

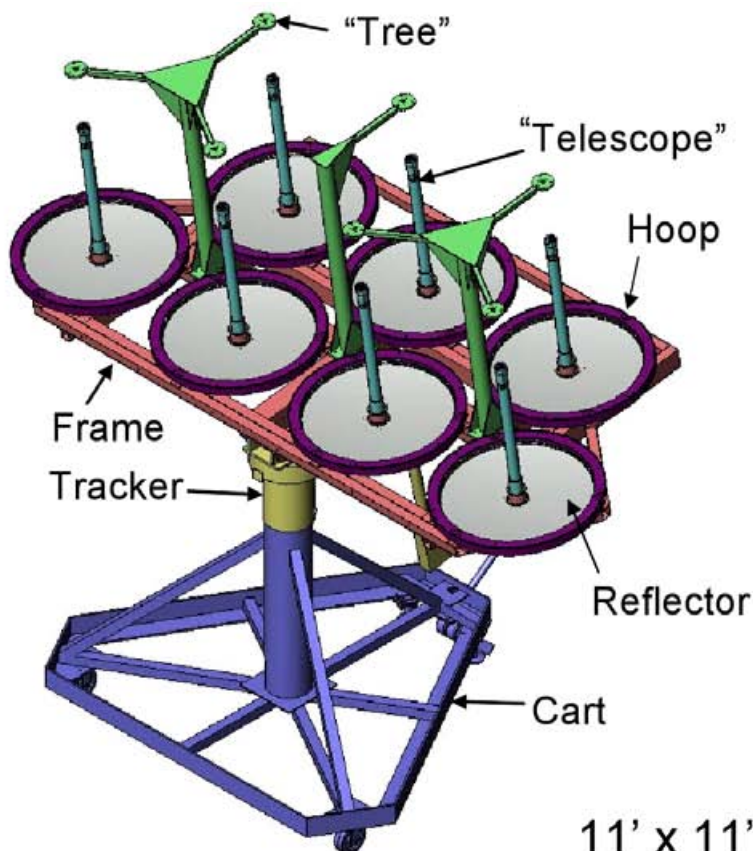
# Background

VG10-110-1

- **Solar power is a readily available heat source for *in-situ* resource utilization (ISRU)**
- **During 1993-1996 Physical Sciences Inc. (PSI) developed a laboratory prototype of the optical waveguide (OW) solar power system for lunar material processing (SBIR Phases I & II by NASA/JSC)**
- **During 2007-2009, PSI developed the ground-based demonstration system (SBIR Phase III by NASA/GRC)**
- **The Phase III system was completed in March 2009 and has been tested at ORBITEC for the carbothermal oxygen production program**

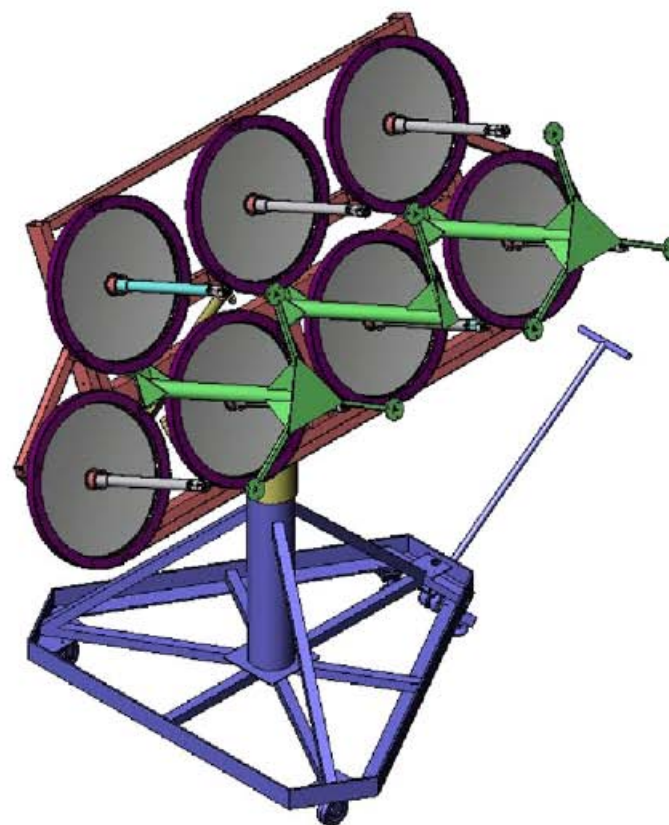
# Solar Concentrator Array with Seven Reflectors

