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VG10-110

Solar Thermal Power System for ISRU Applications Field Deployment and Operation at Mauna Kea, HI

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Background

- **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

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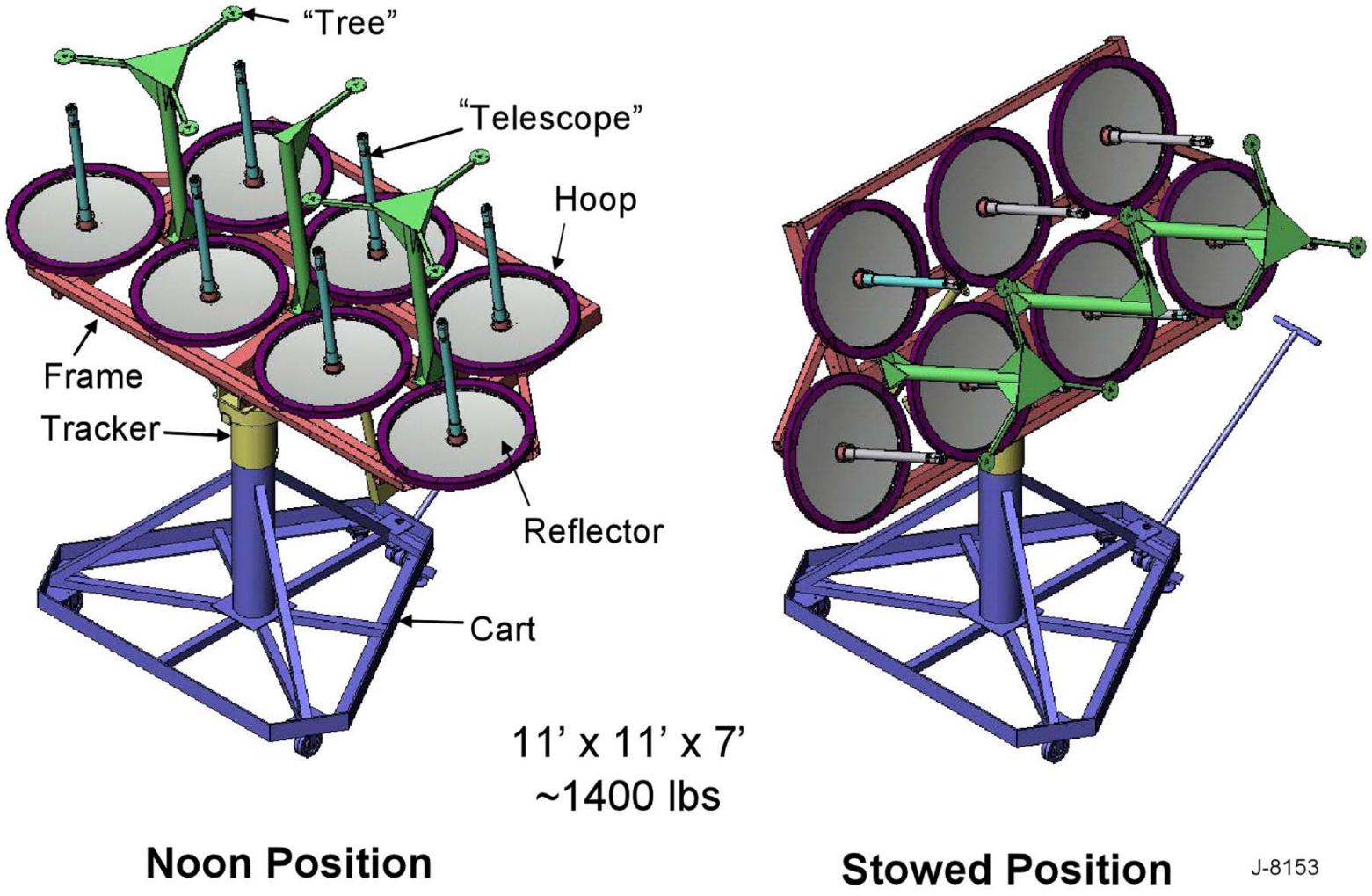

