SDL-IREC Competition Payload: SPEXTRO

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***Abstract*—The purpose of this experiment is to prove that understanding protein folding in zero-gravity could be conducted in a CubeSat form factor. This project will attempt to put this concept to work in a CubeSat that will be launched in a sounding rocket to 30,000 feet made by RIT Launch Initiative. Successfully completing this experiment will raise the Technology Readiness Level to which can be adequetly justified for a CubeSat mission to orbit.**

I. Introduction

The project purpose is to create a 3U CubeSat payload which houses a protein spectroscopy experiment and fly on a sounding rocket in the 2020 IREC. The goal of this project is prove that this experiment can accurately detect protein folding after a rocket launch and in harsh ambient conditions. The success of this experiment will be a "proof-of-concept" of the protein spectroscopy experiment conducted in a CubeSat form factor. This project will be launched on a rocket that RIT Launch Initiative will make to go to 30,000 feet. This rocket will be launched during the Intercollegiate Rocket Engineering Competition in 2020 (IREC 2020).

II. Primary Objective

The primary objective of this payload is a proof-of-concept mission aimed at understanding if protein spectroscopy can be performed in a CubeSat form factor. The experiment is a scientific process in which proteins are analyzed to understand if they folded under free-fall conditions. Due to the mechanics of rocket flight, free fall (similar to that of satellite orbit) is impossible to attain. Hence, the mission is focused on fitting this experiment in a 1U section of a larger 3U form factor and proving the experiment can be successfully conducted in such conditions during descent after jetison.

III. Benefit to SPEX

This project is an ordeal, as is rocketry. Launching payloads on rockets requires rigorous work to understand the intense vibrations and physical conditions as well ensuring the payload can survive the launch and function properly afterwards. The engineering is very involved, right down to the heads of the bolts (smallest details). How does everything fit together? Where do the wires go? These are but a few of the questions this team will learn to answer. The last IREC team gained a lot of experience in this area and collected and recorded it in a final document called *SPEX IREC 2018 Final Report* located in the *SPEX Google Drive: Workgroup Archive*. The next team will learn all these lessons intensively and painfully and will inevitably add to this list of lessons learned. While this may sound negative, it is exactly the opposite. Through the head scratching and confusion comes new ideas and engaging, novel, and rewarding experiences. This project would be massively beneficial to the students involved and thereby the rest of SPEX when these students move onto greater things.

IV. Implementation

There are a few important points that must be understood to understand the scope of this project.

This project will be a joint effort with RIT Launch Initiative. They are providing the launch vehicles and we, the payload. We are doing this together to compete in the Intercollegiate Rocket Engineering Competition in 2020. It must be understood that the project schedule will have a dependence on the LI rocketry team schedule. For instance, test fitting with their SABOT with require the mechanical footprint of the structure to be designed and fabricated. To this end, it is worth the time to obtain a working structure manufactured by the end of the Fall semester. This will serve as a initial integration structure. A important lesson learned from Hyperion was there were many integration issues that could have been sorted out far beforehand if there was a test-fit opportunity. This structure will not be the final design but an important stepping stone for the rest of the project. The manufacturing will be worthwhile training for the engineers when it comes time for the manufacturing of the flight structure.

The team leader will be the role of system engineer and lead designer for the project. The lead engineer will take the role of system engineer and lead designer for the structure. The project scientist will be in charge of getting the experiment working. That includes all of the engineerind, data analysis, and other science that must go into the experiment. A team hierarchy is proposed in Figure 1.

A. Deliverables

The final product of this project will be a flight payload with a fully functional and LI independent communications system, recovery system, protein spectroscopy experiment, and parachute ejection system. The communications system will have an APRS and GPS that operate on different frequencies than LI as to not interfer. The GPS and APRS must have sufficient battery life to support extensive time from rocket integration to launch (2 hrs) and then recovery (12 hours).

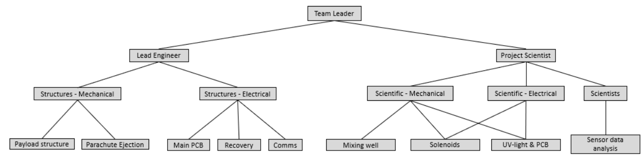

Fig. 1. The team hierarchy is created based upon NASA-led missions. While the structure is not identical it hits the key figures, team leader (principal investigator), lead engineer (system engineer), and project scientist is the same. This structure has been adapted to help the team function well and achieve the goals of the project.

The recovery system will have a buzzer and maybe LEDs, this was discussed but not executed on the 2018 IREC payload. The protein spectroscopy experiment will have the full mixing system with the UV-light and sensor, the data from which will be stored locally and analyzed after recovery. The parachute system will likely include a Peregrine CO2 system, identical to the one used on Hyperion.

B. Milestones

One point that the author must be clear on:

It is my personal opinion that any attempt to achieve perfect free-fall to create the essential experiment upon the limitations of this project is time that could be better spent creating a strong design and achieving a solid scientific result that can serve as "Proof of Concept". This idea will then be green-lit for a future CubeSat proposal and this team could lay the bedrock upon which that CubeSat can be built.

The first goal of this experiment should defining the mission statement and success criterion. This will create a clear path forward for the engineering and science teams. Then the mechanical-science team should strive to create a functional experimental setup. This will be very important due the high complexity. They must first create an initial model with a mixing well, solenoids, protein, and saline. They should first work to attain a good mixing of protein and saline. Then go onto the UV-light and sensor integration and testing. Approach it one step at a time solving the problems with each one, meanwhile the structures team will work on developing an initial manufacturable model.