VG10-110-2



**Noon Position**

11' x 11' x 7'  
~1400 lbs



**Stowed Position**

J-8153

# Solar Concentrator Tested at PSI: March 2009

VG10-110-3



K-0295

**Seven concentrators mounted  
on the tracking array**



K-0297

**Back of the array with  
reactor interface**

# Solar Concentrator: Reactor Interface

VG10-110-4



K-0299

**The reactor interface  
with quartz rod**



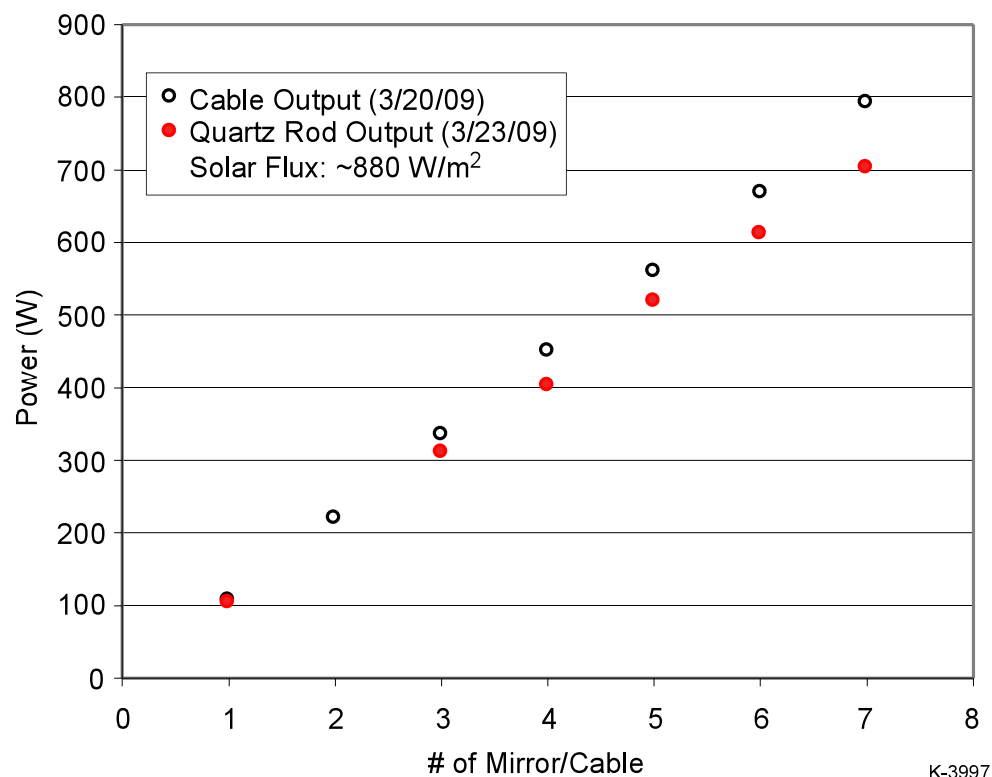
K-0301

**The quartz rod emitting  
solar radiation**



# Solar Concentrator Power Output Fiber Cable vs. Reactor Input Optics

VG10-110-5



K-3997

|  | Concentrator/Cable<br>(3/20/09) | Quartz Rod<br>(3/23/09) |
|--|---------------------------------|-------------------------|
| Ambient Solar Flux (W/m <sup>2</sup> ) | 880                             | 880                     |
| Power (W)                              | 795                             | 703                     |
| System Efficiency (%)                  | 37.8                            | 33.3                    |

# Solar Concentrator System Integrated with the ORBITEC Carbothermal Reactor

VG10-110-6

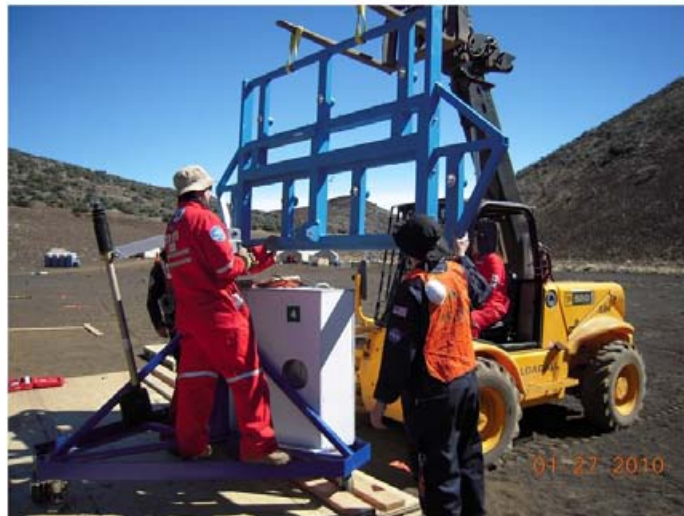
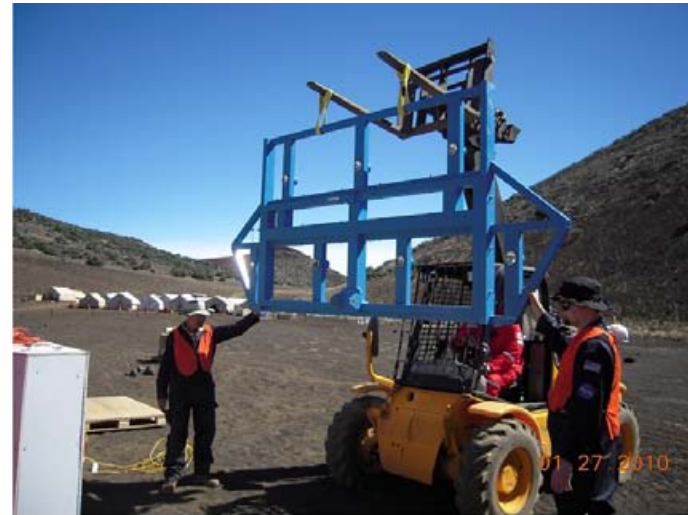


