Low-Cost Light Weight Thin Film Solar Concentrators

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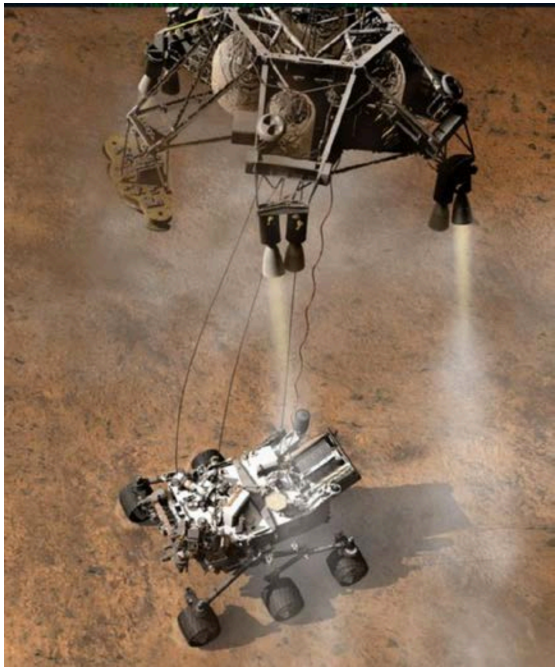
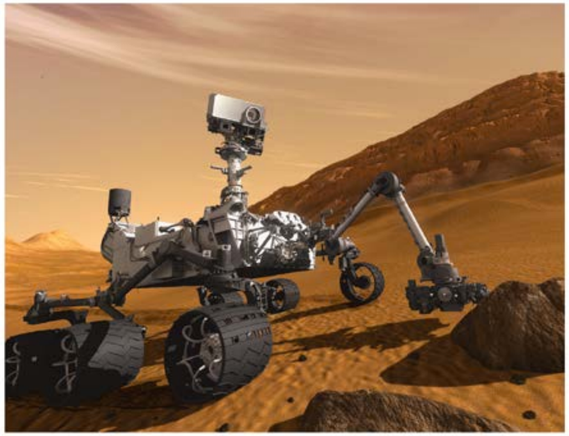
Project Objectives

- Develop a concentrator to meet DOE's cost goal of 6¢/kWh while meeting all stringent technical performance requirements.
- Project leverages extensive space/terrestrial experience by JPL and L'Garde to develop
  - A low-cost concentrator with the following key features:
    - Metallized reflective thin film material with high reflectivity (>93%) with polyurethane foam backing
    - Single mold polyurethane backing fabrication enables low cost high production manufacturing
    - Ease of panel installation and removal enables repairs and results in a low total life cycle cost
    - Approach applicable to parabolic dishes, troughs, and heliostats
    - Technology could be applicable as a retrofit on existing facilities or for new installations
- Optimized overall system to meet $\$75/m^2$ goal
  - Low cost actuators, shared resources, field installation approach achieved through design trades

NASA/JPL

- JPL is a NASA FFRDC operated by Caltech
- 5000+ in a 170 acre plot nestled in Pasadena’s San Gabriel Mountains
- Premier organization known for planetary exploration
  - Best known for its recent Mars Science Laboratory (Curiosity)





Curiosity Rover

JPL Relevant Experience

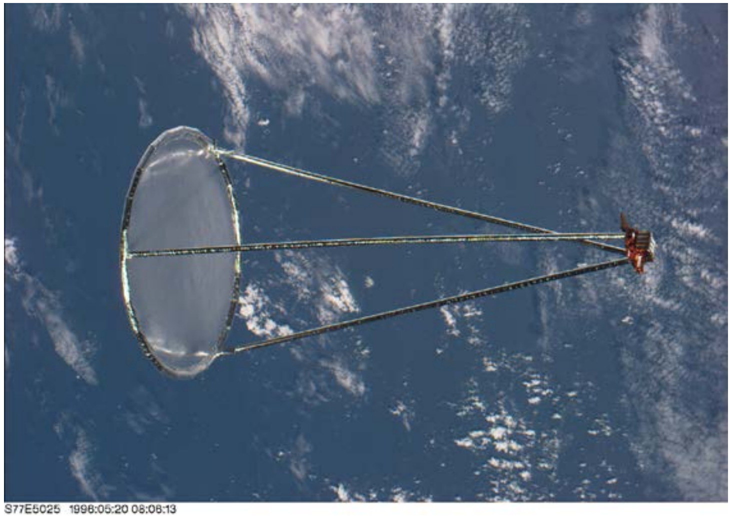
- JPL has been deploying parabolic dish RF antennas world-wide for over 55 years (January 1958) and conducted the supporting wind tunnel testing
  - Currently operating three 70-m dia. parabolic dish antennas around the world along with 34, 26 and 9-m dia. antennas

- In the 70's and 80's, JPL spun off parabolic dish RF antennas into multiple 11-m dia. dishes with JPL-developed silvered glass on glass foam facets
- Demonstration power plant in Osage City, KS in the 80's using JPL technologies

L’Garde

- Small company in Irvine, CA
- Knowledgeable in both lightweight/inflatable structures and reflective thin film technologies
  - Demonstrated an inflatable parabolic dish antenna in space
  - Conducted ground test of inflatable parabolic dish reflectors

L’Garde 3 meter diameter thin film concentrator



Inflatable antenna experiment that flew on orbit in May of 1996.