Solar Concentrator Tested at PSI: March 2009

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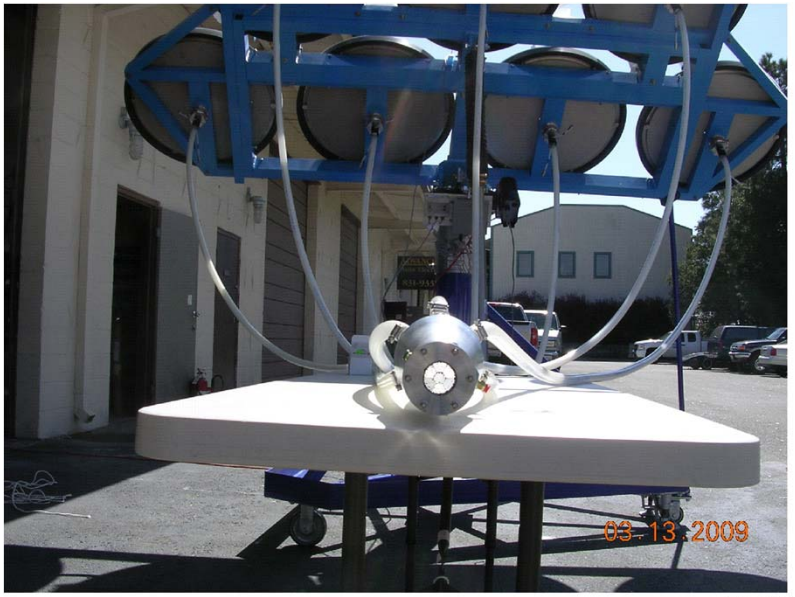
Seven concentrators mounted on the tracking array



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Back of the array with reactor interface

Solar Concentrator: Reactor Interface

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The reactor interface with quartz rod

K-0301

The quartz rod emitting solar radiation

Solar Concentrator Power Output
Fiber Cable vs. Reactor Input Optics

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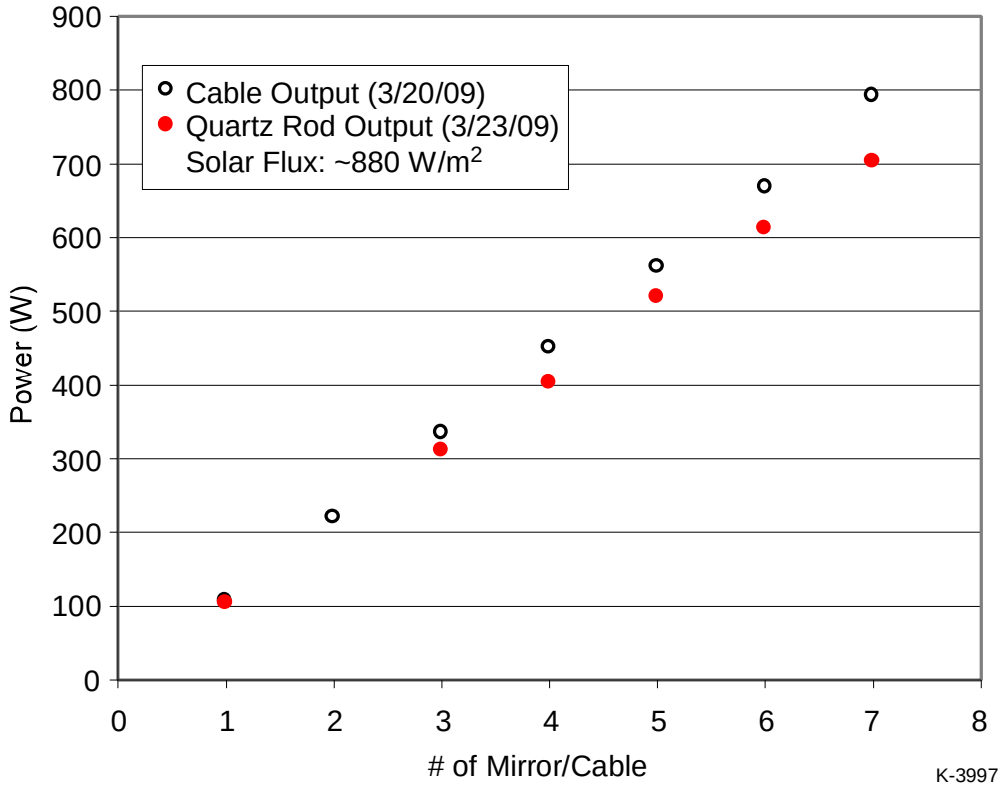