SBIR Rights in Data



# Assembling the Solar Concentrator Array at Mauna Kea Test Site

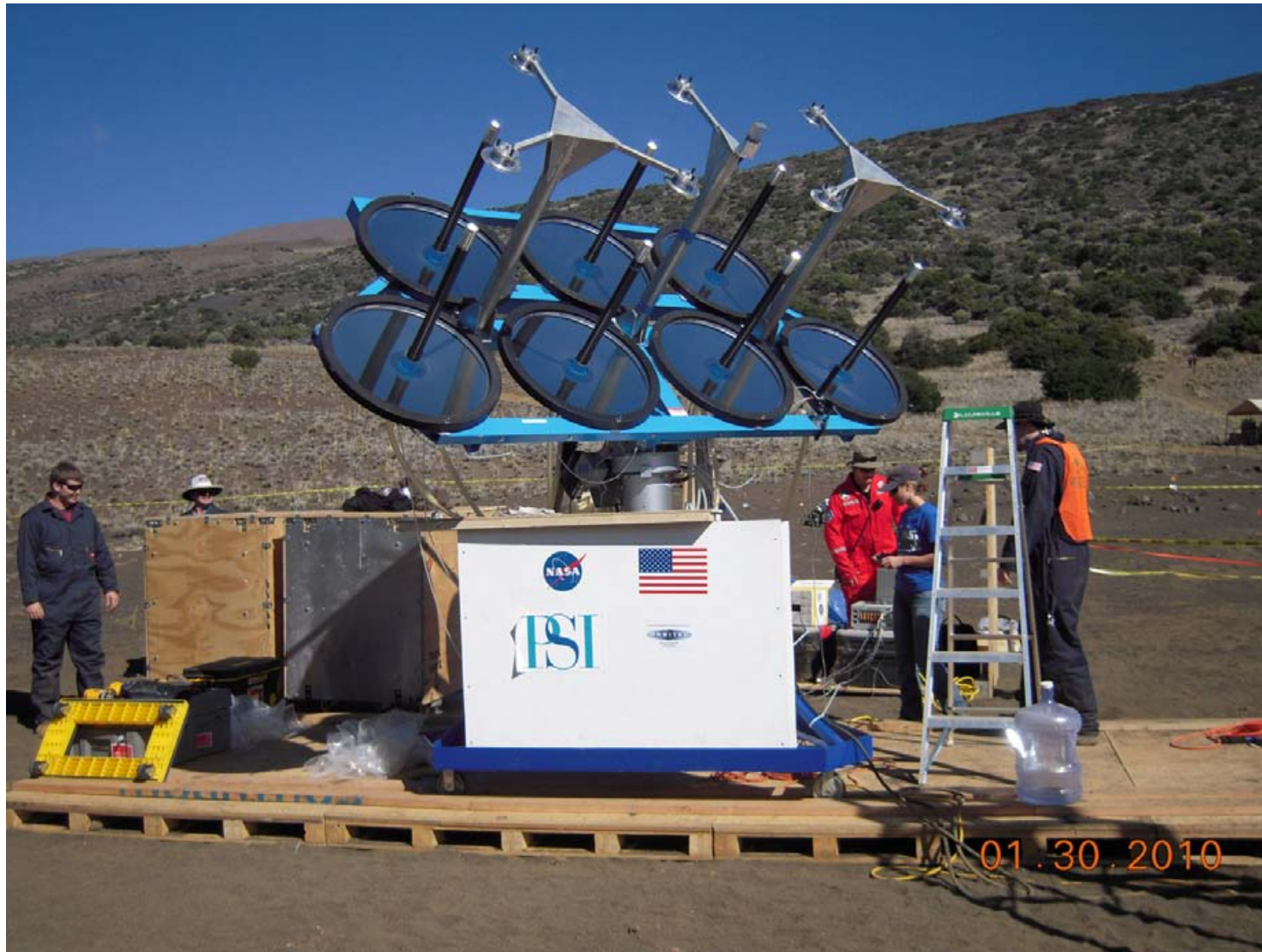
VG10-110-7



K-3562

# Solar Concentrator Array Preparing for Solar