Advanced Dish Development System

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Advanced Dish Development System
Organizations

- Sandia National Laboratories/NREL (SunLab)
  - Project Management
  - Systems Integration
  - Installation and Testing
  - Advanced components
- WGAssociates
  - Concentrator design and fabrication
  - Controls design and fabrication
  - Systems integration support

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Organizations (Cont.)

- Solo Kleinmoteren
  - Stirling PCU
- RSI Mexia
  - Concentrator fabricator
- Paneltec
  - Structural facets
- Others
  - DLR (test support)
  - Schlaich Bergermann und Partner (PCU controls)
  - Peerless Winsmith (Azimuth drive)

Advanced Dish Development System
Markets

- Addresses remote power markets
- Extensive market worldwide for water pumping, village electrification
- Market requirements
  - Reliable and unattended operation
  - Minimal and low technology service requirements
  - Low cost compared to alternatives
- Diesel generators are primary competition

Advanced Dish Development System

OBJECTIVE

Develop and field a fully integrated, stand-alone dish/Stirling solar power generation system at a remote, off-grid Native American site in the Southwestern U.S.

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APPROACH

Design, fabricate, integrate and test an advanced dish system in automatic, unattended operation both on-grid and off-grid under representative loads at the NSTTF

Capitalize on the proven SOLO 161 Stirling PCU and WGA & Cummins solar concentrator and controls experience

Integrate advanced components into the test bed with the objective of improving the commercial viability of the system

Implement as a cooperative project between Sandia and one or more American Indian Applications Partners

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THREE-PHASE PROJECT

Phase 1: (FY99)
- Design, fabricate, integrate and test a first generation (Mod 1) system on-grid at the NSTTF
- Identify one or more Applications Partners (AP)

Phase 2: (FY00/01)
- Operate the Mod 1 system unattended on-grid
- Train AP personnel in system O & M
- Redesign an off-grid upgraded system (Mod 2)

Phase 3: (FY01/02)
- Install and operate upgraded systems at the NSTTF and at an AP's remote site
- Transfer O&M responsibility to AP, monitor system performance, provide follow-on support in FY03 and beyond

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Application Partners

- Native American APs provides realistic testing and better understanding of system requirements
- Significant interest
- Water pumping identified as best application
- Training provided to Kaibab Paiute, Zia, Laguna, and Ramah Navajo Tribes
- Laguna Pueblo selected for first system

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MAJOR COMPONENTS

WGA-500 Concentrator

- **WGAssociates, Dallas, Texas**

SOLO 161 Stirling PCU

- **Solo Kleinmotoren, Germany**

Collector Control System

- **WGAssociates, Dallas, Texas**

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Mod 1 Design

- Grid-connected system
- Fully integrated system designed, fabricated, installed and operated on sun in less than one year
- Concentrator performance exceeds specifications
- Maintainable, easy to work with system

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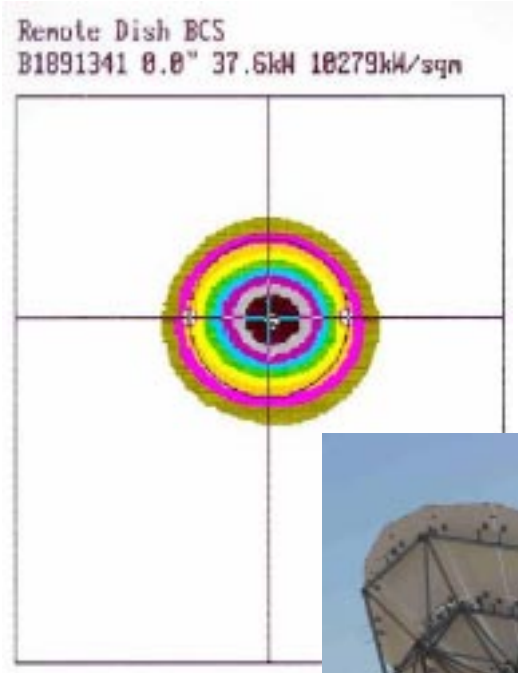
Mod 1 Concentrator Design

- Innovative, light-weight, low-cost thin-walled tubing tracking structure
- Mirror panels
  - 32 panels
  - Glass mirror structural facets
  - < 1 mrd slope error mirrors
- Concentrator exceeded performance specifications



