DOE Solar Energy Technologies Program Peer Review

Technical Track: CSP
Project Name: Dish/Engine Development
Principal Investigator: Chuck Andraka

Denver, Colorado
March 9-10, 2009

Quality

- DOE Team
  - Principal investigator
    - Chuck Andraka
    - 24+ years in CSP
    - Optics, controls, heat transfer, systems
  - Additional Support
    - Rich Diver: Over 30 years in CSP
    - John Quintana: Mechanical tech, 10 years in CSP
    - Chris Beauchamp: Mechanical tech, 5 years in CSP
    - Student Intern Program
    - Sandia resources as needed
- SES Team
  - Nearly 100 employees now on board
  - Key experienced engineering staff
- Awards and notoriety
  - Popular Mechanics “Breakthrough Award”
  - National Geographic, BBC, Discovery Channel, PBS, etc.
  - World record performance

Productivity

- DOE budget
  - Approximately $1M/year
  - In-kind engineering support
  - Facilities and infrastructure
  - Safety and mentoring
- SES Budget (cost share)
  - Approximately $100M in CY08
  - Supplements DOE budget
  - Pays for all hardware and equipment

Accomplishments

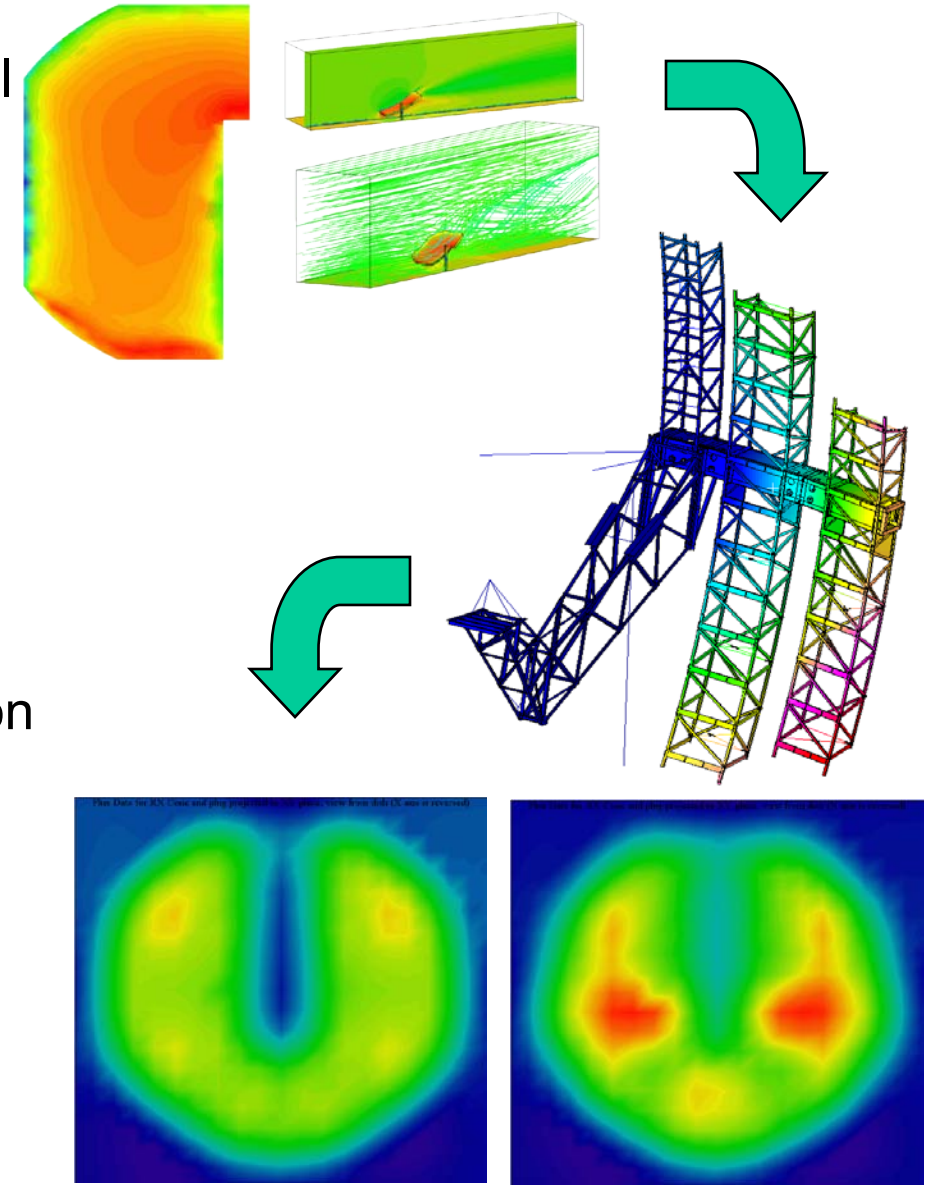
- Substantial systems, optical and thermal modeling supports design approach and systems models to properly size next-generation systems to engine and environmental conditions
- Demonstrated 31.25% net system efficiency after incorporating Sandia and SES system improvements
- Substantial input to design process with expertise and tool development led to a total rotating weight reduction of 6000 pounds (out of 17500)
- Installation of production prototypes begun at Sandia
- Developed and implemented SOFAST Mirror Characterization system for facet production inspection
- Developed and implemented engine simulator for controls development and testing
- Substantial development support of dish and engine controls modernization process
- Development of viable options for rapid assembly and field alignment of mirror systems, in progress
- SES completed AFC, and judged “data adequate”
- First SES production engine operational in test cell
- Established and maintained ES&H controls, documentation, and training processes for entire SES team
- Consistent involvement in reliability improvement evaluations, root cause analysis, option development, prioritization, and design processes
- Assist Infinia with optical and thermal design
  - Upgrade CIRCE for facet deformation
  - Develop design process for single-facet dish

