Delta 9 Reusable Launch Vehicle
Blue Origin, Boeing and USAF Collaboration

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Department of the Air Force
Air Force Space Command (AFSPC)
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Requirements

Must provide propulsion required to lift EELV class NSS missions and support the development of launch systems that are competitive on the international commercial market.

Thrust and Isp suitable for launch integration compatibility with the booster stage of existing or potential future launch vehicles that can support NSS and Civil spacelift missions.

US designed, developed, and produced.

Designed for affordability throughout lifecycle.

US Government data rights or unlimited US manufacturing rights.

Eliminate strategic dependency on foreign materials and manufacturing.

Leverage existing test facilities and infrastructure to the maximum extent possible.

Compatible with vehicle design reliability of 0.98 at a 50% confidence level.

Technical

Describe your launch architecture and booster propulsion specifications relevant to this RFI.

What solution would you recommend to replace the capability currently provided by the RD-180 powered Atlas V family of launch vehicles?

Acquisition

What are your recommendations to the USG regarding developing a new booster propulsion system, in particular, business arrangements relating to propulsion system procurement and vehicle integration?

Environmental

What would you recommend to mitigate potential environmental impacts associated with your propulsion system?

Statement

Recent spectacular successes in the launch vehicle and space transportation industry by Elon Musk and SpaceX have revolutionized the way this industry operates by introducing reusability into the boosters. Commensurate with this industrial revolution has been the concurrent disruption of its participants and their approaches to the design of their products and the operation of their industries, which previously included the complete destruction of the vehicle after every launch, and the subsequent manufacturing of an entirely new vehicle for every mission. This legacy industry has been reluctant to proceed into new reusable launch vehicle designs for reasons that are mysterious even to this USAF RFI responder. The purpose of this essay is to outline a simple new reusable launch vehicle design, where competition may be introduced into this new reusable launch vehicle (RLV) industry - quickly and cost effectively.

The secret of Elon Musk's success in the field of reusable rocketry lies in the fortuitous clustering of smaller 100 klb thrust class engines into a 3 by 3 array of nine engines. This was a result of his need to boost the thrust of his Falcon 5 launch vehicle design upwards into EELV class 1 Mlb thrust vehicles. When it came time to consider booster reusability, it became clear that the center engine of this cluster would have to function as the landing engine. In order to provide the nozzle bell of this engine more room to articulate, a simple geometric transformation of a 3 by 3 linear array into a circular octagonal configuration presented itself, which provided several immediate engineering benefits to the vehicle. This was accomplished by bumping in the four corner engines, or alternatively, bumping out the four side engines, or both, ever so slightly, giving the center landing engine maneuvering room it needed.

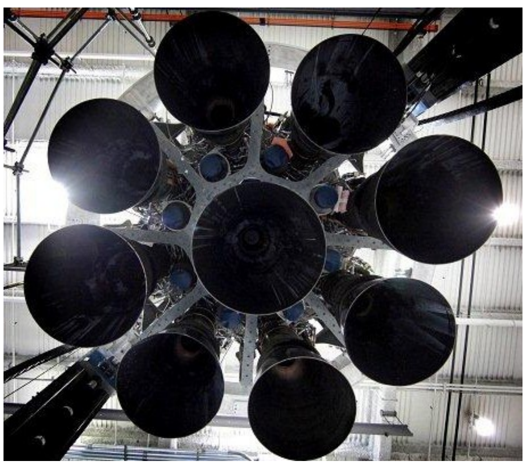
This simple geometric transformation, the 'Elon' transformation, is universal. Its advantage over the close packed hexagonal cluster (seven engines) is that it provides universal four fold lateral symmetry, as opposed to three fold lateral symmetry, simplifying the flight control algorithms by orthogonalizing the engines. It places the outer engines closer to the edge of the vehicle, which evenly distributes the thrusting forces to the place that they are needed the most, the edge and walls of the tankage cylinder. And of course it provides ample thrust vector clearance for critical maneuvering of the landing engine.

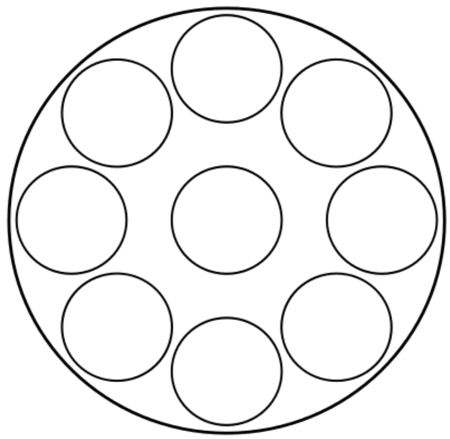
Given this new paradigm of reusable launch vehicles using circular clusters of smaller engines, along with a center landing engine, clearly any new large engine development program would be ill advised, unless the intent was to build extremely large reusable heavy lift launch vehicles for space colonization.

Therefore, it is my intent with this RFI to bring this alternative suggestion to your immediate attention.

