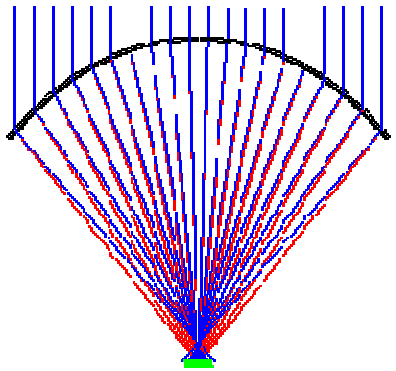
# Using Mirrors with Solar Cells Should Be a Capital Offense…

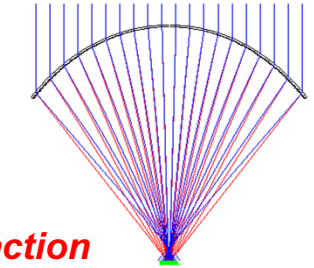
Mark O'Neill

July 25, 2012



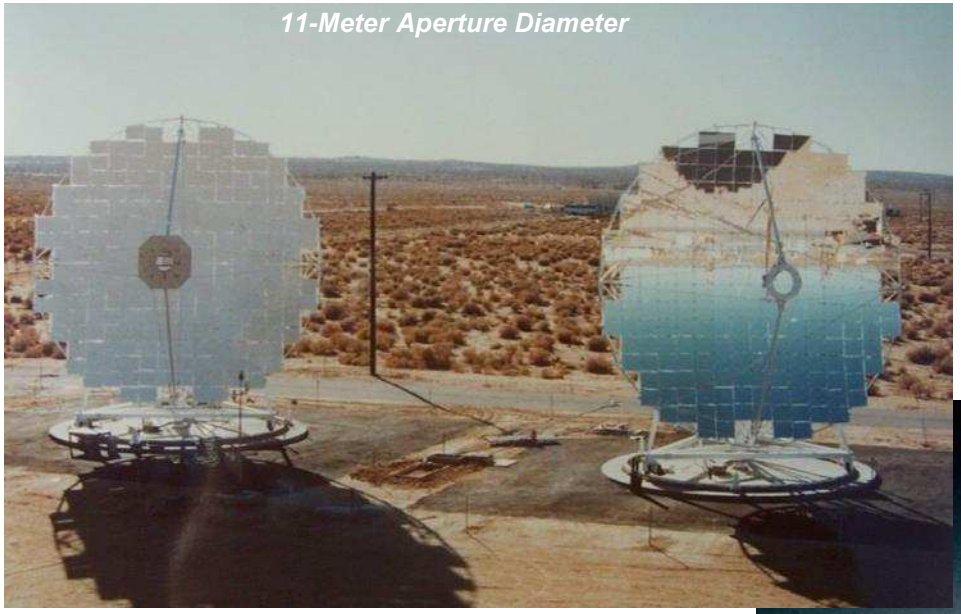
Mark O'Neill, LLC
P.O. Box 2262
Keller, TX 76244-2262 USA
817-380-5930
markoneill@markoneill.com
www.markoneill.com