Major Project Phases and Milestones

- Project will be accomplished in 3 phases over three years

Phase	Key Milestones and Deliverables
Phase 1 (DESIGN & RISK REDUCTION)	• Material selection & fab processes validated
	• System trades to optimize overall system
Phase 2 (DETAILED DESIGN & FAB)	• Facet and back support development
	• Mechanical detailed design
Phase 3 (COLLECTOR SYSTEM BUILD & TEST)	• Integrate 4 kW_t concentrator system
	• Validation testing

Budget Period Summary

- Phase 1 activities for this budget period are grouped under Facet Design/Build and System Studies
- Facet Design and Build
  - ❑ Task 1.1: Facet Design Studies
  - ❑ Task 1.2: Reliability Studies
  - ❑ Task 1.3: Alpha prototype concentrator build
- System Design/Analysis (Task 1.4)
  - ❑ Subtask 1.4.1: Performance optimization
  - ❑ Subtask 1.4.2: Drive mechanisms and controls
  - ❑ Subtask 1.4.3: Mechanical structure design
  - ❑ Subtask 1.4.4: Concentrator thermal modeling
  - ❑ Subtask 1.4.5: Manufacturing plan

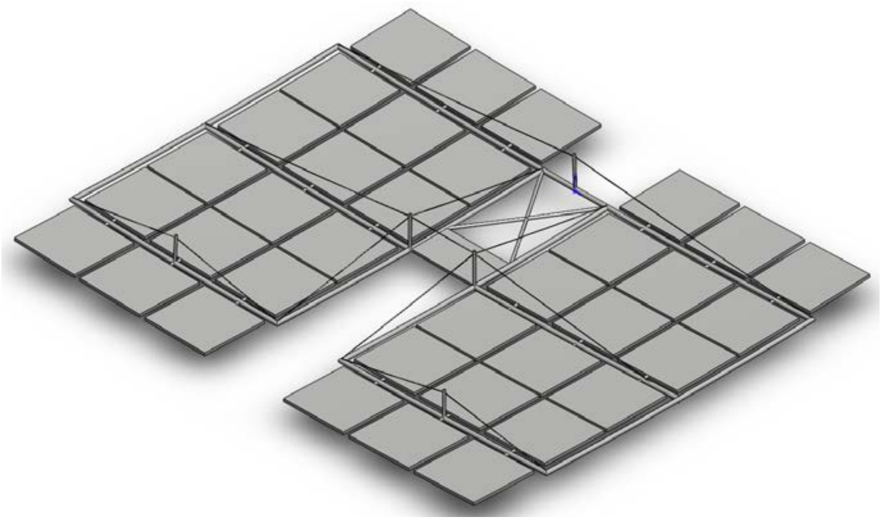
Overall project status

- Late project start – delayed from Oct '12 to Jan '13 due to contractual discussions
  - JPL started work on small amount of risk money
  - Full funding associated with project on 2/28/13
- L'Garde on contract to JPL
- Both teams are charging ahead full steam now and making rapid progress

Task 1.1.1: Facet Design Studies

- Studies driven by the goal to infuse low-cost high performance technologies into current and future CSP applications
  - heliostats (large and small), parabolic trough and parabolic dishes
- Current studies on heliostat designs are looking into design interactions of the mirror module (film and substrate) and support structure

L1 (Large 1) Design



NASA New Technology Report # 49116

- Design features
  - Facets "give" in winds > 35 mph and then self re-latch
  - Guy wires in tension to facilitate focusing and low mass structure
  - A single common drive stows at any altitude angle or elevation with reflective surface either up or down
    - Pointing up (high) for rain cleaning
    - Pointing down (low) for stow during high winds/hail
  - A single standard post mounted azimuth drive

L1 Animation

- L1 stow animation
- L1 facet “give” in winds

Other Design Trades

- Within heliostats we are looking at other options
  - Heliostat cost vs. system performance driving operations, geometry and material selection
  - Space frame derivatives to reduce structural requirements
  - Gradual degradation of heliostats in winds

Task 1.1.2: Structural foam

- We are evaluating several (6-7) candidate closed cell foam materials
  - Accuracy of surface that can be produced with the various materials and associated processes
  - Coefficient of thermal expansion (CTE) match with film
  - Bonding issues and how they influence the fabrication process
- Capitalizing on prior activities at JPL/L'Garde in solar thermal and also from NREL/SNL literature

Task 1.1.3: Thin Reflective Film

- Identified 2 primary candidates – ReflecTech and 3M Solar Mirror Film 1100
  - Samples have been procured; will be tested shortly
- Identified 3 secondary candidates and are in the process of evaluating them based on available literature

Other Supporting Activities

- Gathered standards for optical and structural testing of facets
- Participated in online conferences with industry
- Visited industry suppliers like Rocketdyne
- Obtained codes DELSOL 3, SolTrace
- Discussions with NREL and Sandia on polymer reflective surfaces, surface measurement accuracy
- Gathering information on traditional and novel heliostat power tower companies and their designs
- Developed simple models for wind deflection impact on surface slope errors

Summary

- Large heliostat baseline design developed
  - Further trades on-going
- Baseline reflective material selected and samples obtained for further testing
- Identified 6 candidate foam materials for further evaluation