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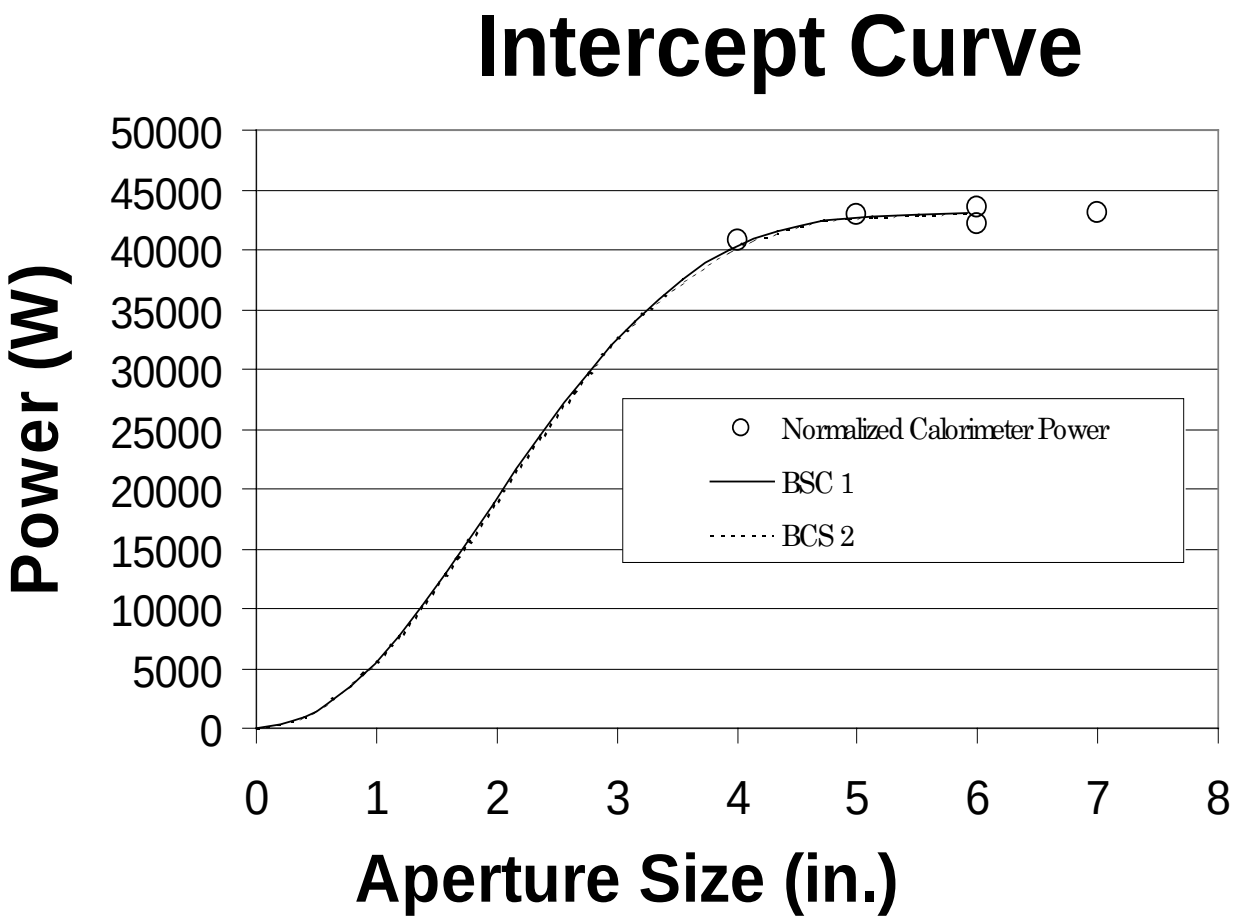
Mod 1 Design



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Power Conversion Unit

- 9-kW$_e$ SOLO 161 Stirling engine with a DIR receiver
- Two-cylinder, V-type
- Helium, pressure controlled
- >40,000 hours solar operation (over half million hours on this engine type)
- 5,000 hrs mtbf from durability tests
- Currently in pre-production for co-gen markets in Germany

