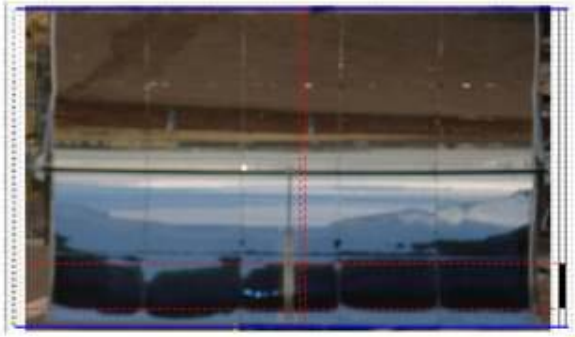
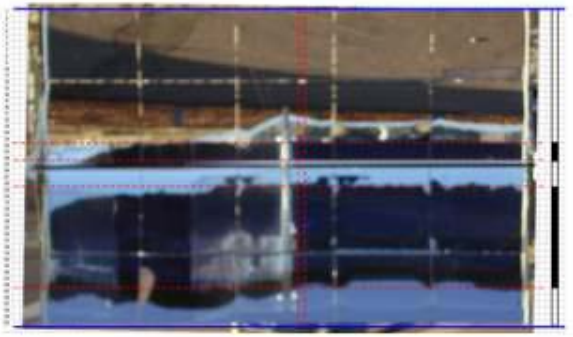
Control room showing tracker and loop controls

# Distant Observer Field Assessment Tool

- Will allow rapid assessment of entire field during and after installation
- Can assess installation quality, foundation settling, mirror alignment, wind and torque effects, receiver alignment and sagging, receiver heat loss, reflector clamshelling, and tracking error
- If field performance is under design, DO can determine why
- Supported by FPL Energy, Sunray, SkyFuel, Abengoa, and Acciona



# Application of Distant Observer to Mesa Top Collector, before and after Receiver Position Adjustment

| Collector optical axis – camera optical axis (deg) | Before adjustment – tested $\eta_{optical} \approx 60\%$ | After K. Gawlik raised the receiver "inches" – tested $\eta_{optical} \approx 75\%$ |
|---|---|---|
| -1° |  |  |
| 0° |  |  |
| 1° |  |  |

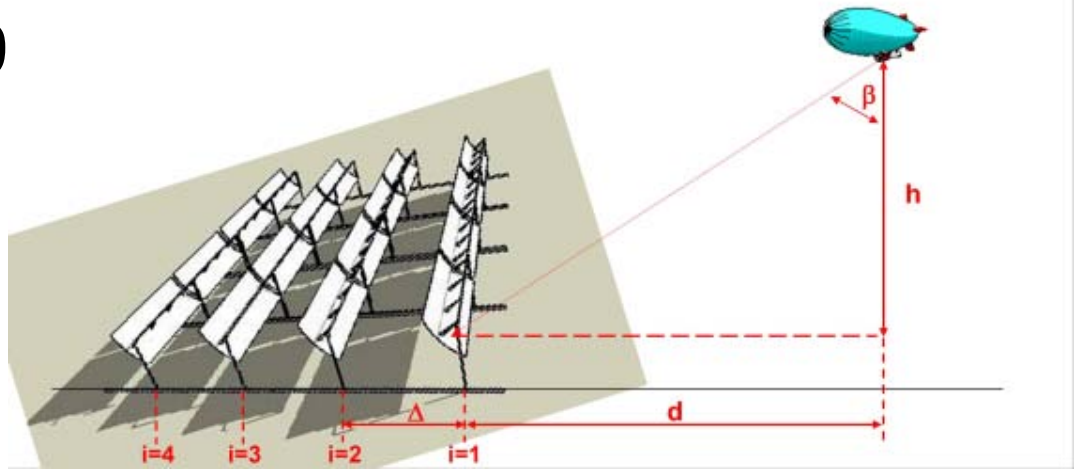
# Comparison of Optical Tool Capabilities

| Capabilities | VSHOT | TOP | Future DO |
|---|---|---|---|
| Mirror slope error | +/- 0.25 mrad | - | +/- 2 mrad? |
| Mirror alignment | - | X | X |
| Real time mirror adjustment | - | X | - |
| Receiver position | - | * | X |
| Receiver sagging | - | * | X |
| Tracking error | - | - | X |
| Effect of collector orientation | - | - | X |
| Large area assessment | - | 1-2 weeks for 30 MW field | 1 day for 30 MW field |

