THE MOON'S ROLE IN HUMAN EXPLORATION OF THE SOLAR SYSTEM. J. B. Plescia[1] and H. H. Schmitt[2]. [1]The Johns Hopkins Unviersity, Applied Physica Laboratory, Laurel, MD. [2]Unviersity of Wisconsin, P.O. Box 90730, Albuquerque, NM 87199,

Introduction: Exploration of the solar system with humans has been the goal of many nations for a long time. Of late, the Global Exploration Roadmap and NASA suggest Mars as the pièce de résistance of human exploration, as Mars may once have supported (or may yet support) life. While this long-term goal may be appropriate, exploration of and the presence of humans in the solar system beyond low Earth orbit is an important technical, philosophical, economic and security objective for the United States. The Moon can and must play a critical role in that exploration if only to train current and future generations in deep space exploration. The Moon serves as a touch stone for the evolution of the solar system as well as providing, an observation platform, test bed, a source for resources and a potential commercial market. A US presence at the Moon also provides a source of national security and pride.

Role of the Moon

Lunar Science: Combined with the results of past human exploration and sample returns, recent robotic missions have provided a wealth of new information from a range of experiments. Our understanding of some lunar questions has been significantly improved particularly in how lunar impact history relates to Earth history and the origin of life. However, those data have also raised significant new questions that will serve as the focus for further lunar research and objectives of lunar missions. The important questions of lunar science have been discussed by LEAG, the Scientific Context for Exploration of the Moon Report, as well as the Vision and Voyages Decadal Survey.

Observation Platform: The Moon provides a location for variety of observatories to study both the Earth and space. The front side can be used as a platform for Earth observation as the Earth rotates beneath the Moon each day providing global coverage. Over the course of a month, the complete daily illumination cycle of the Earth is observed. The farside of the Moon provides a platform to observe the universe from a position that is shielded from the radio noise and scattered light of the Earth.

Test Bed: The cislunar environment and the lunar surface provide a proximal test location for space and surface systems. Before venturing into deep space (e.g., Mars or asteroids) flight systems and operations need to be validated. Cislunar space provides the appropriate deep space environment and does it close to the Earth. This proximity allows for direct interaction with the systems by humans to evaluate their performance, correct problems and to learn how exploration crews should operate in the absence of direct communications with Earth. Systems that will be sent on multi-year excursions that have no ability for rapid return to Earth, and, in the case of Mars, include abort to land concepts, must be demonstrated and validated in an environment as close to the target environment as possible. The surface of the Moon provides a test bed for surface systems. While the details of gravity, composition, particle size, etc. are different between the Moon, Mars and asteroids, operateration near and on the lunar surface can validate aspects such as seals, mobility, life support systems, long-term human performance, and physcological adapatation in low-g environments. These types of validations and tests will significantly reduce the risks of long-duration space flight.

Resources: The use of *in situ* resources provides significant leverage for space flight by reducing the mass of material that must be launched from the Earth. While such an argument is straightforward in terms of energy (launch from earth vs launch from the Moon), the case for use of lunar resources is less clear in economic terms unless a permanent lunar presence has been established for other reasons, such as national geopolitical interest or terrestrial use of lunar He^3 as fusion fuel.

There is abundant evidence that the Moon harbors a ensemble of volatiles, including H and O in the form of molecular H, OH, and H_2O. H and O are the two most important species as they can be used for life support and fuel. N, C and He are also available. Potentially, He^3 fusion can provide continuous deep space propulsion. However, while we know these elements are present on and near the surface and we can infer something about their physical state from our understanding of the lunar environment and previously returned samples, we really do not understand the vertical or lateral distribution or their form. For example, H_2O could be in the form of adsorbed molecules, fine-grained frost on grains, or blocks of solid ice. Because of this, we can not make an evaluationas as to whether lunar resources are economical and/or the best means of exctraction and refining.

In order to understand the economics of *in situ* resources, we must understand not only what is there, but how to extract and process it. At present, we do not understand the species, form and distribution of volatiles at a level sufficient to understand what is required to extract them. Although volatiles can be extracted from regolith anywhere on the Moon, the cold traps at polar latitudes have the highest likelihood of significant near-surface volatiles in permanently shadowed areas and possibly at shallow depth in periodically illuminated areas. Once we understand the distribution, then extraction techniques can be evaluated. The volatiles must also be stored, transported, and transferred to the vehicle that will use them.

The exploration of the polar regions has been discussed on numerous occasions but remains elusive at present. Missions that have been suggested by the US, ESA, Russia and China, may provide some ground-truth and guidance. However, these missions are insufficient to make a decision about the economics of polar resources. Stationary landers and short-range rovers can provide the initial data, but eventually promising regions must be explored on the scale of kilometers and to depths of meters. Only then can the economic case be made for the use of *in situ* lunar volatiles.

Commercial Opportunities: Space tourism and the Tycho Lodge and Spa may be long-term possibilities, but near-term commerical opportunities may also exist. If lunar resources are developed on an industrial scale (e.g., fuel), the mining, processing, storage and transportation could be operated by commercial entities. Other servicing activities and operations could also be conducted by the commercial sector.

National Interest: A permanent US presence in the cislunar environment and on the lunar surface provides national prestige, inspiration and security. The Apollo program was a major factor in the 1960s and 1970s in terms of focusing interest in science and engineering education, new technology, and national pride (note the current US world stature for comparison). A US presence on the Moon and in cislunar space demonstrates that the US has a national interest these spheres and demonstrates our technological capabilities. Much like the US has bases in Antarctica and the US Navy conducts operations and port calls around the world, a lunar presence will demonstrate our interest and resolve.

Conclusions: The cislunar environment and the lunar surface provide the opportunity to conduct lunar, terrestrial and space science, and it allows us to test systems and operations prior to deep space missions to Mars or asteroids, to extract lunar resources and to demonstrate national interest and serve as inspiration and pride. Testing and operations in the lunar environment significantly reduces mission risk for long term missions. Use of *in situ* lunar resources reduces the cost of both lunar and deep space missions.