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Developing the "Lunar Vicinity" Scenario of the Global Exploration Roadmap. G. Schmidt[1], C. R. Neal[2], I. A. Crawford[3], and P. Ehrenfreund[4]. [1]SSERVI, NASA Ames Research Center, Moffett Field, CA (gregory.k.schmidt@nasa.gov), [2]Dept. Civil & Env. Eng. & Earth Sciences, University of Notre Dame, Notre Dame, IN 46556 USA (neal.1@nd.edu), [3]Department of Earth and Planetary Science, Birkbeck College, University of London, UK (i.crawford@ucl.ac.uk), [4]Elliott School of International Affairs, George Washington University, Washington DC 20052 USA (pehren@gwu.edu).

Introduction: The Global Exploration Roadmap (GER, [1]) has been developed by the International Space Exploration Coordination Group (ISECG – comprised of 14 space agencies) to define various pathways to getting humans beyond low Earth orbit and eventually to Mars. Such pathways include visiting asteroids or the Moon before going on to Mars. This document has been written at a very high level and many details are still to be determined. However, a number of important papers regarding international space exploration can form a basis for this document (e.g. [2,3]).

In this presentation, we focus on developing the "Lunar Vicinity" scenario by adding detail via mapping a number of recent reports/documents into the GER. Precedence for this scenario is given by Szajnfarber et al. [4] who stated "We find that when international partners are considered endogenously, the argument for a **"**flexible path**"** approach is weakened substantially. This is because international contributions can make **"**Moon first**"** economically feasible".

The documents highlighted here are in no way meant to be all encompassing and other documents can and should be added, (e.g., the JAXA Space Exploration Roadmap). This exercise is intended to demonstrate that existing documents can be mapped into the GER despite the major differences in granularity, and that this mapping is a way to promote broader national and international buy-in to the Lunar Vicinity scenario.

The documents used here are: the Committee on Space Research (COSPAR) Panel on Exploration report on developing a global space exploration program [5], the Strategic Knowledge Gaps (SKGs) report from the Lunar Exploration Analysis Group (LEAG) [6], the Lunar Exploration Roadmap developed by LEAG [7], the National Research Council report Scientific Context for the Exploration of the Moon (SCEM) [8], the scientific rationale for resuming lunar surface exploration [9], the astrobiological benefits of human space exploration [9,10].

A Summary of the Global Exploration Roadmap [1]: The common goals are as follows:

- Develop Exploration Technologies & Capabilities.
- Engage the Public in Exploration.
- Enhance Earth Safety.
- Extend Human Presence.
- Perform Science to Enable Human Exploration.
- Perform Space, Earth, and Applied Science.
- Search for Life.
- Stimulate Economic Expansion.

Three paths are articulated to get to Mars - Exploration of a near-Earth asteroid; Extended duration crew missions; Humans to the lunar surface. The GER gives 5 goals for the Lunar Surface scenario:

- Technology test bed (surface power systems, long distance mobility concepts, human-robotic partnerships, precision landing).
- Characterizing human health and performance outside Earth's magnetosphere and in a reduced gravity environment.
- Conducting high priority science benefiting from human presence, including human-assisted lunar sample return.
- Advance knowledge base related to use of lunar resources.
- Explore landing sites of interest for extended durations.

The Mapping Process: For this activity, we did not try and map directly to the GER, but rather focused on important lunar science and exploration topics. Two example are reported here (and more will be presented at the workshop): Polar Volatiles and Technology Test Bed/Human Health.

1. Polar Volatiles: The discovery of volatile deposits at the lunar poles brought these areas into focus for future human exploration. The GER goal "Advance knowledge base related to use of lunar resources" certainly is important for this subject. The other documents [2-7] are detailed below using their reference number.

COSPAR [5]. Support studies and precursor activities toward "International human bases"; Sample return missions to the Moon, near-Earth asteroids and Mars.

LEAG-SKGs [6]. Composition/quantity/distribution/form of water/H species and other volatiles associated with lunar cold traps:

- Map & characterize broad features of polar cold traps;
- Determine lateral & vertical extent of polar volatiles;
- Processes and history of water and other polar volatiles.

LEAG-LER [7]. Objective Sci-A-3: Characterize the environment and processes in lunar polar regions and in the lunar exosphere.

SCEM [8]. Priority 4 - The lunar poles are special environments that may bear witness to the volatile flux over the latter part of solar system history.

Scientific Rationale [9]. The Moon is the type locality to study volatile loss, transport, and retention on airless bodies; the polar deposits represent targets for in situ resource applications;

Astrobiology [9,10]. It is possible that some information concerning the importance of comets in ''seeding'' the terrestrial planets with volatiles and prebiotic organic materials can be found. Lunar polar ice deposits will have been continuously subject to irradiation by cosmic rays and, as such, may have played host to organic synthesis reactions of the kind thought to occur in the outer Solar System and on interstellar dust grains.

