SPEX Propulsion: Reaction Control System

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***Abstract*—The purpose of this project is to create a reaction control system utilizing cold gas propulsion. The system will pitch, yaw, and roll in an attempt to keep itself oriented in a specific direction. This is an natural extension on cold gas propulsion as a very common purpose of cold gas propulsion is to provide attitude adjustments for satellites or rocket boosters, such as the Falcon 9. This project will give the SPEX propulsion team insight and experience making a system that has plenty of documentation and industrial usage.**

Nomenclature

CD	Converging-Diverging
PDD	Project Design Document
RCS	Reaction Control System
RIT	Rochester Institute of Technology
SPEX	RIT Space Exploration

I. Introduction

The reaction control system is an extension on our previous project of making a cold gas thruster. We were able to achieve optimal expansion and at least one pound of thrust force. Using cold gas propulsion as an attitude control system , another name for a reaction control system, is very common (if not the most common). Since cold gas thrusters inherently rely mostly on pure momentum exhange, with assistance of a supersonic CD nozzle, they are very appropriate candidates for this type of system. We can utilize the knowledge we have gained from making the cold gas thruster nozzles to make this system. Our method of 3D printing nozzles, with very good results, will allow us to create this RCS with more focus on the structure mechanics.

II. Primary Objective

The primary objective of this project is to provide a more realistic usage of a cold gas propulsion system. As stated above, cold gas propulsion's most common and effective usage is attitude adjustments. This is due to the low-thrust and easy mechanics of the system-type. It is an isothermal process and this allows concentration on the supersonic CD nozzle performance as a function of inlet pressure.

Once the RCS is built, testing will provide us with insight into foreseen and unforeseen issues with cold gas propulsion. We will be able to test our CD nozzles in more comprehensive and significant scenario. This RCS can be used on a CubeSat for attitude control. It could allow the employment of spin-stabilization. Spin-stabilization is effective because of the laws of the conservation of angular momentum.

III. Benefit to SPEX

By writing design documents and familiarizing undergraduate and graduate students from any discipline with this type of approach and execution, SPEX members will be better equipped convey their ideas to others in a methodical and organized manner. Ideally, an abundance of ideas and projects encapsulated in PDDs would outlive their respective authors and continue to sustain SPEX with valuable research opportunities invariant of individual members' absences due to co-ops or graduations. Perhaps in the future, SPEX design documents may be used as baselines for grant applications and other funded research efforts.

A. Mindset

Firstly, it gets people in the right mindset for thinking about what is important and what needs to be considered before taking off on a project. Publishing a PDD imbues a sense of formality that hopefully makes its way into the level of seriousness and merit that is desirable for SPEX to pursue.

B. Traceability

Similarly, a PDD serves to provide the foundation for traceability in requirements and objectives to projects as they grow and change. This prevents blockers such as feature creep, rabbit holes, and spun tires, and hopefully prevents good projects from dying by getting too off track.

C. Accessibility

Having a "plug-and-play" template is the first step to learning how to one's own SPP. It removes a major barrier of starting from scratch, providing example content to which one could refer when creating their own. LaTeX may prove to be daunting for some people, but it is arguably better to encourage people to learn LaTeX than to rely on something like Microsoft Word.

IV. Implementation

In the ideal case, every project begins with a design document. That design document gets sent around to SPEX members (and non-members) to draw support and build a team. Research and work takes place, documented along the way until an ending point is reached (e.g. project completion, end of the semester, team attrition, etc.).

At the end of the project (or end of semester, whichever comes first), the team writes a report of the project with what they did, if it was successful, and recommendations for future projects. A future SPEX member might pick up where the last paper left off, and the cycle repeats.

A. Deliverables

Physical or intellectual property may constitute a project's deliverables. Test articles, test stands, and other hardware, software, as well as posters, presentations or other reports are all valid deliverables. Not all deliverables may be known at the time of writing a PDD, but at least several key deliverables should be identified at the start of a project. This helps guide the final outcome and is a fundamental part of a project's life cycle.

B. Milestones

Deadlines and milestones provide clear goals from which timelines and schedules may be developed, and also set up a project for a series of "sanity checks" along the project's development cycle. Early on, these milestones include design reviews on system and subsystem levels. Later, milestones are usually important tests or experiments. Events such as ImagineRIT may also serve as milestones to mark a project's development progress or completion.

V. Externalities

A. Prerequisite Skills

It is obvious that team members will learn certain skills as a project progresses, but there are always some tasks that require a minimum skill level to provide meaningful contributions to a project's development. These prerequisite skills are best identified by examining past projects and discussing the project with faculty or subject matter experts. It is strongly recommended to be conservative in skill estimation. Underestimate team member skill levels and overestimate the challenge. Many projects have failed because the team overestimated their own abilities or underestimated the difficulty of their project.

B. Funding Requirements

Like prerequisite skills, it is wise to overestimate the cost of components, materials and other resources that a project requires. For physical projects, costs may be estimated by benchmarking the costs of similar systems or determining a representative bill of materials and using the aggregate cost of its items.

C. Faculty Support

Support from university faculty is almost always essential to a project's success. Faculty provide not only guidance and subject matter expertise, but may also connect a team with resources and networking opportunities. SPEX projects do not require faculty support, but it is highly recommended to identify professors with an interest or expertise in a project as early as possible.

D. Long-Term Vision

As SPEX student members get more experience writing these papers, the group will build a library of meaningful work and be able to save it in an organized manner. Knowledge will be preserved and easily shared. Perhaps Project Design Document could eventually get published, in a journal or otherwise…

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