SOCIETY OF PHYSICS STUDENTS
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SPS Chapter Research Award Proposal

Project Proposal Title	Putting It Together: Final Assembly and Testing of Custom Satellite Hardware
Name of School	Rhodes College
SPS Chapter Number	5940
Total Amount Requested	$2,000

Abstract

Rhodes College's 1U CubeSat satellite, RHOK-SAT, is nearing completion. RHOK-SAT is scheduled to launch to the International Space Station in approximately one year. The payload team is now assembling and testing the final hardware meant for the flight model.

Proposal Statement

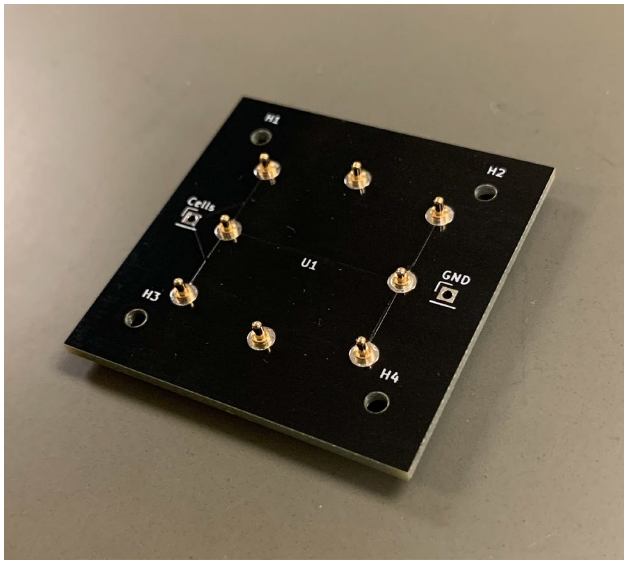
Overview of Proposed Project

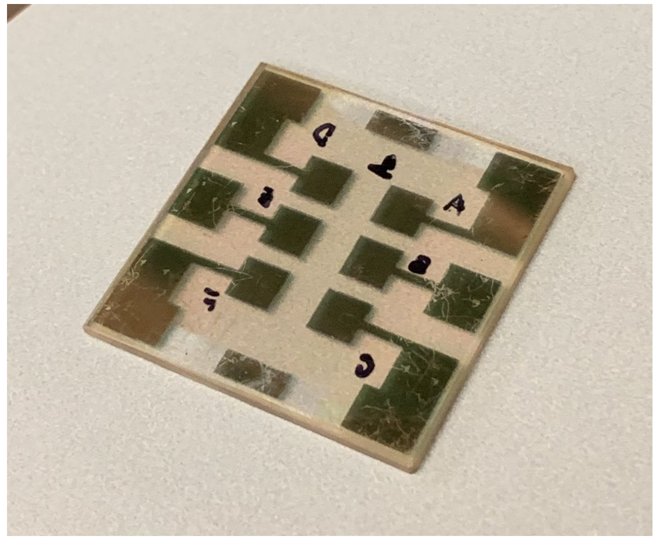
RHOK-SAT, a 1U CubeSat, is a collaboration between Rhodes College and the University of Oklahoma Photovoltaic Materials and Devices Group to characterize the behavior, performance, and degradation of novel perovskite solar cells in Low Earth Orbit (LEO). The perovskites have shown increased efficiencies when compared to traditional types of solar cells and have a self-annealing property but are relatively fragile and sensitive to humidity. These qualities make perovskites a good candidate for deep space missions. RHOK-SAT will be one of the first missions to test and conduct in-orbit measurements of perovskites.

Due to the fragility of the perovskites, they require a dry electrical connection and cannot be soldered to. As a main part of the payload, a pogo Printed Circuit Board (PCB) has been designed to connect to the perovskite using pogo pins, a kind of spring-loaded electrical connector. The pogo pins press the perovskites against an aluminum top plate to create a good connection. The pogo PCB connects to six perovskite samples and has two main circuits per perovskite sample: a resistor circuit and a measurement circuit. The resistor circuit is needed to slow the degradation of the perovskites, as the perovskites experience faster degradation if they are left in an open circuit state. The pogo PCB holds all components necessary to keep the perovskites in a resistive state, as well as analog switches, multiplexers, a control Copper Indium Gallium Selenide (CIGS) solar cell, a custom-built sun sensor, eight Resistance Temperature Detectors (RTDs), and a 60-pin Molex connector. A secondary measurement PCB consists of eight Aerospace Measurement Units (AMUs) used to measure the six perovskites, CIGS cell, and sun sensor. The measurement PCB connects to the pogo PCB via the Molex connector and connects to the satellite via the CubeSat Kit Bus (CSKB).

