Project ATLAS – Hybrid Rocket Motor
(technical research project in Mechanical and Aerospace Engineering)

The Effect of Interplay of Structures of Power on Effort Outcomes in Aerospace and their Impact on Society
(STS research project)

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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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Introduction

Humans' longing for flying is almost as old as time, since the 9th century BC when the Greek myth of Daedalus and his son Icarus was shaped. In the 15th century, Leonardo da Vinci came up with the concept of ornithopters whose wings flap up and down by mechanical means, primarily powered by human body movement. Breaking the unsuccessful line of thought of dynamic wings, the idea of fixed wing aircraft was first recorded by George Cayley in 1799 (Anderson, 2016). It was 1903 when the Wright brothers finally performed powered flight for the first time in history, after the tireless efforts of some great minds that came before. More recently, the subject of aerospace propulsion has seen tremendous development through (i) the two World Wars and the Cold War, (ii) pursuit of space as a commercial zone, and (iii) the drive for sustainable aviation. Focusing on these three recent instances, (i) – (iii), for the science and technology studies (STS) research project, the following research question will be investigated: "how do different interplays of structures of power affect the effort outcomes in the field of aerospace and their impact on society?" The investigation will be carried out through the STS analysis frames of Built Environment and Intersecting Structures of Power. In the technical research project, named Project ATLAS, it is sought to advance hybrid motor technology by designing and constructing a laboratory-scale hybrid rocket motor. The motivation behind this goal is rooted in (ii) pursuit of space as a commercial zone. With the recent years' increasing demand for satellite-based missions, the need for apogee kick motors have grown for the last-mile maneuver to place the satellite in the intended orbit. Hybrid motors are advantageous in this case for their throttle-ability while being lighter than the liquid counterpart. Here, as an impact of (ii), commercialization of academia, specifically in the subject of aerospace engineering, is exemplified.

Technical Research Project

Problem and Significance

Hybrid rocket motor technology offers a range of benefits compared to its solid and liquid counterparts. A hybrid rocket motor usually consists of solid fuel and liquid oxidizer, and with minimizing the plumbing line required, it combines the safety as well as the throttle-ability of liquid engines and the simplicity in design of solid motors (Sutton and Biblarz, 2017). Hybrid motors come short in that their performance characteristics are not consistent throughout the duration of their firing time, making their combustion process difficult to model and predict. Additionally, existing hybrid motor technology is only useful at small scales. As the primary users of this technology, there is an impetus for student rocketry teams and small launch providers such as HyImpulse and Firehawk Aerospace (Perez et al., 2022) to develop means to better characterize the performance of hybrid motors, improve their efficiency, and even investigate methods for constructing them at large scale. If a small hybrid motor can be optimized for predictability and demonstrate performance on par with that of liquid engines, larger corporate entities will be more likely to invest resources in scaling this technology for use in their more massive launch vehicles.

Objectives

Aerospace Capstone Team 3 therefore seeks to advance hybrid rocket motor technology through Project ATLAS. The objective is to design and construct a laboratory-scale hybrid rocket motor which will serve as a testbed for several potential performance-enhancing components, which if verified to increase efficiency, consistency, and predictability, could be used in future rocket motors ranging in scale. Specifically, the team intends to

1. Design a series of injector / fuel grain pairs to optimize O/F ratio and test them under operational loads similar to those typically found in much larger motors (Perez et al., 2022),
2. Design ATLAS as a scaled-down demonstration of a full-size motor to function as a proof-of-concept for future, larger rocket projects at the University of Virginia (UVA), and
3. Work with UVA faculty and test site officials to develop robust safety procedures for motor operation and pass these on to the future UVA student teams.

Approach and Methodology

In order to create a hybrid motor as a stable testbed for highly repeatable experiments, the motor will be designed from readily available materials and commercial-off-the-shelf components with safety, reliability, and cost driving the selections. As a prototype, the motor will be built at a very small scale to reduce cost, complexity, and risk. The motor will be mounted on a fixed test stand for static ground-fire tests. The stand will also serve as a convenient mounting platform for any electronics and plumbing required to control and fuel the rocket. As an additional safety measure, an electronic system that allows remote control of the propellant valves and ignition system will be designed. Operators will be able to start or halt the ignition sequence at any time from a remote location.