* Not a current capability but possible

# Status and Recent Progress

- Feasibility study completed during FY08
  - Conceptual design developed
  - Data acquisition and image processing requirements assessed
  - Capabilities demonstrated
  - Plans for prototype hardware devised
- Prototype system will be deployed during FY09

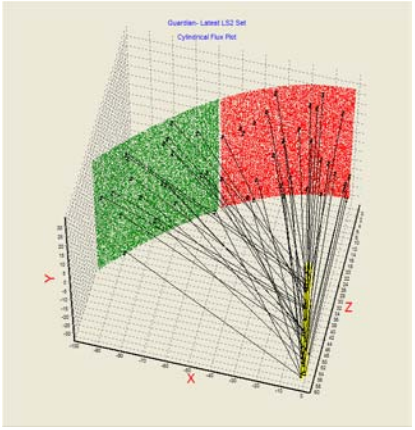


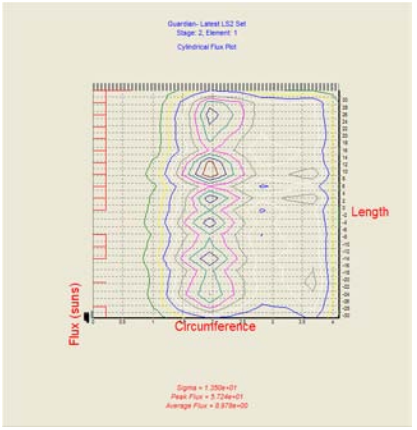
# Optical Modeling

## SolTrace

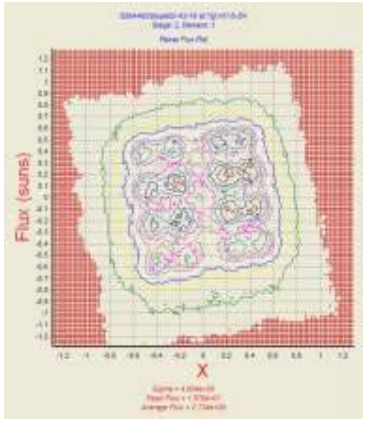
- Optical ray trace modeling code in use by labs and industry to validate designs
- Available on TroughNet Tools webpage
- Copyrighted, patents pending
- Easy to use
- Solar-friendly
- FY08: new geometry options, accepts VSHOT data
- FY09:
  - Increase speed
  - Allow popular geometric model inputs
  - Allow additional surface characterization methods

