Development of the Focal Point Power Trough (FPPT) & PT-2 Advanced Concentrators for Power Generation

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DOE Solar Energy Technologies Program Peer Review

Denver, Colorado

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Contract Info

"Development and Testing of a Power Trough System Using a Structurally-Efficient, High-Performance, Large-Aperture Concentrator With Thin Glass Reflector and Focal Point Rotation"

Midwest Research Institute National Renewable Energy Laboratory Division
Subcontract NAT-5-44440-02

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DOE SETP M-Y Plan Goals (CSP):

- Achieve a design point solar-to-electric efficiency of 25.6% and annual solar-to-electric efficiency of 15.5%
- Use an advanced thermocline thermal storage system that provides up to 6 hours of storage (capacity factor of ~0.43) and cost ~$20/kWh
- Have an installed system cost of $4100/kW (including the cost of thermal storage and oversized solar field) and an O&M cost of $0.016/kWh, resulting in an LCOE of $0.089/kWh

Desired Solar Field Characteristics

- Increased solar field operating temperatures
- Use of molten salt HTF or Direct Steam Generation (DSG)
- Reduced up-front and plant O&M costs

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Technical Focus:
Scale-up of PT-1 concentrator

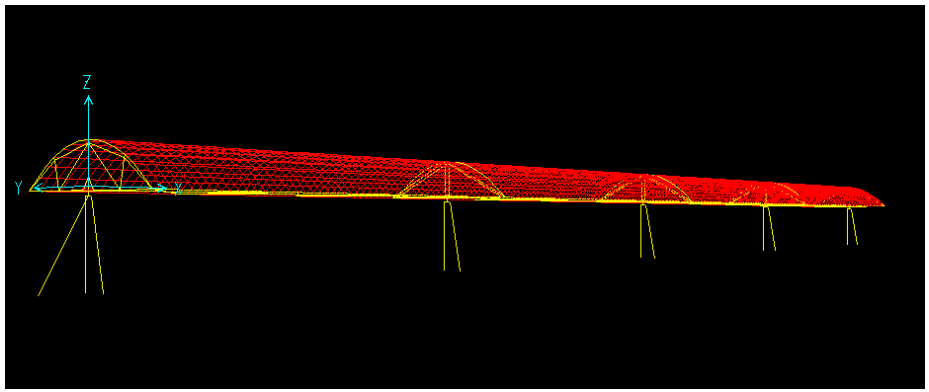
Unique design creates **lightweight integrated structural reflector** from metal sheet (PT-1: 9.6 kg/m2 aperture)

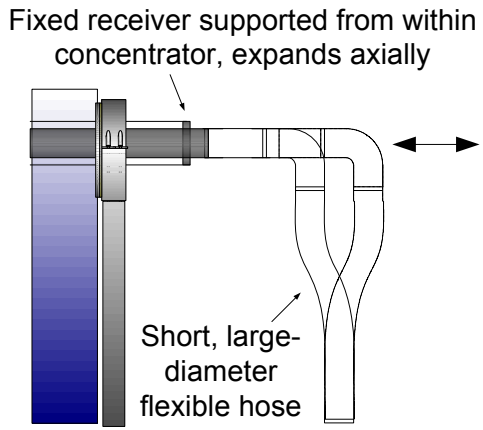
Advantages

- Low material content (= low cost)
- No material supply constraints
- Versatile geometry
- No mirror alignment
- Flexible reflector options
  - Thin glass
  - Front surface film
  - Silvered / polished aluminum
  - Silvered polymer film

Technical Approach: Design Options

Quantify tradeoffs, collect cost data, identify best candidate for deployment





FPPT: Advanced Trough (fixed receiver, >500°C operation)

- Simplified connection from receiver -> header (no balljoints)
- Complex, high-temperature bearings at receiver support and pylons (may delay deployment)
- Potential long term cost & performance advantages
  - Eliminate balljoints, better-adapted to high-temperature HTF