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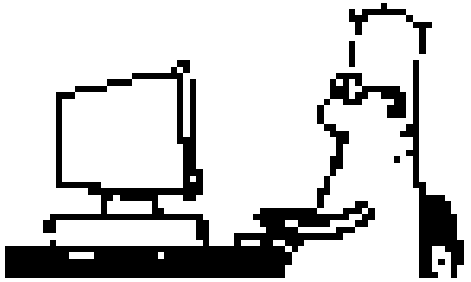
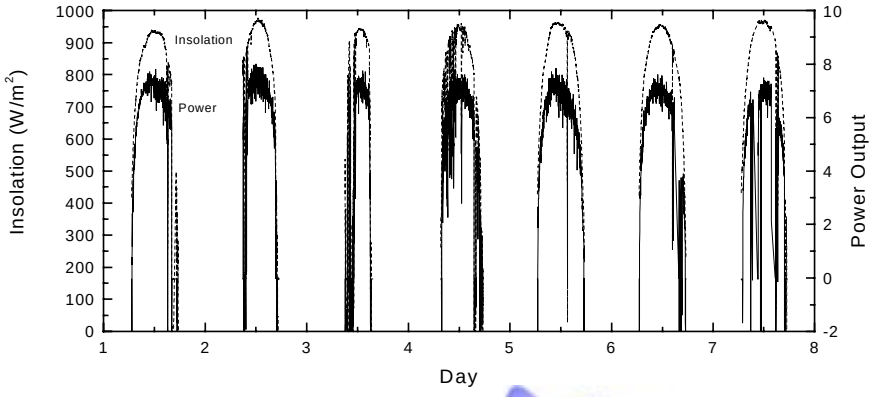
CONTROL SYSTEM

- Provides all functions required for unattended operation and maintenance of the system:
  - Wake-up, Sun acquisition, Sun tracking, Manual pointing, Sun escape, Go-to-stow, PCU start, Fault response, Power system monitoring and control, Automatic error and drift corrections



- Provides for data acquisition, storage to an external computer, and remote monitoring and control via the internet



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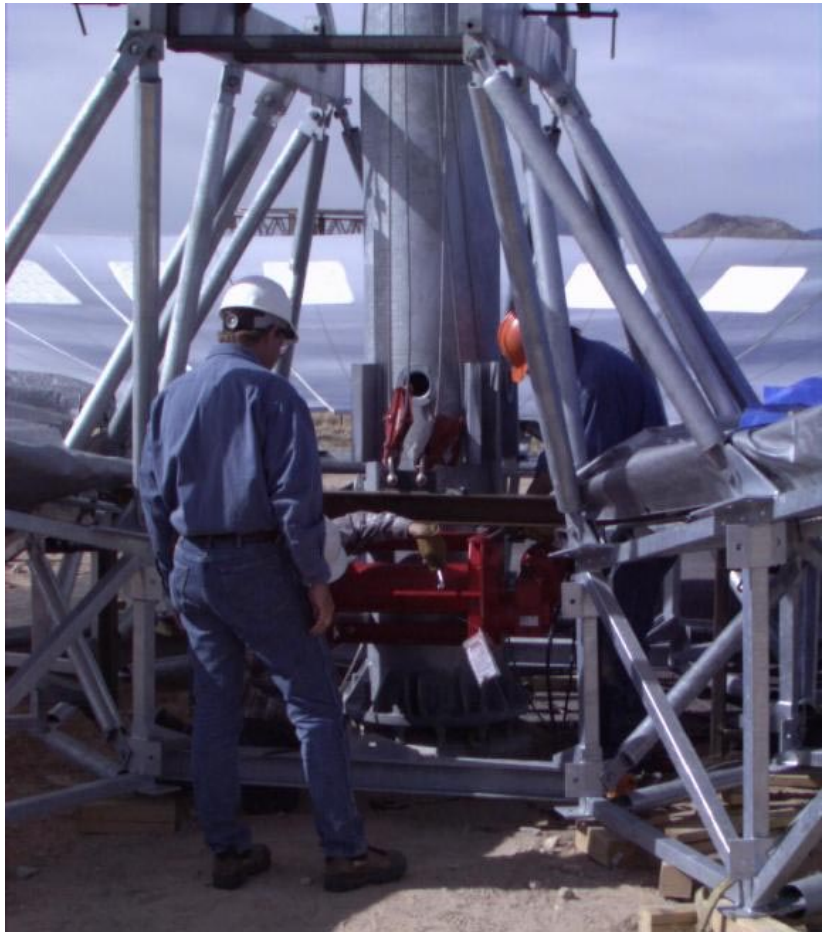
Mod 2 Design