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	Concentrator/Cable (3/20/09)	Quartz Rod (3/23/09)
Ambient Solar Flux (W/m^2)	880	880
Power (W)	795	703
System Efficiency (%)	37.8	33.3

Solar Concentrator System Integrated with the ORBITEC Carbothermal Reactor

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Assembling the Solar Concentrator Array at Mauna Kea Test Site

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Solar Concentrator Array Preparing for Solar Sintering of Tephra

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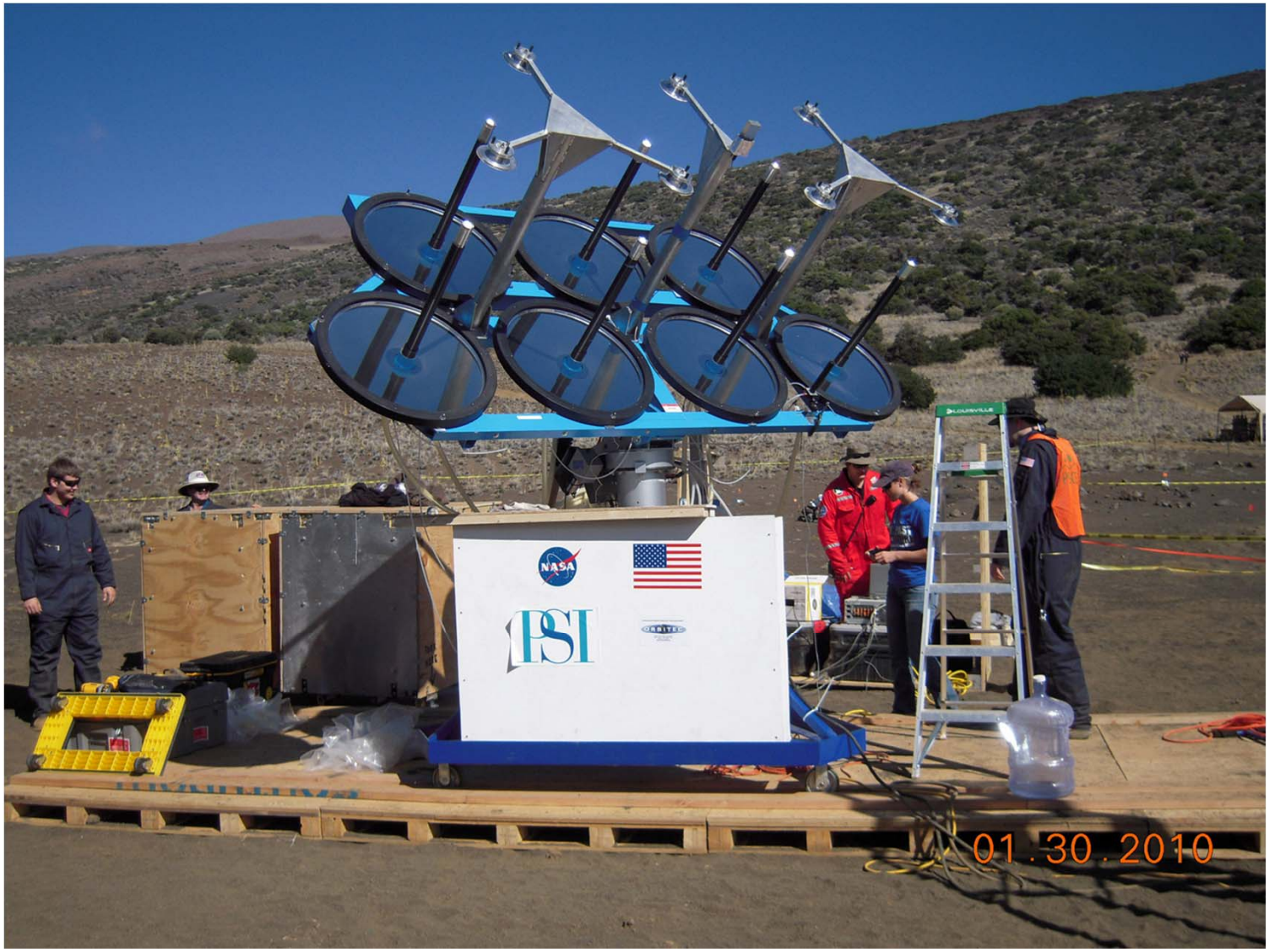

