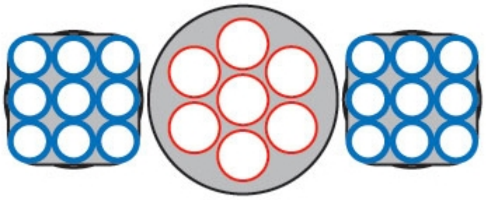
Lunar Direct - Landing on the Moon in a Single Launch

Thomas Lee Elifritz
The Tsiolkovsky Group, Marshall Space Flight Center, Marshall, Wisconsin USA

In a previous paper[1], I discussed options for delivering hydrogen powered Space Launch System (SLS) core stages and launch vehicle upper stages to high Earth orbits, where they can then be aggregated into large autonomous orbiting complexes capable of rendezvousing with, grappling and salvaging satellites, effectively turning geosynchronous orbit into a resource rich station, enabling extraterrestrial operations. In this paper I will attempt to extend this core idea all of the way to the surface of the moon and beyond, using the Space Launch System as an example, and extrapolating to new engines, boosters and vehicles.

The addition of a restartable and throttleable engine to the Space Launch System (SLS) core stages, will enable the delivery of reusable launch infrastructure to the surface of the moon with a single launch; the delivery of a flight ready launch vehicle to the surface of the moon - an unmanned Lunar Direct mission. Direct flights to the moon eliminates the need for staging events, lunar landers, fuel depots and stations, and will motivate the development of lunar ice extraction and solar electrolyzed cryogenic fuel storage.



BOOSTER ASSISTED
Hydrogen Cluster

Booster assisted, hydrogen powered, ground started core stages with multiple engine clusters are capable functioning both as deep space upper stages, and planetary landing vehicles, using their center engines. Payload capacities to low earth orbit (LEO), geosynchronous orbit (GEO), and extraterrestrial orbits (ETO), are dependent upon the number, thrust and efficiency of their attached boosters and engines.

Missions for such large and powerful, high flight rate, duel fuel, reusable heavy lift launch vehicles are currently unfunded. An obvious cost effective method of proceeding, is to repurpose the orbital portion of these launch vehicles into the payloads themselves - the upper stage of conventional launch vehicles and the core stages of any orbital capable launchers. Propulsion and extraterrestrial fuel manufacture and storage are the primary methods by which space exploration and development are expected to proceed, and thus the hydrogen powered core stages and upper stages of launch vehicles are ideal equipment for the task of reaching these distant water bearing planetary bodies, rendezvousing with and landing upon them, and storing the locally produced water, oxygen, hydrogen and regolith found there, and finally lifting those materials out of the large variety of often very deep gravity wells in which they are found.

Additionally, if the mission payloads consist of the upper or core stages and any residual fuel remaining after their target trajectories are achieved, no payload fairing is required. Since target planetary bodies will have no atmospheres, and their surface gravity will be much less than earth, large payloads may be attached to any booster attachment points for subsequent launch and transport to their final destinations.

Taking the example of the poles of the moon, where water ice and volatiles are expected to be found in and around cold, dark polar reservoir craters enabling near term testing of this concept, and where the surface gravity is large enough to capture and settle a significant fraction of the exhaust plume ejecta - one can begin analyzing the propulsion requirements required for implementing this proposal, and then estimating the significant cost reductions that may be afforded for cis-lunar and near earth operations.

Using the Space Launch System (SLS) as an example, clearly this approach will lead to enormous cost reductions simply by not allowing the core stages to reenter the atmosphere and burn up and fall into the ocean after achieving 97% of orbital velocity, as with the currently considered standard NASA scenario. Furthermore, extending the 'core stage direct to deep space concept' all of the way to the surface of the moon will alleviate orbital debris concerns related to the friable nature of cryogenic fuel tank insulation for any near term demonstrations of this technique, also due to the deep gravity well and the very cold temperatures of the reservoir craters, where ice required for their refueling would ultimately be obtained.

The lower gravity of the moon will also necessitate the inclusion of restartable and throttleable landing engines for the core and upper stage system equipped with extendable landing spikes, since space shuttle main engines (SSMEs) that are expected to be used for the initial SLS flights are not restartable, and are only expected to be used through the initial stages and some portion of trans lunar injection (TLI) burns. We can estimate the thrust requirements for the landing engines and the total weight of the spacecraft by assuming that it will be derived from the SLS, since the SLS is already authorized and funded for these missions of beyond earth orbit space exploration, and there are no other dual fuel and engine clustered alternative launch vehicle options available at this time. Working with SSMEs , Merlin 1D engines and throttleable RL-10 upper stage engines, Falcon 9 hydrocarbon boosters and five segment SRBs, it could take 4-5 RL-10s to provide hovering capabilities for a ~ 150,000 lb vehicle - with minimal residual fuel. Clearly a single throttlable RL-10 at ~ 15,000 lbf of thrust represents the minimum landing vehicle size.

Parameter space for these configurations are dictated by gravity losses in surface to LEO transportation and lunar orbit to lunar surface transitions. All other segments may be performed by continuous firing of small fuel settling thrusters - with the bulk of the surface to TLI transition being taken up by the SSMEs. Finally, 'smaller than main engine' lunar injection engines are used for the ballistic parabolic landing arc. Whether this could be multiple RL-10s, or some other modern throttleable engine must be determined. Presumably any performance shortfalls can be made up by the inclusion of multiple, mixed fuel (solid and/or hydrocarbon) boosters during launch and boost phase, ultimately producing quite large launchers.

The remaining SSMEs allow for flights to GEO with grappling arms for demonstrating satellite salvage, a flight to the sunlight crater side area of the lunar south pole, and a flight directly into the depths of a cold dark reservoir crater, relaying data up to the other nearby landing unit, and then back to the Earth. Human missions using hypergolic reusable landers and laboratories carrying in situ resource utilization units would follow to begin resource extraction experiments - directly beside these initial base stations. Future improvements include hard landing surfaces to minimize thrust blast ejecta for reusable landers, more powerful and fully restartable and throttleable, high thrust, closed cycle, main propulsion engines (second generation SSMEs) and high thrust throttleable engines for lunar injection and landing phases.

Reference

Resource Exploration and Exploitation in Near Earth Space - Satellite Salvage, Reservoir Crater Exploration and Asteroid Capture and Derotation, NASA Innovative Advanced Concepts Solicitation Number NNH12ZUA002N.