Sintering of Tephra

VG10-110-8

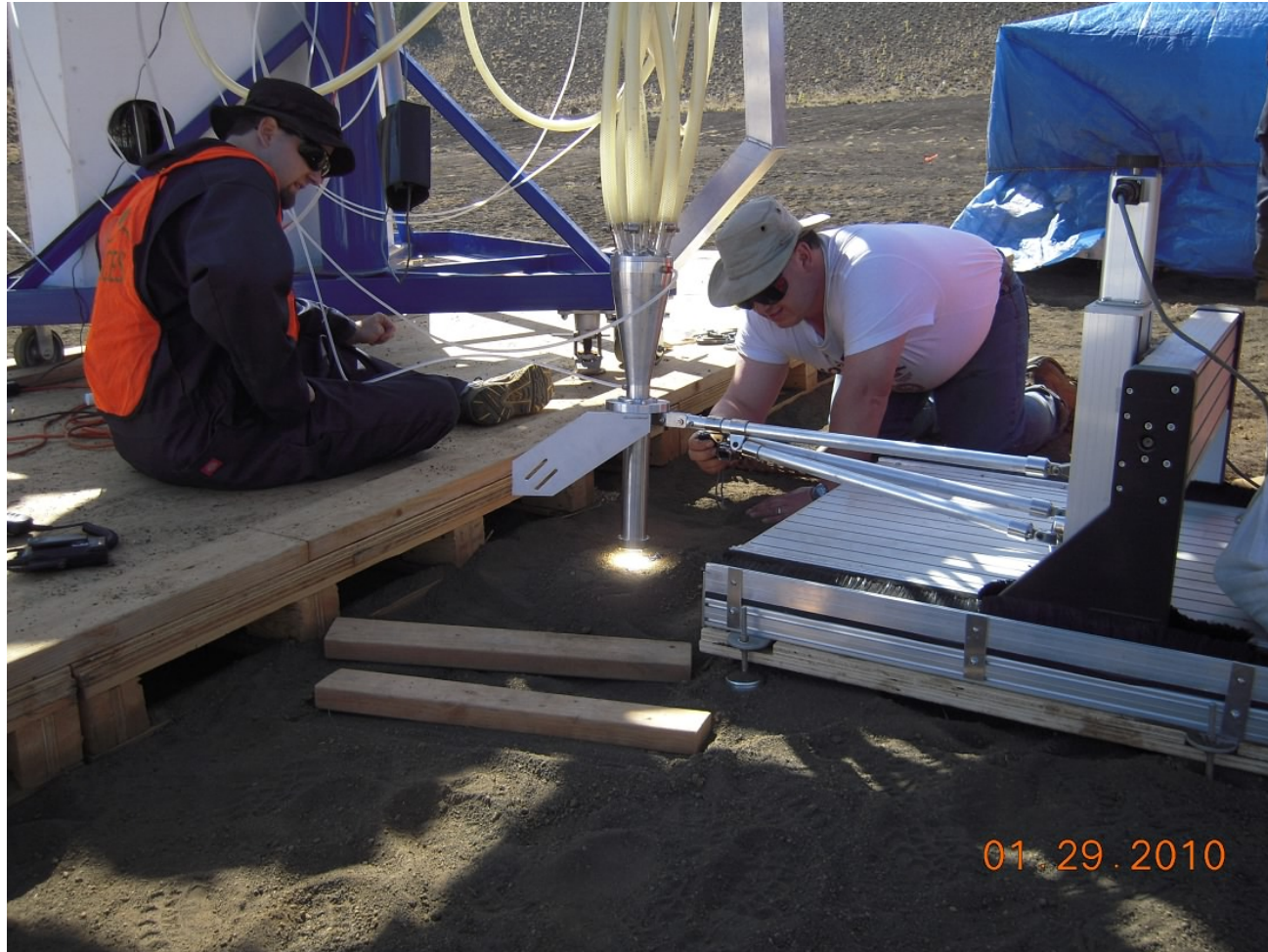


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# PSI Solar Concentrator Integrated with NORCAT Rastering System

