LADDER: The Development of a Prototype Lunar Space Elevator

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Introduction: LADDER is a mission to deploy an operational prototype Lunar Space Elevator (LSE) using currently available technology. The LADDER mission would erect a 264,000 km space elevator from the Lunar surface, past the L1 Lagrange point, to a counterweight deep in cislunar space. The LADDER mission is intended to gain experience with the deployment and operation of a space elevator, deploy scientific instruments and other equipment to the Lunar surface, and return samples of the Lunar surface from Sinus Medii to Earth.

The Prototype Lunar Space Elevator: A space elevator is a structure rising from or near a planetary surface to a sufficient altitude to be held taut by gravity, rotation and orbital dynamics [1]. Typically a space elevator is intended to match its primary body's rotation to allow for an easy transfer of material between some orbit and the surface of its primary. A Terrestrial Space Elevator (TSE) has been considered by the NASA Institute for Advanced Concepts (NAIC), but is a very technically demanding structure, and could not be built using any current material. An LSE, by contrast, is technically much easier and could be built using commercially available string materials such as Zylon or M5. Pearson et al. [2] developed many of the crucial concepts of a LSE, but their proposed mission is much more elaborate than LADDER and would require a functioning Lunar transportation system as a prerequisite. LADDER is intended to achieve both a functioning LSE and to provide a solid scientific return in the same mission, based on one launch from an existing or planned Heavy Lift Launch vehicle. LADDER currently is planned to be executed in a single Discovery class mission, starting with the delivery of 11,000 kg of Zylon HM fiber plus associated equipment to the L1 Lagrange site. While the fiber could be changed if better choices become available, Zylon is sufficient for LADDER [3], and is also commercially available in sufficient quantities for the LADDER LSE.

Figure 1 shows to scale (although with greatly enhanced visibility) the major components of LADDER, the string, the Landing Platform, the supply depot at L1, and the CounterWeight (CW). The CW would use the upper Trans Lunar Injection (TLI) stage for mass, which would provide an important increase in payload mass. In order to lower the delta-V required to insert the TLI upper stage plus fiber into the L1 Lagrange Point, it is planned to use both a lunar gravity assist and solar perturbations with Weak Stability Boundary (WSB) trajectory.

LADDER is being designed with robustness to protect against micrometeorites, and should be able to last for up to a decade assuming the microgram meteorite flux in cislunar space of matches the observed flux of ~ 4 x 10^{-8} m^{-2} sec^{-1} [4].

The Landing Site: LADDER plans to land at or near the zero point of the Lunar coordinate system, at latitude 0, longitude 0 is Sinus Medii. This location is technically the simplest landing point for an LSE, and is a suitable place for a landing station. Figure 2 shows Sinus Medii as observed by Surveyor 6 [5], from ~ 44 km from the proposed landing site.

LADDER Science: The primary science goal of the LADDER technical demonstration mission is the return of the first Lunar samples since 1976. LADDER will both take a core sample upon landing and will deliver one or more microrovers to the Lunar Surface to assist in collecting surface samples. LADDER should have the ability to return up to 10 kg of samples from the first Lift from the Lunar Surface, using a reusable solar-powered lifter. LADDER's ability to return samples from other location

LADDER plans to use Single Cube Retroreflectors (SCR) as Laser ranging targets during deployment of the Landing Platform. Once it reaches the surface, the SCR will remain as a permanent addition to the Lunar Laser Ranging (LLR) retroreflector network, and should improve both the Signal to Noise of the LLR network (the existing Apollo and Lunakhod retroreflectors are both intrinsically less accurate and are also degrading with time) [6].

The LADDER team is actively seeking partners for Lunar science and space science opportunities. Partners should be able to provide autonomous instruments, rovers or other equipment in the 20 kg range or less for delivery to the Lunar surface or to the Counterweight. People interested in discussing these opportunities should contact the authors.

Conclusions: LADDER will provide the core of a new Lunar transportation system for up to a decade after installation, capable of cheaply deploying small payloads to the Lunar surface and lifting samples and other material to L1 and returning them to Earth. With LADDER, sound Lunar surface science can be conducted on a continuing basis for a relatively modest initial investment.

References:

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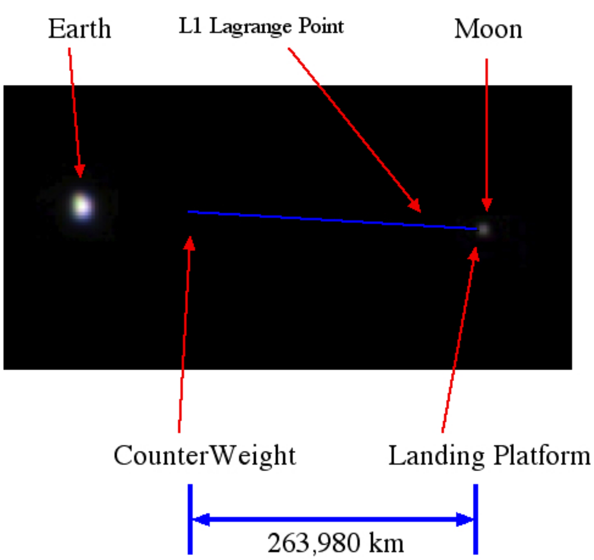

Figure 1. The components of the LADDER LSE, to scale, superimposed on a image of the Earth-Moon system from the Juno spacecraft, taken August 26, 2011 at a distance of 9.66 million km. (Note: the actual LSE would not be visible to the naked eye from such a distance.) Credit-NASA for the original image.

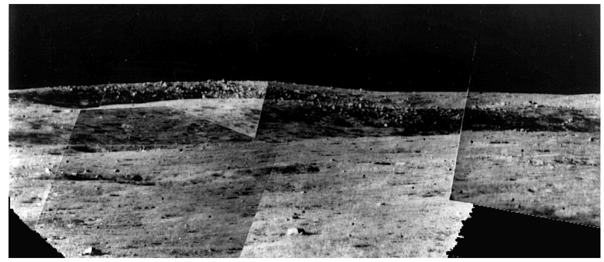

Figure 2. Sinus Medii from Surveyor 6, taken about 44 km from the proposed landing site [Credit – NASA].