Project Scope

Project Objective

The objective of this project is to develop an improved thrust stand for NASA-MSFC that can take accurate measurements of a 0.1N green propellant thruster.

Project Description

Develop and refine a vertically oriented thrust stand which accurately measures the thrust of a 0.1N class thruster utilizing green propellant. Green propellant is a non-toxic fuel alternative to Hydrazine that NASA is looking to utilize in the long term. The thrust stand created needs to be small enough to fit into a vacuum chamber, where testing on the thruster is done. Because of the nature of a vacuum chamber, the developed thrust stand needs to be able to calibrate itself remotely, so that recorded measurements are accurate. If the design is finished before the final deadline, then the thrust stand will be optimized so it can be scaled to measure forces of a 5N thruster.

Key Goals

Key goals elaborate on the project description by highlighting individual objectives of the design. These goals include accurately measuring 0.1N of thrust, manufacturability by a university, and performing a remote, in-place calibration in a vacuum environment.

Thrust measurement is typically done using a thrust sensor that quantifies a net axial force of an object in movement. Use of a thrust sensor is a sponsor-given requirement and must be utilized in a way to minimize external interference on the reading. In past iterations, various fluid and electrical attachments have added an unknown spring constant (k) which skewed the incoming readings. This skewing must be mitigated and tracked with a known uncertainty. If a spring constant remains, calculation and accountability may be included in onboard computation.

The final iteration of the thrust stand must be repeatable and manufacturable by a university. This is critical for potential continuation of research upon conclusion of the project. The project sponsors have also expressed interest in utilizing university teams to continue production of their final product for their internal use. For this to be feasible, a documentation package should be generated including unique design features, uncertainty measurements, part numbers, drawings, assembly guides, potential modifications, and in-place calibration procedures.

Performing a remote, in-place calibration in a vacuum environment is critical to the core functionality and use of the final product. The testing sequence utilizes a custom vacuum chamber with a 12”L X 18”W X 12”H volume allocated for the thrust stand. Because the field environment is equivalent to the conditions within the vacuum chamber, the system calibration must take place after the system is in vacuum. The user must have a way of triggering this calibration remotely after the chamber is sealed and under vacuum.

Secondary Goals

Secondary goals exemplify aspects of the final product that contribute to end user experience but are not core functionality. These goals include scalability, maneuverability, ease of cleaning, and reasonable visibility of critical functions.

NASA-MSFC would like the design to be scalable. A scalable final design would need to be compatible with both 1N and 5N thrusters, in addition to the 0.1N. This enables additional testing within a thruster range that has extremely limited off-the-shelf testing equipment. The thrust stand should also be capable of being lifted and maneuvered into position reasonably by one person. Past iterations have required two people to comfortably place the stand into position for testing and the project sponsors have requested that this be mitigated if possible. The stand should also avoid using material incompatible with Green Propellant and avoid harsh corners and crevices wherever possible to ease cleaning. Leakage is possible within the rocket apparatus, and ease of cleaning should improve longevity to the stand in case of contact with propellant. Lastly, the vacuum chamber required for testing has limited viewing angles from outside. The thrust stand should allow all critical functions to be seen by the user from outside of the chamber.

Primary Market

For this project, the primary market is comprised of those involved in green propellant research at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama. Researchers at MSFC are looking to improve the accuracy of thrust measurements in the millinewton range to validate testing done on thrusters capable of 0.1N of thrust. Current configurations of thrust sensors are prone to inaccuracies due to the increased significance of external factors when operating on a minimal scale. Their current test setup will also drive the development of this project and the conditions under which the thrust stand will operate. For example, thrusters are tested under vacuum-like conditions, meaning electrical components must be able to withstand low pressures and still function properly. For these reasons, green propellant researchers at MSFC will serve as the primary market as they will have the most firsthand experience with the product Team 517 is looking to produce.

Secondary Markets

Beyond those at MSFC, the thrust stand will potentially impact other parties at a secondary level. Chief among these is other US universities. As stated previously, one of the major goals of this project is to generate a build package for use by other universities to replicate the thrust stand's final design. If other universities have interest in testing thrusters in this regime, this stand may function as an option for their research teams. Similarly, having it manufacturable at a university level will make this option more enticing for their research teams since it is producible in-house.

Another secondary market would be CubeSat developers. CubeSats are modular satellites primarily used for technological demonstrations and science experiments, functioning as a low-cost alternative to traditional satellite development. These satellites are usually much smaller than more conventional ones, meaning thrusters required for corrective maneuvers are also downscaled (NASA, 2017). Green propellant and hydrazine thrusters are both utilized in these applications since both are monopropellants, meaning they do not need a separate oxidizer to function. Green propellant is less toxic, easier to store, and has a higher density when compared to hydrazine (Riley, 2015). For these reasons, the development of a better thrust stand may further the integration of green propellant over hydrazine into these thrusters. So, companies or institutions that produce CubeSats may have a vested interest in Team 517's product.

Other government sectors that currently utilize hydrazine would also qualify as a secondary market. These sectors include the United States Space Force and the Department of Defense. For similar reasons, these government agencies may be interested in the benefits that come from the use of green propellant.

