A NEW ARCHITECTURE TO EXPLORE THE POTENTIAL OF LUNAR RESOURCE UTILIZATION.

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Our current national human spaceflight effort lacks both clarity of purpose and a strategic goal reachable for reasonable expenditures of time and money. Despite the obsession with human missions to Mars, a return to the Moon offers more benefits, a larger number of near-term milestones, develops the infrastructure and prepares us for future missions to the planets. We offer a logical, justifiable alternative to the existing program that identifies a compelling purpose for human spaceflight – to learn how to use the material and energy resources of space to create new spaceflight capabilities [1]. As in our previous plan [2], robotic surface elements begin harvesting lunar water prior to human arrival on the Moon, resulting in the creation of a permanent, space-based cislunar transportation system.

We have modified our previously published architecture with two significant updates [1]. First, we use the Space Launch System (SLS) Block-1 and Block 1B configuration launch vehicle to launch the robotic elements that will build the outpost, which accommodates much more mass and volume in a single launch. Second, our new plan minimizes cost for a crew lunar mission cycle by relying upon Commercial Crew launch services for transport to and from a depot and staging node in low Earth orbit (LEO). Crews are launched commercially by any of several providers and returned 6-months later. The crew then transfers to a reusable cislunar transfer stage that travels only between a fuel depot in LEO and a similar facility in low lunar orbit. We use aerobraking during Earth return to recover the reusable cislunar crew stage; this non-propulsive maneuver removes excess energy for an insertion to Low Earth Orbit for rendezvous with the LEO depot and transfer crew to the Commercial Crew vehicle to return home without significant propellant expenditure.

The LEO fuel depot can be provisioned by commercial or government water deliveries from Earth to fuel the cislunar crew stage on its way to the Moon. As lunar surface production grows, we can provision the LEO depot with lunar water for propellant production. The use of both commercial crew and commercially launched water transferred to the LEO fuel depot allows the campaign to better stimulate commercial space industry, transferring technology and experience from NASA to the commercial sector, expanding human spaceflight capabilities and activities off-planet.

Once the crew reaches low lunar orbit, they transfer into a reusable lander that shuttles crew and cargo to and from the lunar surface and the low lunar orbit (LLO) depot. An Orion spacecraft is stationed at the LLO fuel depot that can be used as an assured crew return vehicle at any time in case of emergency. This facility services all lunar surface-bound vehicles, including robotic, human and cargo landers. Activities on the lunar surface are similar to those described previously [2], with lunar water being harvested and processed via robotic machines operated by humans on Earth (teleoperations). The complete outpost system is deployed and operational (including habitat emplacement) prior to the arrival of the first human crew.

As a consequence of this new strategy, we develop more capability to harvest lunar water for propellant compared to the previous architecture. At the end of the 16-year first phase of the architecture, we are producing more than 300 metric tons of lunar water per year (twice the amount generated in our previous architecture [2]), with a production capacity of 500 metric tons per year.

The total estimated cost for this new architecture is $ 87.7 billion [1], about $ 550 million more than our previous plan [2]. In addition, we have examined the possible contributions of international and commercial partners to this architecture, with specific suggestions for both bartered and in-kind contributions. With these possible contributions, we can reduce peak NASA funding to $ 5.5 billion per year while reducing the total program cost to U.S. taxpayers to ~ $ 69 billion, a reduction of roughly one-quarter (25%) from our previous plan [2].

At the end of the first phase of our lunar resources outpost architecture, we will have demonstrated and determined the degree to which humans can effectively use local resources to live and thrive off-planet. At that point, future missions to other deep-space destinations (like Mars) can be undertaken, leveraging the technology gained and lessons learned from the lunar experience as well as utilize the consumables and propellant produced from lunar resources. These new products can be used and exploited by government, commercial, or international entities as we continue to expand our reach in cislunar space and beyond. By adopting a reachable goal (the Moon) that can be achieved for reasonable budgets and timescales, we invigorate our currently moribund and stagnant civil space program while at the same time lay the groundwork for a permanent spacefaring system, one based upon the leverage provided by the utilization of lunar resources to create new capability [3].

References [1] Lavoie T. and Spudis P.D. (2016) Space 2016, AIAA 2016-XXX, 40 pp. [2] Spudis P.D. and Lavoie A.R. (2011) Space 2011, AIAA 2011-7185, 24 pp. [3] Spudis P.D. (2016) *The Value of the Moon: How to Explore, Live and Prosper in Space Using the Moon's Resources*. Smithsonian Books, Washington DC, 243 pp.