# Entech's Background With Reflective Concentrators Led To Our Adoption of Refractive Concentrators

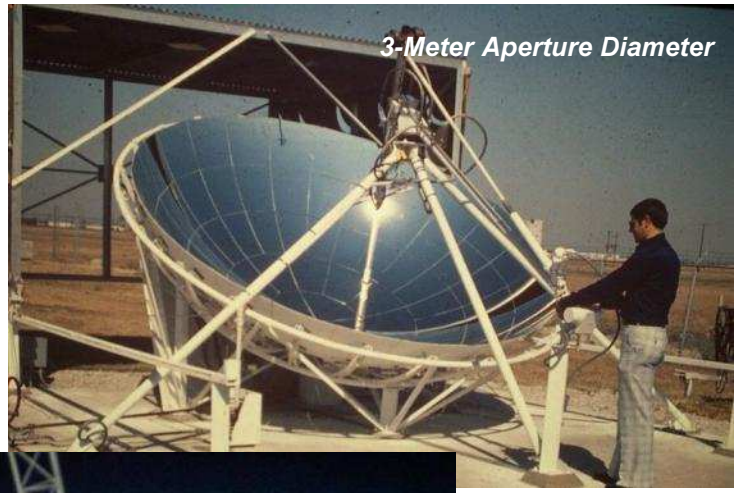


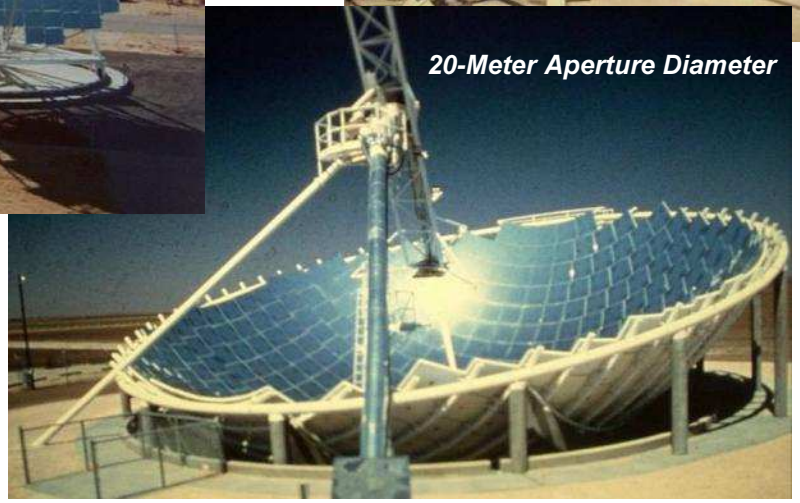
***Entech's Reflective Concentrator Work Confirmed That Its Symmetrical-Refraction Fresnel Lens Approach Is Vastly Superior to Reflective Concentrators for Photovoltaics***

