Modular Space

Engine Recovery Modules for Reusable Space Flight

NASA Innovative Advanced Concepts
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Elimination Criteria

No aerospace focus. Fails to sufficiently address NASA goals or potential space or aeronautics benefits.

The proposed concept is unclear. Fails to present a specific innovative concept.

The mission context is unclear. Fails to identify or propose to study at least one application for which the proposed concept might be used.

Explored before. Revisits a previously studied concept, without identifying a new factor that substantially differentiates the proposal from prior efforts.

Incremental. Proposes typical next steps or aims at only modest improvement, rather than investigating far-term or high-risk "breakthrough" concepts.

Not technically credible. Conflicts with established physics or engineering principles, without acknowledging this and offering a sufficiently plausible defense.

Not programmatically credible. No reasonable path to implementation, without acknowledging the barriers (e.g., requiring unrealistic budgets or policy changes) and offering a sufficiently plausible approach.

Too narrowly focused on technology, subsystems, or investigations of smaller scope (e.g., components, instruments, materials). Some focused analysis may be appropriate to establish the credibility of the underlying innovation, but it must not overshadow the study goal to establish concept feasibility in a mission context.

Primary focus appears to be experimentation or analysis, not concept development. Tests, derivations, characterization of properties, and algorithm development are common examples. NIAC studies often involve some such efforts, but they must not overshadow the study goal to establish concept feasibility in a mission context.

Primary focus appears to be development of tools or processes to improve design, decisions, or technical capabilities. NIAC studies must focus on developing specific aerospace concepts.

Concept

In a series of previous NASA NIAC research proposals over the past few years I have fully developed the concept of launch vehicle reusability through design, where the upper and the core stages of deeply cryogenic launch vehicles may be utilized directly as space based infrastructure for planetary habitation and space tourism, making the surface of the moon instantly habitable, and enabling the remediation of orbital debris, and the utilization of materials from small asteroids for habitat shielding and resources. The only outstanding unsolved issue in this scenario is the recovery of the upper and core stage engines after the payload and tankage have been delivered to their intended orbits. Since these highly efficient and expensive, closed cycle, high performance cryogenic engines will be unnecessary for the transport and function of deep space payloads after they have been injected into their transfer orbits, it would be economically and logistically optimal to return them to the launch site as soon as possible after launch.

With this idea in mind, I have investigated and developed a large variety of high energy, fuel abundant transfer orbits, where upper and core stages and their payloads may be simultaneously delivered to the various near Earth space destinations such as the moon, Mars, and all of the lunar and solar Lagrange points. This concept involves geosynchronous transfer orbits, lunar circumnavigation and free Earth returns, and hyperbolic lunar polar flybys for lunar direct polar landings directly onto the poles of the moon. All of these in flight trajectory modifications involve propulsive maneuvers with momentum changes that are considerably less energetic than those required for their initial launching and orbital injections. These kinds of lower energy burns are inappropriate for engines designed for launching, and if performed by the launch vehicle engines would then subsequently disadvantageously relocate them.

Therefore in order to deliver the powerful and expensive engines of these fully reusable launch vehicles back to their launch sites in a timely fashion, while simultaneously maintaining the requirements for the reuse and repurposing of the pressurized and space rated cryogenic tanks for human habitation needs, one must develop a method of separating and decoupling the propulsive sections of the launch vehicles from their tankage and payloads, at a location where the substantial forces of gravity and acceleration of a fully fueled launch vehicle are transferred to the tops of the combustion chambers of their engines. Additionally the load bearing connections from the fuel tanks to the engine thrust structures must also accommodate a substantial heat shield of the appropriate geometry to allow the aerobraking and reentry of the entire 'engine module' through and into the Earth's atmosphere, and all of the engines, fuel tanks and landing struts and legs for its subsequent orbital maneuvering, reentry and ultimate surface landing.

This concept as sketched out here is not a trivial engineering task, but the advantages are clear enough. The immediate application would be the return of upper stage engines from geosynchronous transfer orbits, where much smaller apogee engines can place the upper stage tankage and payload into circular geostationary orbit for large space platform development. Full upper stage reusability has proven to be a particularly challenging problem. This technique essentially solves that problem and simultaneously obsoletes the severe upper stage orbital debris problem as well. For situations where the entire core stage can reach low earth orbit, the development of large space hotels will be possible, while providing a method of rapid engine return directly to the launch site from low Earth orbit. For direct lunar flights, the core stage engines can fly lunar circumnavigations and free returns directly to Earth after translunar injections. For upper stage translunar injections the same scenario applies, only at a much smaller scale. For instance, with delivery of large core stages to the various Lagrange points, a direct launch to lunar injection flight can deliver the stage to lunar circumnavigation, the engine module can return directly to Earth, the core stage can proceed to deep space and the payload can land directly into the lunar surface. These kinds of hybrid combined flights are capable of opening up the entire near Earth space to human development, using preengineered and repurposed launch vehicle hardware, while reusing the engines.

Discussion

In the future the most expensive elements of launch vehicle systems will be main propulsion engines, consisting of high thrust, high Isp, closed cycle, staged combustion engines with regenerative nozzles, not requiring extensive refurbishment between flights. Thus it will be vital to have them returned to the launch site as quickly as possible between flights, in order to maintain the high flight rates that will be required for the now mandatory international, commercial space development and colonization efforts. On the other hand, the large amount of infrastructure that must be thrown into deep space for this effort requires that the launch vehicle tankage itself be used as primary habitation space for space colonists.