PSI Solar Concentrator Integrated with NORCAT Rastering System

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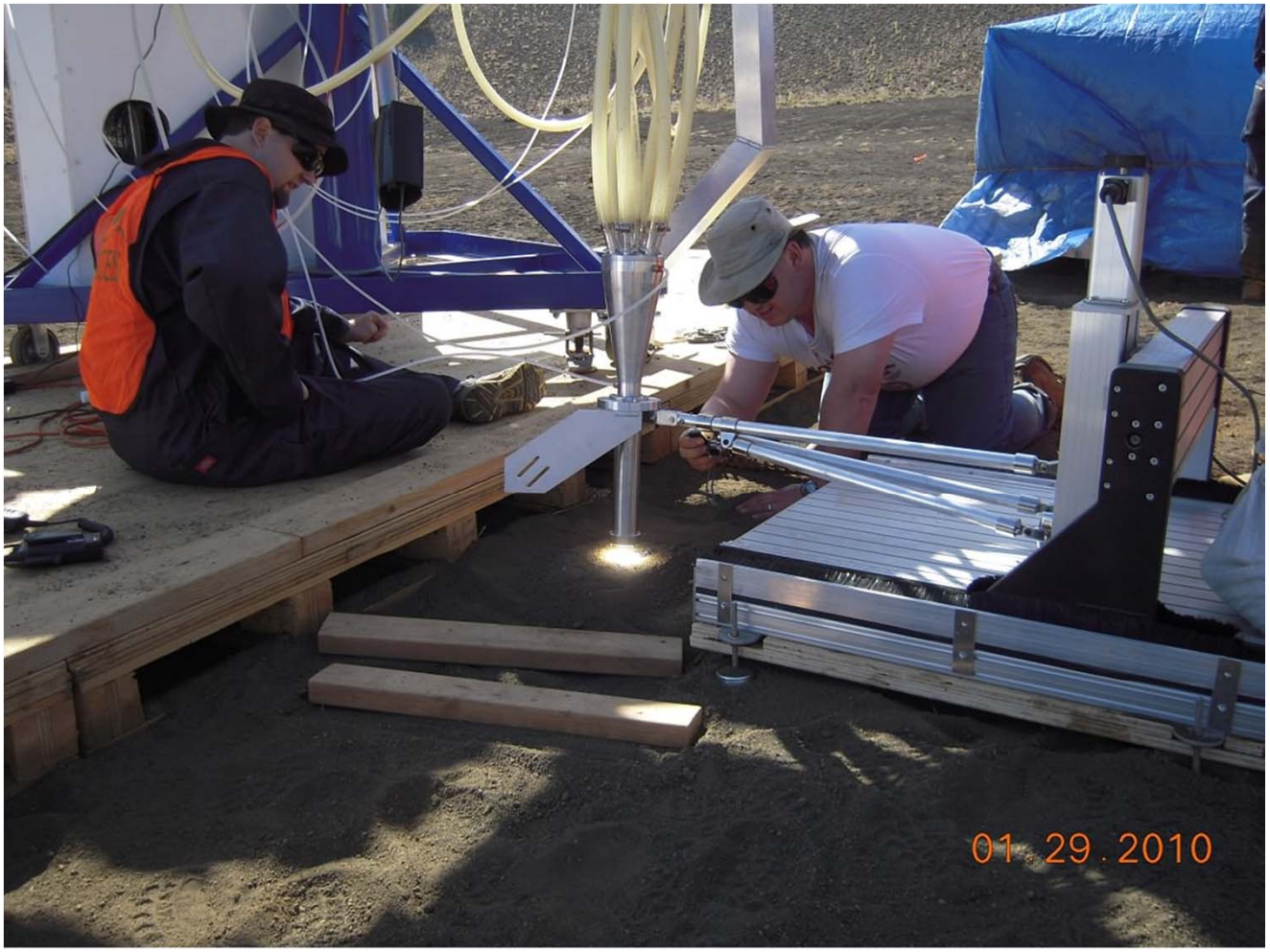