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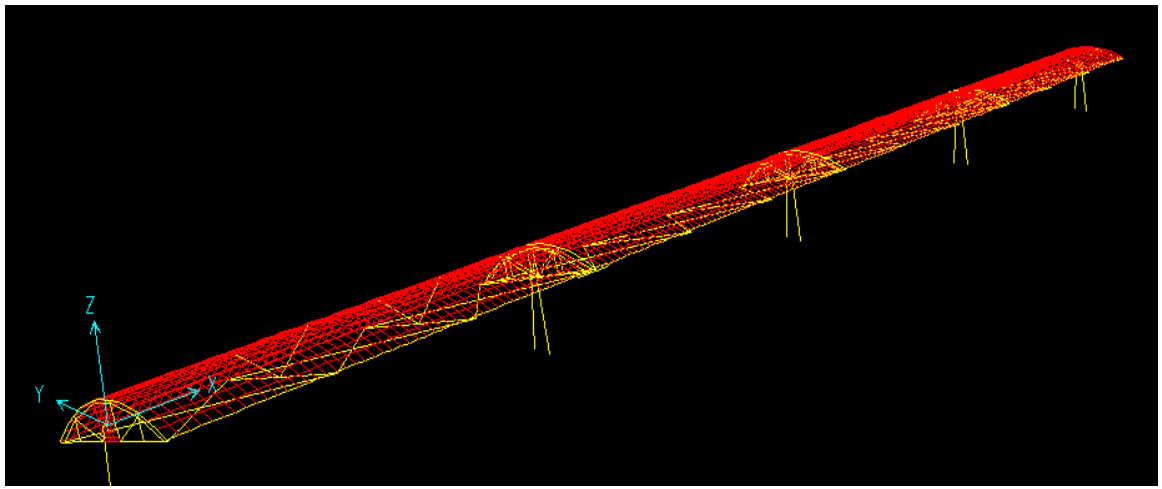


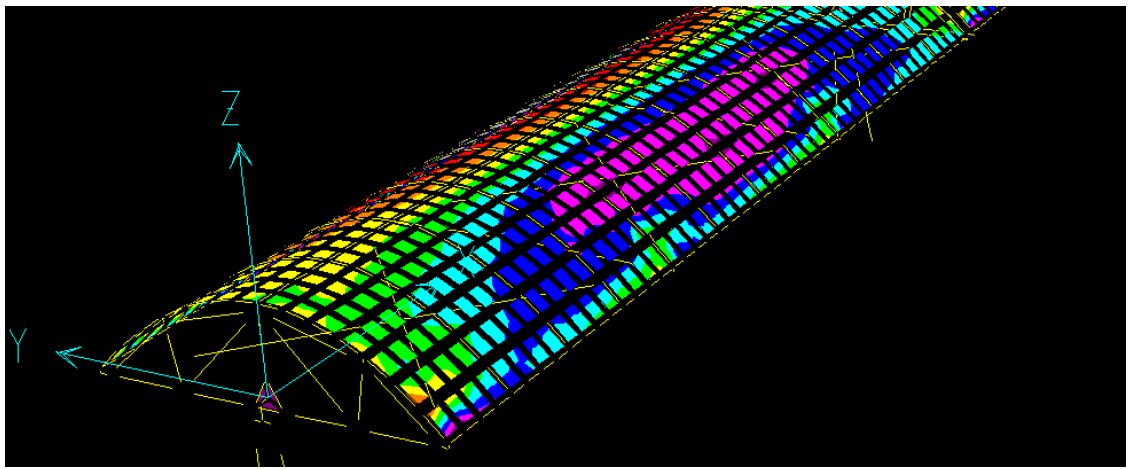
PT-2: Conventional Trough (moving receiver, balljoints)

- Direct scale-up of current product (4x aperture area)
- Low-cost alternative to current LS-2-based designs
- No technological barriers

Technical Approach: Analysis

Understanding IST structure

- Front lattice stabilizes parabolic sheet to make torque tube
- Analytical modeling based in shell buckling theory
- FEA analysis of structural lattice and shear/compression in sheet

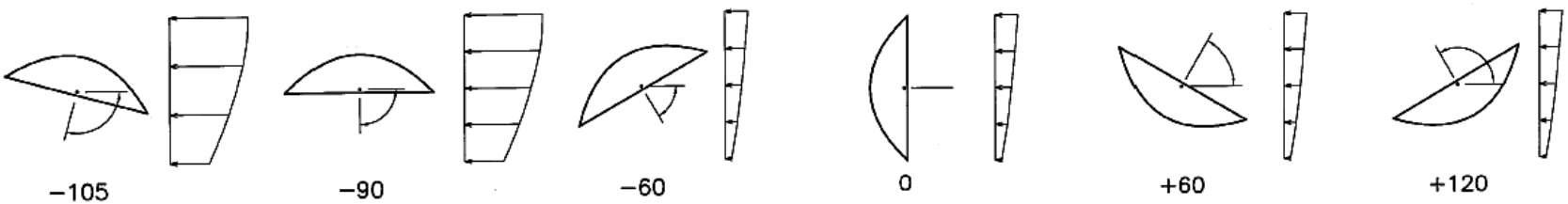


Goal: Develop a model to predict structural performance well enough to design and test prototypes