- Designed for driving a water pump, a need identified by all of our Application Partners
- Primary objective is to reduce cost, especially related to installation at a remote location
  - "Bootstrap" installation of the system
  - “Cookbook Foundation” designs
  - Mounting of the Control Cabinet on the pedestal
  - Redesign of panel mounts
  - Change panel design from 32 to 24 panels



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Mod 2 Concentrator Design

- Design addresses Mod 1 issues
- Kneel-down stow at 25º below the horizon
- Elevation-tracking range of 0° to 96°
- Redesign of Winsmith drive casting
- Panels use Al instead of steel membranes

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Mod 2 Design

- PCU with synchronous generator (vs. induction generator)
  - Synchronous generator drives conventional 480-V, three-phase, water pump equipment at variable frequencies
  - Uses automotive DC starter
  - System operates automatically and unattended pumping water in a simulated well at the NSTTF
- Concentrator power management simplified
  - Uses two 12-Volt lead/acid batteries for concentrator drives and controls
  - 24-VDC drive motors
  - One 12-Volt battery in PCU for starting
  - One common charger from generator output

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Mod 2 Controls Design

- Collector and PCU control systems are “state-of-the art”
  - Versatile and robust development platform
  - Easy to use controls interface, automated activity log and self diagnostics facilitate system operation, maintenance, and troubleshooting
- Integrated collector and PCU controls better than sum of parts
  - Utilize RS 232 digital communications vs. analog signals
  - Vastly simplifies wiring and improves PCU interface
  - Improved coordination reduces parasitics and increases system performance
- Development of a low-cost sun sensor being investigated
  - Low-cost sensors for “three eye” approach identified
  - Innovative “sky view” sun sensor being investigated
- Remote communications still needs to be developed

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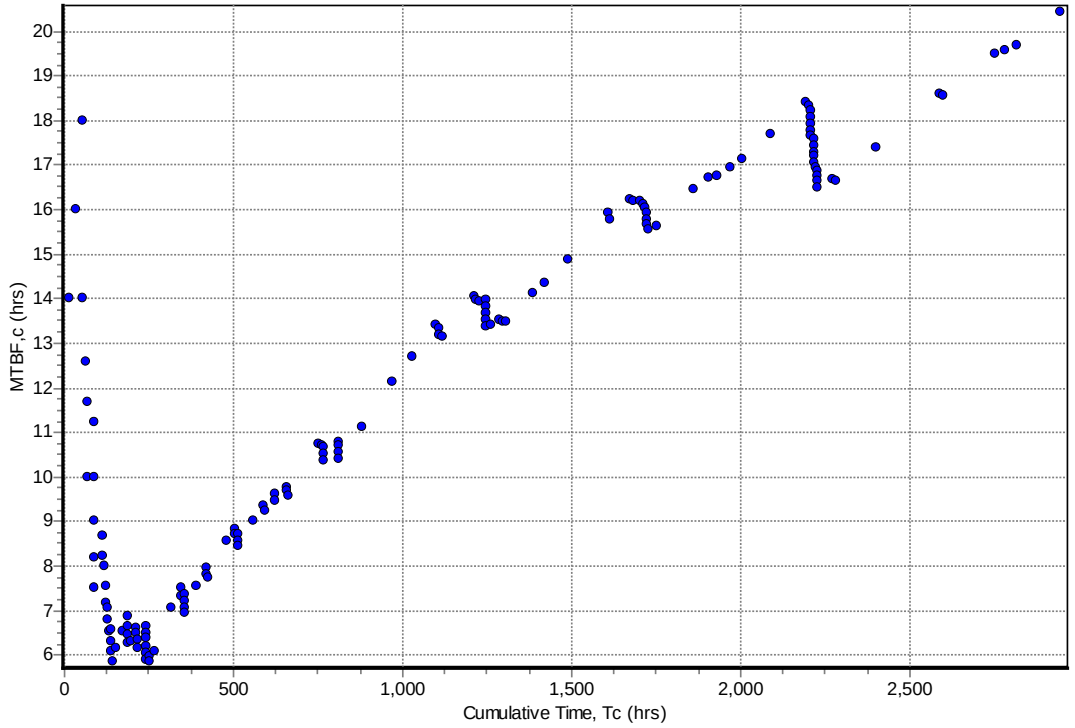
Reliability Improvement

