Sample Return from Shackleton Crater with the Deep Space Tether Pathfinder (DSTP). T.M.Eubanks[1], [1]LiftPort Group (eubanks@liftport.com).

Introduction: The Deep Space Tether Pathfinder (DSTP) is intended to demonstrate the scientific utility of planetary scale tethers and advance the technology to the level required for a Lunar Space Elevator (LSE). The current mission design is based on a 5000 km, 3400 kg, rotating tether to be sent into deep space, providing information essential to future Lunar and Martian space elevators, but also, in the course of a Lunar flyby, significantly advancing Lunar science by collecting and returning a surface sample in a "touch-and-go" fashion from a suitable scientific target. By a suitable matching of the tether rotation and orbit dynamics the DSTP can collect a sanple from regions of high scientific importance, such as from the floor of Shackleton Crater in the Lunar South Polar Region. The collected sample would then be returned to Earth by the release of a return capsule roughly one rotation period later, using the tether to "throw" the sample return capsule back towards the the Earth on a direct return trajectory. After sample release, the DSTP would move away from the Earth Moon system, allowing for long term observations of micrometeorite impacts and other phenomena in deep space.

Planetary Scale Tethers and Space Elevators: A planetary scale tether is a tether, in space, of at least one megameter in length. Such tethers are possible with current technology and offer the means for accelerating the exploration and development of the solar system. A space elevator is a particular use of a planetary scale tether, rising from or near a planetary surface to a sufficient altitude to be held taut by gravity, rotation and orbital dynamics [1]. An LSE [2,3] is technically the easiest elevator to construct in the inner solar system, LiftPort is in the process of designing a LSE Infrasture (LSEI) to be built using commercially available string materials such as Zylon[4]. First deployment is intended within this decade, which will require the advancement of the technology readiness level of various tether and elevator components, such as the engineering for meteorite protection. The LSEI prototype [3] 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.

DSTP Engineering: In order to properly match the stress experiences by a functioning space elevator, the DSTP will have to be of planetary scale, and will have to rotate with tip velocities at the km / sec level. Figure 1 compares the linear density of the DSTP and prototype designs for a LSE and a Martian Space Elevator (MSE); all three designs have roughly comparable stress and the DSTP should thus provide information about the correctness of the prototype Space Elevator designs and information about the dynamics and normal modes of planetary scale tethers.

Sample Return from Shackleton Crater: Current planning is for the DSTP to be sent into deep space to avoid any possibility of interference with the constellations of satellites in Earth orbit. This, plus the engineering necessity of rotating the tether to match the dynamical enviroment of a LSE or MSE, offers the possibility of acquiring samples from any region of the Moon near the boundary of the Near and Far sides, which includes the polar regions. In the Lunar polar regions there are regions never illuminated by the Sun and there has been extensive speculation as to the possible presence of water ice and other volatiles on the floors of such craters, with Sackleton Crater (directly adjascnent to the Lunar South Pole [5]. Sample return from such craters will be extremely difficult using conventional techniques due to a lack of solar power and direct communications with the Earth. The DSTP offers a means of collecting a "touch-and-go" sample [see, e.g., 6] directly from the bottom of the crater, perhaps a decade before a conventional return can be arranged. With appropriate communications between the tips of the tether, the sample collection could be accompanied by the real-time transmission of still and video photographs, using reflected sunlight from the lips of the crater for illumination. Figures 2 and 3 illustrate the Flyby and sample collection period. Despite a relative velocity (for this trajectory) of over 2 km / sec, the sampling tip of the DSTP will he almost motionless over crater floor for roughly 6 seconds. Currentl planning is to not bring the actual tip closer to the surface than the expected ephemeris uncertainty, with the actual sampling to be done by a cannon fired harpoon or other such mechanism.

Conclusions: The entire purpose of planetary scale tethers should be to accelerate and facilite the exploration of space. In order to realize their full potential it will be necessary to advance their technological readiness level, and for such large structures this can only be done by deployment of actual tethers in space and, for a planetary scale tether, in deep space. The DSTP is a crucial first step in the development of space elevators, and in future tether missions, but can be justified on the basis of returned science, in addition to its engineering return. Building the DSTP will thus lead to the LSEI and to future Martian elevators, and to thus to the development of a true transportation infrastructure for the inner solar system.