The initial manufacturable model must be complete by Winter break to stay on a good track. There is enough known information about the sizing of the experiment and other components to make a rough integration scheme. This assembly should favor modularity in the sense that things will change and it should be able to accomodate those changes. An idea would be to create a small structure out of 80/20 (80/20 makes very small structures that will can accomodate the size restrictions). This would allow ease of access and re-positioning. The goal of this model is to fully understand where everything will be placed including the wires. **An important lesson learned from Hyperion was understanding wire layout is essential for integration. There was much work that went into strain relief of tightly packed wires from batteries and limit switches. The limit switches presented a difficult problem in which their wires were protuding normal to the walls of the CubeSat and the extremely close proximity of the Main PCB meant those wires needed to do a 90 deg bend within an extremely tight radius. This could have avoided with properly planning and time for integration studies.**

There will also be two electrical teams, one dedicated to the scientific payload development and the other dedicated to comms, parachute ejection system, and Main PCB design. It is recommended that the Main PCB be designed and ready for fabrication (WITH SPARES!) by the end of January. It will take a month to get all the parts and then a few weeks to get it fully populated. The scientific payload team will work the mechanical engineers to create a functional experiment by the end of the Fall semester (recall: this is not scientifically functional, just mechanical and electrically).

TABLE I
NOTIONAL TIMELINE OF PROJECT MILESTONES.

Phase	Task	Duration
1	Mission Statement & Success criterion	1 week
2	Team leadership assortion	1 week
3	Design and development	6 weeks
4	Initial manufacturing	4 weeks
5	Documentation update	1 week
6	Design iterations	4 weeks
7	Critical Design Review	3 weeks
8	Final design iterations	2 weeks
9	Flight manufacturing	3 weeks
10	Flight integration and full system testing	4 weeks
11	Launch and project review	4 weeks

V. EXTERNALITIES

A. Prerequisite Skills

There are a few positions that will need to be held by experienced engineers/scientists to maintain an appropriate schedule. These positions are; team leader, project scientist, and lead engineer. The team leader should have previous project experience and preferrably system engineering experience, the project scientist should have previous project experience and experience with experimentation in their respective field of study, the lead engineer should have system engineering and past project experience and a strong handle of basic engineering fundamentals in their respective field.

The people working under these personel do not have any knowledge or experience prerequisites. According to their field of study they should be taught the fundamentals early in the project timeline as to not cause schedule slip later on due to lack of experience.

By the end of this project mechanical engineers should have more experience with Computer Aided Design, system fabrication, and system integration. The electrical engineers should have more experience in radio frequency analysis, location tracking (GPS, APRS), and PCB design and fabrication. Scientists (physicists, biologists, .etc) should have a stronger handle on designing and conducting experiments as well as analyzing the data and reporting it in a paper format.

B. Funding Requirements

The Hyperion payload required $3000 to design, fabricate, integrate, and fly the payload. However, since this was the first project SPEX had undertaken of such a magnitude, the budget was used non-optimally (money was spent on items that it did not need to be). Learning from this experience a more accurate budget for the project can be estimated at $2000.

The structure is a 3U CubeSat. Assuming the materials are similar to the previous payload (safe assumption since the design will be off the Hyperion structure), it will cost about $400. However, since this structure may change and require more materials, the price is safely approximated at $600 for the structural engineering side of the project.

The parachute ejection system will likely be the peregrine CO2 cartridge flight-heritage mechanism. This worked well for two separate launches for Hyperion (test launch in May and flight in June 2018). This system costs $180, with additional cartridges this cost will be estimated at $220. We already have a parachute and the material for the canister.

The protein spectroscopy experiment has many 3D-printed mechanical parts which are very inexpensive. The main cost of this experiment will be the battery to run the solenoids, the solenoids, the protein, and the special material for the mixing well. The experiment will be given a budget of $400 to develop the flight-ready assembly. This is on the higher end for cushion in case the material selection takes many different specimens to perfect. This is a complicated matter and was the subject of much research and testing in the Spring of 2019. Since the mixing well requires an unknown ratio of flexibility to strength, it is difficult to deduce the correct material from datasheets. The proteins are bovine and cost $60. The solenoids have not been chosen, but based off testing completed in Spring 2019, they will cost about $30 - $40 each. A battery could cost up to $50, the power requirements for the solenoids are not high but there will be redundency for long wait times.

The electrical systems will be given a budget of $700.

C. Faculty Support

We will require faculty support for funding and recruiting. Dr. Barbosu will be able to help the IREC team reach out to funding organizations to raise money for the project. There should also be opportunities for RIT funding or SEDS funding during the fall semester.

The mechanical engineering department for KGCOE (Kate Gleason College of Engineering) is willing to send out emails to the entire engineering student body for us (probably once a semester). They do this to raise awareness of KGCOE projects that students can join. This will be done for the IREC group to recruit mechanical, electrical, and computer engineers.

D. Long-Term Vision

The long term vision of this project is to enable a CubeSat to carry this payload into space to complete the experiment. This project will prove the experiment can be done in flight conditions. The payload will need to hold together and operate after intense launch vibrations and harsh ambient conditions. It is likely, based of preliminary talks with LI, that they will be launching this payload to 30,000 feet. At this altitude air is sparse and pressure and temperature is low. Conducting the experiment in these conditions is a strong indication this is a feasible experiment.

Acknowledgements

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