A SUSTAINABLE RETURN TO THE MOON Paul D. Spudis, LPI, Hosuton TX 77058 (spudis@lpi.usra.edu)

Our ultimate goal in space is to be able to go anywhere, at any time with whatever capabilities to accomplish any task or job we choose to undertake. We are light-years away from achieving such a goal, largely because we must drag everything we need in space with us from the bottom of a very deep gravity well – the Earth's surface. As long as this paradigm prevails, we will remain mass- and power-limited in space and thus, capability-limited as well.

The Vision for Space Exploration, outlined by President Bush in 2004 and endorsed by two Congresses, is the official space policy of the United States. The Vision is designed to serve national scientific, economic and security interests. It calls for extending human missions beyond low Earth orbit by learning how to use the material and energy resources of the Moon to create new capabilities in space. The VSE was envisioned from the beginning to be accomplished under existing and inflation-growth budgetary envelopes. Thus, our challenge is to design a program in which time (rather than money) is the free variable. We want to make steady, constant progress towards our goals. This requires an architecture that uses small, affordable steps (incremental) that occur at frequent intervals (paced program) and build upon each other with time (cumulative) to create new and lasting space faring capability.

The Moon is key to gaining this new capability. It has the material and energy resources needed to operate and live in space. It is over 45% by weight oxygen, extractable through a variety of well-known industrial chemical processes. Hydrogen is also present; at the equator it occurs in concentrations of up to 100 parts per million, extractable through simple solar thermal heating. But the real "pay dirt" on the Moon is at the poles, where concentrations of hydrogen have been confirmed (the current debate is over what form this hydrogen takes). Water ice likely exists in the permanently dark regions of the lunar poles. Moreover, we have documented areas at both poles that are in near-constant sunlight (a consequence of the low obliquity of the Moon's spin axis). So the Moon's poles contain both the material (water) and energy (sunlight) resources needed for sustainable human presence there.

An incremental architecture designed to take advantage of these possibilities is possible under current budgetary limitations. The key is to pre-emplace much of the assets we need on the Moon robotically, prior to the arrival of humans. Small robotic landers can survey resources and characterize the terrain for an outpost. Slightly larger landers can deliver equipment; rovers with earth-moving attachments can prepare a habitat site. Large solar arrays can be deployed to generate hundreds of kilowatts of electrical power. Small oxygen production equipment can experiment with different processing techniques, characterizing their yields and efficiencies. All of these robotic devices can be teleoperated from Earth (only a three second time delay); each landing incrementally increases our capability on the Moon and independence from terrestrial logistics. When humans finally arrive on the Moon, they move into a turn-key operation – a pre-emplaced outpost, operating and ready for use.

On the Moon, we will learn the skills needed and develop the technologies required to live and work productively on another world. Our objectives are to arrive, to survive and to thrive. Tasks include building a transportation system, preferably with maximum utility and reusability (arrive), closing the life support loop and extracting consumables from local materials (survive), and producing products for export that create new capability in space, such as rocket propellant (thrive). By establishing a space transportation system that can routinely access the lunar surface and return to low Earth orbit, we have created a system that can also routinely access all other points in cislunar space, where all of our commercial and national security assets – and more than 90% of our scientific assets – reside.

Such a strategy has significant implications for the lunar return architecture. The Orion CEV should be designed in a minimalist, Apollo-scale configuration; its function is only to transport crew to and from Earth's surface to staging areas in orbit. Staging can be done from the ISS, making that program an asset in our lunar return. Cargo takes solar-electric "slow boat" routes to an Earth-Moon Lagrangian staging point while the crew arrives later using "fast" chemical transport. The Altair lander is more LM than behemoth; a 20-30 mT vehicle, its only job is to transport crew to and from the lunar surface. The crew lives on the lunar surface in habitats pre-emplaced and built through robotic teleoperation. Vehicles are designed to be reused in space and, eventually, re-fueled on the Moon and in cislunar space.

Creation of this new transportation system completely changes the paradigm of space flight; no longer are we limited to what we can bring up from Earth. Space systems become maintainable and extensible. Very large distributed-aperture sensor systems can be built and upgraded. We will only launch high-information density payloads from Earth, such as complex machines, sensors and computers, and re-fuel stages in Earth orbit for placement in higher orbits (e.g., GEO) or into interplanetary space. Creating this cislunar transport infrastructure is analogous to building a "transcontinental railroad" in space – it will open up the space frontier to an ever increasing and varied customer base, not just academic science and government.

The Vision's purpose was to break the tyranny of the rocket equation by learning how to use what we find in space to create new capability. It was to be undertaken under existing or modestly enhanced budgetary envelopes. We go to the Moon not touch the surface and blast off for Mars but to learn the skills needed to become a space faring civilization. Fulfilling this goal makes space relevant to many different customers, with a wide variety of interests and purposes. The intent of the Vision was to redirect the agency onto a path that creates new wealth, instead of merely consuming it.