



U.S. Department of Energy
Energy Efficiency
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CSP Track

Theoretical Overlay Photographic Collector Alignment Technique (TOPCAT) Development

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**DOE Solar Energy Technologies
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*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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- TOPCAT derived from years of dish alignment
- Accurate alignment critical for dishes
 - Avoid hot spots & melted metal
- TOPCAT alignment similar to the successful approach used on Remote Dishes
 - Accurate alignment with no “hot spots” on receiver
- Extensive solar optics, LabVIEW, digital photography, and hardware expertise
- Team in route to CA for testing latest system
 - Fall & winter best time of year for several reasons
 - Best test window until October
 - Working with SEGS plant operators





- TOPCAT is an optical evaluation tool for parabolic trough solar collectors
 - Practical, rapid, and cost effective
 - Inherently aligns mirrors to receiver of an entire solar collector array (SCA)
 - No equivalent tool exists
- Reduce the cost of parabolic trough solar power
 - Increase optical intercept of existing trough plants
 - Increase aperture with same receiver size of new plants
 - Increased concentration ratios/collection efficiencies & economies of scale lower the cost of electricity
- Potential near-term license of technology to trough developers and/or plant operators



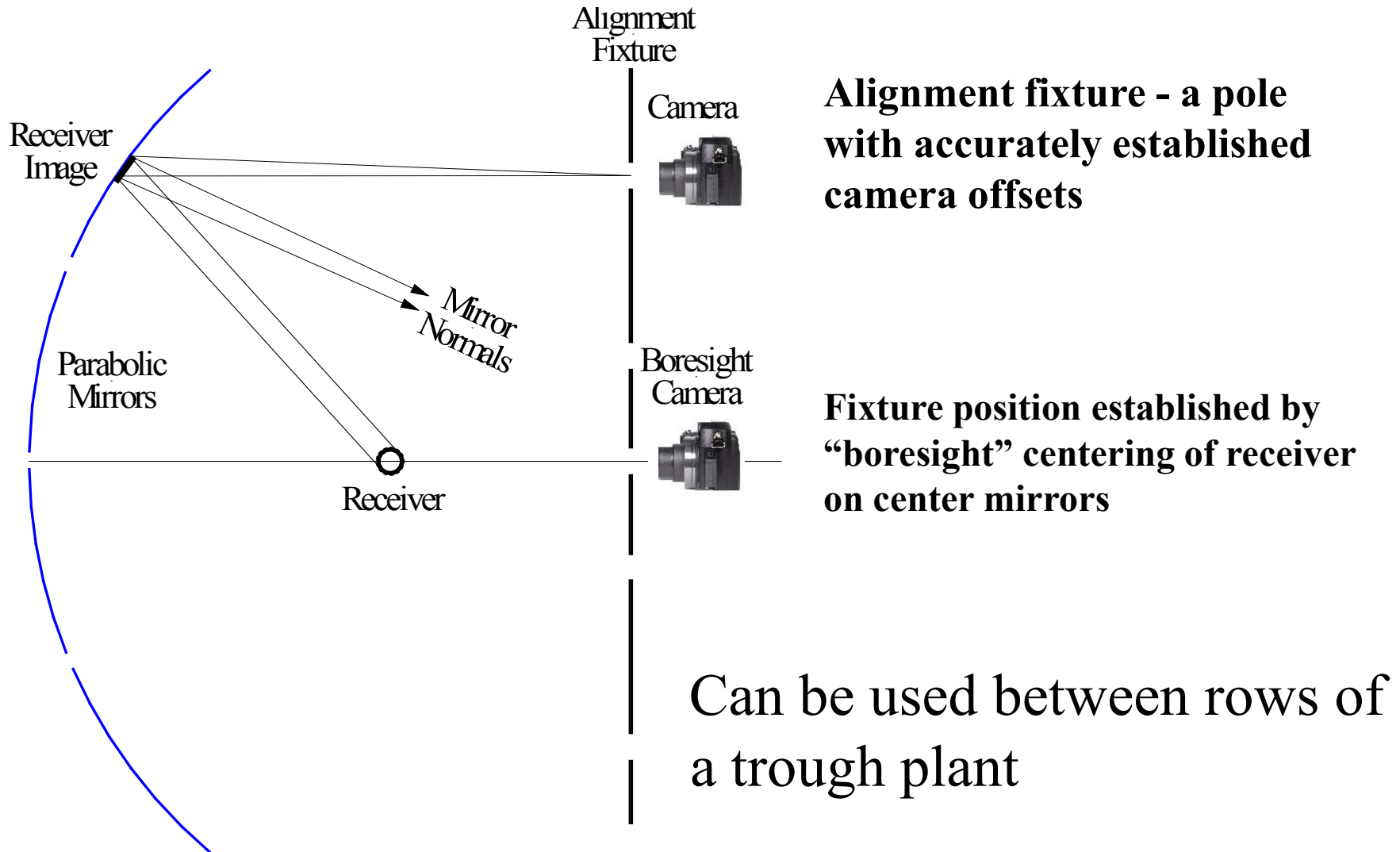
Mirror Alignment – The Ideal Solution*

- **Simple to setup and implement**
- **Minimum of sophisticated hardware**
- **Not require receiver removal**
- **Not require sun or other restrictive weather conditions**
- **Not require line-of-sight to distant observer or light source**
- **Permit accessibility to mirrors for adjustments**

