CubeSat Launch Initiative Phase I: Design & Research

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***Abstract*—The CSLI mission encompasses the entire process of building the CubeSat, launching it, and performing its mission in orbit. This project will be primarily concerned with the first phase of this mission, the design and research of the CubeSat and scientific payload. The payload will be selected during the project to fit needs that the team develops. The CubeSat will be built to incorporate the payload and function at a specific orbit. The final deliverable of this project will be a fully researched and developed payload and CubeSat in a 3D CAD model, with an accompanying document that fully describes the payload.**

I. Introduction

The CubeSat Launch Initiative allows teams to launch small satellites to specified orbits with the launch free of cost. The launch is typically millions of dollars for a satellite mission. However, through the CSLI, the team can hitch a ride on a rocket that is already going up and therefore does not need to pay for the launch, effectively cutting an enormous amount of money. CubeSats are standardized in their dimensions and functional requirements, such as weight, power, etc. One of the most important aspects of a CubeSat is the form factor. A standard CubeSat form is 10 cm x 10 cm x 10 cm, this is defined as a 1U CubeSat, common CubeSat form factors ar 1U, 2U, 3U, and 6U. A 2U is 10 cm x 10 cm x 20 cm, and so on to a 6U where the form factor is 20 cm x 10 cm x 30 cm. This standardized form factor allows a launch provider to put the CubeSat in a standard launch pod. This pod is adaptable to all CubeSats, called a P-Pod. CubeSat contain integrated scientific payloads. These payloads are typically either experiments or technology demonstrations.

This project is the first step in the proposed CSLI mission. The payload is going to be chosen as the first order of business and the mission will be developed.

The phases for this entire CSLI mission are summarized in Table II. The first phase is the primary focus and goal of this immediate project, design and research of the CubeSat with a scientific payload and a technical report on the system. The second phase will be concerned with securing funding. The third phase will be writing the CSLI proposal and submitting it. The fourth phase will be building the CubeSat. This includes the component-level testing and full fabrication of the system. The fifth phase, testing, will concern with system-level testing and scientific payload testing. The goal of this phase is to verify that the CubeSat will function as intended. The sixth phase will be the launch phase. The seventh phase will be communciating with the CubeSat in-orbit to perform its scientific goals and complete the mission.

II. Primary Objective

The primary goal and focus of this project is the first phase, outlined in section I and Table II. The team will choose a scientific payload, design the CubeSat and payload, perform the necessary orbital calculations, power requirements, etc. The final goal of this project is deliver a full CAD design, with all the necessary integrated electonic components. This CAD model will include a fully researched and developed scientific payload. There will also be a technical report in the final deliverable package, which is further described in subsection IV-A.

III. Benefit to SPEX

This project would be beneficial to SPEX for the following reasons; experience (project management, engineering, coding, etc.) given to current members, opportunities for data analytics on collected data, PR, provides base for further funding and sponserships. The PR for this would be great for getting recognition in the aerospace community. A successful CubeSat is difficult to attain. If SPEX is able to excute this project well, it would be a serious step in being national recognized as an aerospace/astronautical research group. The marketing team at RIT SPEX would be able to leverage this project to get interested companies to donate supplies, money, or their time so RIT SPEX can build and grow in their research. The experience for the team would be great because it would bring a project from pure design and research to flight. Allowing students to be part of that project lifecycle would be tremendous for growth in their respective field.

IV. Implementation

This project will start with a small design and research team. That team will be responsible for picking and appropriate payload. Once the payload is chosen, the design of the CubeSat will begin. The team will bring in members that have experience in the relevant categories, such as radio communication, structural engineering, software and firmware development, etc. The team will be responsible for creating thorough documentation on every aspect of the CubeSat to ensure future members will be able to pick it up and keep going without unnecessary time-loss and scope-creep. The team will strive to attend as many RIT poster sessions as possible, once ready, to build recognition of the project, its goals, and its status. That is imperative for when the funding phase arrives.

The project will follow *the Need-Driven Process*. This involves following a need-based mission. The steps involved in developing this mission are listed in Table I.

TABLE I
STEPS FOR THE NEED-DRIVEN PROCESS

Step	Description
1	Define mission needs
2	Identify principal players
3	Define timeline over which the program needs to be completed
4	Quantify mission details
5	Define alternate combinations of mission elements
6	Develop alternative mission concepts
7	Critical requirements
8	Performance Assessments and System trades
9	Quantify how well the broad objectives
10	Creating a baseline design
11	Revise system requirements and constraints
12	Design iterations
13	Begin traditional systems engineering process
14	Flow down numerical requirements

Step 1 of the process is to define the needs that the mission must achieve. What are the quantitative goals, and why? This information should come from a mission statement of what the mission is attempting to achieve. Step 2 identifies the prinicipal players (aka stakeholders) and the space community of which they are a part. Step 3 defines the timeline over which the project needs to be excuted to be useful. Step 4 quantifies how well the team wishes to achieve the broad objective, given the team needs, applicable technology, who the users are, and cost and schedule constraints. These requirements are flexible and subject to change throughout the project. Step 5 defines the alternate combinations of mission elements or the *space mission architecture* to meet the mission objectives and requirements. Step 6 develops alternative mission concepts. In step 7 we identify the prinicpal cost and performance drivers for each alternative mission concept. In step 8 the team will conduct performance assessments and system trades. It will define in detail what the system is and does. Step 9 quantifies how well we are meeting both the broad objectives and the needs of the end user as a function of either cost or key system design choices. In step 10 the team will select one or more baseline system designs. In step 11 the team revises the system requirements and constraints consistent with what the team has learned, and in step 12 the team will explore other alternatives and iterate upon the design. The team will translate the now better-defined objectives, constraints, and requirements into well-defined system requirements in step 13. Finally in step 14 the team flows down these numerical requirements to the components of the overall space mission.

