Undergraduate Thesis Prospectus

Designing a Rocket Motor for use in a Flight Vehicle

(technical research project in Aerospace Engineering)

Flying to the Future: The Increasing Amount of Spaceflight and Relation to Private Development

(sociotechnical research project)

by

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October 28, 2023

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Research Problem

How can human spaceflight be expanded?

People have always been curious and exploratory, which is how humans became a widespread species. Oftentimes the goal is for more resources and space. Humanity is facing a new frontier that has only been a distant dream before, exploring and colonizing the solar system. There are many advantages to using space as a tool, but the foremost is to protect the planet from looming resource disasters, such as climate change (United Nations, 2019). Spaceflight has been a bastion in researching sustainability, and using these techniques can aid us. In the long term, moving our procurement and production of goods and energy off earth, we can preserve the earth, as well as protect it from any cosmic threats (Andrews, 2019).

Designing and Manufacturing a Solid Rocket Motor for a Flight Vehicle

How to develop and build a solid rocket motor for use in a flight vehicle?

This is a Capstone project in the Mechanical and Aerospace Engineering Department. The Technical Advisor is Haibo Dong, the entire project team is 30 people, and the Motor Design sub team is me, Jack Vietmeyer, and Noah Hassett.

This project is based on the constraints of the *Spaceport America* competition that have been modified to suit a glider payload (ESRA, 2023). Gaining experience in designing and building real systems is essential to becoming an engineer, and future classes could compete for the *Spaceport America Cup* as a class. This project has all aspects of Aerospace engineering, including Aerodynamics, Control systems, Structural design, Materials science, and Thermal Analysis.

The goal of this project is to design a rocket motor using solid propellant to launch a flight vehicle of 20kg to an altitude of 5000ft(1524m). The flight vehicle will then deploy a payload that will measure atmospheric data. This flight vehicle design could also be used to launch other payloads in the future. This project has hazardous materials, and the components are exposed to extreme conditions, so caution in both manufacture and design is critical for both success and personal safety. Extensive design considerations and simulations must be used for the structure, aerodynamics, thermal properties, propulsive properties, and dynamic trajectories. The pieces must be manufactured with precision, and each component tested individually as well as in a system. A small prototype will be made to determine the properties and run tests, before producing the full version which will be tested before use. If successful, the motor will deliver the rocket to the design altitude on a predictable trajectory. This will prove that the processes and methods used to produce the rocket are of high quality, and the efficiency and types of rockets can be expanded upon this work in future classes.

Flying to the Future: How Private Providers Have Impacted Spaceflight

Since 2011, how have private-sector companies competed to build confidence in spaceflight as a profitable domain of business enterprise?

Previously spaceflight has been seen as either as a costly option for niche uses, or as a scientific endeavor. Now spaceflight options are more plentiful, economic, and diverse (Mathieu & Roser, 2022). The shrinking costs allow for new opportunities and alter how space is utilized. Newfound private interest marks the transition of human spaceflight as pure exploration, to utilization as a resource. According to National Aeronautics and Space Administration (NASA) timelines, people on the moon and begin work on a lunar base as soon as 2024 (NASA, 2020), and SpaceX claims to be able to land on Mars soon (SpaceX, 2023b). With the innovation private business can bring, it is important to understand the development and competition to ensure that spaceflight maintains a high degree of safety and sustainability. Understanding how private investment and techniques have changed spaceflight since the decommissioning of the Space Shuttle in 2011 is crucial to ensuring a prosperous future.

There is a plethora of papers related to the risks and opportunities of private human spaceflight with four main categories, economic effect, regulation, human health and safety, and responsible use. Frischauf et al., (2018) discusses the economic effects of the emerging private spaceflight industry, and how Germany will fit into this new market. This article focuses on economic opportunities and market growth while making predictions on how Europe may fit into this picture. Kim (2018) discusses the potential for the industry to experience a bubble effect as many tech industries. The paper cites the high amount of investment from angel investors and venture capital, the lack of regulation, and the unclear business models as factors to a potential bubble. von der Dunk (2011) discusses the legal aspects of regulation, and potential models from previous law with regards to tourism. New laws may include those of traffic, corporate liability, and private competition. The medical effects are viewed by Griko et al., (2022), as there are many risks associated with spaceflight for even short durations, new methods will be needed to mitigate the risks of low gravity and radiation. Behrens & Lal (2019) discuss the factors that affect the small satellite ecosystem, and the importance of keeping Low Earth Orbit (LEO) clean to maintain access to space.