- NREL developed data base is being used to record incidents
- Engineering solutions for faults aggressively pursued
- Reliability is steadily improving
- More systems and operation time needed



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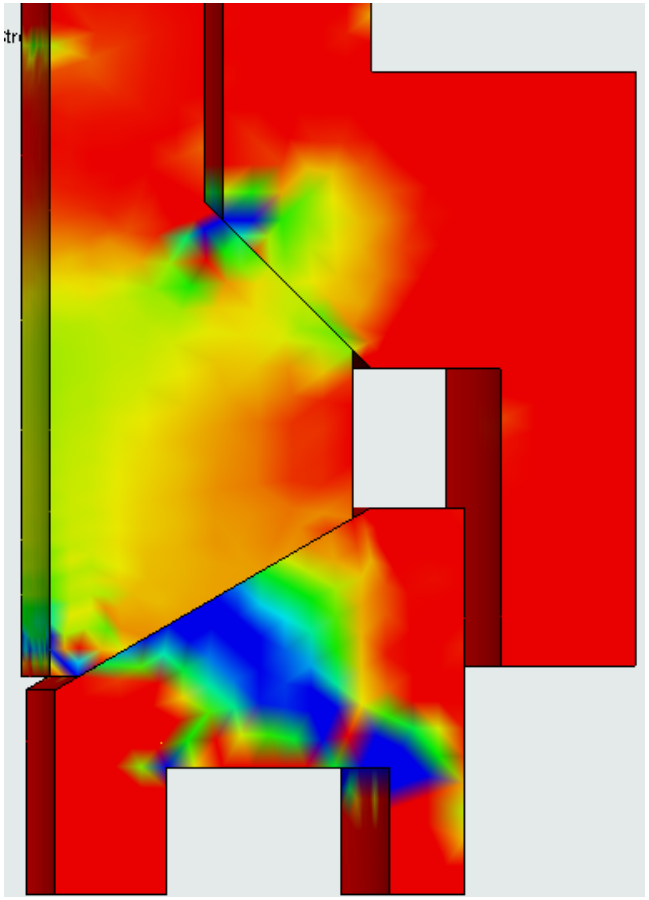
Reliability Improvement

National laboratories expertise is key to system improvement. Some examples in the ADDS project include:

- PL Seal analysis and improvement
- Flux distribution analysis and improvement
  - Flux mapping
  - Hot spot mitigation
  - Infrared thermography
  - Alignment techniques
  - CIRCE modeling
  - Tracking system improvements
- Receiver brazing issues
- Receiver materials and design
- Control software improvement
- Vibration measurement and mitigation
- Materials selection and analysis
- Structural analysis
  - Mirror panel deflection
  - Dish structure deflections
- Cost reduction/ DFMA
- Reliability tracking and improvement
- Installation improvements

