COLD OPERABLE LUNAR DEPLOYABLE ARM (COLDARM) AND TECHNOLOGIES TO SURVIVE AND OPERATE DURING LUNAR NIGHT. R. L. McCormick[1], D. E. Newill-Smith[1], A. J. Kennett[1], R. P. Dillon[1], R. E. Fleischner[2], G. C. Levanas[2], L. J. Fradet[2], [1]Jet Propulsion Laboratory, California Institute of Technology, [2]Motiv Space Systems, Inc

Introduction: The Cold Operable Lunar Deployable Arm (COLDArm) is a robotic manipulator leveraging cryogenic capable technologies to enable survival and operation throughout the lunar night. COLDArm is developed in a partnership between NASA Jet Propulsions Laboratory (JPL) and Motiv Space Systems, Inc. The project is funded through the Lunar Surface Innovation Initiative (LSII) and is managed by NASA Space Technology Mission Directorate's (STMD) Game Changing Development (GCD) Program. The COLDArm payload is targeting a future lunar technology demonstration on a Commercial Lunar Payload Services (CLPS) lander. In addition to lunar night applications, the manipulator and technologies could enable future missions detailed in the Decadal Survey to other solar system destinations.

COLDArm System: A COLDArm system diagram is shown in Figure 1. The COLDArm manipulator is similar in design to the Mars Phoenix and Mars InSight robotic arm. The arm is approximately two meters in length, four degrees of freedom (DOF), and has a tip force greater than 40 newtons in the primary workspace. The initial baseline experiment utilizes a titanium 3D printed geotechnical property scoop to collect geotechnical properties about the lunar regolith. A Robotic Avionics and Sensor Kit (RASK) leverages the Mars Helicopter avionics to provide command and data handling (C&DH) capabilities and stereo cameras. These avionics are located at the baseplate in a warm electronics box (WEB). Flight Software (FSW) was developed using the Fprime framework and leverages FSW from Mars Helicopter. The following technologies are used in the COLDArm system to enable cryogenic manipulator operation, but could also be used as component technologies for other applications.

Bulk Metallic Glass Actuators: The bulk metallic glass (BMG) gears at each robotic joint eliminate the need for heaters on the robotic arm. Each robotic joint utilizes a BMG planetary gearmotor and BMG strainwave gear which can operate at colder temperatures without the need for wet lubricants. Both the BMG planetary gearmotor and BMG strainwave gear have successfully completed life testing in cryogenic thermal vacuum environment required for a lunar technology demonstration.

Dual-Axis Controller for Extreme Environments: The Dual-Axis Controller for Extreme Environments (DACEE) motor controllers are utilized to control robotic arm motion. These motor controllers were developed by Motiv under the Small Business Innovative Research (SBIR) program to eliminate the reliance on a WEB and eliminate the need for heaters. The DACEEs have been successfully demonstrated operation at 100 Kelvin.

Cryogenic Capable Six Axis Force Torque Sensor: A cryogenic capable six axis force torque sensor is located at the end effector. The sensor is used for fault protection and to measure ground interaction loads during interactions with the ground, payloads, or the spacecraft. The design leverages the design used on Mars Perseverance Rover Sample Handling Assembly (SHA) arm and has been demonstrated at cryogenic temperatures.

Testing and Future Work: The various component technologies have all been demonstrated at cryogenic environments. An engineering model (EM) COLDArm system has been integrated and tested at the system level. Previous system level testing includes system check-outs and geotechnical property ground interaction testing with a lunar simulant. Future testing will include additional risk reduction environmental testing at the robotic joint and DACEE technology levels. The system will then be exposed to vibration and thermal vacuum testing, including to cryogenic temperatures.

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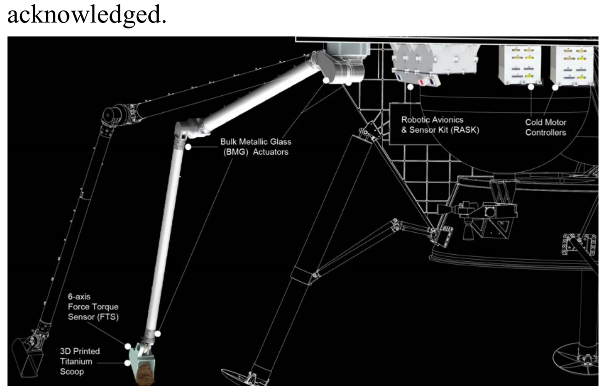

Figure 1: COLDArm System Diagram