The Evolution of a Reusable Space Launch System (SLS)

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The fundamental problem of the NASA Space Launch System, as designed, is that it is not reusable. 2014 Congressional NASA Authorization and Appropriations actions appear poised again to fix the Space Launch System design into legislation, forcing an impractical expendable heavy lift launch vehicle project onto an unsustainable space exploration program serving no discernible usefulness.

Although several evolutionary paths have been put forward to increase the payload of the launcher with a J-2X powered upper stage, a center fifth engine, and liquid, possibly F-1 powered boosters, thus far nobody but myself has suggested that with even a modest improvement in booster capability, or even with the booster as it is designed with the five segment solid rocket boosters, the SSME powered core stage itself is easily capable of reaching a wide variety of low to high earth orbits and escape velocity, depending only on the amount of fuel it can carry and the total number and efficiency of the boosters.

Simple booster simulations have now indicated that great gains may be made in booster efficiency by crossfeeding multiple, parallel staged, outer boosters into a engine clustered core booster stage. In this manner early staging of the reusable boosters back to the launch site may occur, or a ballistic reentry to a well positioned terrestrial spaceport or landing barge is possible, thus allowing the fully fueled core stage booster to easily attain orbital velocities, where it may be immediately pressed into service as fundamental space infrastructure, i.e. - cryogenic fuel storage facilities, habitation, storage space, etc.

The failure of the Space Launch System to be competitive with the proposed new commercial, large diameter, engine clustered, and booster assisted, all liquid powered, reusable heavy lift launch vehicles for direct trajectory flights to both the moon and Mars is now apparent to all but uninterested observers. In this paper I offer several viable paths for Space Launch System evolution to full reusability within the framework of a much larger space infrastructure development and a planetary protection program.

Asteroid retrieval missions have been suggested as an appropriate use of the Space Launch System. However this effort requires large solar arrays, solar electric attitude control systems and propulsion, and asteroid capture and transfer capabilities that could be more immediately implemented and tested with low Earth orbit and geosynchronous satellite salvage operations. These systems in turn could be installed directly onto the orbital capable core stages and then delivered directly to their destinations. These economies of design can only be achieved in launch vehicle scenarios where the core stage is not purposely destroyed minutes after launch, rather with booster assistance proceeds directly to high orbit. This also requires a cryogenic fuel insulation system that is space rated with respect to debris shedding.

For its use as a lunar direct polar moon base vehicle, the diameter of the core stage would have to be increased to ten (10) meters with six (6) Space Shuttle Main Engines and a center J-2X landing engine. The core stage itself will have to be capable of both single and multiple symmetric engine shutdowns. The solid rocket boosters would have to be replaced with multiple Falcon Heavies with cross feeding. The trans-lunar cruise phase and terminal landing sequence will require a hypergolic thruster system. The cryogenic fuels will require a thermal sunshade even for the short direct flights to the lunar poles. Upon landing on the poles of the moon, very large rotating solar panels will need to be deployed, and communications, navigation, global positioning and remote sensing systems will need to be operating.

The fundamental problems with core stage to orbit launch scenarios and deep space SLS flights using space shuttle main engines are the hydraulic pressure head value for cryogenic fuels at the turbopumps, and the maximum acceptable acceleration of the engines and cryogenic tankage at main engine cutoff. Direct flights with modern reusable heavy lift launch vehicles prefer maximum acceleration near large planetary bodies to leverage fuel efficiencies by minimizing gravity losses outbound from the Earth to deep space, and also inbound to the moon, which may not be appropriate or even possible with SSMEs. Stretching these tanks only exacerbates these sensitivity issues with the space shuttle main engines, and only a limited number of these engines are available in the near term, requiring the eventual reengining of the vehicle, should use of the higher energy hydrogen powered stages be deemed appropriate here.

The actual launching of all liquid fueled reusable heavy lift launch vehicles will require specialized booster carrier posts with integrated turbine fed water deluge pipes for acoustic vibration abatement. Although the individual booster elements will be quite light when empty, fully fueled they present a launch danger such that only specialized launch pads far from any public and industrial infrastructure are appropriate. The fact that Blue Origin (hydrogen/Moon) and SpaceX (methane/Mars) bid for use of the only available heavy lift launch pads at Kennedy Space Center is revealing of the large sizes and extremely powerful nature of the anticipated new fuel abundant direct flight space launch architectures.

The Space Launch System as designed, utilizes extremely heavy and dangerous solid rocket boosters that must be transported clear across the country by rail, stacked fully fueled in the Vehicle Assembly Building for long periods of time, hauled out to the pad on the maintenance intensive, large, heavy and slow moving crawler pad, and then launched with a labor intensive workforce. With development costs of tens of billions of dollars, per unit launch costs of a billion dollars apiece and anticipated launch rate of only once every four years, with no funded missions whatsoever, clearly this design cannot compete with any vastly less expensive commercial reusable heavy lift launch vehicle replacements, with higher payload capacities, greater launch frequencies, clearly developed missions, and fully reusable boosters.

With the design of the Space Launch System approaching preliminary design review and about to be legislated into law a second time since 2010, clearly now is the time again to consider canceling the offending program outright, deferring to the vastly cheaper and technologically superior commercially available all cryogenic liquid boosters, soon to be completely reusable and using entirely new engines. Given that the program is barely salvageable as it stands, a decision must be made either to convert the vehicle to a fully reusable orbital capable core stage, with clearly defined satellite salvage and orbital debris removal precursors to the asteroid deflection and retrieval missions and lunar base construction, or to alternatively sell the program off to a commercial entity that is competent and capable enough to execute it within clearly defined, market driven, launch vehicle products, prices and delivery schedules.

To reiterate, the NASA Space Launch System as a conventional expendable heavy lift launch vehicle is doomed to failure on cost, schedule and technical feasibility grounds, compared to all new liquid fueled reusable launch vehicles using new engines and launch vehicle stacking and integration technologies. Both congress and NASA appear unable to come to grips with this fundamental technical failure of our national space policy, and those institutions charged with its execution, with regards to this SLS design. The purpose of this paper is to bring this glaring failure to your immediate attention, and offer several avenues of escape, in lieu of program cancellation, which appears to be unacceptable to all principles and stakeholders involved. Although many technical hurdles need to be solved in order to implement rudimentary reusability to the Space Launch System, by doing so several immediate missions for the system instantly materialize, at costs and schedules that appear to be very achievable within the current budget environment. This leads directly to the reconciliation of heretofore disparate goals outlined by opposing factions within the space advocacy community, thus enabling sustainable space development.