Low Cost Nanosatellite for Undergraduate Research

T.J. Tarazevits*,
RIT Space Exploration, Rochester Institute of Technology
Rochester, N.Y.
Email: *tjt3085@rit.edu,

***Abstract*—This proposal defines a semester long research project to reproduce the nanosatellite constructed for the $50Sat project. Students would be tasked with taking the existing designs and fabricating and assembling components into a complete, functional spacecraft. This project leverages a low-cost, proven design to build critical skillsets within SPEX as well as producing tangible flight-proven hardware.**

I. Introduction

$50SAT (Eagle2) was a collaborative education project undertaken by Morehead State University to produce a nanosatellite at extremely low cost (<$250). The satellite was launched via AMSAT in 2013 and continuously operated for over two years. It was also the first use of the PocketQube form factor for nanosatellites. This project would build upon their open source design and implementation of a satellite, to produce a fully functional ground model that replicates all major satellite subsystems and operating modes.

II. Primary Objective

The goal is to apply members' knowledge to complete the satellite engineering development process at a small scale using a proven design. Members will engage in the fabrication, assembly and testing of space-ready hardware and work through the unique challenges presented in such designs.

III. Benefit to SPEX

This project will have several key benefits to SPEX in the near and long-term. This project will create a practical astronautical engineering skillset among SPEX members, and will provide opportunities when engaging with employers to showcase the application of member skills.

A. Technical Skill Development

This multidisciplinary project will require members to learn and apply technical skills to achieve success. Skills learned during the course of this project can be applied to many other SPEX activities as well as leveraged for future job opportunities. The scope of this project is ideally suited for undergraduates to undergo the whole development process and gain experience with fabrication and testing techniques on actual space-rated designs.

B. Published Content

The end goal of this project is to replicate the results of the original $50SAT hardware design. The team should produce a report describing the work done, any modifications to the original design, as well as any unforseen technical challenges encountered during the development process. This will be used internally to inform future projects relating to nanosatellites.

Images, videos, and test result data will be available to share via the SPEX website.

IV. Implementation

The project will begin by evaluating the existing designs generated by the $50SAT team, followed by fabrication of subcomponents, and then a final assembly and testing phase.

A. Deliverables

The primary deliverable will be the finished, functioning nanosatellite unit. In addition, the team should include a report consisting of the following sections:

- A summary of the development process, including any unforseen issues that arose during development and detailed explanations on how they were addressed.
- Details on any changes to the original design and well as the reasoning for those changes
- Detailed operations guide for handling and operating the satellite
- Where possible, instruction guides for assembly of key components and subsystems that future teams could leverage.
- Test procedures and results for key areas including radio performance, thermal and structural tolerance, and software qualifications

The published designs also include an arduino-based radio receiver station. The team could develop this component as well, or preferably, leverage other teams and their projects to satisfy this requirement. Finally, the team will need to generate a presentation poster that could be used at ImagineRIT or other public SPEX events to highlight the project.

B. Milestones

If this project is conducted over a semester timeline, the team will need to expediently cover the required areas defined below.

This project will take place over three technical domains: electrical, mechanical, and software.

For the electrical systems, the team will need to review the existing PCB designs, primarily to determine whether it is feasible to manufacture and populate them on campus. Also the team will need to determine if all components required are still available, and if not, find suitable replacements and make the necessary design changes. PCB assembly will be the system with the longest lead time and should be prioritized first to ensure no bottlenecks on the critical path. Once assembled, each will need to be tested, and integrated within the system structure.

For the mechanical systems, the team should evaluate the feasibility of manufacturing the frame on-campus. Any tweaks to the internal structure and placement of internal components should be locked down as early as possible. The mechanical team will also be responsible for testing the frame and whole assembly for verification against thermal and vibration requirements.

For the onboard software, the team should review the existing code, and try to demonstrate functionality on similar hardware to prevent dependency on the electrical team. Once the primary electronics are ready, the software should be tested for functionality on the system hardware.