*Richard B. Diver, 1995, “Mirror Alignment and Focus of Point-Focus Solar Concentrators,” Proceedings of the 1995 ASME/JSME/JSES International Solar Energy Conference, Maui, HI.



Theoretical Overlay Photographic (TOP) Alignment Approach





- **TOP alignment proof-of-concept experiments (2005)**
 - Characterize stock LS-2 module at Sandia with Nikon D-70 digital camera
 - Approach validated with Distant Observer
- **Developed and tested a trailer-mounted field deployment system (2006-2008)**
 - Fixture suitable for commercial RP-2 trough power plants
 - Develop data acquisition and image analysis software ~35 sec per module data rate
- **Developed and currently testing a pickup truck mounted field characterization system (2008-present)**
 - Fixture suitable for commercial RP-2 & RP-3 trough power plants
 - Mobile and agile commercial-ready system
 - Streamlined bore sighting, module-to-module alignment algorithm, & data acquisition & analysis
- **Evaluate the optical alignment of commercial plants (2008-present)**
 - Aligned 2 LS-2 loops in California in 2008. Results qualitative, mixed, but encouraging
 - Many lessons learned and improvements incorporated
 - Quantitative calorimetric before/after measurement on LS-2 and LS-3 loops in progress
 - Additional characterization planned





- Truck-mounted fixture driven through field
 - Troughs pointed horizontally
 - Distance to trough guided by survey marks
 - Truck stops when cameras frame module
 - Raise or lower to boresight fixture as needed, level, take images, move on
- Field worker facilitates process
 - Communicates with control room
 - Paints survey marks
 - Adjusts trough orientation, if needed
- Post-process data and align later
 - Image analysis software analyzes images and generate adjustment instructions
 - Possible to align while trough operates





- 1: Stop with cameras centered on trough module
- 2: Raise or lower fixture to boresight center camera on receiver and boresight gauge
- 3: Level camera fixture using self leveling program
- 4: Acquire and store images from all cameras
- 5: Drive to next module





Trough Alignment Utility

PLANT: KRAMER JUNCTION - SEGSVII SCA: 021408_151152_21J2N Completed Mirror Row: 1 2 3 4

Row Edge Lines: Top Left, Top Right, Bottom Left, Bottom Right

Configuration:

- Set Mirror Calibration
- View Plant Map
- Select Data Folder
- Print Utility
- Module Report
- Row Washer Report
- SCA Image Report

	6N	7N	8N	9N	10N	
Row1	0 0	0 0	0 0	0 0	0 0	2 0
Row2	0 2	0 0	0 3	2 1	1 2	1 0
Row3	0 3	3 3	3 5	3 3	3 2	1 0
Row4	0 1	0 0	2 2	1 1	1 0	0 0

Remaining Modules: 6

11664x359 0.8X Signed 16-bit Image 26 (607,176)

