



**Tesseract CubeSat Bus with
Deployable Solar Panels
A Warren J. Baker Endowment Fund Project**

Final Report

California Polytechnic State University, San Luis Obispo

May 29, 2015

Intro

The PolySat program at Cal Poly creates small cube-shaped satellites in accordance with the CubeSat specification developed in a partnership between Cal Poly and Stanford. Undergraduate and graduate students work in every stage of development of these satellites, and we also reach out to high school students during the summer. As such, the programs are greatly involved in fostering the growth of the “learn by doing” philosophy, allowing students studying in STEM fields to collaborate with industry partners and participate in worthwhile projects that are relevant to their areas of interest.

Companies from industry and universities often work together to accomplish a flight mission, where the industry provides a payload to perform experiments in space, and the university will create the surrounding “bus,” including avionics systems, batteries, radios, solar panels, and the CubeSat structure itself. These scientific payloads sometimes have large power requirements, but due to the size limitations of a CubeSat, only so many solar cells that can physically be mounted on a satellite. This limitation is what drives the need for solar panel systems that can be deployed in space.

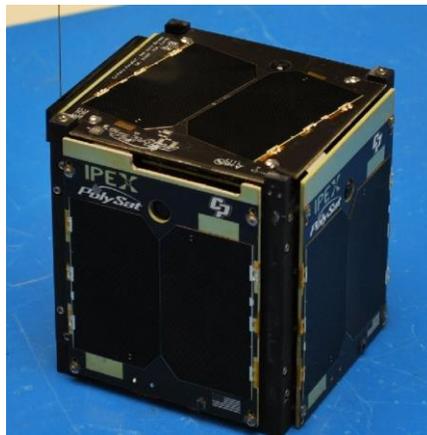


Figure 1. Image of a 1U CubeSat (PolySat's IPEX flight unit). IPEX launched December 5, 2013 on an ATLAS V rocket.

Executive Summary

With the desire for high power generation from research payloads, the need to increase solar cell capacity on CubeSats is apparent. Tesseract is Cal Poly's first iteration of a structure designed to meet this need. The main objectives for the Tesseract project are to develop a more advanced baseline system with higher power generation and to incorporate lessons learned from recent PolySat missions (IPEX, LEO, and ExoCube) into the system design.

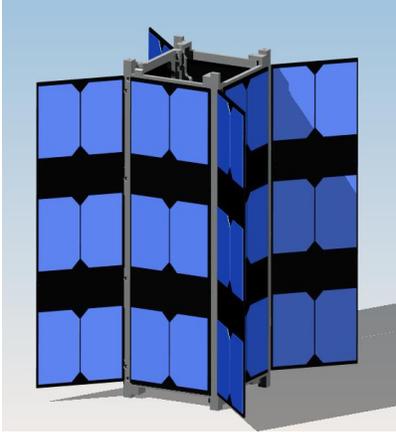


Figure 2. Early conceptual design of a 3U CubeSat with deployable solar panels.

By pushing the limits of structural design and electronic placement, the PolySat team was able to design the Tesseract system to incorporate a total of eight deployable solar panels with a solar cell capacity of 154 cells (up from a maximum of 36 cells possible on previous structure designs); a feat that even some companies in industry have yet to match. In addition, manufacturing and assembly lessons learned from previous satellites were taken into account during the design to ensure forward progress of PolySat's buses. A large portion of the mechanical structure was manufactured by students in Cal Poly's own Mustang '60 shop using the CNC mills available there. Once a physical structure was procured, two main tests were performed. The first was vibration testing to simulate the rocket launch environment, where the structure (with panels) was shaken to NASA GEVS Acceptance standards. This test was performed to ensure that no components would fracture or deploy prematurely. The second test was a thermal deployment test, to verify deployment could be executed in hot and cold environments. Both tests were successful, resulting in no damaged components and in smooth deployments in the expected environments. Though more testing is always encouraged, the Tesseract system is recommended for use for future missions which require more power generation than can be provided by a standard structure.



Figure 3. Tesseract ETU (engineering test unit). One side of solar panels (no cells) can be seen in the deployed configuration.

Major Accomplishments

- A CubeSat bus has been developed with eight deployable solar panels which more than quadruples our current solar cell capacity.
- The lessons learned from previous satellite missions were incorporated into the design to progress the PolySat program and future missions.
- The structural and electrical design of a potential spacecraft has been performed entirely by students.
- Many structural parts were manufactured by students on campus using the Mustang '60 facility.

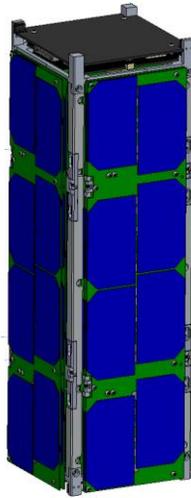


Figure 4. CAD image of Tesseract with deployable panels in the stowed configuration. The solar cells are indicated in blue.