Modern participants in the space industry can be grouped into four categories. First are the regulatory bodies, including NASA, the Department of Defense (DoD), and the FAA. NASA's stated mission is "Exploring the secrets of the universe for the benefit of all" (NASA, 2023). This effectively means ensuring the success and safety of American spaceflight, and NASA is in the unique position of being a regulatory body, launch provider, and consumer. NASA has extensive experience in regulation and launches and is shifting to regulation as the private sector expands. The DoD today is primarily a customer of launch vehicles, but they also work with the Department of State (DoS) to regulate the kinds of technology that is launched and made public to comply with International Traffic in Arms Regulations (ITAR). The FAA's stated mission is "to provide the safest, most efficient aerospace system in the world.", which here means the handling of in atmosphere traffic, as NASA performs the structural and launch safety. Large amounts of area must be cleared for space launches to occur, which can disrupt flights. This problem will only grow in the future and new ways to deal with launches will be necessary.

The second are the traditional launch providers, normally associated with other military technologies and are generally large companies that have other services. The main group of traditional American launch providers are Boeing and Lockheed Martin, which have a joint venture named the United Launch Alliance (ULA) (ULA, 2023). ULA produced the Delta and Atlas series rockets, which were the dominant service provider over a decade for many DoD launches until SpaceX won a GPS contract in 2016 (Klotz, 2016). ULA focuses mostly on DoD services, but they are also developing human spaceflight systems with the Orion crew capsule and the Space Launch System (SLS) (Lockheed Martin, 2023; Boeing, 2023). ULA uses mostly government contracts for revenue, so the development pace is long, and historically prone to delays as seen in the numerous occurrences with SLS and Vulcan (Davis 2017; Howell, 2023).

Next, is the private companies that only focus on spaceflight and make most of their revenue from commercial flights, including SpaceX, Blue Origin, Rocket Lab, and more. The largest is SpaceX, which provides the highest number of launches with the lowest kg to orbit cost

(Zandt & Richter, 2023; Mathieu & Roser, 2022). SpaceX (2023a) claims a mission of “Making Humanity Multiplanetary”. As a private company its goals must align with generating profit. It does this through reusability of rockets, reducing costs, and providing other services such as satellite internet called Starlink (Starlink, 2023). SpaceX is one of the few private companies to compete for both government contracts and private launches. SpaceX also has a radically different design cycle from traditional companies, focusing on fast development and testing known as rapid prototyping, which can have potential benefits in the efficiency (Jones & Richey, 2000). Blue Origin only provides space tourism now, but they plan to expand into heavy lift flight with New Glenn, as well as provide engines to ULA with the BE-4. They also won a lunar lander contract for Artemis, which will expand the providers for human spaceflight to the moon (Blue Origin, 2023). Most other launch providers, such as Rocket Lab, are small satellite launch service providers focusing on specialized missions instead of the high value missions of other companies.

The final group of participants is the private consumers of launch services. The number of consumers is rising quickly, and each consumer has specific goals and needs. There are forces that all consumers want, lower prices, more capability, and more flexibility. The current use cases for launches include communication networks, GPS, astronomy, imaging, and tourism but the near future applications could include private space stations, low G manufacturing, asteroid mining, power generation, and more. The market for the space industry could jump to $1 trillion by 2030, creating potential for many types of consumers (Brukardt et al., 2022). The lowering cost to orbit also makes space stations and bases far more feasible, which could potentially develop their own kinds of economies.

In conclusion, the goal of this sociotechnical research paper will be to study how the space industry has gotten to where it is today since the lull in American spaceflight after 2011, and how these circumstances may affect the decision making of the industry in the future. Many parallels can be drawn to other times in history when a new technology or a new frontier has drastically changed the state of the world and the behavior of people, from discovering the Americas, the invention of the car, and the .com bubble. There is also extensive previous research to draw from in a variety of fields that can be used to study previous predictions and predictions of the future. Spaceflight is transitioning from the government sector to the private sector, and using the existing history of how these participants have come to their positions and how they plan to continue in the future can help prevent the same pitfalls that humanity has fallen into time and again, as where great opportunity lies, great responsibility is needed.

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