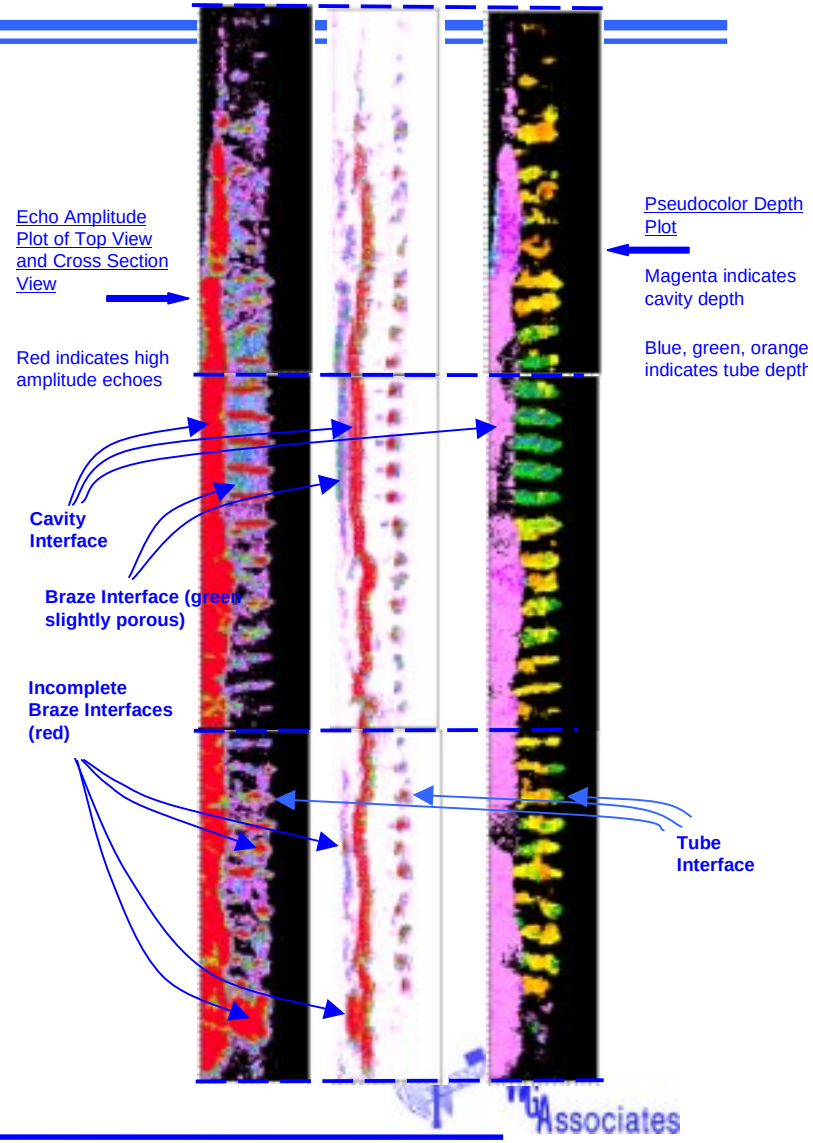
ADDS Case Study: Solo PL Seal

- Problem: Oil migrating past seal into cycle
  - No evidence of wear or seal failure
- Tools Used:
  - Observation of tested parts
  - Finite element analysis of seals
  - Material characterization
- Findings:
  - Oil vaporizing from rod due to high frictional heating
    - Increased engine pressure (power)
    - Increased engine speed (50Hz to 60Hz)
- Action
    - Redesign seal angles and length
    - New design on test
    - Reduced friction also improved engine performance
    - Direct impact on Solo commercial product



ADDS Case Study: Receiver Brazes

- Problem: Braze failures on receiver manifold
- Tools used:
  - Sandia ultrasound imaging technology
  - Sandia braze experts
- Findings:
  - Flaws in braze joint
  - Pinhole leaks just the tip of the iceberg
  - Improper braze design
- Action
  - Minor modification to braze fixture eliminated problem
  - Braze now flows to full penetration
  - Simple ultrasound equipment recommended and implemented