The Boeing Corporation, as a large airframe designer, manufacturer and integrator, does not build engines for their aircraft, rather, they purchase them from outside manufacturers for their own use. Indeed, they do not even operate the aircraft that they build, rather, they sell them to outside operators. Given that the SpaceX Falcon 9R already represents an adequate replacement vehicle for the Atlas V, and the Delta IV and Delta IV Heavy already represent adequate backup vehicles for the Falcon 9R, the prudent method of proceeding would be to reengine the Delta IV core with a large cluster of smaller hydrogen engines much in the way SpaceX has done with the Falcon. If you can't beat them, join them.

I posit the obvious candidate engine for this purpose would be the Blue Origin BE-3 hydrogen engine. In this manner a competitive alternative reusable launch vehicle could be fielded before the year 2018. In fact, given the larger diameter core required for the low density hydrogen fuel, a suite of four Aerojet solid rocket motors could be added between the landing legs to double the initial thrust of the vehicle. In what follows I will discuss the pros, cons and caveats of this new “Delta 9” reusable launch vehicle.


Falcon 9 Octaweb Photo - SpaceX.


Octaweb Engine Layout Graphic - Wikipedia


BE-3 Engine Photo - Blue Origin

Consider the numerical specifications of a Boeing Delta 9 reusable launch vehicle, reengined with nine Blue Origin BE-3s. The thrust of the BE-3 prototype is 110 klb, making the initial liftoff thrust of the vehicle very nearly 1 Mlb, much greater than the 750 klbs of sea level thrust of the Rocketdyne RS-68. The thrust of an upper stage powered by a single vacuum rated BE-3 would be four times the thrust of a single Rocketdyne RL-10, making it more efficient and effective for any anticipated future missions. Adding four Aerojet solid rocket motors between the landing legs and adjacent the engine interstitials doubles the initial liftoff thrust of the vehicle to 2 Mlbs, thus making the core orbital capable, and thus leaving the upper stage fully fueled for any anticipated future geosynchronous or deep space missions. The deep throttling capabilities of the Blue Origin BE-3 tap off cycle would nearly trivialize landings.

A hydrogen powered Falcon 9 clone such as the Delta 9 would not be without its problems, however. The Delta IV core would certainly need to be completely redesigned and reengineered for more fuel, for leg and SRM attachments, and for a heavier upper stage with greatly increased payload capacities. The deep atmosphere aerodynamic issues related to the increased volume of the low density hydrogen requires the oxygen fuel tanks be placed above the hydrogen, in order to raise the center of gravity up to the center of pressure of the vehicle, which could be problematic for the use of common bulkheads. On the other hand, given the increased masses and volumes of the payloads and upper stage, it may be possible to compensate for this effect enough so the order of fuel and oxidizer tanks could be reversed.

The major problem confronting the hydrogen powered Delta 9 reusable launch vehicle is related to the increased efficiency and Isp of the hydrogen fuel, which renders the reentering booster stage as 'hot'. This would certainly necessitate downrange landing sites - either a barge or other floating sea platform, strategically located islands, for which there are many viable candidates on the east coast, and at least one viable candidate on the west coast (San Nicolas Naval Facility), to another continent entirely, or even low Earth orbit, if the vehicle performance parameters permit that. The most reasonable solution would be to advance the technology enough so flight rules could be developed for land overflights, or change ITAR regulations of the commercial space flight industry to accommodate international flights.

Long downrange hot hydrogen boosters will also require innovative means to bleed off speed in order to reduce the aerodynamic and thermodynamic loads on the airframe, an area where Blue Origin is also actively working. This would involve a combination of techniques and effects, including reentry heat protection, deployable and movable grid fins and wings, reentry burns or thrust idling and landing legs. It would also encompass the increased insulation required for deeply cryogenic fuels and the associated increased thermodynamic stresses, metal fatigue and embrittlement effects known to be a problem with hydrogen. These are areas where increased funding from the Air Force would be extremely beneficial, but are not regarded as necessary if the goal is simply to speed up alternative reusable launch vehicle development, and to introduce new competition into the emerging commercial space flight industries.

Conclusion

The Delta 9 reusable launch vehicle concept consists essentially of a Falcon 9R clone, implemented in hydrogen fuel, using the recently developed and tested Blue Origin BE-3 tap off gas generator engines. With possible multiple (4) Aerojet SRM booster assistance, the deep throttling capabilities of the BE-3 engine permits innovations such as deep throttle backs during boost, for core stage to orbit capabilities.

The intent of such a program is to produce separate propulsion, airframe and operations sectors for the emerging commercial space flight industry in the same way our current airline industries are structured. This specific vehicle is designed in such a way as to motivate our legacy aerospace companies to begin participating substantively and competitively in this new commercial spaceflight industry, within their respective market niches and areas of expertise, while driving the industry forward with substantial Air Force funding, in much the same way that NASA has done with the COTS program, but focused more on specific Department of Defense space launch needs, with near term operational time frames (2018). The most obvious existing tank suitable for modification into the required launch vehicle would be the Boeing Delta IV Medium, but alternative airframe providers and technologies would not be ruled out.

Reference

The Delta V Reusable Space Launch System

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