Technical Approach: Analysis

Wind Analysis

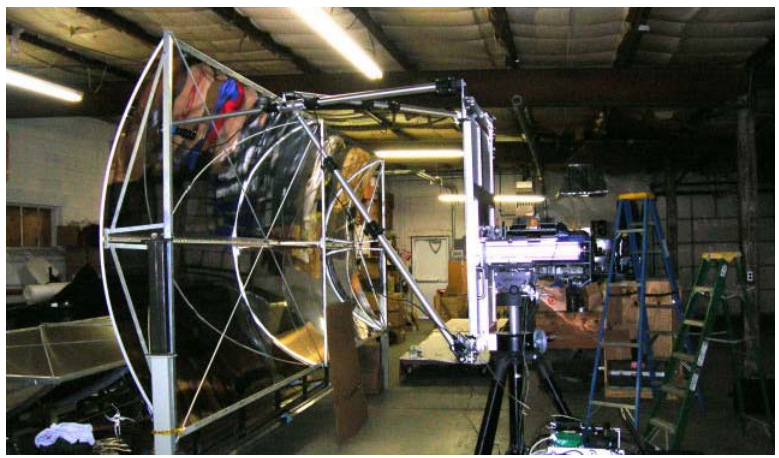
- Analyze Cermak Peterka Peterson (NREL / Solargenix) wind tunnel test data
- Develop design criteria based on building codes
- Estimate loads under operating (40mph) and survival (96mph) winds
  - Lift, drag, beam, and torsion loads under multiple orientations
  - Torsion under survival wind is governing design condition



Technical Approach: Validation

Real-World Verification

- Phase I: Validation of model ¼-scale trough (PT-1)
  - VSHOT of PT-1 to quantify optical performance
  - Structural testing of PT-1, comparison with model
  - Design and predict performance of full-scale trough
- Phase II: Prototype and test full-scale prototypes
  - Structural testing of PT-2 and FPPT, compare with predictions
  - VSHOT test to measure optical performance



Technical Approach: Validation

Validation of Structural Modeling Technique for PT-1

- Create torsion with force at corner of module, restraining center
  - Simulation of field configuration, experienced high wind failures
  - Compare to historical designs & "baseline" established for this project
  - Analysis resulted in 70% gains in PT-1 strength ("Upgraded Steel")
  - Close agreement between analytical/FEA model and test results
  - Deviation from model at end of load range due to change in shape of prototype (can be corrected w/ accurate rod tensioning, Phase II)

Technical Approach: Manufacturing & Cost Analysis

- Design for Manufacture & Assembly (DFMA) effort integrated into design tasks
- Cost data is being collected, tabulated
- Phase II will produce estimated costs of all components for both PT-2 and FPPT concentrator systems
- Cost data will provide valuable tool for comparison and decision-making

LEC impact of both concentrators can be derived at end of Phase II

Phase I Tasks

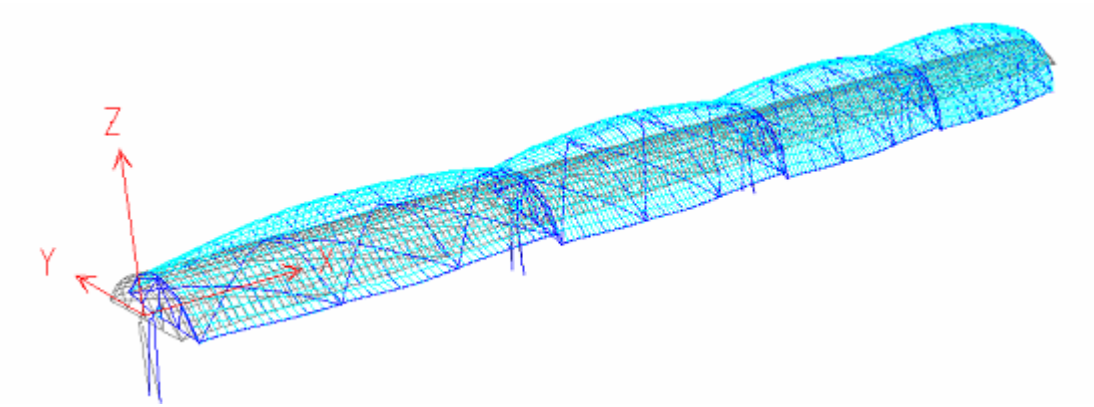
- Analyze wind forces on trough collectors
- VSHOT optical & structural testing of PT-1
- Modeling and analysis of FPPT concentrator
- Preliminary design of FPPT mechanical & control systems

Phase II Tasks (ongoing)

- Design of PT-2
- Build and test PT-2, FPPT (structural and VSHOT optical)
- Refine FPPT mechanical systems
- Cost analysis and comparison (PT-2 vs. FPPT)