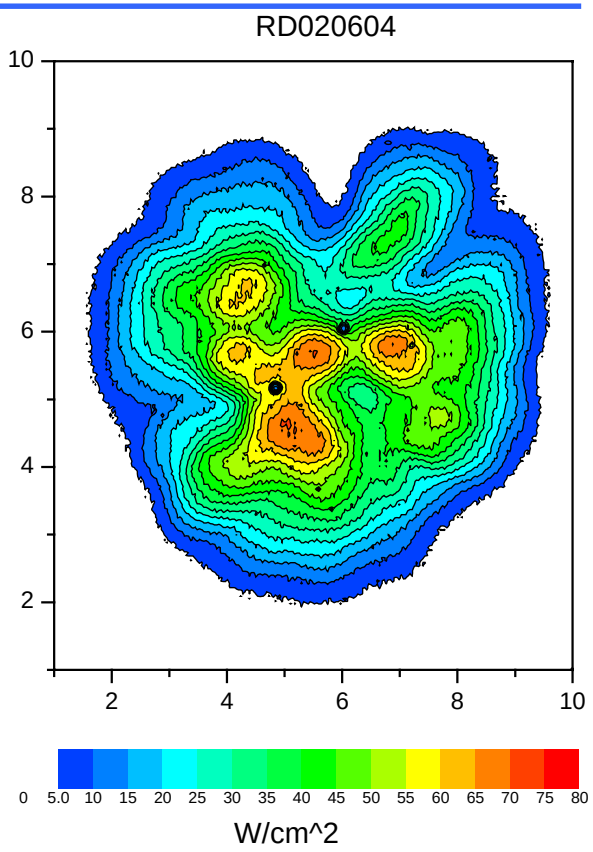


ADDS Case Study: Tracking Issues

- Problem: Poor capture on transition from open-loop to closed-loop tracking
- Tools used:
  - Numeric modeling and algorithm development
  - Sensor development
- Findings:
  - Lack of orthogonality parameter (open loop)
  - Slow response of thermocouples sensors
- Action
  - Software changes
    - Orthogonality parameter added
    - Thorough testing in hardware and simulation
  - Develop low-cost tracking flux sensors
    - Simple low-cost design
    - Rapid response
    - Demonstrated 10-milliradian capture range

ADDS Case Study: Flux Hot Spots

- Problem: Flux hot spots on receiver reduce performance and lead to receiver tube failure
- Tools used:
  - SunLab Beam Characterization System (flux mapper)
  - CIRCE2 optical analysis computer program
  - Stress analysis
- Findings:
  - Gravity induced structural deflections lead to overlap of images from the inner and outer rows of mirrors
  - Improper bore sight can contribute to flux pile up
- Result:
  - No increase in aperture diameter
  - Peak flux reduced from ~90 to about 75 W/cm^2 on receiver
  - Simplified and improved alignment technique



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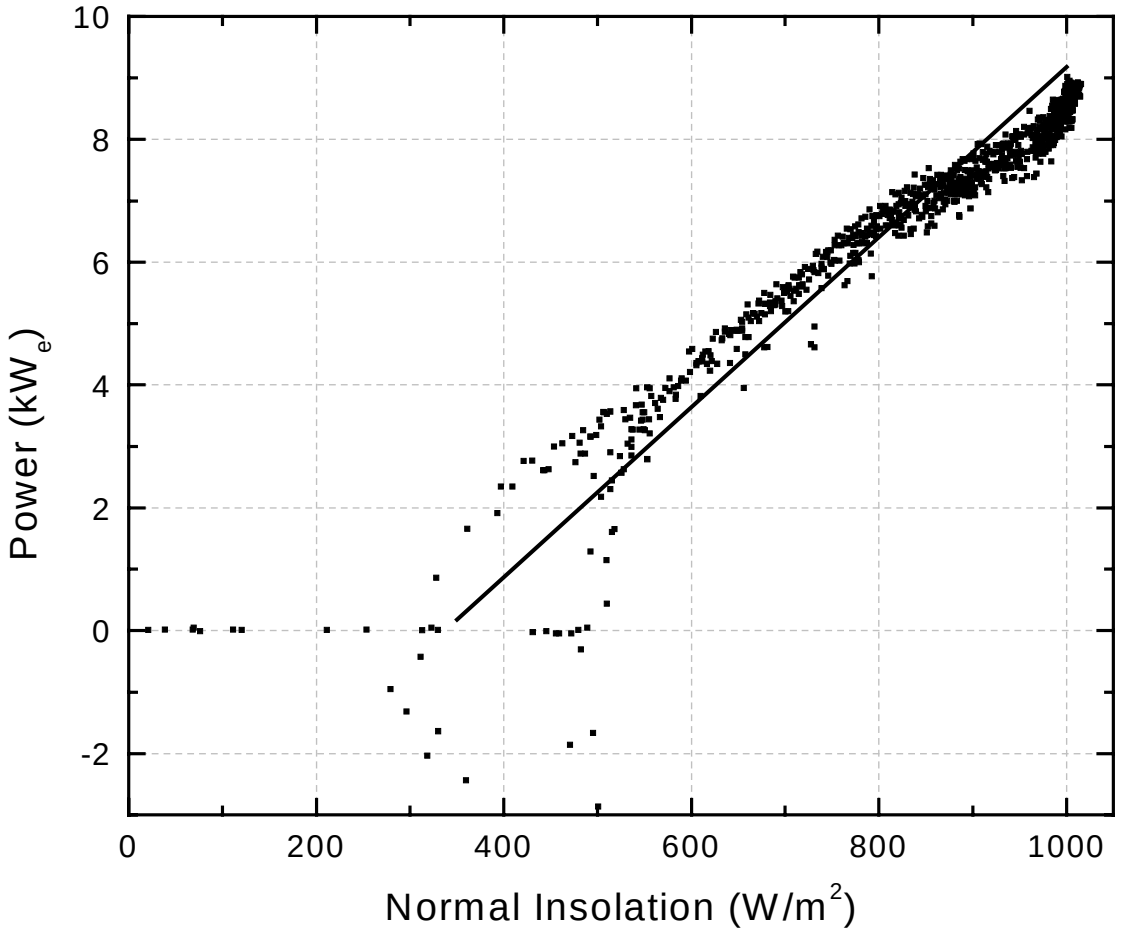
Performance