**Parabolic Dish/Test Bed Concentrators Built for JPL and Transferred to Sandia-Albuquerque**

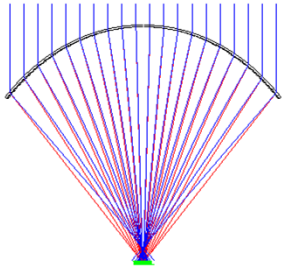


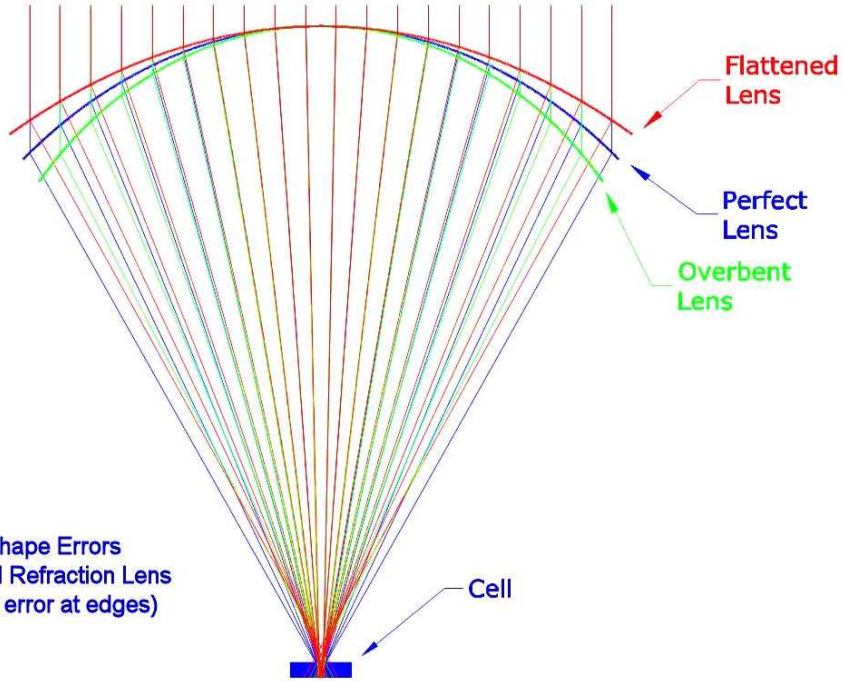

**Spherical Bowl Solar Concentrators**



# Direct Ray-Trace Comparison of Shape Error Tolerance of Symmetrical-Refraction Lens Versus a Reflective Concentrator





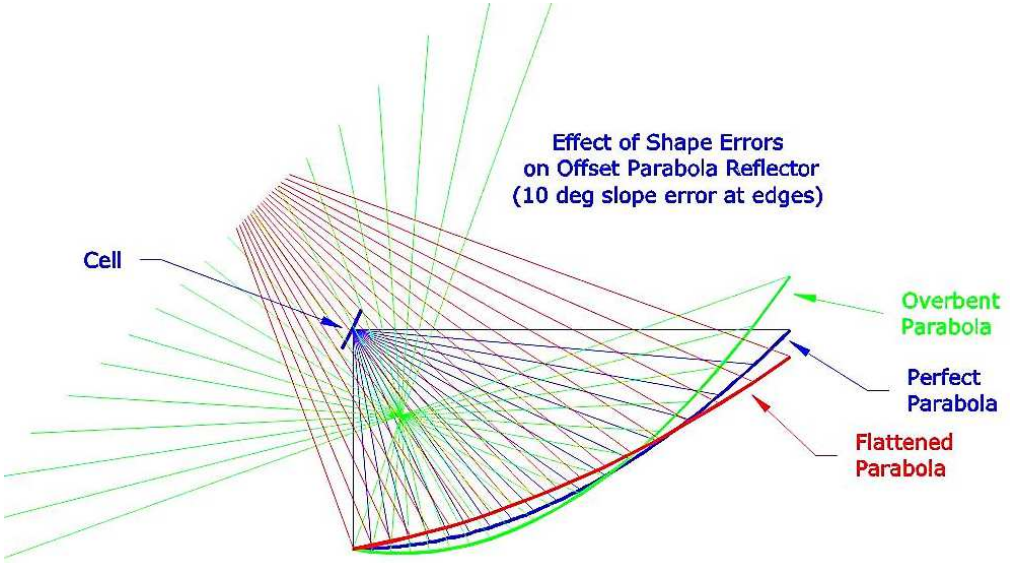

Identical Slope Error Distributions for Lens and Reflector (0 deg at Middle and 10 deg at Edges)

The Same Slope Error Causes About 300 Times More Defocusing for a Reflector of Any Kind than for Symmetrical-Refraction Lens

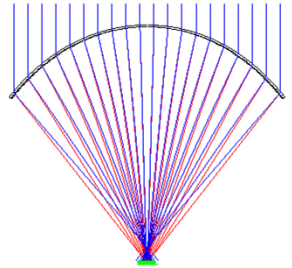
Incident Solar Rays Not Shown for Reflector to Make Reflected Rays More Visible

While Not Shown Here, a Similar Ray Trace Analysis Shows the Entech Solar Lens to Have a 100X Shape Error Tolerance Advantage Over Flat Fresnel Lenses