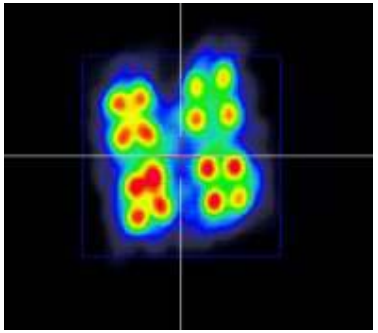
## Troughs



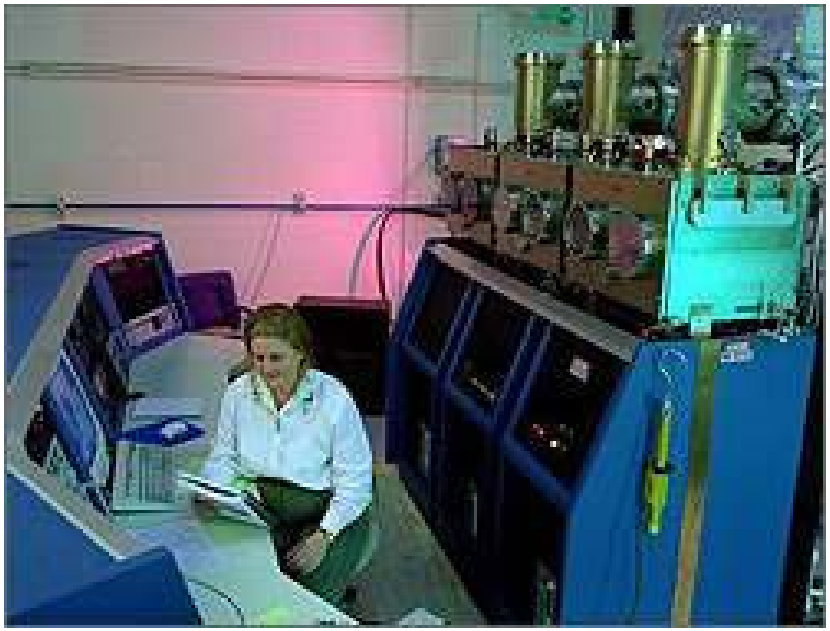

## Heliostats

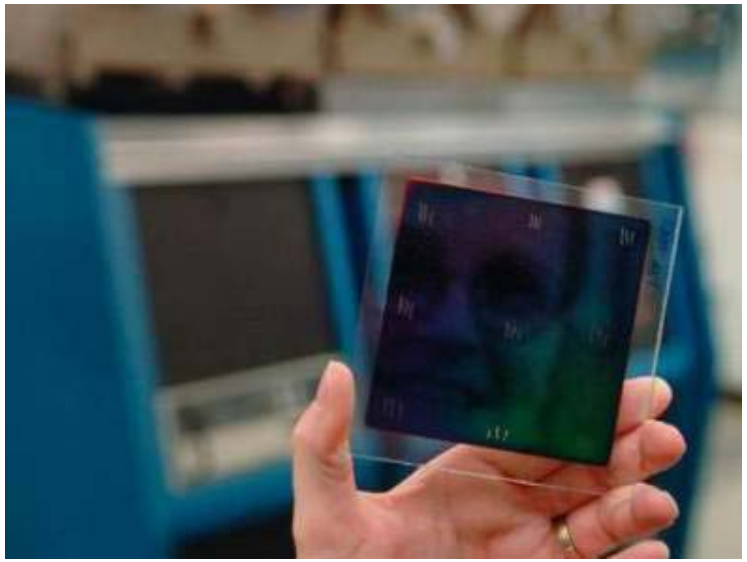


# Advanced Absorber Coating

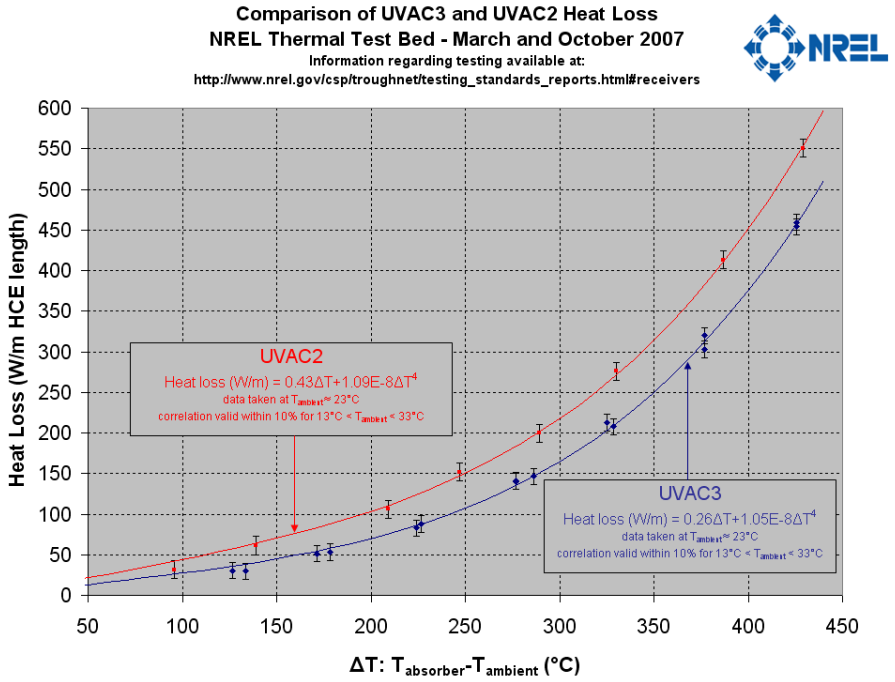
- Deposited improved, solar-selective coating with emittance = 0.07, absorption > 95%, stable > 500°C
- Filed for patent (11/07)
- Negotiated CRADA and negotiating license agreement