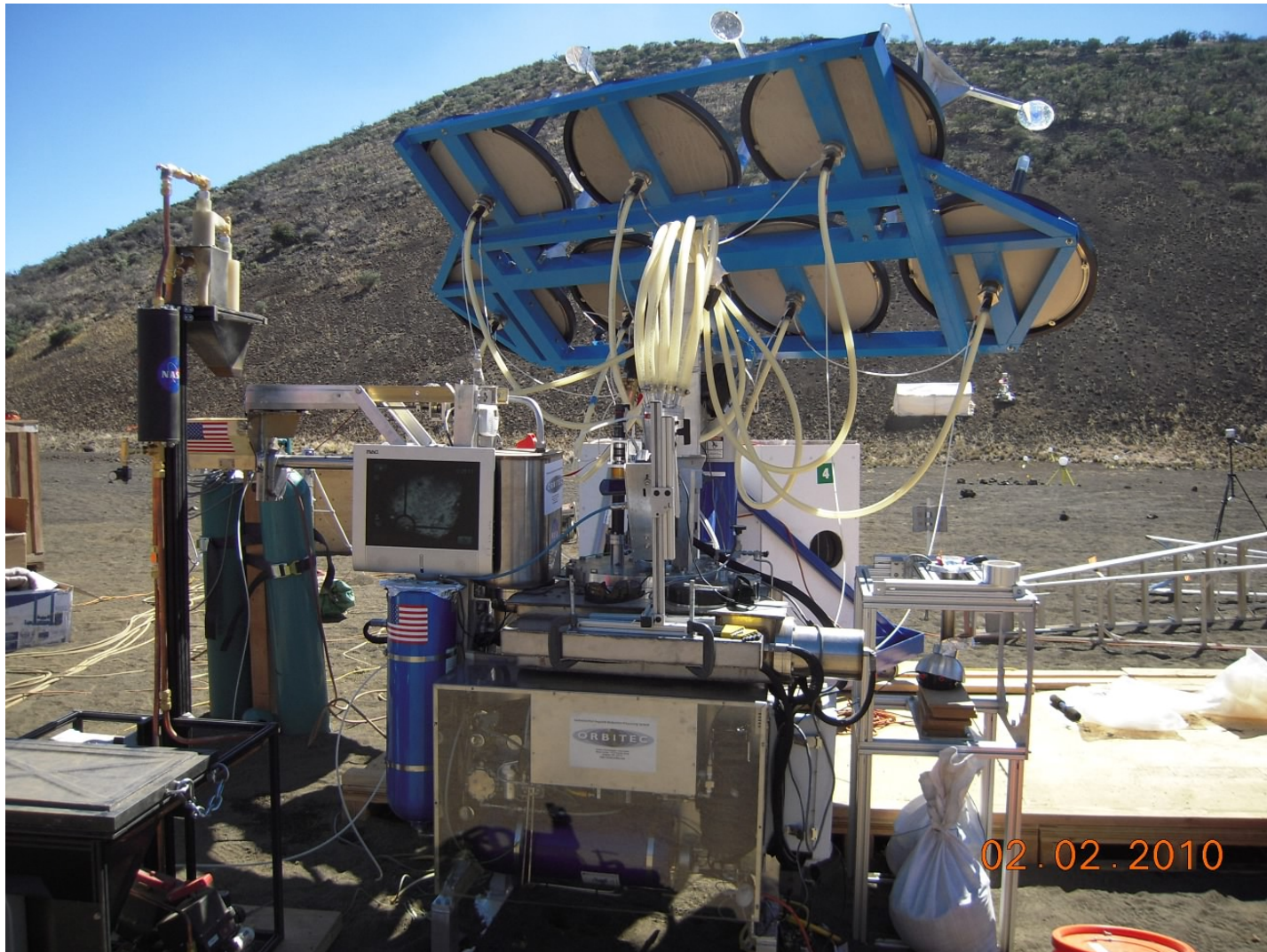
VG10-110-9



K-3568

# PSI Solar Concentrator Integrated with ORBITEC Carbothermal Reactor

VG10-110-10



K-3575



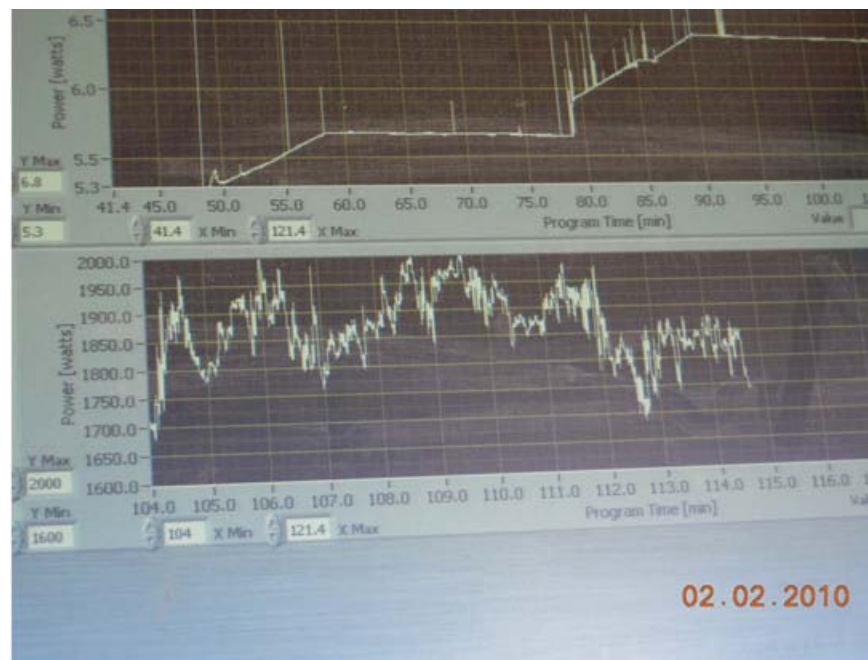
# Carbothermal (CT) Reactor Operation

VG10-110-11



K-3576

**CT reactor displaying the  
Tephra melt on screen**



