Carbothermal Reduction Demonstration Prototype Design A. J. Paz[1], D.O'Connor [1], J. Michel[1] , B.C. White[2], A Colozza[3], N Azim[4], C Bond[4], J Kania[4], 1NASA Johnson Space Center, 2101 NASA Parkway, Houston TX 77058, [2] Sierra Space ,1212 Fourier Drive, Madison WI 53717, [3]NASA Glenn Research Center, 21000 Brookpark Rd, Cleveland OH 44135, [4]NASA Kennedy Space Center, 1st St SE, Merritt Island FL 32953. (Contact: aaron.paz-1@nasa.gov)

Introduction: Lunar regolith is approximately 45% oxygen by mass. The majority of the oxygen is bound in silicate minerals. The carbothermal reduction process has been proven to be effective at removing oxygen from lunar regolith simulants [1]. The Carbothermal Reduction Demonstration (CaRD) project aims to increase the Technology Readiness Level (TRL) of a combined solar concentrator and carbothermal reduction system. The CaRD project is divided into two design cycles, a brassboard and prototype. The prototype design completed a prelimenary design review on January 10th, 2024.

Solar Concentrator: The solar concentrator consists of two carbon-composite mirrors arranged in a crossed-dragone configuration. The crossed-dragone geometry allows for the solar concentrator structure to be stowed during launch and deployed on the lunar surface. As part of the CaRD ground demonstration, the solar concentrator will be coupled with a carbothermal reduction reactor being developed by Sierra Space. Concentrated light will be focused to a high enough flux that it can be used to melt regolith (simulant) contained within the reactor where oxygen can be extracted in the form of carbon monoxide. The carbon-composite mirrors were developed by Composite Mirror Applications and delivered to NASA in February of 2024. The concentrator development is led by Glenn Research Center.

Optical Shutter: The optical shutter protects the reactor from concentrated solar energy during time periods where a reaction is not taking place and the focal point needs to be aligned. The shutter is designed to withstand high temperatures and provide a measurement of the flux produced by the solar concentrator. The optical shutter development is led by Johnson Space Center.

Carbothermal Reactor and Fluid System: The carbothermal reactor is being developed as part of a separate Tipping Point project awarded to Sierra Space, but is being integrated into the CaRD prototype as part of a solar-carbothermal demonstration. In addition, Sierra Space has developed a flight-forward fluid system designed to drive the carbothermal reaction for the CaRD project.

Gas Analysis System: The CaRD prototype will include a gas analysis system that is capable of analyzing carbothermal reaction products and quantifying carbon monoxide (CO) production, which will be used to determine performance data. This system is based off of the MSolo instrument currently manifested on the PRIME-1 and VIPER missions. The gas analysis system development is led by Kennedy Space Center.

Avionics and Software: Some functions of the CaRD prototype, such as deployment, sun-finding, and sun-tracking will use a "test-like-you-fly" approach as part of prototype testing. These functions will be demonstrated using avionics and software that can translate to a flight demonstration with minimal redesign. Avionics and software development is led by Kennedy Space Center.

Ground Support Equipment: In order to demonstrate the sun-finding and sun-tracking functionality of the CaRD prototype, a heliostat and turntable with be utilized as part of the ground support equipment being developed for CaRD prototype testing at JSC's Energy Systems Test Area. The heliostat will provide sunlight to the solar concentrator in a way that represents the sun's approximate angle above the horizon of the lunar surface around the south pole. The turntable is designed to rotate at a speed that represents the movement of the sun above the lunar surface horizon. The ground support equipment also includes a lander mockup that will provide an angled surface representative of the potentially sloped lunar terrain where this technology could eventually be deployed. Ground support equipment development is led by Johnson Space Center.

References:

[1] Gustafson, R., White, B., & Fidler, M. (2011). 2010 field demonstration of the solar carbothermal regolith reduction process to produce oxygen. In *49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition* (p. 434).