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PSI Solar Concentrator Integrated with ORBITEC Carbothermal Reactor

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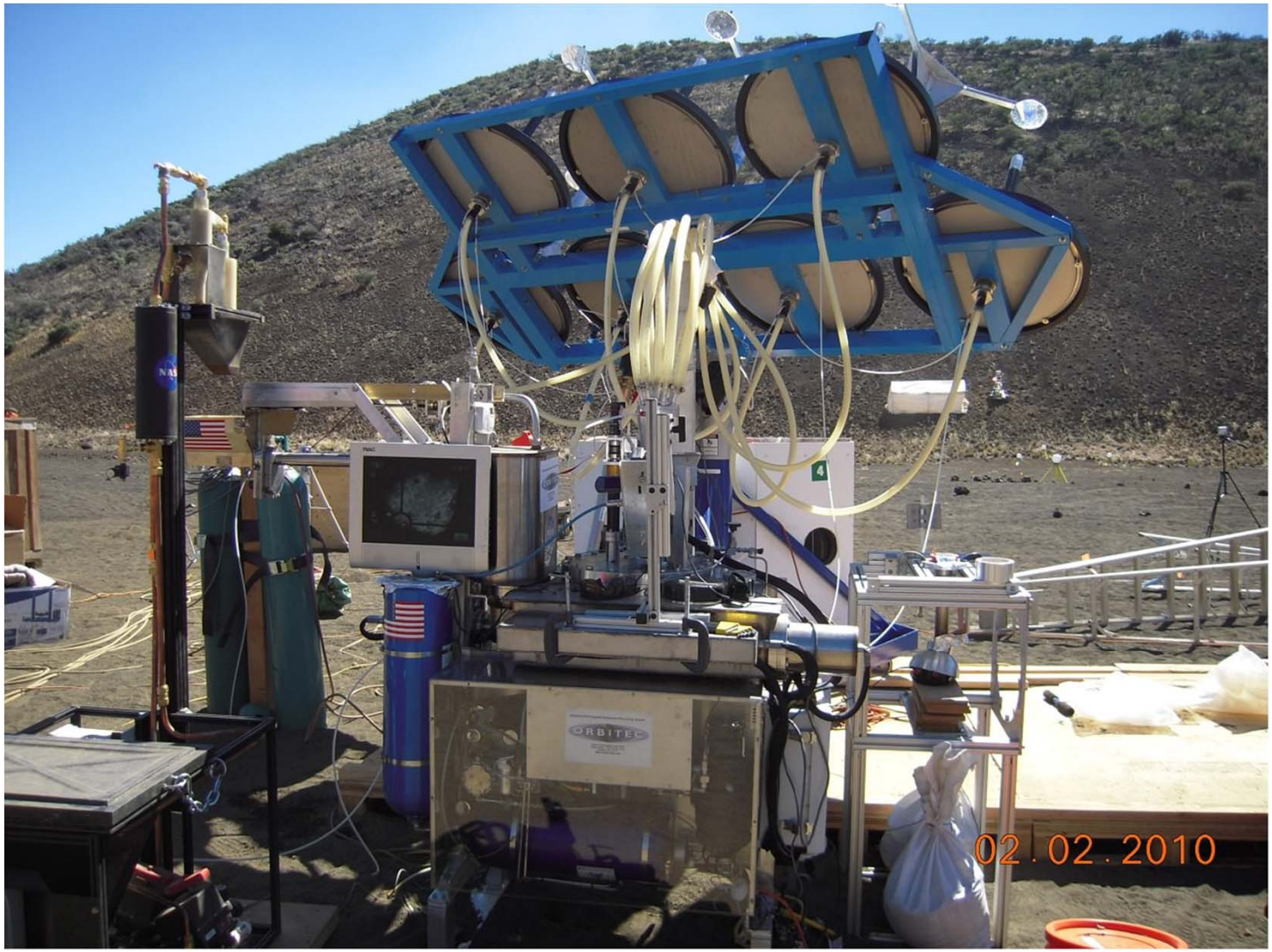