The timeline below is preliminary:

- Review the existing $50SAT designs and materials – no more than 2 weeks
- Subsystem development - concurrent
  1) Order PCB design and/or assembly - 6 weeks
  2) Review changes to mechanical strcuture and order materials - no more than 2 weeks
  3) Setup software environment and prototyping test bed - no more than 4 weeks
- Testing of individual subsystems - 2 weeks
- System Assembly - 1 week
- System testing - 2 weeks
- Generate documentation and delivery to SPEX

Schedule slip is tolerable, since there are few external considerations within the fall semester, e.g. a competition or public display event.

V. Externalities

A. Prerequisite Skills

Firstly, this project requires technical skillsets across multiple disciplines in order to be a success. The members that make up this project team will need applicable skills to their working domain and general awareness of the space environment and constraints.

Electrical team members should have basic soldering skills, with at least one member familiar with PCB design and layout. Each board is flight-proven, but should be verified by members with applciable electrical engineering knowledge. Assembly of those boards will require SMT mounting skills. Also, prior experience working with solar cells is a plus.

The frame and interal structure of the satellite requires mechanical engineering design and fabrication skills. Mechanical team members should be able to machine required components and finish final assembly. At least one member should have the ability to run structural and vibrational FEA on the system designs. At least one member should have the ability to run thermal FEA.

The software is written in Basic for the PICAXE processor, but will need computer science skillsets to validate the codebase and make any necessary modifications. Software team members should be familiar with C/C++ and object-oriented programming. Experience with hardware interfaces such as I2C/SPI is a plus.

The ground station and radio communication will require knowledge of physical radio properties and various radio modulation techniques. Other astronautical engineering skillsets may be required, dependent on unforseen technical challenges.

B. Funding Requirements

This project should not exceed $500 in total costs incurred.

The original $50SAT project cost less than $250 in raw materials so this project should be within a similar range. Potential sources for cost inflation include going with an external assembler of the PCBs, and unforseen changes in the design.

An Interactive Learning Grant (ILG) should be able to cover the total expected cost of the project, however it would be prudent to have backup funding available in case of budget overruns. The project team should give the SPEX administration a preliminary BoM and cost estimate once their initial review of the designs are complete, to aid in securing funding.

C. Faculty Support

Faculty support is recommended for teams pursing this project. The electrical subsystems would most significantly benefit from faculty advisement to review the final assembled board and solar panel assemblies. Also the radio and antennas system testing would benefit from SPEX advisor expertise and oversight.

D. Long-Term Vision

This project would result in SPEX's first functional, space-rated hardware project.

Future teams could utilize the same low cost design philosphy while pushing the boundaries in one or more subsystems over time to create a more compelling spacecraft. The skils learned from this project would mitigate the risk of future projects with increased technical complexity.

If this project was iterated on, hardware developments and experience gained from these projects could be applied to a CubeSat or other nanosatellite that would actually fly in space, through a launch partnership like CSLI.

Acknowledgements

The author would like to thank Professor Bob Twiggs at Morehead State University and the rest of the $50SAT team for publishing open source design for the mission, allowing similar student teams to work on flight-proven hardware.

TABLE I
ESTIMATED TIMELINE

Phase	Task	Duration
1	Review the existing $50SAT designs and materials	no more than 2 weeks
2	Subsystem development	6 weeks
2	Order PCB design and/or assembly	6 weeks
2	Review changes to mechanical strucuture and order materials	no more than 2 weeks
2	Testing of individual subsystems	2 weeks
3	System Assembly	1 week
4	System testing	2 weeks
5	Generate documentation and delivery to SPEX	1 week

