SkyFuel

The Sunrise Of Solar Power™

Development of an Advanced, Low-Cost Parabolic Trough Collector for Baseload Operation

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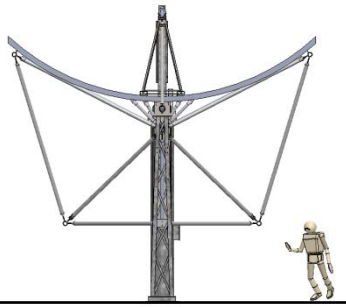
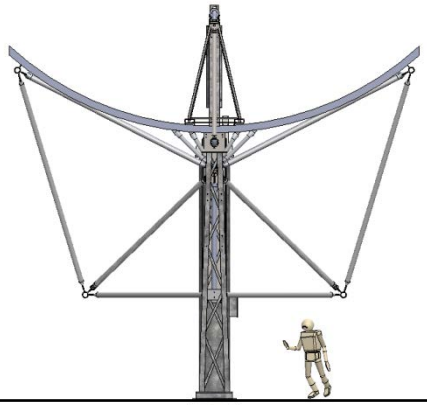
SkyTrough® DSP: “Dispatchable Solar Power”

Project Objectives

- SkyFuel is developing a commercial parabolic trough collector with:
  - LCOE of 9 ¢/kWh$_e$ in 2020
  - Capacity factor of 75%, suitable for baseload operation
  - Larger aperture than any trough in commercial operation today
  - Maximum operating temperature in excess of 500ºC
  - Ability to use molten salt directly as the HTF

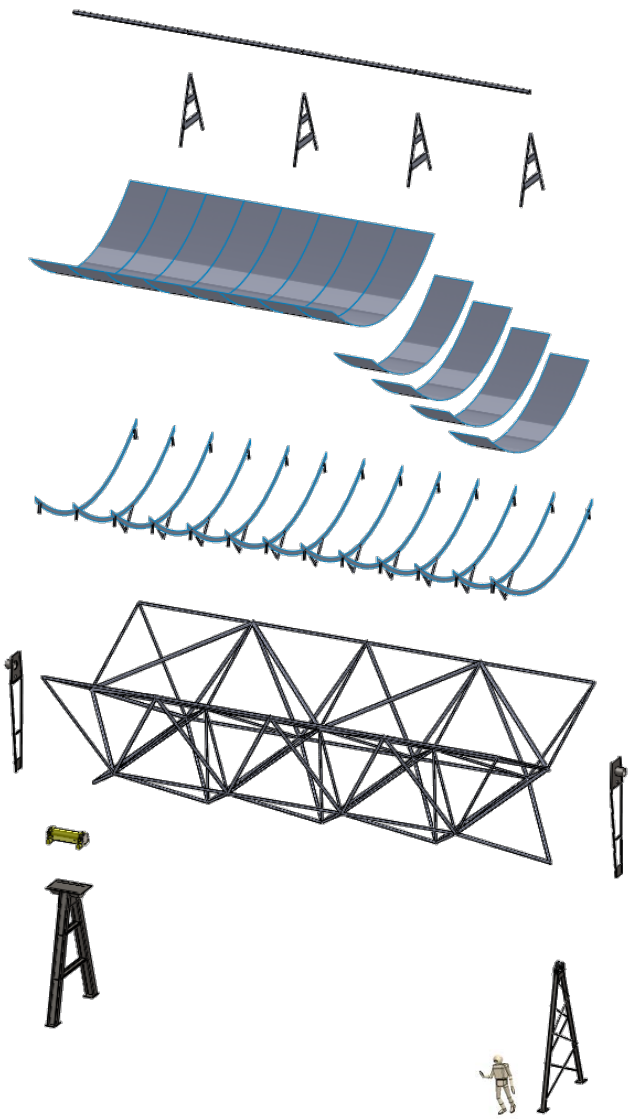
- At project completion:
  - Install a full-scale, fully operational, single module loop with molten salt as the HTF

SkyTrough® vs. SkyTrough® DSP

	SkyTrough® 	**SkyTrough® DSP** 
Aperture width	6m	~8m
Maximum operating temperature	400°C	500°C
Heat transfer fluid	Thermal Oil	Thermal Oil or Molten Salt
ReflecTech™ Mirror Film	ReflecTech™PLUS - Abrasion resistant coating	ReflecTech™PLUS, advanced construction with: - Integrated abrasion resistant and anti-soiling coating - Increased specular and hemispherical reflectance - Reduced cost