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Carbothermal (CT) Reactor Operation

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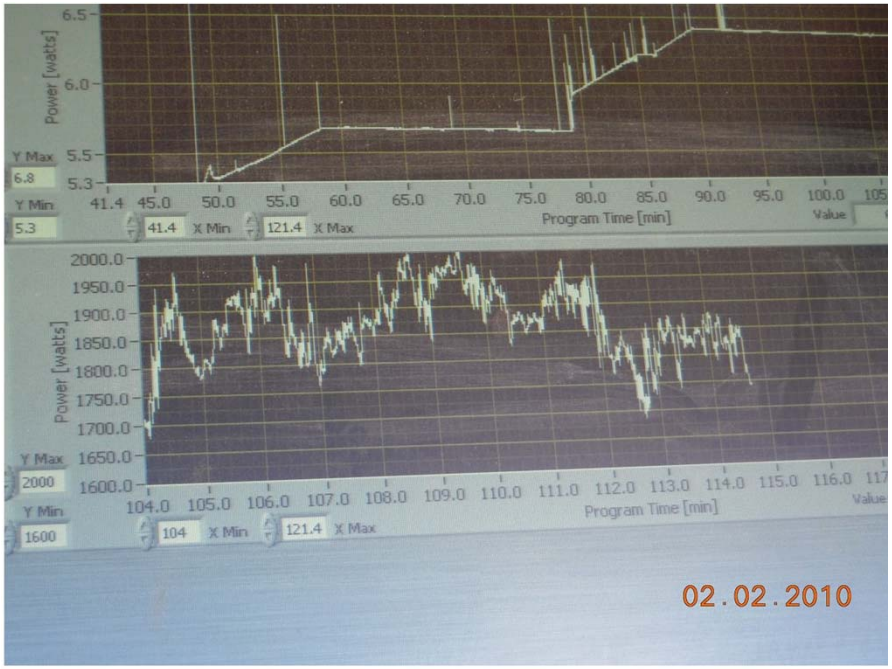
CT reactor displaying the Tephra melt on screen



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Tephra melt temperature (°C)