# Receiver Heat Loss- Laboratory Measurements

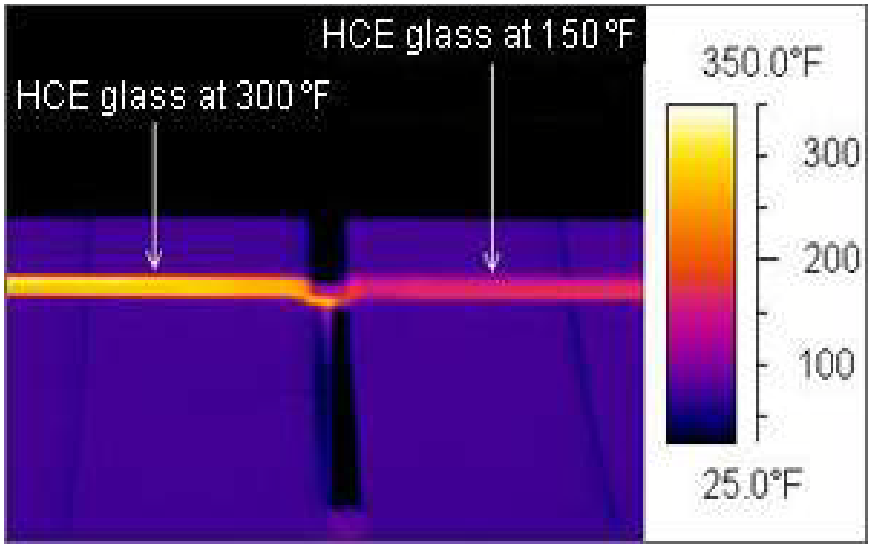
Receiver test rig




Test results showing reduced heat loss for Solel UVAC3 receiver compared to UVAC2; new Schott receiver will reduce LEC by 0.5 cents per kWh (SAM)

