Student Researched and Developed High Power Rocket

(Technical Topic)

Commercialization and the Future of Spaceflight

(STS Topic)

A Thesis Project Prospectus Submitted to the

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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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Technical Topic: Aerodynamics and Structures for Rocket Design

The goal of this technical project is to construct a student researched and designed rocket to carry a payload to a target altitude of 5000 ft. The rocket will undergo two separation events to deploy a drogue chute and a main chute, as well as the payload. Throughout the launch and flight, all components of the rocket need to remain together for easier recovery. In addition, the structures will need to be able to withstand the forces at launch and during flight to ensure that no system failures will occur. The decisions made by the aero structures team have been informed by computer modeling and simulation, and will further be verified through testing once manufacturing begins. This paper will focus on the aerodynamic and structural components of rocket design, particularly the nosecone, body, couplers, and fins.

The nosecone is a key aerodynamic feature of the rocket. Shape and height will be determined based on computational fluid dynamics (CFD) simulations to determine what geometry will result in the lowest drag force. Elliptical and ogive are the nosecone shapes under consideration. The material of the nosecone needs to be lightweight, strong, and heat resistant enough to maintain integrity during launch and flight. As such, carbon fiber has been selected. Additional reinforcements will be made of aluminum.

The body of the rocket is the primary structural feature. It will house the payload, parachutes, and the avionics. The inner diameter of the rocket body will be 6 inches. The length of the body tube will be determined based on the required space of the avionics and controls, the parachutes, and the payload, which is dependent on the mechatronics and controls team. Additionally, the body will need to be able to accommodate the separation events. It will be constructed in three separate sections to do so. The body tube presents an interesting design challenge in regards to material selection. Because the body is housing avionics and communications, it cannot be made of anything that creates interference with signals being sent out or received. This includes carbon fiber and aluminum, which are both commonly used in the aerospace industry for their light weight and strength. To work around this, fiberglass was chosen to create the body, as it does not obstruct signals.

The couplers are another important structural component of the rocket. The challenge for coupler design is to ensure that the rocket stays together during launch and flight, but it also must reliably separate once the separation charge has been detonated. If this fails, the parachutes will not be able to deploy, and the rocket will plummet to the ground. The couplers, like the body, will be made from fiberglass for the same reason. The couplers will be held in place by steel screws on one end and by nylon screws on the other. This is so that when the separation charge goes off, the nylon screws will shear and the coupler will disconnect, allowing for separation and subsequent deployment.

Finally, the fins are the primary aerodynamic component of the rocket. They will ensure stable, predictable flight, which is key for safety. The rocket will have four fins which will allow for easy alignment on the body tube. The fins will be a clipped delta shape with a trapezoidal airfoil. Fin dimensions will be determined through finite element analysis (FEA) and CFD analysis. This is so that the effect of dimensions on things like the center of pressure and on fin flutter can be controlled. This rocket will have interchangeable fins so that future students will be able to test fin designs before construction of the entire vehicle has been completed. The fins will be held in place by aluminum brackets. Two manufacturing techniques have been chosen for the fins. The first design has a honeycomb structure in the center and layers of carbon fiber on the outside. This design will be more difficult to implement, but it will result in lighter fins. The second design is a contingency plan if the first one does not work, and will involve milling the fin shape out of a plate of carbon fiber. This will result in a heavier fin, but the manufacturing process will be much easier.

Next steps for the project include finalizing designs and ordering materials. Once materials arrive, teams will begin manufacturing components. Components will be ground tested before launch to determine if each system works as intended, and if the final product will be fit to launch. The ultimate goal is a successful launch by the end of the year.

STS Research Topic: Continued Prevalence of Expendable Launch Vehicles in Spaceflight

Introduction

The primary purpose of the proposed research paper is to investigate trends in spaceflight to see if expendable launch vehicles (ELVs) will see a decrease in use as interest in reusable launch vehicles (RLVs) grows. Historical precedent exists for both ELVs and RLVs, though ELV use has been far more extensive. Modern rocketry has its roots in the early 20th century. Early concepts for liquid-propellant rockets were developed first by Konstantin Tsiolkovsky in 1903, followed by Robert Goddard in 1919 and Hermann Oberth in 1923. Goddard would eventually go on to build his design in 1926, which earned him a reputation as the founder of modern rocketry. However, it wasn't until World War II that the foundation for crewed or extraplanetary spaceflight was established. World War II saw extensive use of rocket artillery as well as the first guided missile systems, namely the V-2 missile created by German scientist Werner Von Braun. In 1946, after the war had ended, the United States gained access to V-2 missiles which were subsequently used for high-altitude research purposes. These missiles were retrofitted to include second stages, much like the concepts written about by Tsiolkovsky and Goddard earlier in the century. Further improvements in missile technology were made during the Cold War with the development of intercontinental ballistic missiles (ICBMs). Like their predecessor the V-2, ICBMs were also repurposed for rocketry fairly soon after their creation as a result of the Space Race of the 1960s. Missile series such as Titan, Atlas, and Soyuz were used for early spaceflight as ELVs with the use of the Soyuz series continuing into the modern day. Launch systems became increasingly more complex as more effort went into facilitating crewed spaceflight, resulting in multistage rockets such as the Saturn V which was used for the duration of the Apollo missions. The next big step in the development of rocket technology was NASA's Space Shuttle program, which was announced in 1972 (Van Riper, 2004). The Space Shuttles were the first RLVs to be used, and since their retirement, several private companies such as SpaceX have worked on their own RLVs.