Afternoon Cloud Diminishing the Solar Power

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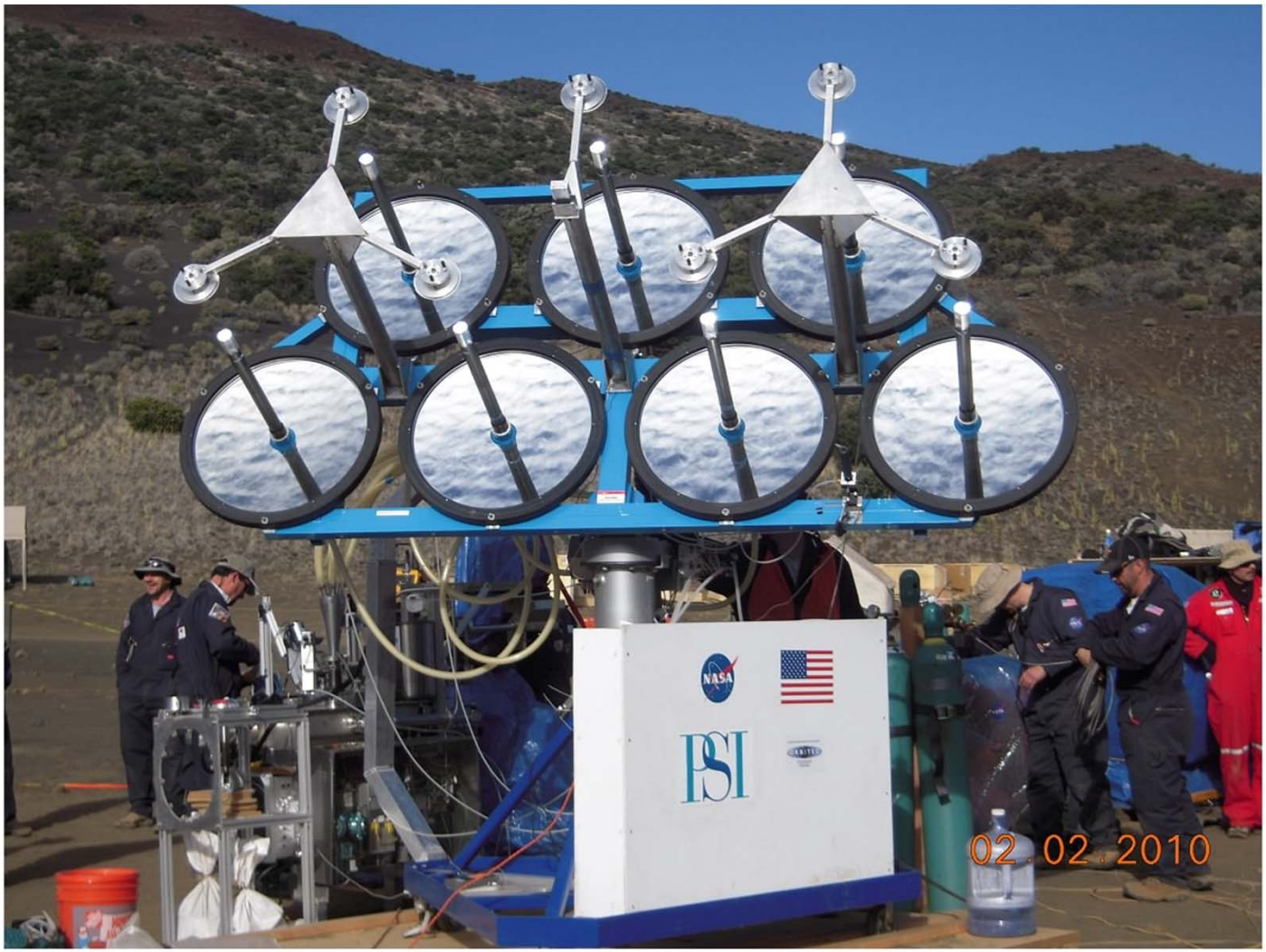

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Measurement of Ambient Direct Solar Flux

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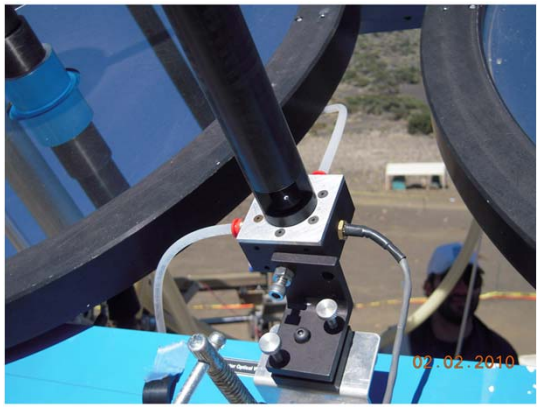
K-3174



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Date	Ambient Solar Flux (W/m^2)	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

Power Output Measurement

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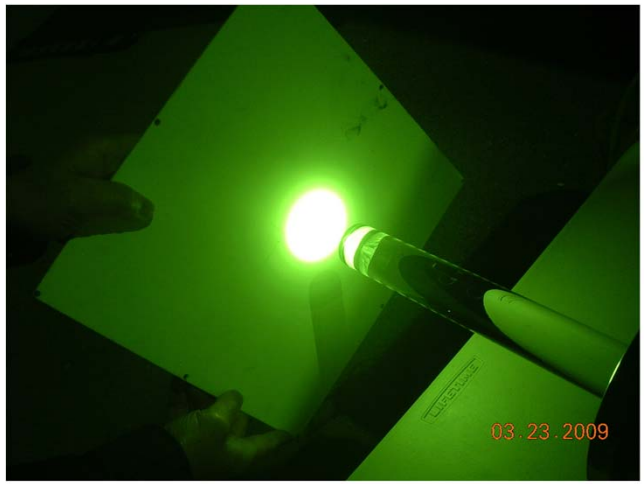
Cable Output