Expenditure of Funds

PolySat was awarded \$5000 from the Warren J. Baker Endowment Fund for Tesseract. The funds provided were used for purchasing circuit boards and components, hardware, aluminum stock, and manufacturing. Most costs were tracked and can be found in Table 1. The actual final costs may vary slightly due to shipping, tax, and other small factors.

Table 1. Expenditure table of the Warren J. Baker funds for Tesseract.

Item Purchased	Vendor	Cost
Circuit Boards	ITEAD Studio	\$407.80
Electronic Components and Cabling	Digikey, ITEAD Studio	\$299.05
Deployment Mechanism Boards	Miga Motor Company	\$146.39
Test Cover-Glass	Ted Pella	\$36.31
Hardware and Aluminum Stock	McMaster Carr	\$398.10
Manufacturing Tooling and Fixtures	One-Way Manufacturing	\$98.37
Rapid Prototyped Parts	Cal Poly Mechanical Engineering Dept	\$654.07
Externally Manufactured Parts	Protolabs FirstCut	\$2,046.43
Total Estimated Expenditure:		\$4,086.52

Contributing Students:

Oliver Woolsoncroft, Mechanical Engineering Graduate Student

Vanessa Faune, Mechanical Engineering Undergraduate Student

Edgar Uribe, Mechanical Engineering Undergraduate Student

Felix Haimerl, Mechanical Engineering Undergraduate Student

Kyle Teixeira, Mechanical Engineering Graduate Student

Eric Baumgarten, Mechanical Engineering Graduate Student

Wesley Williams, Mechanical Engineering Undergraduate Student

Zachary Frangos, Mechanical Engineering Undergraduate Student

David Baker, Mechanical Engineering Undergraduate Student

Peter Rivera, Mechanical Engineering Undergraduate Student

Jimmy Tang, Electrical Engineering Undergraduate Student

Jeff Weaver, Electrical Engineering Graduate Student

Alex Saunders, Electrical Engineering Undergraduate Student

Kristina Forystek, Electrical Engineering Undergraduate Student

Kyle Muldbakken, Electrical Engineering Undergraduate Student

Maci Miri, Electrical Engineering Undergraduate Student

Alex Wargo, Electrical Engineering Undergraduate Student

Robert Potter, Aerospace Engineering Undergraduate Student

Trent Voris, Aerospace Engineering Undergraduate Student

Faculty Advisors:

Dr. John Bellardo, Computer Science Department Professor

Dr. Jordi Puig-Suari, Aerospace Department Professor

Associated University Association:

PolySat

Impact to Student Learning

Reflections from Jimmy Tang

My name is Jimmy, and I am a third year electrical engineering student. The Tesseract project has furthered my skills in circuit board layout and component placement. For these tasks, I had to communicate and work with the mechanical team in order to find out board profiles and connector placements. I also got the chance to interface with professionals from businesses in order to get the boards manufactured for our use. I am grateful to the Warren J. Baker Endowment Fund for the opportunity to work on this project.

Reflections from Vanessa Faune

My name is Vanessa, and I'm a fourth year mechanical engineering student. I was one of the students fortunate enough to be able to work on Tesseract as a senior project. Throughout the course of the project, I've learned about structural design for a spacecraft, and performed engineering finite element analysis on the satellite in order to ensure its survivability. I also participated in assembly and manufacturing of the parts. Learning about the manufacturing process using the CNC mill has been especially useful to me, as I would like to pursue a career involving manufacturing in the future. I would like to thank the Warren J. Baker Endowment Fund for the chance to work on this fantastic senior project!

Reflections from Oliver Woolsoncroft

My name is Oliver, and I'm a mechanical engineering graduate student. Over the past year, it has been my pleasure to be the project leader of Tesseract. As leader, I have learned a lot about scheduling, managing a multi-disciplinary team, and budgeting for a project. I have had experience in previous missions before Tesseract, and through this project I was able to pass down my experience to newer members of the program as well as make necessary design changes for this iteration of our CubeSat bus. I also gained a big-picture point of view for projects, which (mixed with my previous technical experience) helped me secure a career after graduation. I owe a big thank you to the Warren J. Baker Endowment Fund! Thank you so much for making this possible, and for helping to further the progress of the PolySat program.



Figure 5. Two PolySat students working on the Tesseract ETU.

Conclusion

The funds provided were able to pay for the development, manufacturing, and testing of a new CubeSat satellite bus for PolySat. With Tesseract's successful vibration and thermal deployment tests, the Tesseract team can recommend use of this design for future use, and would also recommend additional testing as more changes are made. Tesseract will be the foundation upon which new missions are designed, and opens up doors for missions requiring high power generation. In addition, this project allowed many senior members of the program to pass down knowledge to newer members, and encouraged a multi-disciplinary learning environment among many engineering students.