SOLAR THERMAL POWER SYSTEM FOR ISRU APPLICATIONS: FIELD DEPLOYMENT AND OPERATION AT MAUNA KEA, HI. T. Nakamura and B. K. Smith, Physical Sciences Inc. 6652 Owens Drive, Pleasnton, CA 94583, nakamura@psicorp.com, smith@psicorp.com.

Physical Sciences Inc. (PSI) has developed the solar thermal power system during the past two years (December 07 through April 09) under the SBIR Phase III program supported by NASA/GRC [1]. A full assembly of the solar concentrator array is given in Figure 1. In this figure, seven concentrators, the frame, tracking system and cart are described.

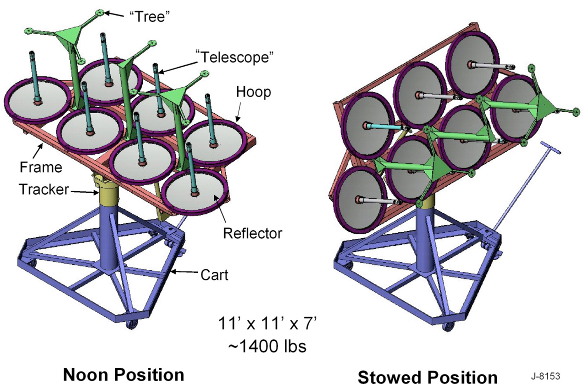

Figure 1. Fully assembled solar concentrator array with seven concentrators.

The solar thermal power system was built and system performance testing was conducted in March 2009 at PSI's solar laboratory. In the Mauna Kea Test we addressed the issues associated with: (i) on-site operation and maintenance; (ii) integration with oxygen production and surface stabiliza-tion processes; (iii) thermal and mechanical integrity of the system components; and (iv) adverse environment effects on the system.

Field Deployment of Solar Thermal System: PSI participants arrived at the Mauna Kea Analog Test Site on January 27, 2010. We started opening the crates, took out the system components and moved on to assembly and integration of the system. The following day, January 28, we started integration and fine tuning of the system components.

Figure 2 shows the fully integrated solar concentrator sys-tem. Performance characterization of the solar concentrator system started on January 29, 2010. Power measurement of the solar concentrator was conducted. We measured ambient solar flux intensity and power output from the optical fiber cable for each concentrator train.

Sintering Tephra. The first test we participated was solar thermal sintering of Thephra. Solar concentrator cable was connected with the sintering optics. The sintering optics connected to the solar concentrator was

Figure 2. The fully integrated solar concentrator system.

integrated with the NORCAT X-Y raster-ing system for initial shakeout. Figure 3 shows the combined system undergoing the initial test. The solar power delivered on the Tephra surface was about 540W. In this test, we tested the effect of the standoff distance between the sintering op-tics and the Tephra surface (heat flux intensity), rastering speed (total thermal power) and rastering pitch.

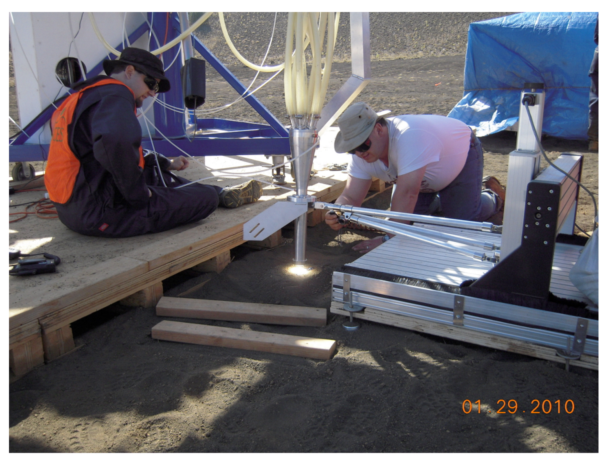

Figure 3. PSI solar sintering system integrated with NORCAT rastering system undergoing initial shakedown tests.