**Symmetrical-Refraction Fresnel Lens Is Unique in Its Shape Error Tolerance**

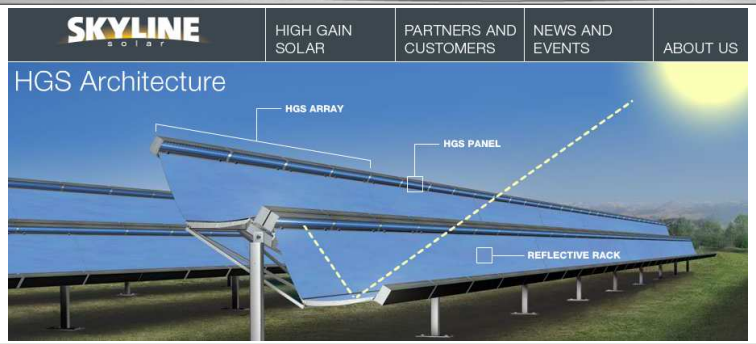


# Skyline Solar Parabolic Trough Focal Lines from One of Their Website Videos – Note Focal Line Variation

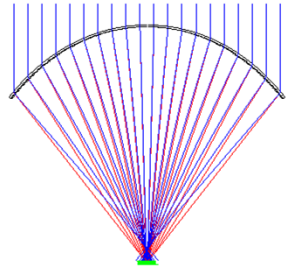


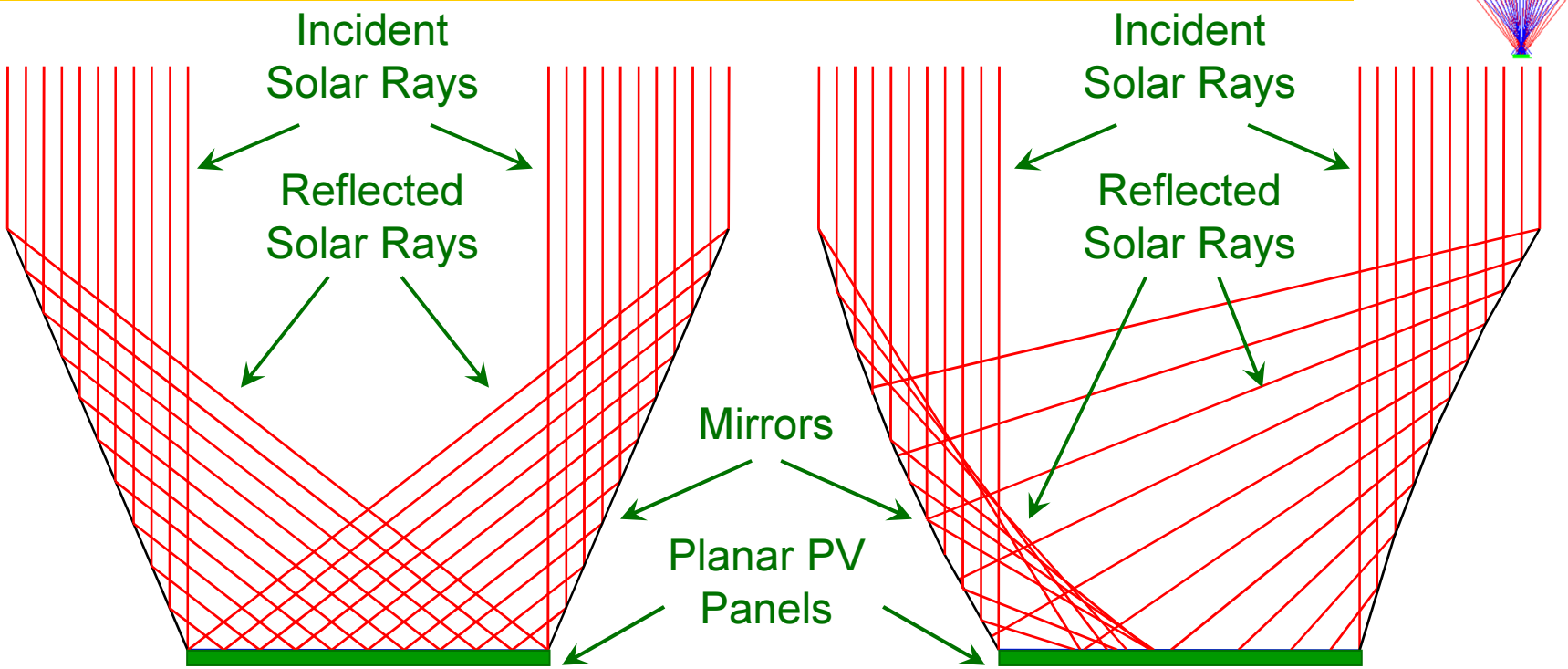
http://www.skyline-solar.com/video/SkylineSolarJune102010.mov






# Ray Traces for Perfect and Distorted 60 Degree Mirrors for 2X Flux Augmentation



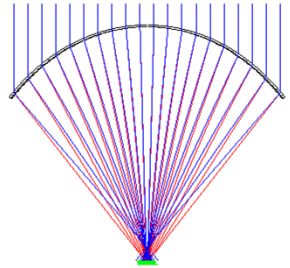



**Perfect Mirror Shapes – Uniform Flux and No Lost Rays**

**Mirrors with Same End Points but with 10 Degree Slope Errors at Both Edges – Concave on Left (Flux Spikes and Voids) and Convex on Right (Many Lost Rays)**

**Using Reflective Optics with Solar Cells Has Led to Many Failed Solar Arrays, on the Ground and in Space, Including the Hughes/Boeing 702 $1.8 Billion Loss**

# Terrible Terrestrial Experience with ARCO Solar (Now SolarWorld) 5 MW Mirror-Augmented Photovoltaic Panel System at Carissa Plains, California



***Performance Degraded 10% per Year***

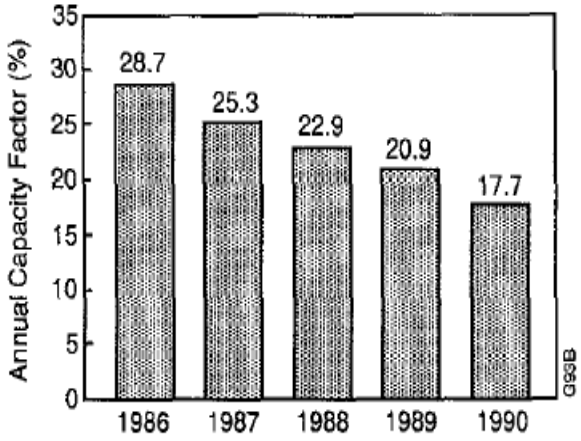



Figure 1. Decline of power plant capacity factor.


