THE ROBOTIC ARCHITECTURE OF MOON EXPRESS: EXPLORATION, RESOURCES AND DELIVERY

Paul D. Spudis[1,2], Robert D. Richards[2] 1. Lunar and Planetary Institute, Houston TX 77058 2. Moon Express Inc., Cape Canaveral FL 32920

Moon Express has recently released information on a planetary exploration architecture that describes a variety of spacecraft configurations and missions. The spacecraft may be used singly or combined and configured to carry out a variety of missions to the Moon and in cislunar and deep space.

Moon Express Spacecraft. The MX-1 spacecraft is self-propelled, having a 250 kg wet mass with a total delta-v of 5.8 km/s. Depending upon the launch vehicle selected, it is capable of carrying up to 30 kg of payload to the surface and provide up to 200 W of electrical power to serve a variety of payloads. The MX family of spacecraft are capable of being combined and configured in a modular fashion to accomplish a wide variety of deep space missions. Two MX-1 can be stacked to create a single, two-stage vehicle (MX-2) for orbital maneuvers, translunar injection, and various trans-LEO operations. Depending on the mission, this spacecraft enables orbiters, landers, and deep space (planetary) probes. Five MX-1 units can be employed in a platform configuration (MX-5) for missions to the lunar surface. Such an arrangement provides the capability to land 300 kg on the Moon from GTO or 50kg from LEO. The MX-9 consists of nine MX-1 stages, arranged in a cluster of 8 outboard and 1 inboard that can land 500 kg on the lunar surface, including the option of landing a fully fueled single MX-1 ascent stage for a sample return journey [1].

Moon Express Missions. We have devised several missions designed to address a variety of exploration and scientific goals. The first mission will likely orbit the Moon to validate the basic spacecraft design, refine its operational properties and test our custom propulsion system in real space operations. Payloads are still being evaluated but among the possibilities is a multispectral imaging system designed to map the global spatial and temporal distribution of the 3 micron hydroxyl and water spectral absorptions discovered by the Moon Mineralogy Mapper (M^3) on the Chandrayaan-1 orbiter [2]. This feature is important for understanding the nature and conditions of lunar water deposition and migration, a crucial aspect of the lunar water cycle. We are evaluating a spectral imager designed by APL (MIMSI) for compatibility with this mission [3]. An MX-1 in polar orbit could map the water band over the entire Moon, with emphasis on its distribution at high latitudes and implications for this water as a source for polar volatiles.

For the first lander mission, we have tentatively selected an area of regional dark mantling deposits near Rima Bode. This material appears to be rich in Fe and Ti and is optically mature. Because the concentration implanted solar wind gas is positively correlated with fine grain size and Fe- and Ti-rich compositions, we expect this deposit to be rich in adsorbed solar wind hydrogen [4]. Recent work on M^3 spectra indicates that juvenile water from the lunar interior might also be present [5]. We plan to directly measure the bulk hydrogen content of the Rima Bode pyroclastics while also mapping any 3 micron spectral feature associated with surface water. Payload is a spectral mapper and neutron spectrometer, possibly the neutron instrument being tested for NASA's Resource Prospector mission [6]. These data provide ground truth for orbital measurements. We will select a near-polar landing site, probably between 70° and 85° latitude.

An early landed mission will emplace the International Lunar Observatory telescope [7], a privately designed and operated instrument designed to conduct observations of the galactic center from the south pole of the Moon. We are in process of selecting a landing site that gives an unobstructed view of the galactic center and southern sky, undergoes near-constant solar illumination to power the spacecraft and maintains a constant or near-constant line of sight for communication with Earth. Two sites meet these requirements, both on peaks near the south pole of the Moon.

The robust capability provided by the modular MX-1 spacecraft can be adapted to a variety of missions for government, commercial, educational and international users. Likely future missions include the return of lunar samples to Earth for both scientific and operational uses, the emplacement and delivery of surface networks, rovers and instrument packages, and the exploration and prospecting of polar ice deposits using hard landers, fixed stations and surface rovers.

Conclusions. The advent of inexpensive access to deep space locales means that they will not remain exotic much longer. The Moon Express line of services and systems enable a variety of activities in cislunar and deep space for many diverse users.

References [1] http://www.moonexpress.com/robotic-explorers/ [2] Pieters C. M. et al. (2009) *Science* **326,** 568. [3] Hibbitts K. (2017) Water cycle on the Moon. SCIS/LPI http://tinyurl.com/ya69gquu [4] Gaddis et al. (1985) *Icarus* **61**, 461. [5] Milliken R.E. and Li S. (2017) *Nature Geoscience* doi:10.1038/ngeo2993 [6] Elphic R.C. et al. (2008) *Astrobiology* **8**, 639. [7] http://www.iloa.org/