# Receiver Heat Loss-Field Surveys

## HCE Temperature Survey System

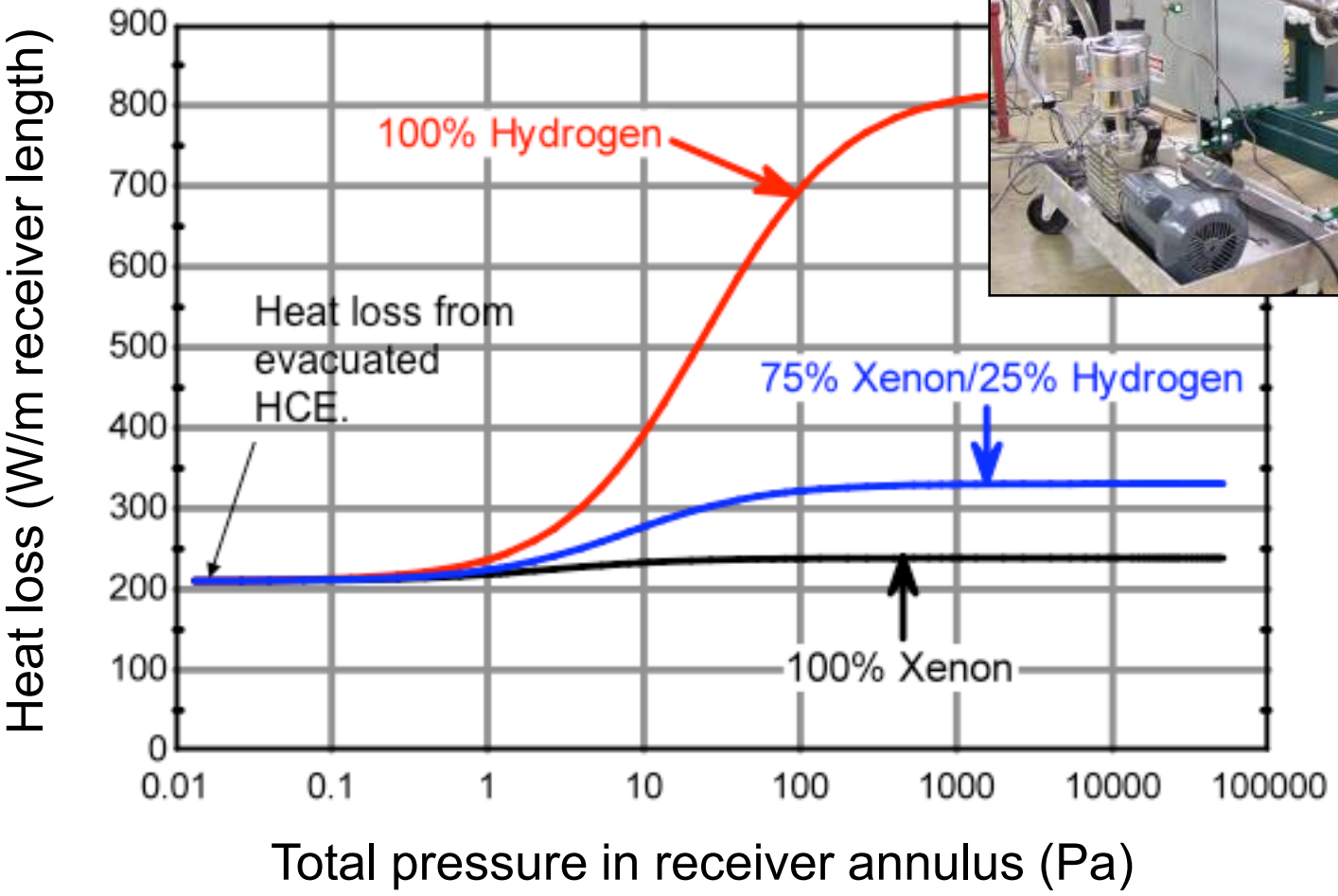



Infrared image of hot and cold tubes

Camera and GPS for exact positioning

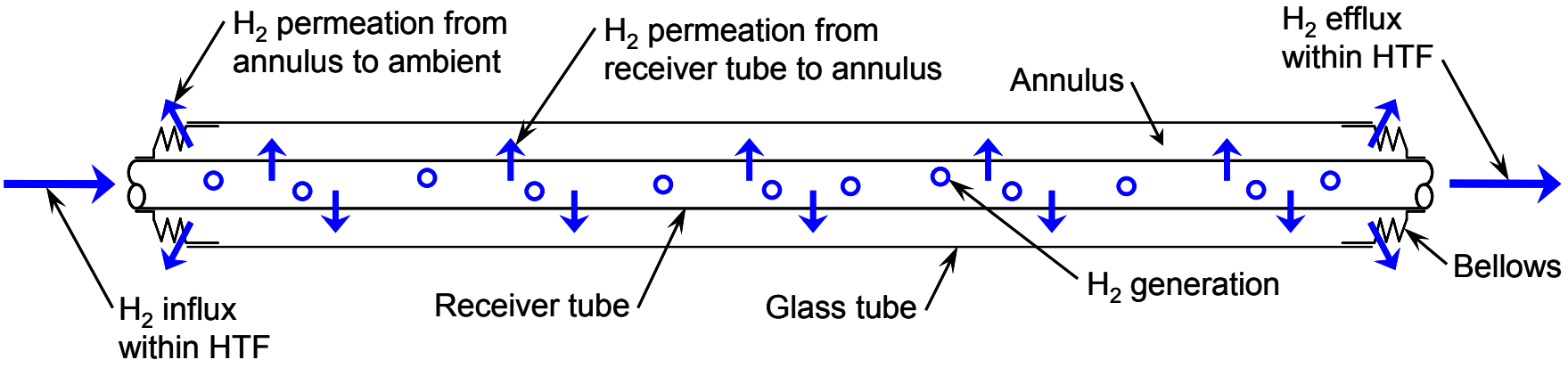
Technology successfully transferred to industry (FPL Energy); two people can survey 30 MW field in two days