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Quartz Rod Output

Performance of the Solar Concentrator System

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

Dust on the Primary Mirror

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Dust Deposit on the Primary Concentrators

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Seven Primary Concentrators Cleared of Dust Deposit

- **10% Power Increase by Cleaning**

Effect on Cable Inlet

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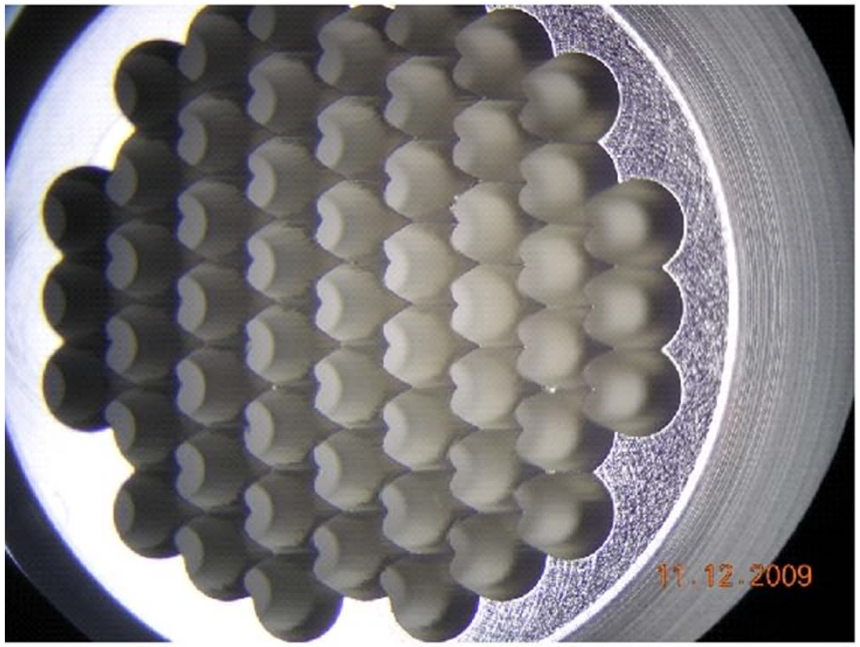

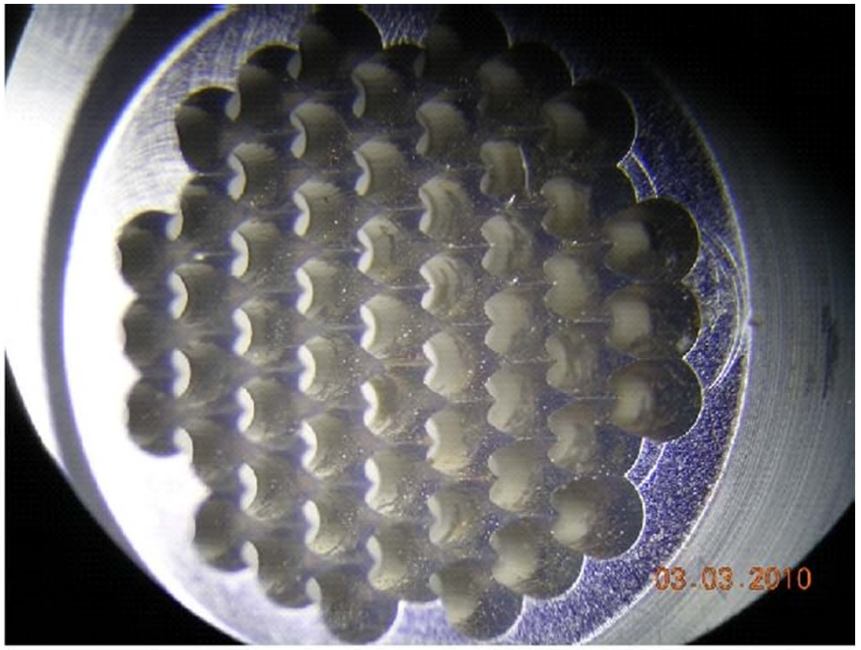

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New Cable Inlet

Cable Inlet After Test

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

Summary

- **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^2)
  - 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

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

Acknowledgements

- **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

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