Scientific/Technical Approach

- Industry-led program
  - Leverage Sandia expertise in key areas
    - Optics
    - Systems
    - Controls
    - Materials
    - Failure analysis
  - Responsive
  - Consultation role is critical to SES success
  - Development in key areas
    - Optics
    - Controls

Scientific/Technical Approach: Combined Models

- Trade “deflection budget” for “optical budget”
  - Peak flux
  - Aperture size
  - Power balance
- Modern analysis tools
  - CFD
  - FEA
  - Optical model
- 4000-pound rotating weight reduction
  - 17500 pounds reduced to 13500 pounds
  - Improved optical stiffness
  - FY07 effort
  - Rectangular dish design
- Approach now in SES’s “toolbox”

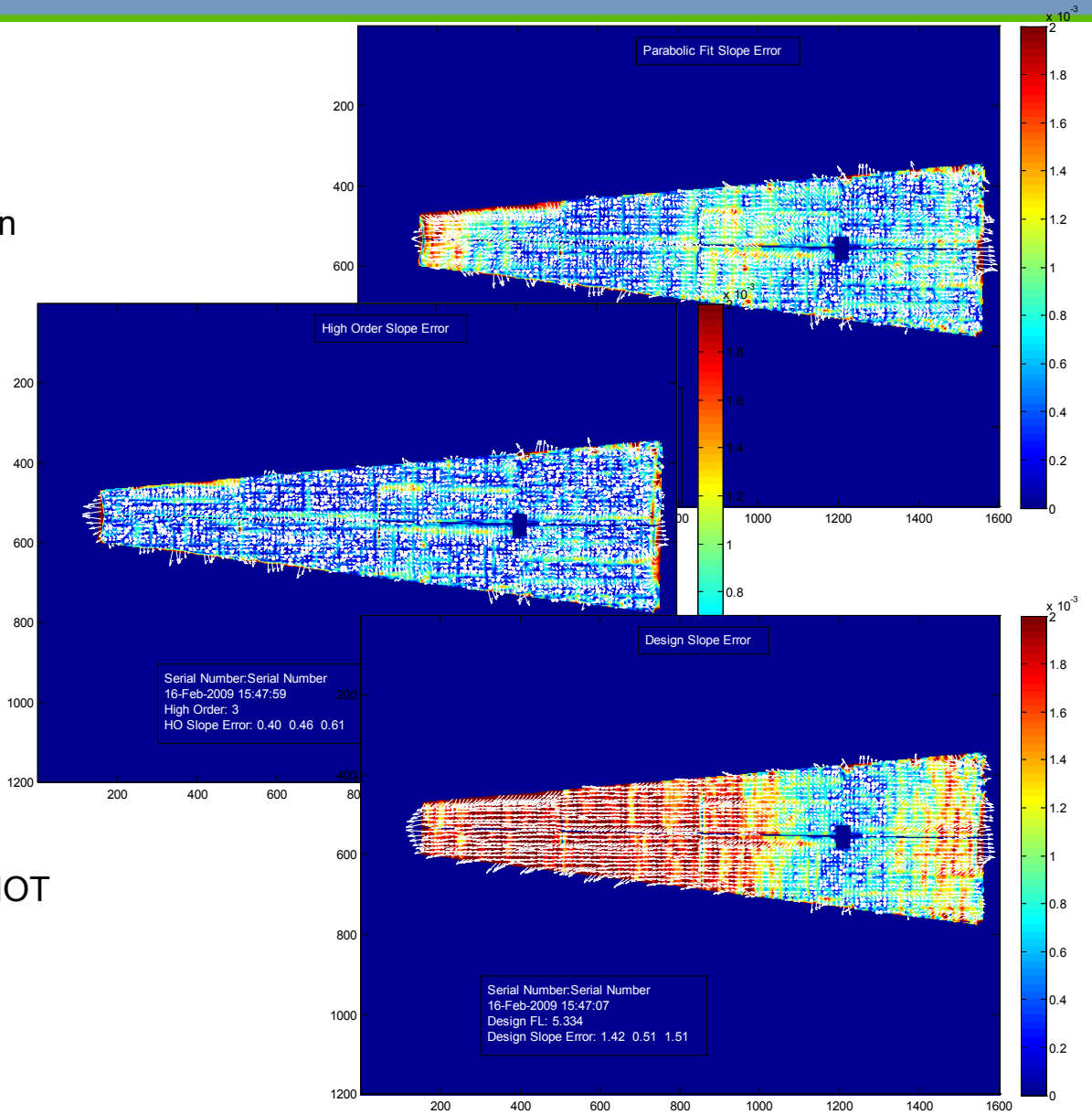


Approach: Installation of Production

- Four production prototypes being installed at Sandia
- Culmination of substantial DFMA process
  - 6000 pound weight reduction compared to MPP dishes
    - Leverages combined analysis tool approach
  - Structural approach maximizes stiffness
  - Substantial optical design support
  - Every aspect modernized
  - 60% part reduction in PCU
  - Substantial Sandia involvement
    - Optics
    - Thermal
    - Controls
    - Systems
- SES-funded hardware and infrastructure
- Rapid path to additional installations
  - (6) X1 production units upgrade MPP
  - 1.5MW in AZ

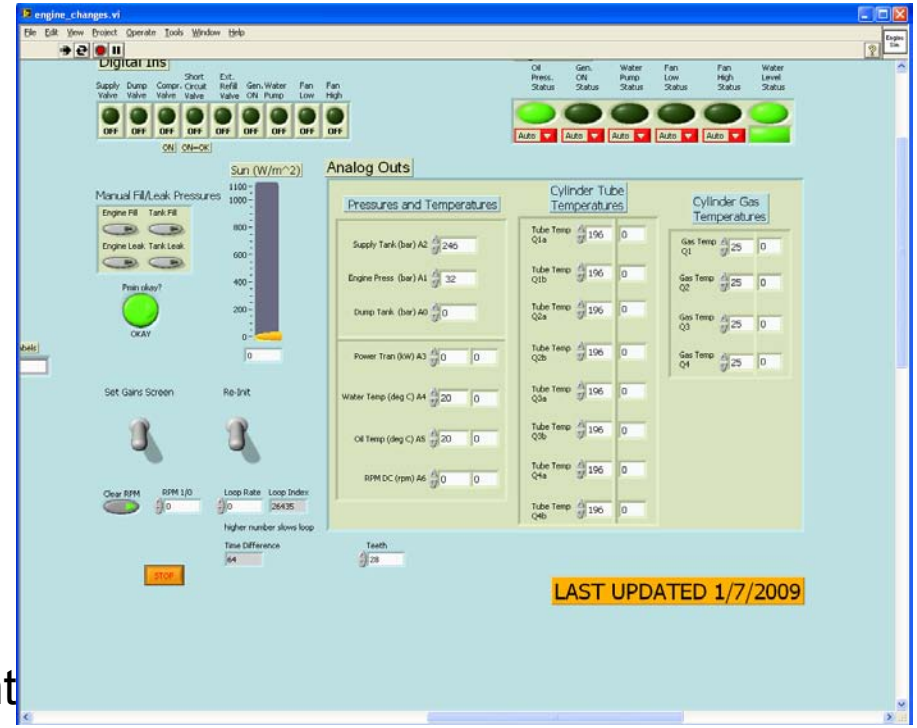
Scientific/Technical Approach: SOFAST Mirror Characterization

- Rapid mirror characterization
  - Slope error
  - Mirror shape
  - Suitable for production inspection
    - 10 seconds per facet
    - Self-correcting setup
- Based on fringe reflection
  - Optical imaging
  - Active target
- Key enhancements
  - Self-boresighting
    - Data suitable for direct analysis