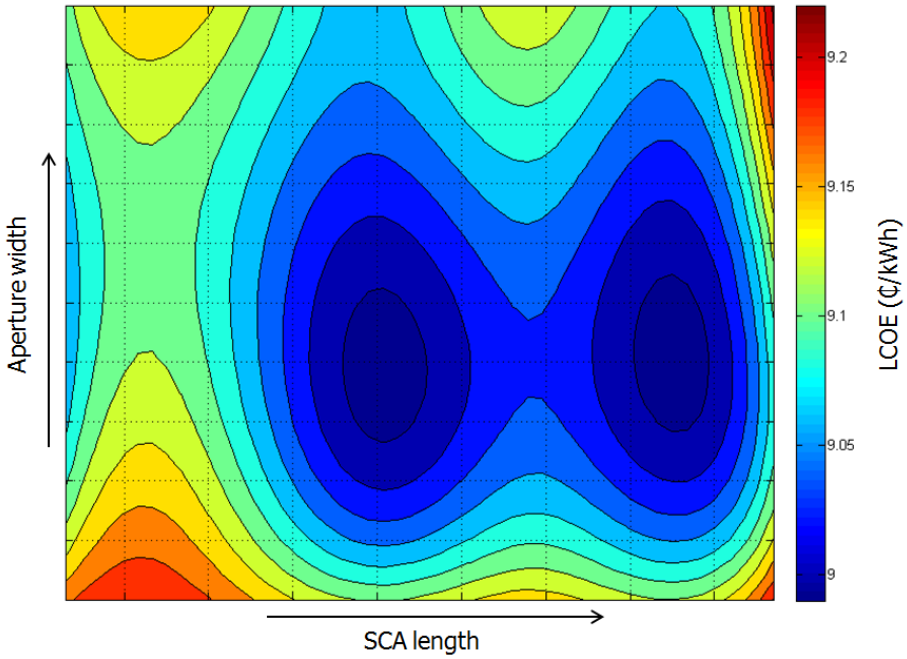
Project Update

- Through Spring 2013, SkyFuel has completed:
  - Analysis of the optimal trough aperture for minimizing solar field cost
  - Detailed structural, optical, and thermal models for the SkyTrough® DSP
  - The majority of collector component design
- Manufacturing and testing are underway for key components
- In addition, we have completed a production run of advanced construction ReflecTech™ Mirror Film suitable for installation on the demonstration salt loop



Project Update: Trough Size Optimization

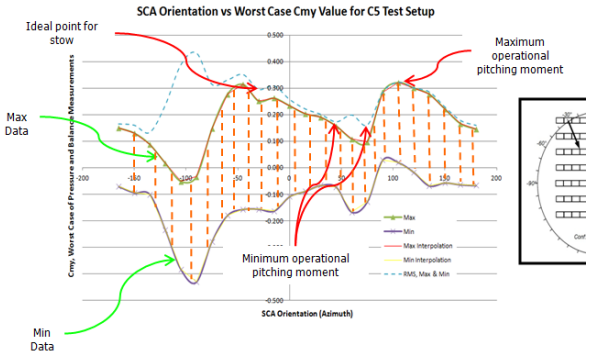
- Analyzed over 1,500 discrete cases, varying:
  - Module aperture width
  - Number of modules per SCA
  - Receiver size, receiver count per module
- Optimized component design for each case
- Defined component cost based on indicative pricing
- Established optical performance with ASAP
- Used SAM empirical model to determine LCOE
- Evaluated design against future market conditions such as changing component costs, technology



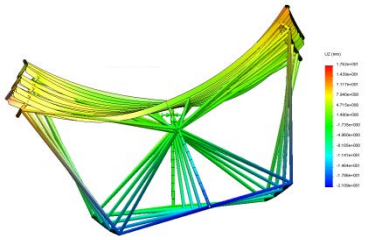
Project Update: Structural Design

- Initially considered space frame, torque box, and torque tube designs
  - Accounting for both production and installation costs, space frames were found to have significantly lower cost

- Structural design of a parabolic trough space frame is primarily influenced by torsional load coefficients
  - Torsional load increases with the square of aperture width
  - Collected solar energy increases linearly with aperture width
  - This suggests an ultimate limit on aperture width



