Design Philosophy of Biofueled Hybrid Engine Launch Vehicles

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Summary

bluShift has spent a considerable amount of time researching the needs and desires of the sub-orbital space community and shaping our designs and engineering philosophy around what we learned. We intend for our debut sub-orbital vehicle, *Starless Rogue* to offer new and exciting capabilities tailored specifically to the academic research community. The following summarizes the engineering philosophy that bluShift developed while designing a sub-orbital launch vehicle which is powered by a hybrid-rocket-engine.

Design Requirements and Customer Needs

After interviewing potential stakeholders, bluShift identified the priorities for a sub-orbital launch vehicle: maximize zero-g time (>6 minutes); reduce acceleration (under 5 g, minimal spin); maximize payload diameter (60 cm or more); provide access to the space environment (pressure equalization, optical and RF transparency); reduced recovery time (researchers can retrieve their payload quickly after landing); and provide regular bite-sized launches (to minimize launch disruptions and give customers more influence on mission parameters).

bluShift's Design Philosophy

bluShift has followed these guiding principles during *Starless Rogue's* development: 1) Focus on finding the optimal parameters based on fundamental principles rather than on exotic materials and processes to force a solution. 2) Consider the natural advantages and disadvantages of the IP at our disposal and work within those strengths, 3) futureproof our design as much as possible, and 4) focus on the minimum viable product (MVP).

Engineering Strategy and Challenges

bluShift adopted a hybrid propulsion system (liquid oxidizer with a solid fuel) after founder Sascha Deri discovered a fuel with important sustainability implications. The design framework of *Starless Rogue* is centered around this discovery and provides a foundation for the design strategy. Here are some examples of conflicting design requirements when working with hybrid rockets: 1) Hybrids have nearly the performance potential of liquid rocket motors, with roughly half the complexity, which reduces weight. 2) Our hybrid uses self-pressurizing oxidizer—no pump equals simplicity and weight savings. However, the entire oxidizer tank gets heavier with increasing operating pressures, this results in a lower optimal operating pressure to minimizes vehicle weight, counter to the temptation to increase engine pressure to improve motor performance (ISP). 3) The fuel in a hybrid rocket is in the combustion chamber, rather than stored in a low-pressure tank. To minimize the weight of the large combustion chamber, hybrid rockets usually have an optimal operating pressure lower than liquid fuel rockets. 4) If the oxidizer is pumped, a fuel/oxidizer combination that has a high oxidizer-to-fuel ratio may be beneficial because a smaller portion of the total propellant must be stored as fuel in the pressurized combustion chamber. 5) Scaling hybrid rocket engines is difficult, so bluShift chose to design and use a rocket engine than can be easily clustered and staged to form a orbital vehicle, this sets a minimum motor size. 6) Solid hybrid fuels typically burn from the inside out as a tubular shape. How fast a fuel burns, along with how long it needs to burn, sets a minimum vehicle diameter. A small diameter vehicle flies higher with less drag but has a limited burn period, resulting in higher payload acceleration. A balance between these three conflicting effects must be found and is governed largely by the burn characteristics of the specific fuel.

Flight Performance and Results for Customer

bluShift considered all the factors in a hybrid propellant vehicle rather than falling into false optima (like maximizing pressure to boost performance without considering weight penalties). bluShift was able to design a launch vehicle that will provide services to sub-orbital customers while using bluShift's green bio-derived hybrid rocket fuel. *Starless Rogue* will provide 6 minutes of 0-g time; a maximum acceleration of 5 g's; and a 61 cm diameter payload bay with up to 50 kg capacity. bluShift plans regular launches from our own site in Maine.