A Low Cost Spacecraft Architecture for Robotic Lunar Exploration Projects

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Abstract. A program of frequent, capable, but affordable lunar robotic missions prior to return of humans to the moon can contribute to the Vision for Space Exploration (VSE) NASA is tasked to execute. The Lunar Reconnaissance Orbiter (LRO) and its secondary payload are scheduled to orbit the moon, and impact it, respectively, in 2008. It is expected that the sequence of missions occurring for approximately the decade after 2008 will place an increasing emphasis on soft landed payloads. These missions are required to explore intrinsic characteristics of the moon, such as hydrogen distribution in the regolith, and levitated dust, to demonstrate the ability to access and process in-situ resources, and to demonstrate functions critical to supporting human presence, such as automated precision navigation and landing. Additional factors governing the design of spacecraft to accomplish this diverse set of objectives are: operating within a relatively modest funding profile, the need to visit multiple sites (both polar and equatorial) repeatedly, and to use the current generation of launch vehicles. In the US, this implies use of the Evolved Expendable Launch Vehicles, or EELVs, although this design philosophy may be extended to launch vehicles of other nations, as well. Many of these factors are seemingly inconsistent with each other. For example, the cost of a spacecraft usually increases with mass; therefore the desire to fly frequent, modestly priced spacecraft seems to imply small spacecraft (≤ 1 Mt, injected mass). On the other hand, the smallest of the EELVs will inject ≈ 3 Mt. on a Trans Lunar Injection (TLI) trajectory and would therefore be wasteful for launching a single, small spacecraft. Increasing the technical capability of a spacecraft (such as autonomous navigation and soft landing) also usually increases cost. A strategy for spacecraft design that meets these conflicting requirements is presented. Taken together, spacecraft structure and propulsion subsystems constitute the majority of spacecraft mass; saving development and integration cost on these elements is critical to controlling cost. Therefore, a low cost, modular design for spacecraft structure and propulsion subsystems is presented which may be easily scaled up or down for either insertion into lunar orbit or braking for landing on the lunar surface. In order to effectively use the ≈ 3 Mt mass-to-TLI of the EELV, two low cost spacecraft will be manifested on the same launch. One spacecraft will be located on top of the other for launch and the two will have to be released in sequence in order to achieve all mission objectives. The two spacecraft could both be landers, both orbiters, or one lander and one orbiter. In order to achieve mass efficiency, the body of the spacecraft will serve the dual purposes of carrying launch loads and providing attachment points for all the spacecraft subsystems. In order to avoid unaffordable technology development costs, small liquid propulsion components and autonomous, scene-matching navigation cameras may be adapted from military missile programs in order to execute precision soft landings.

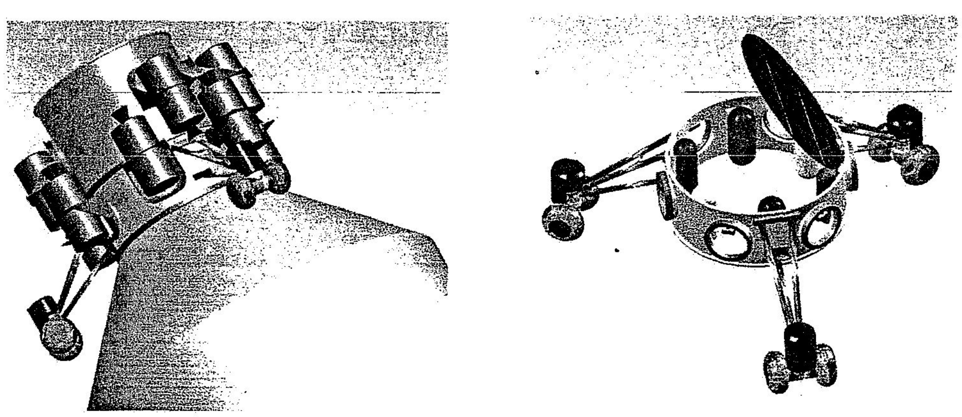

FIGURE 1A, B; Low Cost Lunar Exploration Spacecraft Concepts. Figure on left shows two spacecraft stacked on EELV for launch (lunar orbiter on top, lander on bottom); black cylindrical shapes are solid rocket motors. Figure on right is lunar rover platform, after solid rocket motor separation; up to 100 kg of payload may be accommodated inside ring structure.

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PRINCIPAL AUTHOR'S BIO (~50 WORDS)

Lawrence Lemke is a senior Aerospace Engineer with NASA-Ames Research Center, where he has been engaged in advanced space mission design and advanced space technology development for 25 years. Previous work includes novel Mars airplane and Mars exploration lander mission designs using high performance missile propulsion and avionics subsystems. He has a BS in nuclear physics, from Portland State University and MS and Engineer degrees from Stanford University in Aerospace Engineering.