Major Accomplishments

- **Validated structural design tool using PT-1**
- Demonstrated improved strength (70%) and optical performance (22%) in PT-1 based on VSHOT & structural analysis
- Demonstrated potential of PT-2, FPPT to reduce material content 30%-50% over competing designs



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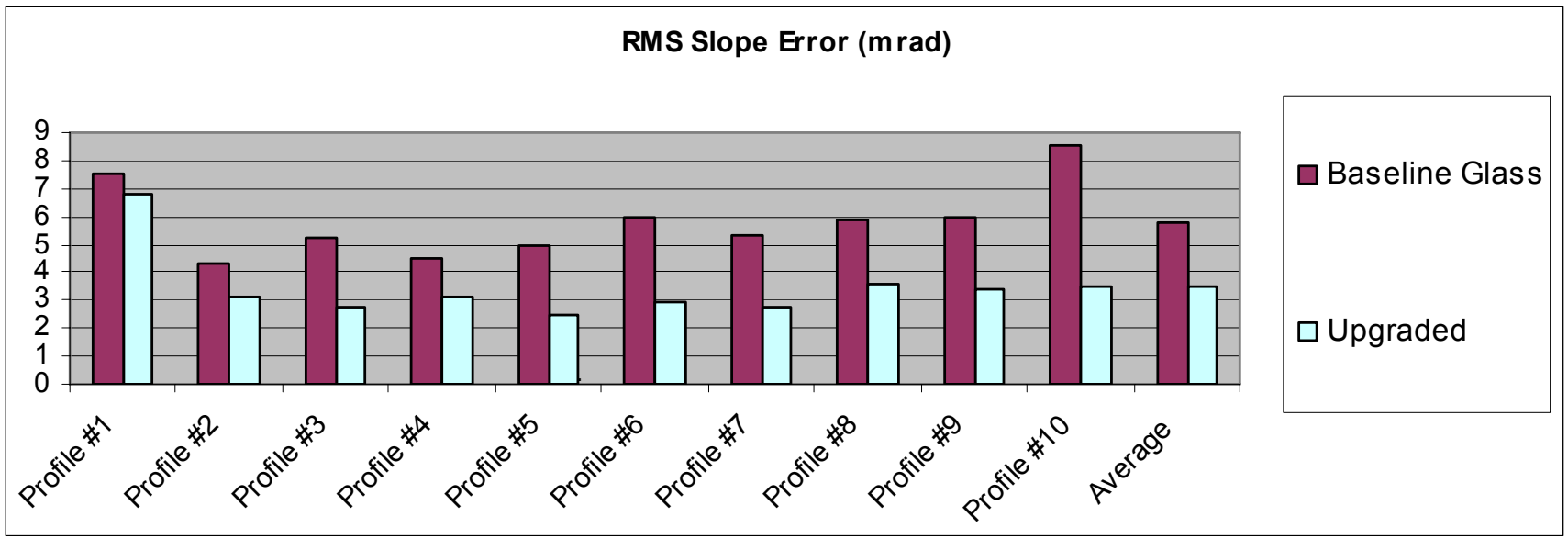

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Bottom Line

IST Solucar can produce lightweight, accurate collectors

- FPPT predicted optical intercept 98%
- Material content ~16kg/m2
- No field focusing, no supply constraints
- Adaptable technology
  - Scale-up / change geometry (difficult w/ sagged glass)
  - Amenable to multiple reflector technologies
- Lower-cost solar fields, higher field efficiency

Successful completion of Phase II will accelerate achievement of DOE cost and performance goals

Project Milestones

- Phase I (May ’05 – June ’06)
  - Testing of Baseline and Upgraded PT-1 (Sept ’05-Feb ‘06)
  - Preliminary Design Design of FPPT Concentrator (Feb ’06)
  - Development of Mechanical Systems for FPPT (April ’06)
  - Phase I Final Report (June ’06)

- Phase II (Oct ’06 – Oct ‘07)
  - Completion of PT-2 Design (Jan ’07)
  - Testing of Prototypes (June ’07)
  - Prototype Mechanical Systems (Aug ’07)
  - Cost & Manufacturing Analysis (Sept ’07)
  - Full Report for NREL (Oct ’07)

Future Directions

- Analysis – deployment candidates
- Deploy test row at SEGS or other location
- Deploy advanced trough for laboratory research with Molten Salt or DSG
- Research thin glass and front surface reflectors
- Additional scale-up (6m+)

<u>End Goal</u>

Deploy new trough for pilot-scale commercial plants in 2008

Acknowledgements

We would like to gratefully acknowledge the **Department of Energy** and **Midwest Research Institute NREL** for their technical and financial contributions to this project