References:

[1] Edwards, B.C. (2003) *The Space Elevator*, NASA NAIC Phase II Final Report.
[2] Pearson, J., Levin, E., Oldson, J., and Wykes, H. (2005) *Lunar Space Elevators for Cislunar Space Development, Phase I Final Technical Report*, NASA NAIC Research Subaward No.: 07605-003-034, Star Technology and Research, Inc.
[3] Eubanks, T.M. and Laine, M., (2011) *LADDER: The Development of a Prototype Lunar Space Elevator*, 2011 Annual Meeting of the Lunar Exploration Analysis Group, 2043.
[4] *Zylon Fiber PBO Technical Information* (2001) Toyobo Corporation, Ltd, available from http://www.toyobo.co.jp/seihin/kc/pbo/technical.pdf
[5] Haruyama, J., et al., (2008) *Lack of Exposed Ice Inside Lunar South Pole Shackleton Crater*, Science, 322, 938.
[6] Sears, D.W., et al., (2004) *Lack of Exposed Ice Inside Lunar South Pole Shackleton Crater,* Advances in Space Research, **34**, 2276-2280.

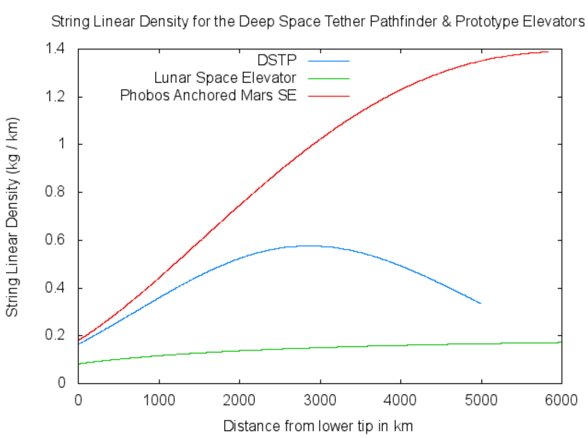

Figure 1: Tapering of the DSTP compared to that of the Phobos Anchored Martian Space Elevator and the Prototype Lunar Space Elevator. The DSTP will prove design aspects of both elevators in realistic conditions in deep space.

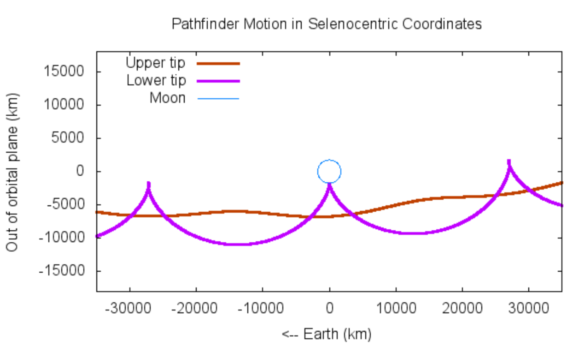

Figure 2: Trajectories of the two tips of the DSTP during the Lunar Sample return period, as seen from a selenocentric reference frame. In this model, the sample tip has about 1/10th the mass of the counterweight, which thus undergoes a much smaller rotation.

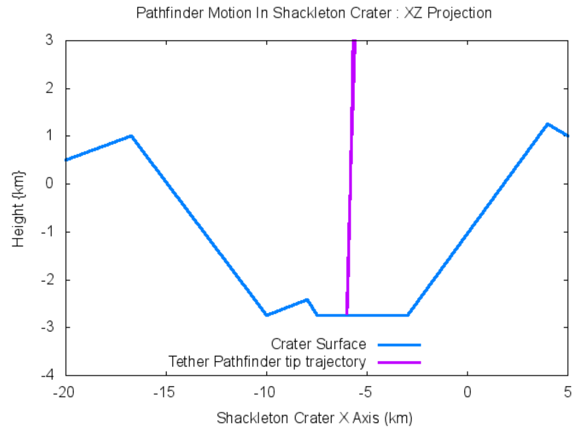

Figure 3: The path of the DSTP sampling tip during the sample collection process. The sampling tip is inside the crater for roughly 60 seconds, with roughly 6 seconds within 100 meters of the surface.