Dish Stirling Development

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the U.S. Department of Energy under Contract DE-AC04-94-AL85000.
• Dish Stirling most efficient solar conversions approach
  – 29.4% net conversion efficiency demonstrated

• Stirling Energy Systems to commercialize mature technology
  – Based on McDonnell Douglas successful designs
  – Substantial redesign for cost
  – Deployment model for utility scale plants

• PPA’s in place for 800 to 1750MW
  – Two large plants in California
  – Allows jump to automated production
  – Production rate path to low cost
Project Description

• Support Stirling Energy Systems in Commercialization of dish-Stirling Technology
  – Operation of Model Power Plant
  – Reliability improvement
  – Next generation design support
  – Cost reduction

• Industry-led Technology Partnership
  – Substantial private financing
  – Presentation is on Sandia-Centric tasks
  – CRADA agreement protects SES data
Goals and Objectives

• “Do what it takes to make SES successful”
  – Technology transfer
  – Design and analysis support
  – Aggressive reliability improvement program modeled on ADDS
  – Cost reduction design
  – Tours for investors and partners
• Baseline reliability
  – Understand what we have
• Lead reliability improvement program
Baseline Reliability

- Delivered baseline reliability milestone report to DOE
- Classified primary fault issues
  - No “Show Stoppers”
  - Legacy hardware a consistent problem
- Developed processes for root cause analysis
  - XFRACAS commercial software
  - Tiger team approach
  - Automated web tools for monitoring performance
- SES currently staffing up in key areas
  - Systems engineering
  - Electronics/controls
- Performance Excellent
  - Over 30% gross efficiency (un-calibrated)
  - Over 25kW net per dish (calibrated)

Total System Hours
Over 8500
Progress: Incident Tracking

- Failure Reporting, Analysis and Corrective Action System (FRACAS)
  - Reliasoft “XFRACAS” software implemented
    - Web-based
    - Technician training
- Web-based data mining tools developed
  - Real-time data extraction
  - Critical to fault resolution
- Ownership of issues established
  - Issues prioritized based on criticality criteria
  - Team leaders own problems
  - Management interest and tracking
Progress: Compressor Valve

- Greatest problem area in 2005
  - Inconsistent gas control system valve operation
    - Sticking open
    - Sticking closed
    - Abnormal wear
- Sandia-led attack
  - Careful characterization led to clear engineering specification
  - Low-cost valve replacement
  - Reduced valve size by 150x
- No compressor valve faults last 12 months!
- Qualifying additional high volume US manufacturers
- Integrated compressor valve blocks ordered
- Additional Gas Management System work underway
Progress: Hardware Improvements

- **Alignment**
  - Sandia-developed alignment strategy
  - Substantial performance improvement (60-80% decrease in head delta T)

- **Oil leaks**
  - Developed modified oil galley assembly approach
  - Provide redesign support

- **Electrical**
  - Rework old controls to improve workmanship
  - Analog filters improve digital stability

- **Instrumentation**
  - Developed methods for consistent thermocouple installation
  - Understanding and improving motor position sensors
  - Controls characterization
MPP Operation

- Over 8500 hours operation
  - Routine unattended operation
  - Stakeholder demonstrations
  - Development and qualification testing
- Substantially improved dish performance
  - Reflectivity
  - Mirror slope error
  - Alignment
  - Can overpower engine in Albuquerque conditions
  - Up to 27kW new output
  - Little cost increase
Progress: Design Support

• Integral with reliability improvement
  – Reliability issues are designed out (Some known issues will continue until redesign implemented)
  – Cost reduction efforts must be monitored to prevent inadvertent system degradation
  – Better design processes will lead to analytically-verified designs

• Sandia experience and capabilities critical support to SES for rapid next-generation development
  – Systems viewpoint
  – Field experience
  – Sandia people on design review boards
Integrated Design Tools

• Integrate CFD, FEA, and Sandia Optical Analysis
  – Developed understanding of key structural interactions
  – Sandia proposed integrating tools to define optical impact of design changes
  – Modeling and integration by SES and their engineering consultants
  – Eliminate “deflection budget fallacy”

• Successful integration
  – Validated with MPP physical and optical measurements
  – Redesign reduced rotating weight by about 4000 pounds
  – Resulting structure stiffer, reducing flux hotspots that impact performance and reliability
  – Located source of subtle optical distortions

• Excellent example of Labs-Industry leveraged teamwork

• Structural team success hinged on this model
Field Systems Model

- Integrated performance and revenue stream model
- Evaluate field spacing impacts
  - Dish-to-dish shading
  - Dish layout including stagger
  - TMY2 or other environmental data
  - Site slope
  - Incorporates measured data effects
- Rolled out to SES
  - Used in developing 1MW installation layout
- ASME paper 2007
Progress: Design Support

Alignment Tool Development

- Sandia/SES/Schuff Steel collaborative effort
- High rate production tools needed
  - On-site assembly plant
  - In-field re-alignment for repairs
  - Substantially faster approach proposed
- Machine vision camera system
  - Field trials underway
  - Software development for automation
  - Extensive Sandia alignment experience critical
Progress: Design Support

Cost – Performance trade-offs

- Systems-level view
- Mirror Options
  - Evaluated impact of slope error
    - PCU aperture size
    - Receiver cavity thermal losses
  - Hard to pay for cheap mirrors
- Dish/System sizing
  - Design to max vs. averages
  - Evaluate engine performance
Controls Characterization

• Develop understanding of present PCU controls
  – Vintage hardware and software
  – Incomplete documentation
  – Sandia-developed engine simulator basis provided

• Assist SES in characterizing and understanding dish controls
  – SES aggressively hiring controls team
  – Sandia experience with the WGA/SES dish controller critical
Sandia Plans for FY07

• Reliability Improvement continues priority#1
  – Teaming with new SES personnel
  – XFRACAS tool guides development

• Support controls team
  – Understanding of controls software
  – Continue cataloging fault areas
  – Suggest/develop algorithms for improved controls
  – Support engine controller modernization
Sandia Plans for FY07

• 40 unit support (next-generation prototypes)
  – Leverage experience
  – Aggressive schedule
  – Installation of prototypes at Sandia

• High volume production design support
  – Build design tools with SES team
    • Tool validation
    • Technology transfer: ESG
  – Build SES personnel technical capability
  – Consult, emphasize a systems view
    • Easy to compartmentalize

• Alignment tool development
  – Coordinate efforts with Schuff and SES
  – Field and Assembly building tools
Advanced Development

- Labs need to look beyond daily needs
- Next generation
  - Cost reduction
  - Performance enhancement
  - Life extension
- Key areas
  - Facet design
  - Advanced dish design
  - “Levelizer” receiver concepts
  - Maintenance predictive controls algorithms
  - Sensors and advanced controls concepts
Summary

• Reliability improvement processes impact every “facet” of system
  – System operation
  – Maintenance
  – Redesign
  – Deployment
  – Cost reduction
• MPP Daily operation improving
  – Addressing reliability issues
  – Evolving priorities
  – Excellent system performance
• Improved systems a strong focus
  – Near-term deployment a key to improved reliability
  – Prototypes at Sandia
• Successful labs-industry partnership
  – U.S. Industry-led teaming
  – Leverage DOE/Laboratory experience
  – Analytical and hardware improvements clear