DEVELOPMENT AND APPLICATION OF AN IN-SITU AND FLIGHT STERILIZATION SYSTEM FOR LUNAR MISSIONS. E. P. Seto[1], N. Y. Bouey[1], D. Bergman[1], K. Bywaters[1], T. Coohill[2], [1]Honeybee Robotics (epseto@honeybeerobotics.com), [2]Siena College (tcoohill@siena.edu).

Introduction: The renewed goal to return to the Moon as part of the Artemis program will require us to address the practice of Planetary Protection [1]. Our funded project will be important for upcoming Planetary Protection strategies for lunar missions near permanently shadowed regions (PSRs) and future approaches to manned missions on the Moon. In particular, PSRs have scientific value for studies of the process of chemical evolution and most importantly, due to the presence of water-ice. With knowledge gaps regarding PP and PSRs, PSR missions have been temporarily assigned as Planetary Protection Category II-L with requirements (NASA Interim Directive 8715.218) [1]. Therefore, our funded work furthers NASA's science objectives by investigating methods of sterilization and ensuring that contamination is minimized for future lunar exploration.

Figure 1: Human and robotic activity at future lunar sites provides opportunity to introduce biological and organic contamination on the Moon (Jason Roberts/NASA)

Our funded research will examine new sterilization strategies for microbial reduction using synergistic effects of multiple Ultraviolet radiation (UV) wavelengths in combination with heat and without heat. Ultraviolet radiation (UV-10-400nm) is a well-known sterilant often used to inactivate microorganisms and kills mainly by direct effects; that is, the photon is absorbed by an important cellular component (like DNA), which is then altered and loses its functionality. The predominant usage of UV mercury lamps emits only one wavelength (254 nm) while UV-LEDs can be configured to emit certain target wavelengths.

Research: Broader contamination challenges lie ahead regarding a more sustained presence on the Moon (and eventually on Mars). Planetary Protection aims to minimize the transfer of Earth microbes and biological contaminants on outbound spacecraft designed for exploration targets within a potential for harboring life (Committee on Space Research (COSPAR), 2011) [2]. Microbial contamination is present on spacecraft as a result of manufacturing, assembly, and testing operations and will remain part of the mission lifecycle unless removed by surface decontamination or sterilization techniques. Contamination may also be environmental or inadvertently introduced from human flora. Bacterial spores are of particular concern in the context of PP because they are shown to be resistant to sterilization treatments as well as simulated space environment exposures [3]. Bacillus have demonstrated resistance to space factors such as desiccation, ionizing radiation, making them one of the many organisms of interest [4]. Unfortunately, common bioburden removal techniques such as cleaning (mechanical wiping) and sterilization (dry heat microbial reduction) are insufficient for addressing contamination issues of increasingly complex missions. The limitation for incorporating an alternative bioburden reduction technique is partly due to limited funding for research studies.

The overall goal of this effort is to develop procedures, test multiple UV wavelengths with and without heat, and incorporate heaters and UV LEDs in a vacuum chamber to simulate space conditions. This will be the first comprehensive study that will define procedures and parameters for testing multiple UV wavelengths with or without the combination of heat and vacuum while providing data that will advance our knowledge for future sterilization technology development. Tests without vacuum will also be performed to compare and provide data for ground-based sterilization applications.

The findings of this work will be used to reduce complexity, cost, mass and time associated with implementation of an in-situ sterilization system. The LED diode geometry can be optimized to expose hardware at different angles and distances while heaters will clean the hardware without the need for a complicated or high-powered electrical system. Honeybee Robotics has been developing numerous geo-related tools for robotic exportation and this technology can be incorporated on the drills and tools that will be exploring regions near PSRs. Additionally, this technology can be implemented for future missions, launch vehicles, or incorporated as an in-situ sterilization system that can be utilized by Astronauts.

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