Are Living Systems the Key to Sustainable Lunar Exploration?

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Introduction: Elements of sustainability in science, operations and politics, should be incorporated into long range planning for Lunar Exploration [1]. Before lunar exploration (on, of, and from the Moon) can enter a sustainable phase it must first experience a growth phase. Alternative definitions for sustainability, models and metrics for sustainability, and a survey of analogs should be acquired, analyzed and synthesized. - leading to recommendations for further research and a timeline for refinement. Exploration in the national interest [2, 3] also offers a broad set of development perspectives with the insight of greater payback from longer duration or more intensively populated missions. The issues of Living Systems and Sustainable Exploration span the possible mission option space – whether to enable a lunar base, Mars mission or other missions with long duration cruise phases [Augustine] with lower crew risk and lower launch mass requirements than a brute force approach.

Sustainability: A design for sustainability must take many factors into consideration. Alternative definitions of Sustainability are evolving in different contexts, whether with regard to the environment, science, politics, economics or operations. It also implies a steady state, which, in this case, would be preceded by a growth phase whose goals, scope, scale and pace are yet to be defined. In a culture often defined by growth, it is a challenge to understand and operate within steady state boundaries. During the formulation stage, these definitions should be refined and supporting models, metrics and analogs should be analyzed. The development of a reference model (framework) will be helpful going forward – both to establish a management model and a communications tool to engage the community and facilitate consensus building. The LEAG Roadmap is still evolving and will be an essential planning tool. Sustainability is still a long way from autonomous self-sufficiency. Political sustainability may be the greatest challenge [6].

Living Systems: Living Systems is the term of reference [4] where overall system performance and viability (mission success) depend on the reliable functioning of interacting complex biological systems and their environments. Humans are in the loop in all possible exploration missions, whether remotely through robotic proxies or physically present at the surface of the object being explored. Knowledge gained from basic research will enable future systems with enhanced reliable performance and enable mission planners to reduce risks and costs while defining systems requirements for future missions. Space Biology holds the key to space based living systems.

Biology:

Space Biology: Biology (Human - effects & countermeasures, cellular or plant systems used in a closed ecological environmental support system (CELSS)) may hold the key to sustainable lunar exploration - both in terms of public support and operational efficiencies for life support. It is still an open question as to whether humans can truly live on other worlds [5] – not merely for days, weeks of months but for extended duration missions of years – much less permanently in long term settlements. The transportation logistics and costs imply that long duration stays are attractive, yet the risk mitigation is not well understood. The opportunities to study regulatory mechanisms – spanning radiation tolerance, immunology, bone turnover and DNA repair, and opportunistic microbial evolution in a closed environment may have significant implications for long duration operations as well as earth based human health and environmental protection.

Astrobiology: The origin of life on Earth and its subsequent evolution to our current state were influenced by the early and continued bombardment of the inner solar system and the solar radiation environment. Studying the Moon as a witness plate will provide insights into how they influenced our evolutionary past

References:

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