Experimental data will be gathered with a constructed data acquisition (DAQ) system for the verification of the functionality of the design tested. DAQ system will consist of several pressure, temperature, and load sensors, as well as a camera that feed data into a DAQ hub. The hub will feed the data to an operator's computer remotely, allowing for both the recording and real-time monitoring of test data. The sensors will be placed strategically on the test stand and within the motor itself to gather relevant, low-noise data at points of interest.

Two areas of improvement over traditional hybrid motor designs will be explored. Cost reduction from manufacturing complex, high-performance oxidizer injectors will be sought by 3D-printing one out of high-temperature plastic resin. The resin injector is expected to endure the thermal loads produced during combustion. To allow greater flexibility in design, the fuel grains will also be 3D-printed from ABS plastic. The faster speed at which these injectors and fuel grains can be produced will allow the team to experiment with several designs, and each pair of an injector and a compatible fuel grain will be tested under operational loads. Fig. 1 shows the section view of a conceptual design for the ATLAS hybrid rocket motor.

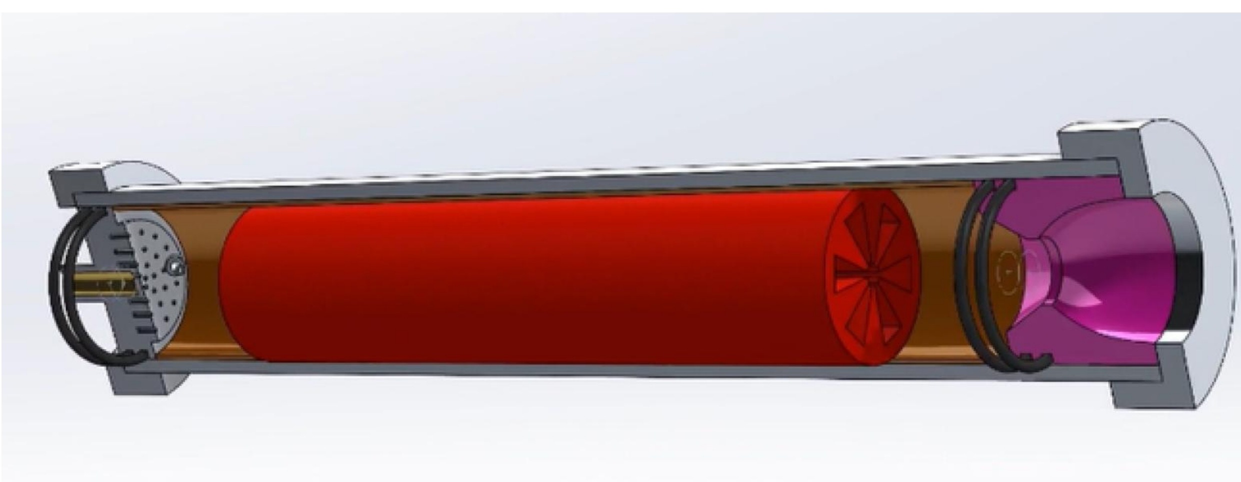

Fig. 1. Section view of a conceptual design for the ATLAS hybrid rocket motor.

STS Research Project

STS Analysis Frame and Research Methods

In *Making Technology Masculine*, Oldenziel analyzes the erasure of women and immigrants in the field of engineering through the STS analysis frame of Structures of Power. She focuses her discussion on higher education, professional organizations, and media as main structures of power and how each entity contributes toward the erasure of minority groups in engineering (Oldenziel, 1999). For the investigation of the research question "how do different interplays of structures of power affect the effort outcome in the field of aerospace and their impact on society?," the same STS analysis frame of Structures of Power will be mainly employed, and the analysis will be shaped by how each structure of power leads in building an environment in which the impact of the effort outcome is evaluated. In this latter part of the analysis, the STS analysis frame of Built Environment will also be in play. Throughout the investigation, the influence of one structure of power over the others will be studied through qualitative assessment or comparison of quantifiable parameters such as government spending or workforce where applicable.