APPENDIX A
$50SAT REFERENCE IMAGES

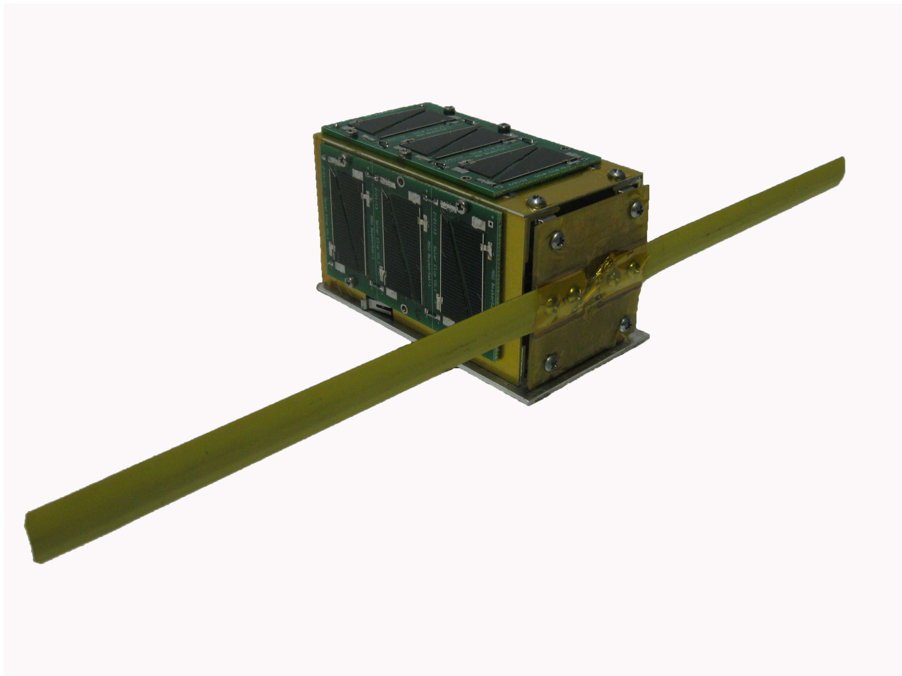

Fig. 1. 3D rendering of the complete $50SAT satellite.

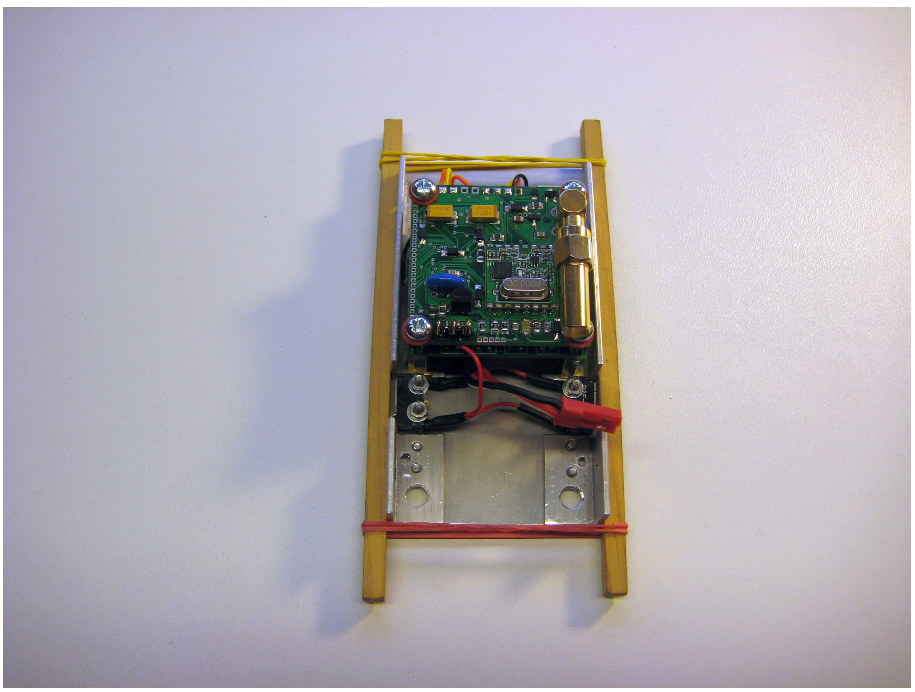

Fig. 2. View of the layout of the internal electronics.