These steps are derived from *Space Mission Engineering: The New SMAD*, from the space mission engineering process chapter concerning the need-driven process for projects.

A. Deliverables

The team will make 2 or 3 postings on the RIT SPEX website, per semester, with progress and science updates to keep the project in outside contributors/persons of interest's field of view. The team will be required to have a poster for Imagine RIT and the undergraduate research symposium in the spring and summer terms, respectively.

The documentation for a project of this size and length is essential. Since the project is going to take a few semesters, at minimum, to complete. It is important to have enough documentation on each aspect to be able to bring new members up-to-speed as easy and quick as possible. The documentation should cover the following; fully end-to-end CubeSat assembly, necessary hardware, a full drawing packet on the CubeSat design, design requirements, engineering requirements, payload functionality, payload description, payload integration specifications, PCB design, PCB layouts, PCB components, power requirements and distribution diagram, radio signal mapping, and FEA simulation analysis. These documents should be saved in individual locations and concatenated into a master document, for easy reference.

There will be weekly meetings to discuss progress on different aspects of the project being investigated by different persons. Each member will be expected to discuss their progress and contribute to a master logbook in which documentation will be recorded for future reference. The documents can range from code to articles on specific calculations or designs, etc. Powerpoints are preferred for presenting to other members.

This phase of the project will be considered complete when the following is delivered; a fully developed CAD model, electrical diagrams describing the electrical functionality, , and a full technical guide to the CubeSat. This technical guide will outline the product, engineering requirements, mechanical and electrical design, operations, orbital calculations, and requirements. It will not be drafted in the CSLI standard, it will be geared more toward informing the general person. This document will essentially outline how the CubeSat works and all thought and decisions that went into the design.

B. Milestones

The milestones for this project include surpassing each step laid out in section IV. The more general project milestones are choosing a payload, designing the payload, CubeSat structure, CubeSat avionics and software. Then also creating a risk assessment based on the first design iteration.

Once these first milestones are completed the team will go through a concept design review. This will give them early feedback based on their design decisions and allow them the opportunity to address concerns before the system design is frozen. Then the team will iterate upon their design further, figure out more details and go back for a project design review with another risk assessment. After the project design review the team will make final design iterations and prepare for the funding phase. Preparation for funding will include making many documents and graphics to show the project to potential investors and or to please already dedicated investors.

V. Externalities

A. Prerequisite Skills

The team will have a maximum of 7 members during the design and research phase. At minimum, the team will need 3 mechanical engineers, 1 electrical engineer, and 1 computer scientist (or avionics specialist). It would be most beneficial to have mechanical, electrical, software engineers, physicst, and a computer science major. The team members will be responsible for fulfilling roles that may extend beyond the reach of their speciality. While it extends beyond their speciality, it will not extend beyond their capability. In the event that is unavoidable, outside help will be sought through professors or the appropriate student body.

In general, it is expected that mechanical engineers will be profficient in Solidworks and MATLAB. Solidworks is the chosen 3D modeling software due to wide availability and experience. MATLAB will be used for calculating orbits or performing mechanical analysis. It is not required for people that have a refined coding ability. Mechanical engineers will need to have taken a strength of materials, thermodynamics, and the university physics sequence, or equivalent courses. They will also be responsible for performing finite element analysis on the system. This requires previous knowledge on the subject.

Electrical engineers may be responsible for designing circuit board layouts, coding the boards, or figuring out the electrical requirements for the payload in general.

B. Funding Requirements

The funding requirements for this design phase are minimal. There may be some cost during feasability studies if a particular technology must be demonstrated. But that will likely be low-cost. The official cost estimation for this phase of the project will be $300. All the programs the team will need, ANSYS, Solidworks, KiCAD, etc., will be provided by the university or by sponsers.

C. Faculty Support

Faculty support is difficult to gauge based on the ambiguity of the payload. Since the payload is completely unknown at this time, the extent of faculty support will be considered when the payload is selected.

D. Long-Term Vision

This project is conerned, only, with the first phase of the CSLI mission. The future phases will be investigated by another project. The future phases are summarized in Table II.

The team that works on this project does not need to be on the future stages of the project. The goal of the rigorous documentation is to allow any and all members to pick up where this team left off, with minimal reading to get caught up to speed.

TABLE II
CSLI Phases

Phase #	Title	Purpose
1	Design & Research	Chose payload, design CubeSat, write CSLI (without funding section)
2	Funding	Secure funding
3	CSLI Submission	Get CSLI proposal reviewed and submitted
4	Build	Build CubeSat with Payload
5	Testing	Perform system-level testing
6	Launch	Launch the CubeSat
7	Science	Retrieve data from CubeSat and payload

Acknowledgements

The authors would like to thank T.J. Tarazevits and Philip Linden for their support.