    - No physical re-setting
  - Added shape errors
    - Twist
  - Fully archiving
  - 600k+ points per facet
  - Results compares well with VSHOT
  - Fast
  - Low cost
- Deployed at SES supplier
  - January Milestone met



Scientific/Technical Approach: Engine Simulator

- Labview based engine simulator
  - Generate all sensor outputs from an engine
  - Develop simple parametric models of engine response
    - Data-based rather than model-based
    - Successful approach used on Solo engine
- Accurately exercise controls
  - Characterization
    - "Black Box"
    - Speeds design process
    - Protects engine hardware
  - Development
    - Modernized controls
    - New algorithms
- Deployed
  - Two copies in use by SES
  - Key to rapid controls development



Relevance/Impact of Research

- Performance
  - Record set at 31.25% net to grid
  - Performance directly impacts revenue stream
  - Highest performing solar system
- Prototype development
  - Significant cost reduction
  - SES led
    - Key DFMA experts involved
    - Involvement of production partners
  - Sandia consultation in solar areas
- Demonstration of prototypes
  - Critical for deployments
  - Schedule driven
  - Supports financing

Future Directions

- Complete 4 “X0” installations at Sandia (immediate)
  - Proof of success
  - Fine tuning
- Upgrade 6 Sandia MPP units to “X1” (2009)
  - Production units
  - Field-level controls tuning
  - PF correction
- 1.5MW demonstration plant (2009)
  - Arizona
  - Proof of field level capabilities
    - Controls
    - Assembly and Deployment model
    - Interactions with utility
  - Basic building block of large plants
    - 60 units
- Large deployments (2010)
  - SDGE: 300-900MW
  - SCE: 500-850MW