Additionally, private space companies serve as another secondary market. In smaller applications, green propellant can save on hydrazine storage costs and improve safety measures for these companies. So, they would also have a vested interest in the thrust stand as it helps to validate the further use of green propellant thrusters.

On a final note, a few more markets would include those interested in space travel, propellant disposal companies/propellant workers, and university students. This project aims to propel space travel forward in a safer, more sustainable manner. In this way, those interested in space travel may see the thrust stand as a next step in the advancement of space travel. For propellant disposal companies, green propellant may be cheaper than hydrazine to get rid of. For propellant technicians, a less toxic substance would mean a safer work environment. For university students, having the ability to reproduce the thrust stand can grant them engineering experience and exposure to real world thrust testing. For these reasons, secondary markets such as these would have interest in the production of Team 517's thrust stand.

Assumptions

The assumptions act to limit the scope of the project to assure Team 517 stays within the boundaries of their assigned project. For testing, it is assumed that the stand will operate under a vacuum with a minimum pressure of 1e-6 Torr and a normal pressure of 1e-3 Torr. The thruster will be provided by MSFC whose operation will be controlled by their technicians. As of now, Team 517 will not have too many specifics on the thruster due to security reasons at NASA and will only be given thruster dimensions for sizing purposes. Also, green propellant will be fed into the thruster by NASA technicians, but feed lines will have to interface with the thrust stand Team 517 produces. In a similar manner, the thrust stand will not have to endure forces far above the thruster's capability, and all data will be read into LabView. It is also assumed that the thrust stand will be visible from view ports embedded within the testing chamber and fit within the dimensions mentioned in the Key Goals.

It is assumed that the personnel of Team 517 will work together and cooperate to build a test stand that fits within the parameters set by MSFC. Team members will also adhere to any scheduling set by NASA and Senior Design 1, whether that be for travel, deliverables, or other situations that arise. Regarding travel, it is assumed that the team will venture to Huntsville, Alabama once per semester to gauge the testing facility in the fall and perform testing in the spring. It is assumed that when testing eventually takes place, the team will maintain the proper safety precautions posted by MSFC. It is also assumed that the sponsors for this project will remain in contact with Team 517 and provide guidance for the thrust stand as the project continually evolves. Funding for this project will be provided by MSFC and other resources may be provided by them as well upon communication through the proper channels.

On a final note, it is assumed that unforeseen circumstances may occur that will stop either an individual team member or the entire team from completing a task on time or to completion. In projects such as this, things will go wrong, and Team 517 may have to face increased adversity at times.

Stakeholders

The primary stakeholders for this project are Team 517's contacts at NASA-MSFC, Ms. Ebony Bland and Ms. Nicole Vaughn. As the sponsors for this project, Ms. Bland and Ms. Vaughn's interests lie in further validation of their 0.1N thruster and potentially their 5N model. In conjunction, they also serve as mentors in this process, offering insight into how MSFC breaks down their project structure. Meeting weekly, they also provide requirements for the project, updates, and input that will be essential for the completion of this project. Team 517 also serves as primary stakeholders for this project, primarily having an interest in creating a quality product that can be utilized as a future talking point in their careers.

As the senior design professor, Dr. McConomy also has input and investment in the project. As a staple in the Senior Design realm, Dr. McConomy has valuable advice and guidance to offer that will be essential to the design of the product. He also has control over Team 517's project grade. The TAs for Senior Design 1, Jacob Schmitt, Tripp Lappalainen, and Elias Hasse, also have a stake in this project. Primarily, they will control the grades for many of the assignments in this class. As the advisor, Dr. Berger is a closer and more immediate source of help throughout the product design stages. He will be present for monthly meetings to discuss weekly reports, offer advice on pitfalls to avoid, and answer questions that may arise and need input on. Another stakeholder is Dr. Christopher Burnside, Propulsion Engineer at MSFC. Dr. Burnside offers experience and validation to the project due to his interest and expertise in the subject field. Like Nicole and Ebony, he also has interest in validating thrusters to help further the implementation of green propellant.

Conclusion

In conclusion, Team 517 aims to create a thrust stand that can help NASA-MSFC, as well as interested universities, study the capability of the non-toxic recycled green propellant rocket fuel. Measurements of the thrust and axial forces of that are output by the thruster are of specific interest to Team 517's sponsors at NASA-MSFC, and these measurements will be conducted on a 0.1N scale thruster. Working with such a small thruster will require there to be a high amount of accuracy in measurements. The final design will be created with the interests of NASA-MSFC in mind, though a secondary market is also universities that may want to study green propellant. Team 517 is working primarily with Nicole Vaughn and Ebony Bland to design this thrust stand, though other interested parties are Dr. Christopher Burnside, Dr. McConomy, and Dr, Berger, who all have a stake in the project.

References

About CubeSat Launch Initiative - NASA. (2017). NASA. https://www.nasa.gov/news-release/about-cubesat-launch-initiative/

Riley, H. F. (2015). Green Propellants - NASA. *NASA*. https://www.nasa.gov/centers-and-facilities/white-sands/green-propellants/