# HCE Inert Gas Injection



# Hydrogen Mitigation

- Developed model of hydrogen evolution in current HTFs
- In FY09, working with industry partner to implement mitigation procedure



# Scientific/Technical Approach: Summary

- Addressing barriers/needs:
  - Optical accuracy
  - Receiver thermal losses
  - Field performance degradation
  - Cost
  - Modeling capability
- Close collaboration with industry
- Optical testing, materials development, and analysis all aimed at providing near-term improvement in parabolic trough collectors
- Strong emphasis placed on experimental accuracy/uncertainty analysis
- Topnotch graduate student interns utilized to minimize cost, develop labor pool

# Quality, Productivity, Accomplishments: Summary

- Strong team of solar, optical, and materials experts
- State-of-the-art facilities for laboratory and field optical and thermal measurements
- Milestones all met on time and within budget
- Results are of immediate benefit to industry: improved mirror design, overall optical design, total field, and receivers; hydrogen mitigation

# Publications


- E. Lupfert; K.J. Riffelmann; H. Price; F. Burkholder; T. Moss. "*Experimental Analysis of Overall Thermal Properties of Parabolic Trough Receivers*", ASME Journal, 2007
- F. Burkholder; M. Brandemuehl; C. Kutscher; E. Wolfrum. "Heat Conduction of Inert Gas-Hydrogen Mixtures in Parabolic Trough Receivers," presented at the ASME International Conference on Energy Sustainability, Jacksonville, Florida, August 2008
- G. Jorgensen; F. Burkholder; A. Gray; T. Wendelin. *"FY 2008 CSP Milestone Report: Assess the Efficacy of an Aerial Distant Observer Tool Capable of Rapid Analysis of Large Sections of Collector Fields."*
- C. Kennedy. *"Progress to Develop an Advanced Solar-Selective Coating*" presented at 2008 SolarPaces Symposium in Las Vegas, Nevada, on March 2008. Selected for publication in ASME-*Journal of Solar Energy Engineering* (JSEE).
- G. Glatzmaier and D. DeVoto. "FY 2008 CSP Milestone Report: Modeling Hydrogen Occurrence in Parabolic Trough Power Plants," October 2008.

# Relevance/Impact of Research

- Optical mirror measurements of immediate benefit to Abengoa, SkyFuel, Reflectech, GlassTech, Saint-Gobain Flat Glass, Ashai Flat Glass, RioGlass Solar, Guardian, etc.
- Transfer of VSHOT to industry
- Overall collector measurements of immediate benefit to SkyFuel, others
- Improved SolTrace processing and input will enable industry to evaluate designs more efficiently and lower cost
- Field IR measurements of receivers led to FPL Energy replacing millions of dollars of receiver tubes
- Working with industry to develop new absorber coating
- Hydrogen mitigation technique will provide benefit to all trough installations using oil heat transfer fluid

# Future Work

- Continue to improve VSHOT and explore other techniques
- Continue to test latest receivers (e.g., new 8-cm Schott receiver)
- Support deployment of advanced receiver coating
- Enhance SolTrace optical modeling tool
- Evaluate inert gas and field mitigation of hydrogen infiltration
- Develop Distant Observer technique to quickly survey large field during and after installation