For these two conflicting requirements to be reconciled, it will be necessary to create a separate vehicle for the propulsion elements for the launcher, a reusable 'engine module', with all the necessary systems for reentry and landing from geosynchronous transfer orbit and lunar circumnavigation with free return, including heat shields, attitude control, maneuvering and landing thrusters, parachutes and landing legs. Additionally, a method of transferring the enormous loads of fuel, tankage and payloads to the engines must be developed, that does not compromise the structural and mechanical integrity of these systems tightly packed into a unified module, and yet does not add a significant weight burden to the spacecraft.

The sheer volume, mass and cost of the infrastructure needed in deep space to accomplish a reasonable space colonization and development program, without dispersing the incredibly expensive cryogenic propulsion assets far and wide to locations where they cannot be appropriately reused or returned to Earth, clearly indicates that such a system of engine recovery must eventually be developed, and this proposal in my mind is the most logical manner of proceeding. The fact is - that the moon provides an easy and fortuitous deep gravity well for returning, diverting and otherwise deflecting spacecraft back to Earth where they can be easily recovered by aerobraking and reentry, or provided with Oberth effect propulsive maneuvers back into deep space or on to Mars. And the moon also provides a multitude of nearby deep space Lagrange point destinations where deep space solar powered observation points may be operated indefinitely, easily accessible to massive infrastructure deliveries as I have indicated here. The separable engine module described here will eliminate the need for payload development entirely.

The purpose of this NASA Innovative Advanced Concepts (NIAC) research proposal is to investigate and identify credible geometric and structural paths how this challenging concept can be accomplished. The concept of orbital rendezvous with a fuel tanker, a reverse operation of engine module decoupling, enables the transfer of delivered fuel through low thrust fuel settling and then engine module ignition. If NASA wishes to attain the goals that they have set for the nation, in a reasonable amount of time and at reasonable costs without the program killing behavior of destroying, losing or casting adrift engines, then some significant breakthrough must be achieved in the areas of upper and core stage reusability, beyond merely recovering and reusing the primary boosters in an aircraft like fashion, as per SpaceX.

References

Space Colonization
The Space Case – The Case for Space
Lunar Injection, Circumnavigation, Flyby and Gravity Assist Trajectories
Resource Exploration and Exploitation in Near Earth Space, Satellite Salvage, Reservoir Crater Exploration and Asteroid Capture and Derotation, NASA Innovative Advanced Concepts NIAC Solicitation NNH12ZUA002N.
The Lunar Direct Polar Moon Base Concept, NASA Innovative Advanced Concepts NIAC Solicitation NNH13ZUA001N.
Internal Inflatable Pressure Vessels For Pressurized Upper Stage Fuel Tanks, NASA Innovative Advanced Concepts NIAC Solicitation NNH14ZOA001N-14NIAC.
Commercial Space Stations, NASA RFI Solicitation NNHXXZCJ001L, Evolving ISS into a LEO Commercial Market.
Asteroid Redirect Mission – The Archimedes Group, NASA Broad Agency Announcement NNH14ZCQ002K.

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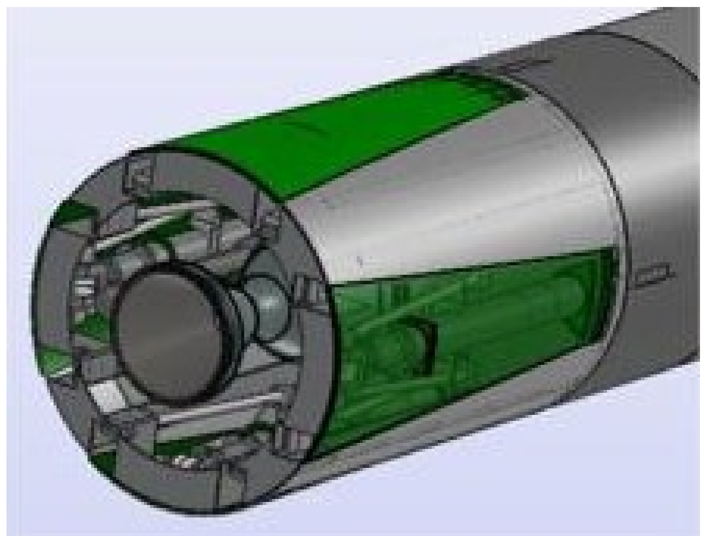
Concept

- Stage Zero Reusable Launch Vehicle Engine Module
- Pressurized Cryogenic Stages as Space Infrastructure
- Core and Upper Stages as Basic Spaceflight Payload
- Internal Inflatable Habitats and Oxygen Storage Tank
- A Preengineered Total Human Spaceflight Solution
- Separable Engine Module
- Thrust Load Transmission
- Heat Shield Integration
- Fuel Line Decoupling
- Maneuvering Capability
- Rendezvous and Coupling
- Aerobraking and Landings

Benefits

- Space Colonization
- Space Tourism Hotels
- Lunar (Polar) Habitats
- Planetary Surface Habs
- Geostationary Communications Platform Delivery
- Allows Near Term Recovery of Cryogenic Engines
- Enables High Flight Rate Fast Engine Turnarounds
- Increases Payload Fraction of Reusable Launchers
- Closes Upper Stage Reusability Problem
- Eliminates Upper Stage Orbital Debris
- Reverses to Fuel Tanker Rendezvous



Study Approach

- Basic System Design Requirements Definitions
- Geometric Vehicle Loads Path Structural Analyses
- Heat Shield, Aerobraking and Reentry Orientation
- Similarity Analyses with Cross Fed Main Boosters
- Sanity Checks for Integration and Recovery Ops

Landing Engine Integration
Parachutes vs. Landing Legs
Water vs. Land Recovery
Passive vs. Active Landings
Orbital Phase Space Analyses
Proposed Mission Simulations
Comparison with Falcon Heavy

Evaluation Notes