Edge: Upper, Lower

Create Overlay

Process SCA

Next Images

Exit

TOPAAP LabVIEW Vision program analyzes images and calculates needed adjustments



MIRROR MOUNT ADJUSTMENT INSTRUCTIONS

ADJUSTMENTS MADE USING WASHERS - 0.047" THICK

SEGS VII DATE/TIME: 021408 15:11:52

QA CHECK

As viewed from behind module **FACING WEST - 180 degrees**

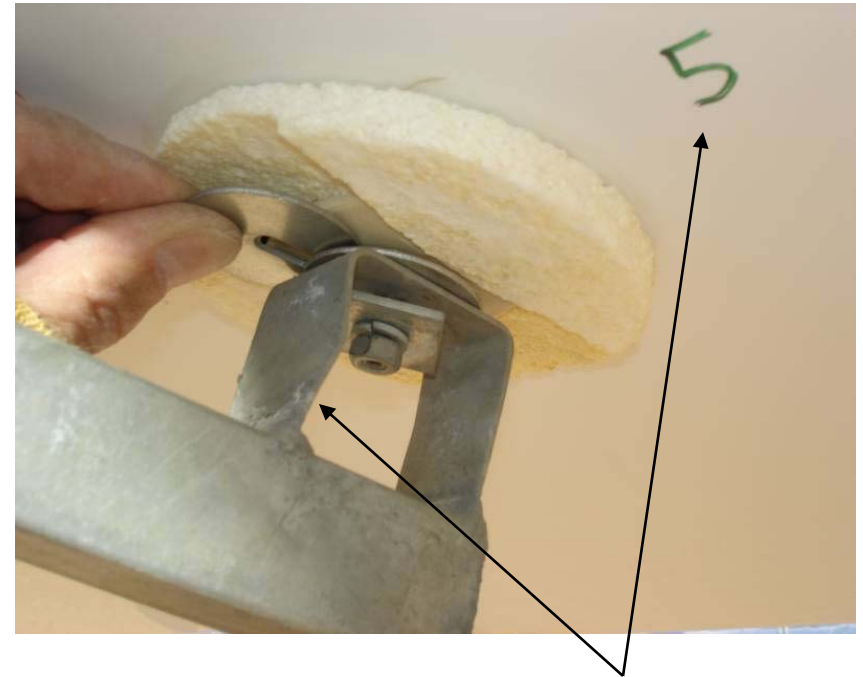
		21J2N									
		6N		7N		8N		9N		10N	
ROW2	0	0	X		0	0	0	0	0	0	
	0	2			3	2	1	1	2	1	
ROW1	0	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	2	

X = Broken/Missing RP

- TOPAAP produces worksheets prescribing adjustments
 - Frame of reference of worker behind mirrors
 - Two worksheets per module: East & West facing
- Adjustments made from ground or 3 foot stepladder



- Quality processes & tools developed for applying worksheet instructions in the field
- Split washers (1.4 mm thick) inserted to correct alignment
 - Mounts only need to be loosened
 - Overall process quick and easy

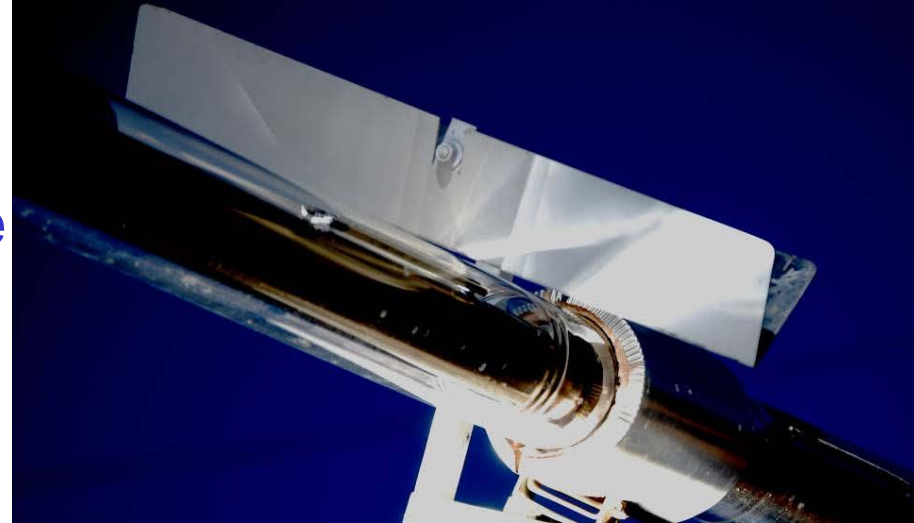


Note the large number of washer called for & dented mount



- Apparent significant improvement in optical performance
- Edges of mirrors line up after alignment
- 40 to 97 washers needed for each of the modules aligned

Flux spillage before



Flux spillage after





- Developed two generations of field characterization systems
 - Addresses requirements of commercial trough power plants
 - 35 sec/module demonstrated
 - <30 sec/module expected with new system
 - Significant performance improvements observed
 - Benchmarked labor & material costs indicate very low payback period
- Improved bore sight approach invented and implemented
 - Bore sight gages no longer needed
 - Module and mirror alignment simultaneously addressed



- Continue to refine and test the TOPCAT system at commercial solar power plants
- Quantify improvements on at least one LS-2 loop and one LS-3 loop in California with comparative calorimetric technique
 - Performance of aligned loop compared with neighbors, before and after alignment
 - Inherently accounts for insolation, cleanliness, & other factors
- Transfer/license to industry
- Apply overlay approaches to heliostats (TOPHAT) and dishes (TOPDAT)



- TOPCAT was derived from years of parabolic dish alignment experience
- Meets requirements of an ideal system
- Two generations of hardware developed and tested
 - Testing to date indicates potential significant improvements
 - Benchmarked labor & material cost indicate extremely cost effective performance improvement
 - Second generation system currently in the field
 - Hardware and software nearly ready for commercial use
- TOPCAT is an enabling technology for higher concentration ratio troughs
- Interest by industry