Since the retirement of the Space Shuttles and the creation of SpaceX, spaceflight has moved towards commercial solutions. The primary goal of commercial launch vehicles is to make space more accessible, essentially promising to lower the operational cost of launch systems as well as to increase the number of launches per year (Reddy, 2018). Because of this, RLVs might be a more viable and economically feasible option than ELVs. As with any engineering venture, it is important to balance cost, time, and safety appropriately, and the different types of systems may not be conducive to the same balances.

STS Framework

The framework being used for this analysis is the Social Construction of Technology (SCOT) framework. SCOT was introduced as an alternative to the Empirical Programme of Relativism (EPOR) by Wiebe Bijker and Trevor Pinch in 1987. Where EPOR approaches technological development from a fairly linear point of view focusing predominantly on the influence on and by scientists and researchers. SCOT, however, presents what Bijker and Pinch call a “multidirectional model,” where this development can be viewed from a much wider perspective by considering a number of relevant social groups (Bijker, 1987). In addition to these social groups, SCOT explores interpretive flexibility, closure, and stabilization (Humphreys, 2005).

Within the SCOT framework, social groups are defined as people who view or interact with a piece of technology in the same way. In a 2005 article by Lee Humphreys which elaborates on the SCOT framework, four generic social groups are established. The established groups can either directly or indirectly interact with the technology, and can further be categorized as organized or individual. The four groups identified by Humphreys are producers, advocates, users, and bystanders. Producers are organized social groups with direct monetary stakes in the technology. Advocates are organized social groups with indirect or political stakes in the technology. Users are individuals who interact regularly with the technology, therefore creating a personal stake. Bystanders are individuals who do not directly interact with the technology, but whose opinions and values may drive the further development of technology (Humphreys, 2005). These groups influence and are influenced by technology, and their continued interaction determines how technological development proceeds.

Interpretive flexibility, closure, and stabilization are the remaining core aspects of SCOT, and they are closely related to one another. Flexibility is the idea that a specific technology may have different applications depending on the user. Humphreys proves the example of automobiles to demonstrate this–a sports car and a pickup truck have two fundamentally different purposes, but they both fall under the umbrella of automobiles. Closure is the process by which an artifact loses its interpretive flexibility. Using the automobile example, the broad category of automobile has lots of flexibility, but as different types of automobiles are defined, such as sports cars or pickup trucks, the increased specificity reduces the number of different ways to use the vehicles. Finally, stabilization is the process by which a particular design for a technology emerges as the predominant or defining design (Humphreys, 2005).

This framework is relevant to the topic of the future of spaceflight for several reasons. Rocket technology historically has provided a great example of interpretive flexibility and stabilization. Some of the first rockets in regular use were repurposed missiles, and systems derived from missiles coupled with multiple stages became the standard vehicle for spaceflight. Analyzing these processes occurring in the past may provide useful insight into the present and future status of the industry. Additionally, spaceflight is a field in which relevant social groups have significant bearing on technological development. For this analysis, relevant social groups will be identified as follows. Producers are contractors and companies such as Northrop Grumman and SpaceX who create ELVs and RLVs for use. These companies want their systems to be used so that they can continue to get funding for more projects and products. Users include those who wish to access space, whether it's a space agency like NASA, an academic research group, or even the producers themselves. Advocates are governmental entities such as the military or the National Oceanic and Atmospheric Administration (NOAA) who benefit from access to space. In this case, the bystander group is very extensive because of the far reaching effects of what spaceflight has to offer. This includes anyone from people who use satellite services such as satellite radio or GPS to people who use innocuous things such as memory foam pillows, which was a technology invented for spaceflight.

Methodology

For the STS portion of this thesis, I plan to do the following. First, the specific entities within the previously described relevant social groups will be identified, and their motivations and objectives will be explored. This will reveal the underlying social factors that could possibly have an effect on current and future spaceflight technology. Additionally, a review will be conducted of launch systems that are currently in use as well as systems that are still in the development phase. This state of the art review will illuminate emerging technological trends which will provide insight into how much interpretive flexibility there is, as well as whether it appears that stabilization is occurring or if spaceflight is approaching closure.

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