

IN SITU BIOLOGICAL CONTAMINATION STUDIES ON THE MOON: IMPLICATIONS FOR FUTURE PLANETARY PROTECTION AND LIFE DETECTION ON MARS. D. P. Glavin¹, J. P. Dworkin¹, M. Lupisella¹, G. Kminek², and J. D. Rummel³, ¹NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA, daniel.p.glavin@nasa.gov, ²European Space Agency, DG-X, 2200 AG Noordwijk, The Netherlands, ³NASA Headquarters, Planetary Science Division, Washington, DC 20546, USA.

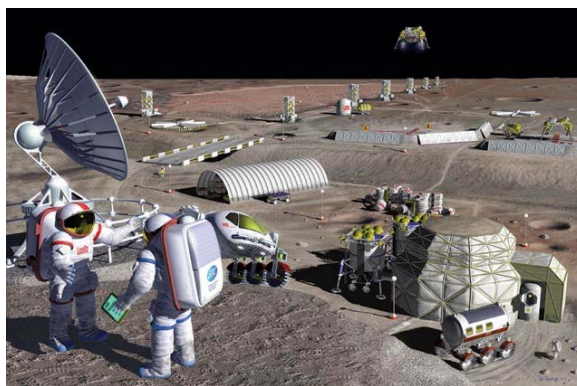
NASA and ESA have outlined new visions for solar system exploration that will include a series of lunar robotic missions to prepare for, and support a human return to the Moon, and future human exploration of Mars and other destinations. One of the guiding principles for exploration is to pursue compelling scientific questions about the origin and evolution of life. The search for life on objects such as Mars will require that all spacecraft and instrumentation be sufficiently cleaned and sterilized prior to launch to ensure that the scientific integrity of extraterrestrial samples is not jeopardized by terrestrial biologic and organic contamination [1,2].

Under the current Committee on Space Research (COSPAR) planetary protection policy for the Moon, no sterilization procedures are required for outbound lunar spacecraft. Future *in situ* investigations of a variety of locations on the Moon by highly sensitive instruments designed to search for biologically derived organic compounds would help assess the contamination of the Moon by lunar spacecraft [3]. These studies would provide valuable "ground truth" data for both Moon and Mars sample return missions and help define planetary protection requirements for future Mars bound spacecraft carrying life detection experiments.

The current planetary protection policy for the Moon related to forward contamination is not at all stringent since the probability that terrestrial life can grow in the harsh environment on the lunar surface is very low. Even survival on the lunar surface is difficult to imagine with the Moon's nearly nonexistent atmosphere, intense ultraviolet, galactic and solar cosmic radiation, lack of liquid water, and large temperature extremes. However, experiments carried out on NASA's Long Duration Exposure Facility (LDEF) have shown that even after 6 years in space, a large fraction of spore forming bacteria will survive if they are not directly exposed to solar UV radiation [4]. These results certainly suggest that bacteria can be delivered to the surface of the Moon by robotic spacecraft. Although bacterial growth on the Moon remains unlikely, survival of terrestrial bacteria on non-UV exposed regions, such as the interiors of lunar spacecraft, the permanently shadowed south polar region of the Moon or below the lunar surface cannot be ruled out.

It also should be emphasized that even if bacteria delivered by lunar spacecraft are inactivated or steril-

ized on the Moon, due to the harsh surface conditions, the organic compounds such as amino acids, fatty acids, and nucleic acid bases from dead cells will remain and could leave a terrestrial fingerprint in lunar samples returned to Earth. *Apollo* soil samples returned to the Earth were immediately analyzed for bacterial and organic contaminants in the Lunar Receiving Laboratory. Although no viable organisms were detected in the *Apollo 11* and *12* samples [5], terrestrial amino acid contaminants were present in these samples [6]. However, since these lunar samples were not analyzed for organic compounds on the surface of the Moon, it remains unclear how much if any of the amino acid contamination in the lunar soils occurred during collection.



Human and robotic activity at a future lunar (or Martian) outpost provides will provide an opportunity to understand the nature and extent of terrestrial biological contamination in preparation for future life detection missions on Mars. Painting by Pat Rawlings.

In order to prepare for future manned lunar missions by 2020, NASA is planning to send a series of robotic orbiters, landers, and rovers to the Moon, beginning in 2008. For both robotic and human missions, *in situ* measurements that target biologically derived organic compounds in lunar soil samples as well as on spacecraft surfaces could be carried out using highly sensitive instrumentation. These "ground truth" experiments on the Moon also would be particularly useful for assessing the degree of organic contamination in lunar soil samples prior to their return to Earth, as well as the stability of organic compounds in sun-exposed and shadowed regions on the surface of

the Moon. In addition, *in situ* experiments carried out at previous lunar landing sites such as *Apollo* could provide important information regarding the extent that extravehicular activities by the *Apollo* astronauts contaminated the Moon during lunar surface operations. At present it is not known whether or not past human contamination of the Moon is detectable in localized regions, or limited to the *Apollo* landing sites, themselves. Although the lunar surface environment may represent a worst-case scenario for the survival of microorganisms and even terrestrial organic matter, lunar exploration provides a unique opportunity to use the Moon as a test-bed for future Mars exploration, where the search for evidence of life has become a primary objective.

The use of sensitive robotic experiments to detect contamination that may still be present nearly 40 years after humans first explored the surface of the Moon may be critical to help establish a contamination baseline, but there are broader contamination challenges regarding a more sustained human presence on both the Moon and Mars. Such considerations should be kept in mind as we prepare for sustained human exploration [7,8]. Human exploration could, in fact, confound the search for life on Mars, since the presence of humans will dramatically increase the amount of terrestrial organic material, potentially making the detection of indigenous organic matter exceedingly difficult, if not impossible.

Future robotic and human missions to the Moon will provide a unique opportunity to carry out ground-truth experiments using *in situ* life detection instruments to help understand the extent of forward contamination by robotic spacecraft and human presence over a limited range of conditions and time. The ability to maintain a pristine environment while conducting life detection experiments during both human and robotic exploration can be tested on the Moon. Ultimately, these experiments will help guide future planetary protection requirements and implementation procedures for robotic and human missions to Mars.

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