- Mod 1 peak system efficiency is about 18-20% (net)
- Performance improvement also being addressed



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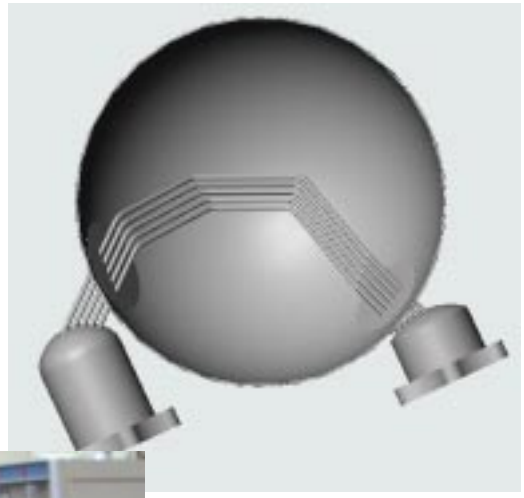
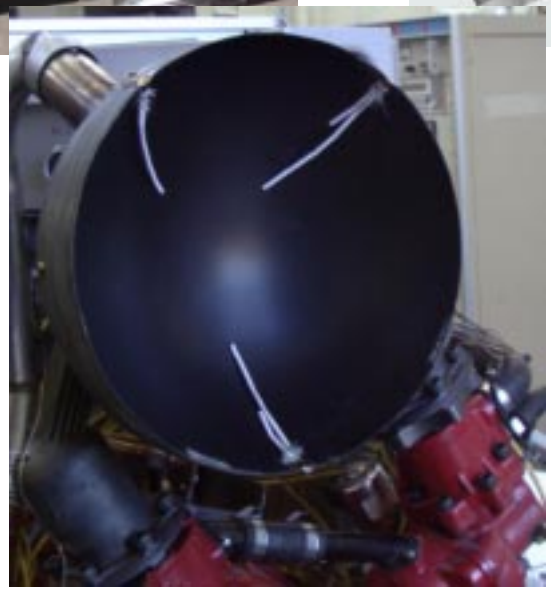
Advanced Components

- ADDS facilitates evaluation of components in a systems context
- Operation with heat-pipe receiver
- Operation with hydrogen working gas





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Commercial Interest

- Success of the ADDS project is attracting commercial interest
- WGA is working with an independent power producers and a large technology company to develop commercial projects pursuing commercialization of the ADDS system
- There is significant interest in WGA technology applied to 30 to 60-kW Brayton hybrid system for utility applications

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Summary

- The ADDS project has been an excellent R&D test bed
  - Addresses remote power applications
  - Advanced components and systems integration are evaluated in a system context
  - Involves real-world testing on American Indian lands
- The ADDS project has been successful
  - THE SYSTEMS WORK!
  - Mod 1 demonstrated unattended operation and specified performance of grid-connected system
  - Mod 2 off-grid water-pumping system successfully demonstrated
  - Reliability and performance improvement being addressed
- The ADDS technology is ready for the next steps
  - Continuous system improvement
  - Deployment on the Laguna reservation
  - Large-scale deployment (10+ systems) in Nevada or elsewhere