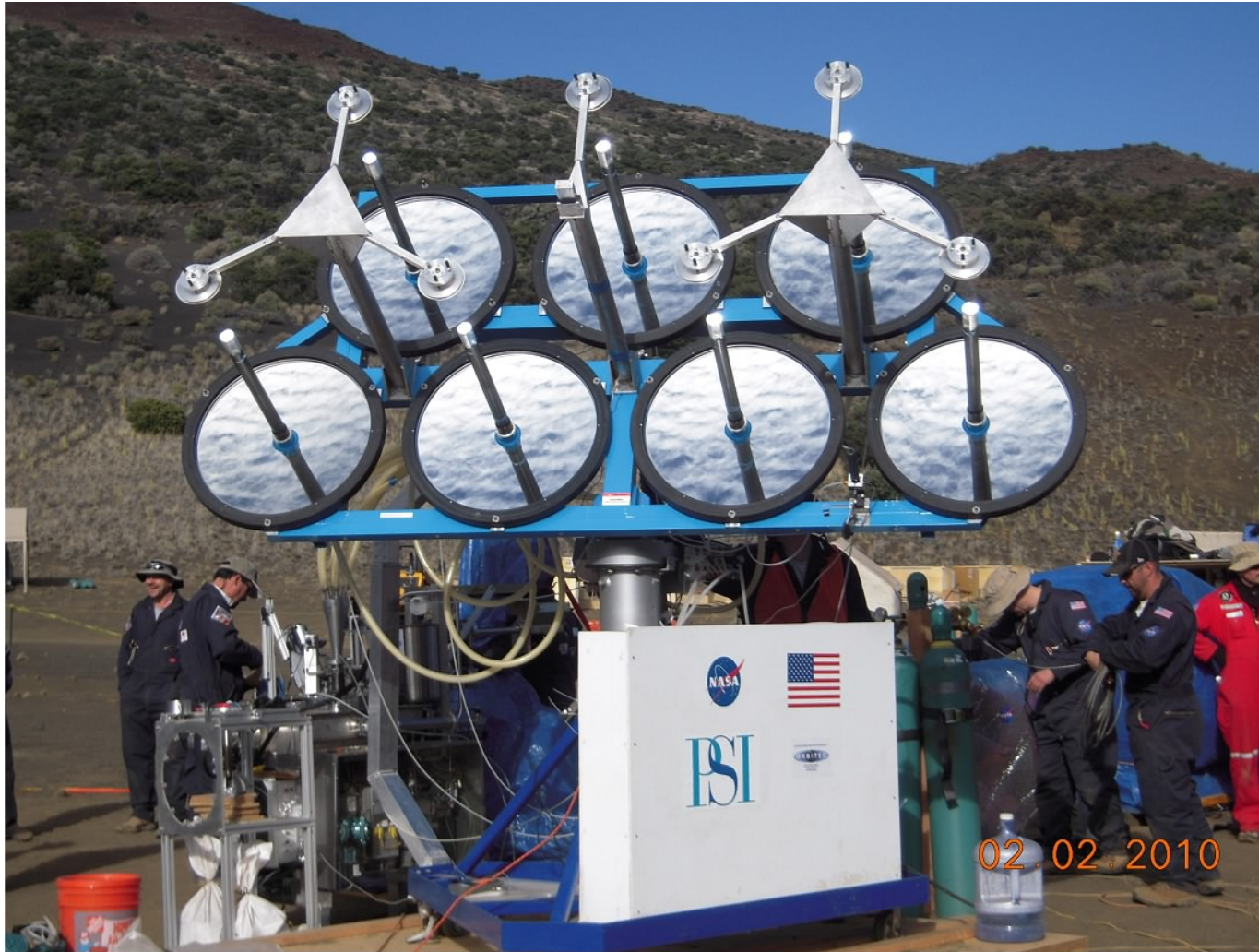
K-3577

**Tephra melt temperature (°C)**



# Afternoon Cloud Diminishing the Solar Power

VG10-110-12



K-3578

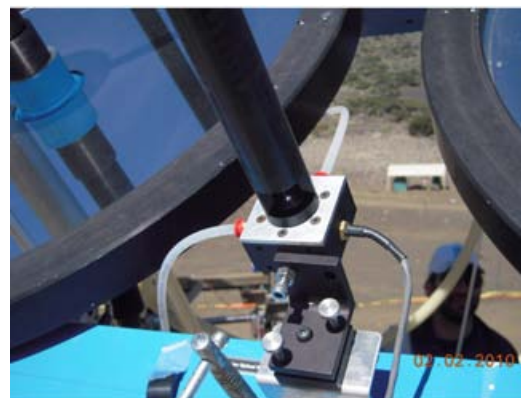
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# Measurement of Ambient Direct Solar Flux