Background, Problem Establishment, and Research Outcome

A little before the first successful human, powered flight by the Wright brothers in December 1903, Samuel Pierpont Langley demonstrated free (non-human) flight over 3/4 miles powered by a steam engine in 1896. Shortly after in 1898, "motivated by the Spanish-American War, the War Department, with the personal backing of President McKinley himself, invited Langley to build a machine for passengers" (Anderson, 2016). The invitation was sent with a fund of $50,000 (equivalent to approximately $1.8 million today). This is arguably one of the earliest instances where a government organization funded a research and development (R&D) effort in a meritocratic manner. Despite the investment, Langley was never successful in carrying out human, powered flight. In October and early December 1903, he made two attempts where his aircraft was launched from a boat on a river only to slide into the water, both times. The failure was not perceived well that the War Department cut the fund stating, "we are still far from the ultimate goal (of human flight)," and the press reported the failure with derision, which discouraged the public from human flight (Angelucci, 1973). Langley, who had not received formal education beyond high school but was merely fueled by his childhood interest in astronomy, retired from the aeronautical scene in this ridicule. In this example, the government, media, and the public as three different structures of power influenced Langley's motivation and efforts; the government was in pursuit of technological advantage that they awarded Langley with a fund. The media added a negative opinion in their reporting of the fact of failed demonstrations that then forged the public's impression on Langley himself. This led the government to cut the fund. One can see that this exchange between the structures of power built a societal environment that discouraged human flight.

By the end of World War II (WW2), American officials and others oversea shared a view on aerospace as the critical field for the nation's superiority over other powers. Namely, the United States (US) and the Union of Soviet Socialist Republics (USSR) competed over defeated Germany's booty in the form of technical facilities, equipment, and personnel in the field of aerospace, established on the beliefs that:

(1) "These [aerospace] technologies would be decisive in future warfare," and

(2) “Along with nuclear energy, they were prime symbols of a nation state’s technological and scientific prowess and, thus, of its power in international relations” (Neufeld, 2012).

WW2, where the government and the military were the primary power holders, was crucial in building this environment established upon these beliefs among the political powers. Under this environment, the launch of Sputnik, the first artificial satellite to be placed into the Earth’s orbit by the USSR in 1957, was initially perceived with very different reactions by three different structures of power within the US: scientists, government officials, and the public. Scientists were elated by the news; Detlev W. Bronk, president of the U.S. National Academy of Sciences, wrote a letter to the head of the Soviet Academy of Sciences congratulating them for their “brilliant contribution to the furtherance of science.” The public, on the other hand, rather reacted with regret that “man’s greatest technological triumph since the atomic bomb” had been scored by “the controlled scientists of a despotic state” (Divine, 1993). The sense of common danger existed in the Senate; Senator Stuart Symington wrote that Sputnik was “proof of growing Community superiority in the all-important missile field.” In this instance, the launch of Sputnik by the USSR under the environment where aerospace was viewed as the indication of a nation’s prowess triggered a sense of defeat among the public, which was reflected in the government’s fret, which together pushed the scientists to overcome the USSR. In response, the National Aeronautics and Space Administration (NASA) was created the following year. In May 1961, President John F. Kennedy announced that the US would land a man on the moon before the end of the decade. All told, the US spent about $30 billion on the space race until the moon landing in 1969 (Domitrovic and Broadwater, n.d.).

Notwithstanding the similar structures of power involved, Langley failed while the space race saw victory. As such, it can be conjectured that the different outcomes are attributed to the different interplays of the structures of power, and hence, as an outcome of the STS research project, an ideal intersection of different structures of power for the most desired outcome could be established. Additionally, in the context of the technical project, the STS research project will be able to investigate the driving force of the commercialization of academia, and there lies the significance of the proposed STS research project.

Conclusion

The technical project aims to design, manufacture, and hot fire the ATLAS hybrid rocket motor. The STS research project aims to investigate the effect of different interplays of structures of power on the effort outcomes in the field of aerospace and their impact on society. The STS research project can enhance the technical project by elucidating the context in which what aerospace engineering students today study stands, and how that context is structured. Potential findings include that the development in hybrid motor technology is sought after by the commercial players in the space industry, and this context consists of government initiatives like the On-orbit Servicing, Assembly, and Manufacturing (OSAM) by NASA and the United States Space Force, higher education (UVA), and economy. Additionally, potential impacts of this study include the establishment of ideal intersection of different structures of power for the most desirable outcome. The study can then lead to further, ethical discussion on whether there is a good or bad motivation for certain technological development, which is applicable to a wider range of subjects.

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