***When System Was Being Dismantled, Array Power Was Actually Higher When Mirrors Were Removed!***

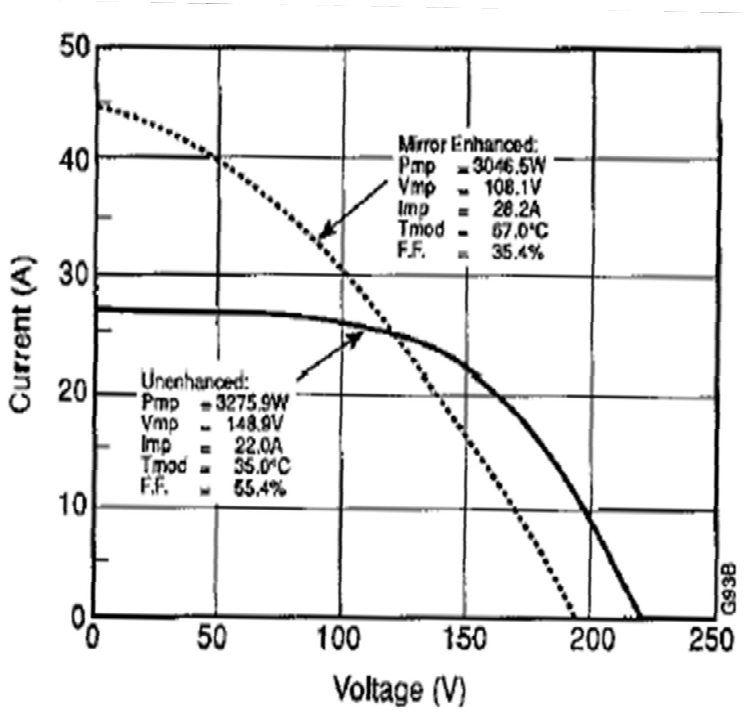
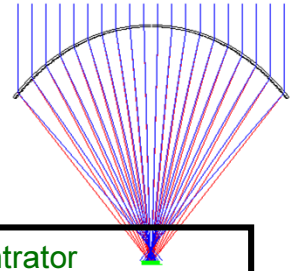



Figure 7. Tracker I-V curves, with and without mirrors.

***Figures 1 and 7 from this Reference: Wenger et al., "Decline of the Carissa Plains PV Power Plant: the Impact of Concentrating Sunlight on Flat Plates," 22nd IEEE PVSC, 1991.***

# Sandia's PV Concentrator Team Abandoned Reflective Optics in the 1980's After Numerous Field Tests



**Concentrator Optics**
Today's concentrator optics are the product of many years of development effort. **Refractive Fresnel lens technology is the optics of choice** today because of its low cost, its tolerance to tracking and alignment errors, and its relatively high efficiency. **Reflective approaches including parabolic troughs, dishes, compound parabolic concentrators, and central receivers have all been investigated. In addition, luminescent and holographic techniques have been explored. For all of these approaches, the cost-effectiveness has been evaluated and none have been found to have the potential of Fresnel lens technology.** Furthermore. progress in Fresnel lens technology continues at an impressive rate. It is projected that optical efficiency will eventually be 90 to 95% and lenses will cost $\$15/m^2$.

Dan Arvizu, "Photovoltaic Concentrator Research Progress," 18th IEEE PVSC, 1985.

***(Incidentally, Dan is currently the Director of the National Renewable Energy Laboratory.)***

Two important lessons-learned in concentrator technology which have significantly impacted the concentrator technology development program are:
1) turntable tracking structures are considerably more costly than "rack and post" (BDM, DFW and G. N. Wilcox) or "pedestal" (Sky Harbor) structures and
**2) reflective optics are much poorer performers than refractive optics (Fresnel lens systems).** The Sea World project was canceled and the Sky Harbor collector design changed because of the cost of the turntable systems; a significant portion of this cost was for installation. The two parabolic trough projects experienced considerable difficulty in trying to adapt solar thermal collectors to PV, and the resulting performance was 6-7 percent. The Fresnel lens systems have been essentially trouble-free and perform at over 10 percent efficiency. **As a result of these experiences and other development data, turntables and reflective troughs have been dropped from the DOE concentrator development program.**

Ed Burgess, "Design and Installation Experiences from Nine Intermediate-Sized Photovoltaic Systems: A Critical Analysis" 16th IEEE PVSC, 1982.

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