2. Technology Test Bed/Human Health: The Moon represents a key asset for testing planetary exploration technologies and understanding the effect of the space exploration on human health because of its proximity to Earth and its hostile environment. The GER is quite expansive about such issues listing three main goals:

- Develop Exploration Technologies & Capabilities.
- Technology test bed (surface power systems, long distance mobility concepts, human-robotic partnerships, precision landing).
- Characterizing human health and performance outside Earth's magnetosphere and in a reduced gravity environment.

In addition to the test documents, a recent study highlight the Moon as an ideal place to study the effects of long-duration space exploration [11]. The test documents map to these in the following ways.

COSPAR [5]. Synergies of robotic/human exploration; Robotic Village concept of ILEWG and ILRP.

LEAG-SKGs [6]. There are many SKGs highlighted that relate to this topic and these are: Solar event prediction; Radiation at the lunar surface; Biological impact of dust; Maintaining peak human health; Radiation shielding; Dust and Blast ejecta; Surface Trafficability; Plasma environment and charging.

LEAG-LER [7]. This roadmap is forward looking in that it proposes to use the Moon to go elsewhere. As such there are several goals and objectives that relate directly the technology and human health:

Goal FF-A: Identify and test technologies on the Moon to enable robotic and human solar system science and exploration.

Goal FF-B: Use the Moon as a test-bed for missions operations and exploration techniques to reduce the risks and increase the productivity of future missions to Mars and beyond.

Goal FF-C: Preparing for future missions to other airless bodies.

Objective Sci-D-9: Investigate the production of oxygen from lunar regolith in lunar gravity;

Objective Sci-D-14: Study the fundamental biological & physiological effects of the lunar environment on human health and the fundamental biological processes & subsystems upon which health depends;

Objective Sci-D-15: Study the key physiological effects of the lunar environment on living systems & the effect of countermeasures;

Objective Sci-D-16: Evaluate consequences of long-duration exposure to lunar gravity on the human musculo-skeletal system;

SCEM [8]. While this report focused on lunar science, understanding the pristine lunar environment is important for designing mitigation technologies in order to provide safe living and working conditions. Therefore the SCEM maps into this through "Priority 8 - Processes involved with the atmosphere & dust environment of the Moon are accessible for scientific study while the environment is in a pristine state."

Scientific Rationale [9]. This document emphasizes the importance of using the Moon to understand the effects of the space environment on human health: 1) Monitoring human adaptation to prolonged exposure to partial gravity may offer significant insights into vestibular disorders and a range of processes beyond associated in aging, disusepathology and lifestyle conditions such as the metabolic syndrome and cardiovascular disease; and 2) There would be much to learn about life support (e.g., bio-regenerative food, breathable air, and water closed-loops), and medical support provision, from human operations in a lunar base beyond research into partial gravity effects.

Astrobiology [9,10]. Use of the Moon to understand the long-term effects of the space environment (e.g., the radiation, microgravity, psychological aspects) is required because our knowledge is not sufficient. Several areas of investigation are highlighted: Study of the adaptation of terrestrial life to the lunar environment; Use of the lunar environment: for *panspermia* experiments and as a test bed for planetary protection protocols; as a test-bed for the development of bioregenerative life-support systems, for long-term use on the Moon and future long-duration deep space exploration missions (see also [11]).

Conclusions: Our major conclusion is that while the GER has broad goals that define a framework for international cooperation in human space exploration, detail from existing, well-established & community developed documents can be mapped to these goals. By broadening the scope of this effort to include other internationally developed documents and space agency roadmaps the GER can become an important long-range planning document for human space exploration.

References: [1] Global Exploration Roadmap (2013) http://www.globalspaceexploration.org; [2] Logsdon (2008) *Space Pol. 24*, 3-5; [3] Schaffer (2008) *Space Pol. 24*, 95-103; [4] Szajnfarber et al. (2011) *Space Pol. 27*, 131-145; [5] Ehrenfreund et al. (2012) *Adv. Space Res. 49*, 2-48. [6] Strategic Knowledge Gaps for the Moon First Human Exploration Scenario (2012) http:// www.lpi.usra.edu/leag/GAP_SAT_03_09_12.pdf [7] Lunar Exploration Roadmap (2013) http://www.lpi.usra.edu/leag/ler_draft.shtml [8] NRC (2007) http://www.nap.edu/catalog/11954.html; [9] Crawford et al. (2012) *Planet. Space Sci. 74*, 3-14. [10] Crawford (2010) *Astrobiology 10*, 577-587. [11] Goswami et al. (2012) *Planet. Space Sci. 74*, 111-120.