Integration of Solar Thermal Power System with Carbothermal Reactor. After the solar sintering test, the solar concentrator system was integrated with the CT reactor for the oxygen production experiment. Carbothermal (CT) experiments. Figure 4 shows the PSI solar concentrator integrated with the ORBITEC CT

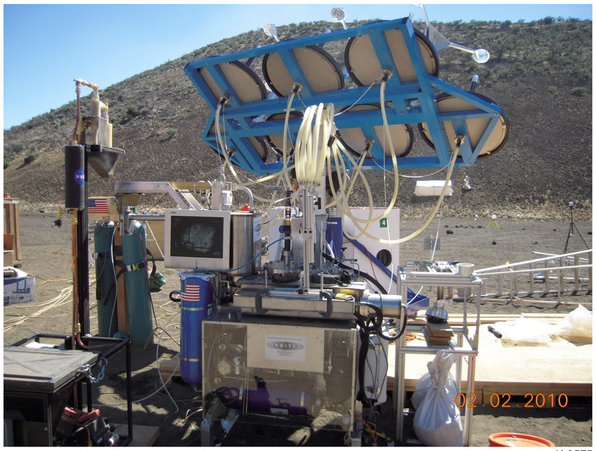

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Figure 4. PSI Solar Concentrator integrated with ORBITEC CT with the Tephra Feed Hopper.

reactor. The Tephra feed hopper was installed by the CT reactor to feed Tephra. The monitor installed at the CT reactor shows the video image of the Tephra melt during the carbothermal reaction process.

Tephra melt experiments were conducted on February 1, 2, 3, 4, 5, 6, 8, and 9. Temperature of the Tephra melt was measured by a two-color pyrometer during the melt experiment. The temperature data showed that Tephra melt temperature was in the range of 1800C. This is the design temperature of the solar thermal power system.

Solar Concentrator Operation and Performance: *Ambient Solar Flux Measurement.* The ambient solar flux (direct) was measured by the imaging solar flux sensor which cuts off the non-direct solar flux. Daily account of solar flux was recorded during the test.

Power Output Measurement. Power measurement data were taken periodically during the test. Detailed discussion on the data will be given in the full paper.

Dust on the Primary Mirror. The test site was very dusty and the wind kicked up the dust regularly. Consequently, the primary mirror and the secondary mirror became covered with dust. We tried the following cleaning methods: blowing with compressed; and water spray followed by compressed air blowing. The third method we tried was to wash the reflective surface with water using a fine paint brush, then wiping the surface with soft paper. The performance data we analyzed indicted that, by cleaning the dust deposited on the primary mirrors, we increased the power by 9.5%.

Conclusions and Recommendations for Future Work: Two PSI members participated in the ISRU Analog Test from January 27 through February 11, 2010. PSI conducted two tests: Solar Sintering of Tephra Surface with NORCAT; and Solar Powered Carbothermal (CT) Oxygen Production with ORBITEC. The solar concentrator system operated as designed, providing solar power to the sintering system and to the CT reactor.

The PSI/NORCAT team successfully demonstrated solar sintering of Tephra, paving the way to lunar surface stabilization with solar thermal sintering of lunar regolith. We successfully prepared a sintered pad (15in × 15in). With valuable lessons learned during the solar sintering experiment, we are ready to design better sintering optics for the next generation of solar thermal sintering.

The PSI/ORBITEC team conducted a series of very successful Carbothermal (CT) oxygen production experiments. The PSI solar concentrator provided solar thermal power necessary for the CT reaction. The solar thermal power delivered to the CT reactor created the Tephra melt at 1700 ~ 1800C, sufficient temperature for CT reaction. In total ORBITEC conducted 18 CT reaction tests. On February 9, the PSI concentrator, the ORBITEC CT reactor and the JSC Electrolyzer were operated remotely from the command post at JSC, Houston.

Based on the successful tests conducted at Mauna Kea, we recommend that the second generation multi-use solar concentrator system be developed. The second generation solar concentrator system shall have a light weight composite concentrator array with high optical surface precision.

Acknowledgements: The PSI team would like to thank those who helped us in preparation, set up, deployment and operation of the PSI solar concentrator. Collaborations with NORCAT and ORBITEC personnel have been very effective, stimulating and rewarding. Our participation in this ISRU Analog Test, Mauna Kea, HI was made possible by the Phase III SBIR contract administered at NASA/KSC, NNK10EA03P, Mr. Anthony Muscatello, the technical contact.

[1] Nakamura, T. and Smith, B.K., “Solar Thermal System for Oxygen Production from Lunar Regolith: Ground-based Demonstration System,” Phase III Final Report to NASA/GRC, NNC08CA59C, April 2009.