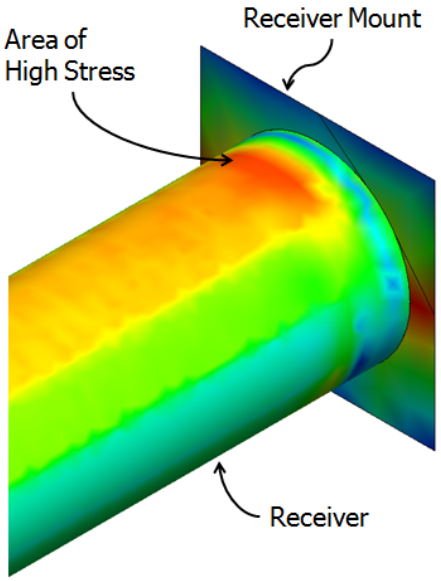
- Examined twist in structure under wind loads, including this error in performance calculations
  - Space frame design is limited by structural integrity, not twist error;
  - A frame strong enough to structurally withstand expected torsional loads already has twist error below an acceptable limit: further reduction of twist error would not pay for the additional weight needed in the frame

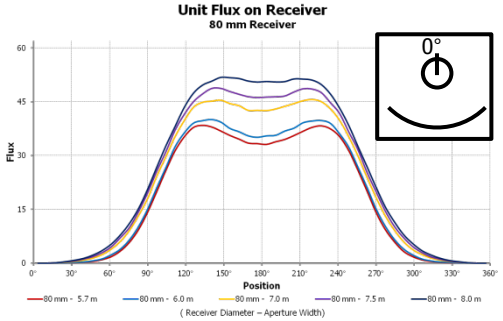


- Conducted similar loading analysis to finalize design for all other structural components (torque plates, pylons, receiver supports)

Project Update: Receiver Modeling

- Receiver stress and service life prediction:
  - Receiver service life was investigated using an analytical approach
  - Stresses in the receiver were determined from modeling pressure and temperature distributions in an operating receiver
  - Receiver service life prediction considered stress and endurance limits of the material, corrosion, aging, and the impact of chromium carbide precipitation at high temperatures
- Based on the data available and the analytical models, the receivers should have a service life greater than 30 years in the field with molten salt
- Additional testing will be done to verify fill/drain and freeze recovery procedures
- This work on receiver stress, corrosion, and aging has been submitted as a conference paper to SolarPACES 2013





Project Update: Improved ReflecTech™ Mirror Film

- Improvements to ReflecTech™ Mirror Film are being developed:
  - Increased specular and hemispherical reflectance
  - Abrasion resistant coating
  - Anti-soiling functionality
  - Reduction in specific cost

- Positive results so far, with advanced formulations currently undergoing accelerated weathering tests
- Specularity goal of 1.3 mrad demonstrated to be achievable

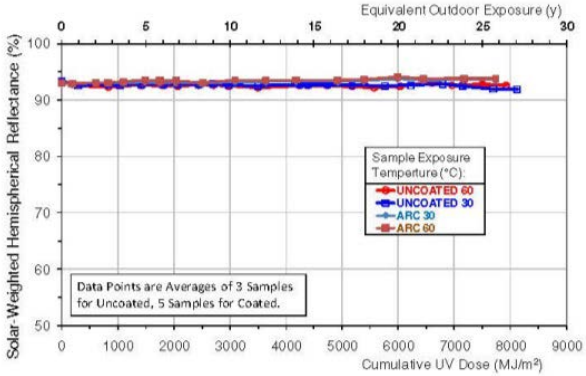


Fig 1. UAWS test of uncoated and ARC coated ReflecTech® after 25+ years equivalent UV dose at 30°C and 60°C.