VG10-110-13



K-3174



K-3175

| Date    | Ambient Solar Flux (W/m <sup>2</sup> ) | Comment  |
|---------|--|--|
| 1/28/10 | 821                                    | Clear but overcast                                   |
| 1/29/10 | 872 ~ 992                              | Thin high cloud                                      |
| 1/30/10 | 821 ~ 889                              | Partially cloudy                                     |
| 1/31/10 | 889 ~ 1006                             | Overcast with high cloud                             |
| 2/1/10  | 434 ~ 650                              | Cloudy   |
| 2/2/10  | 684 ~ 1078                             | Clear at noon, high cloud towards the end of the day |
| 2/3/10  | 1000 ~ 1026                            | Clear  |
| 2/4/10  | 914 ~ 1034                             | Clear  |
| 2/5/10  | 995 ~ 1078                             | Clear  |
| 2/6/10  | 944 ~ 1060                             | Clear  |
| 2/8/10  | 981 ~ 1033                             | Clear  |
| 2/9/10  | 872 ~ 1051                             | Warm, Clear with thin high cloud                     |

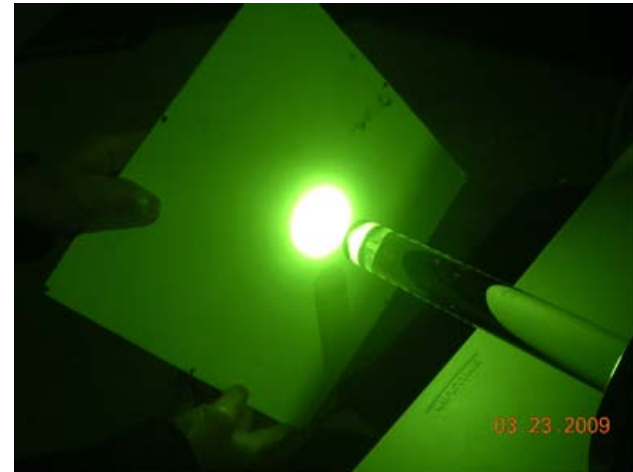
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# Power Output Measurement

VG10-110-14



K-3586



K-0303



K-0298

**Cable Output**



**Quartz Rod Output**



# Performance of the Solar Concentrator System

VG10-110-15

|                                    | <b>San Ramon,<br/>CA</b>   | <b>Hawaii Analog Test 2010</b>                                    |                 |                 |                 |  |   |
|------------------------------------|--|---|-----------------|-----------------|-----------------|--|---|
| Date                               | 3/20/09  | 1/29/10   | 2/3/10          | 2/4/10          | 2/5/10          | 2/6/10                                 | 2/9/10  |
| Solar Flux (W/<br>m <sup>2</sup> ) | 880  | 924   | 1054            | 989             | 1023            | 1057                                   | 859   |
| Nominal Cable<br>Power (W)         |  | 619   | 646             | 614             | 625             | 707                                    | 557   |
| Figure of Merit                    |  | 0.282   | 0.256           | 0.259           | 0.2556          | 0.280                                  | 0.271   |
| True Cable<br>Output (W)           | 795  | (865)**   |                 |                 |                 |  | (657)**   |
| System Eff. (%)                    | 37.8   | 39.2*   |                 |                 |                 |  | 32.0*   |
| Quartz Rod<br>Output (W)           | 703  |   |                 |                 |                 | 607                                    |   |
| System Eff. (%)                    | 33.4   |   |                 |                 |                 | 24.0                                   |   |
| Comments                           | Pre-ship<br>test results.<br>Silver coated<br>S.S. Inlet<br>Optics, New<br>Fiber, Clean<br>Mirrors | First test<br>in Hawaii.<br>Al<br>deposited<br>Al Inlet<br>Optics | Mirror<br>dusty | Mirror<br>dusty | Mirror<br>dusty | Dust<br>cleaned<br>from all<br>mirrors | Low flux<br>early in<br>the<br>morning,<br>higher flux<br>(~ 1050)<br>later in the<br>day |

# Dust on the Primary Mirror

VG10-110-16



K-3587

**Dust Deposit on the  
Primary Concentrators**



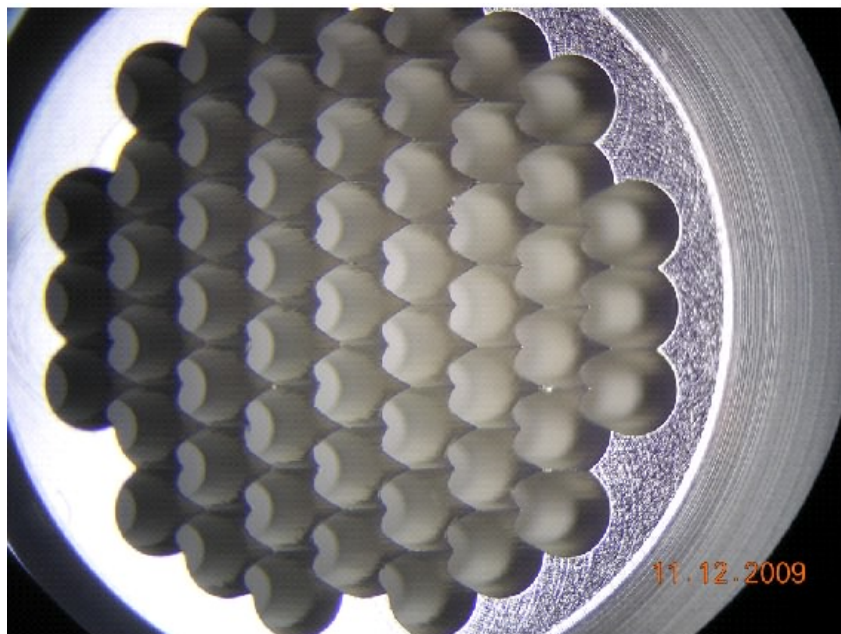
K-3589

**Seven Primary Concentrators  
Cleared of Dust Deposit**

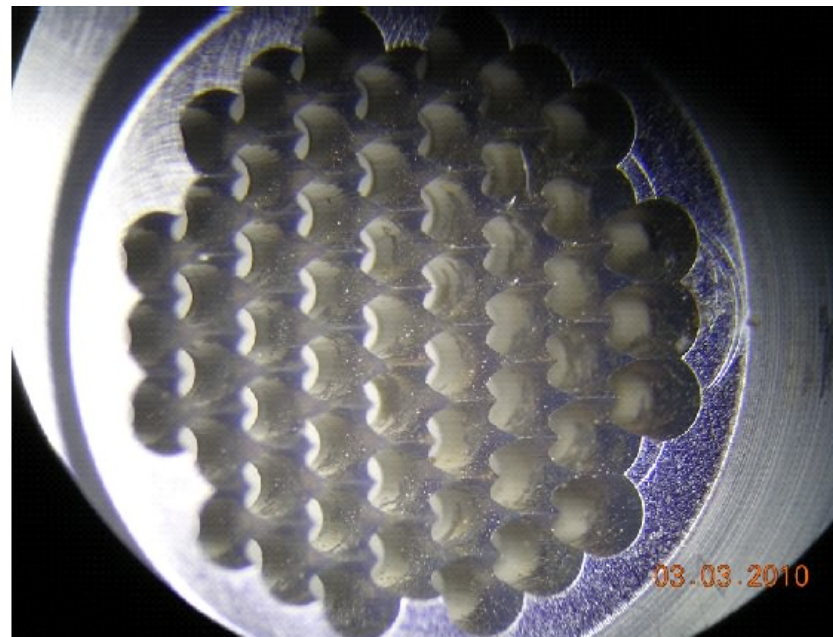
- 10% Power Increase by Cleaning

## Effect on Cable Inlet

VG10-110-17



**New Cable Inlet**



K-3571

**Cable Inlet After Test**

- **Deterioration of cable inlet decreased performance by 6%**



# Summary

VG10-110-18

- **PSI team deployed and operated the solar concentrator system in environments that are not encountered in laboratory test setting**
  - Solar flux varied in a broad range (450~1050 W/m<sup>2</sup>)
  - Dust effects on primary reflector and cable inlet
  - Freezing temperature in the night
- **PSI/NORCAT Team demonstrated solar sintering of Tephra**
  - Lunar surface stabilization with solar thermal sintering of regolith
  - Sintered a 15 in x 15 in Pad
  - Single layer due to time constraint
- **PSI/ORBITEC Team conducted a series of Carbothermal (CT) oxygen production experiments**
  - Tephra melt at 1700~1800 C
  - 16 successful CT reaction tests

# Remote Operation from NASA/JSC

VG10-110-19



**PSI Solar Concentrator (middle), ORBITEC CT Reactor (right) and NASA/JSC Water Electrolyzer (left) operated remotely from Houston, TX**

# Acknowledgements

VG10-110-20

- **The PSI team would like to thank those who helped us in preparation, setup, deployment and operation of the solar concentrator**
- **Collaborations with NORCAT and ORBITEC personnel have been very effective, stimulating and rewarding**
- **Our participation in the ISRU Analog Test, Mauna Kea, HI was made possible by the Phase III SBIR contract administered at NASA/KSC (mnk10ea03P), Dr. Anthony Muscatello, the technical contact**
- **The solar concentrator system deployed at Mauna Kea was developed under the SBIR Phase III program supported by NASA/GRC, Dr. Alloysius Hepp, the technical contact**



# Unsung Hero Leveling the Test Site

VG10-110-21



**SBIR Rights in Data**