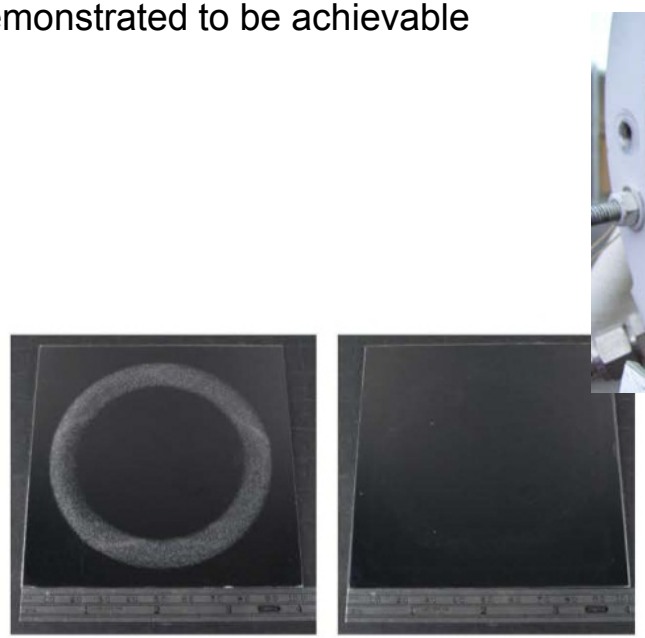
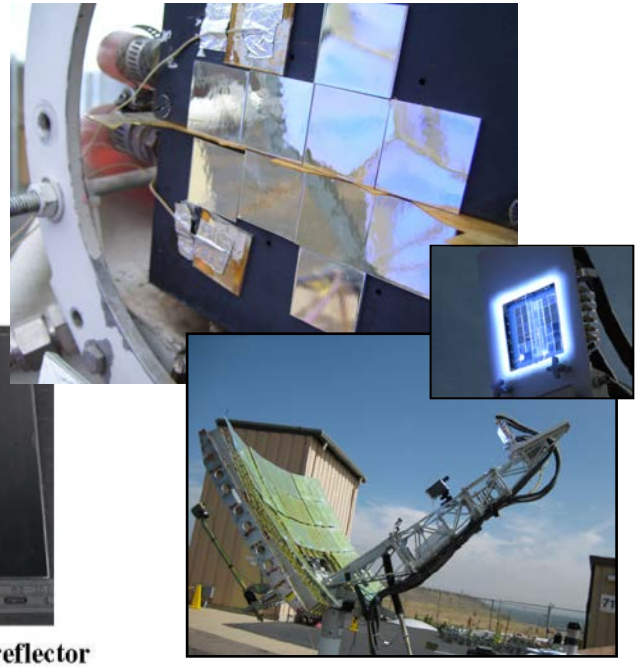


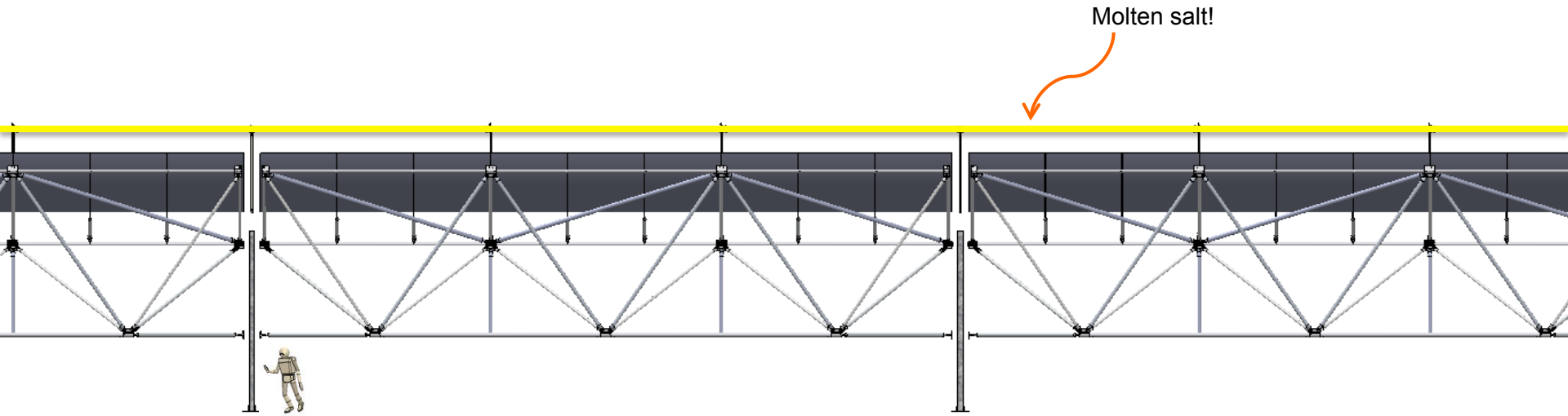
Fig 4. Taber abrader damage to polymer film reflector sample without ARC coating (left) and almost no damage with ARC coating (right).



Project Update: Component Design for Molten Salt

- Majority of collector design complete, with manufacturing and testing of key components underway

- In developing a large aperture collector for use with molten salt, SkyFuel is:
  - Experimenting with binary and ternary salts
  - Exploring commercial and custom flexible piping solutions compatible with molten salt
  - Building an in-house test stand for developing receiver fill/drain and freeze/thaw procedures



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Questions?