Alongside characterizing perovskites, the goal of this research project is to provide a valuable engineering opportunity to Rhodes students. As Rhodes is a small liberal arts school without a formal engineering program, this CubeSat project is a unique opportunity and is undertaken by undergraduates from a variety of different majors. Assembling the PCBs will provide a hands-on learning experience and grow student's skills in soldering and 3D printing, while testing will help students learn problem-solving skills through creating testing procedures and environments.

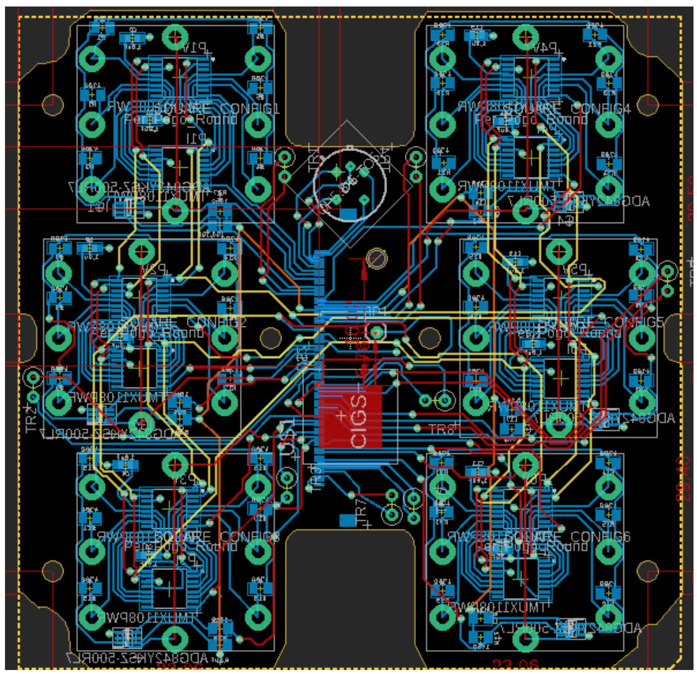
RHOK-SAT is closely connected to the Rhodes chapter of SPS. Nearly all students involved in the RHOK-SAT team are members of SPS and several of the faculty act as advisors to the Rhodes chapter. SPS's mission of increasing accessibility and interest in physics is at the core of the RHOK-SAT project.





A perovskite testing PCB with pogo pins

A perovskite slide



Computer-Aided Design model of pogo PCB

Background for Proposed Project

RHOK-SAT will be ready for launch by the end of June 2024. RHOK-SAT is a joint 1U CubeSat satellite project between RHodes College and the University of OKlahoma to characterize the performance and degradation of novel perovskite solar cells in space. The perovskites require a special mounting system in order to create a good electrical connection without breaking them. The face plate-pogo PCB apparatus has been designed for this purpose and includes six perovskites and eight RTDs. This setup allows the cell performance and thermal data to be collected simultaneously, which will provide valuable information to drive solar cell innovation forward.

Expected Results

Currently, the RHOK-SAT payload team is working towards two main goals:

- Successful assembly of PCBs and integration of payload
- Successful testing of all experimental parts

Description of Proposed Research - Methods, Design, and Procedures

The satellite's payload PCBs were developed using Autodesk EAGLE and is exported to a Gerber file to be sent out to the fabricator. We will be ordering our flight model PCBs from Osh Park, a US based PCB fabrication company. On arrival, the PCBs will be ready to be assembled, as we have all components ready to integrate onto the boards. To assemble the PCBs, there are in total ~600 solder points spread across the two PCBs which need to be precisely soldered.

Assembly of the Pogo board requires 9 different kinds of components:

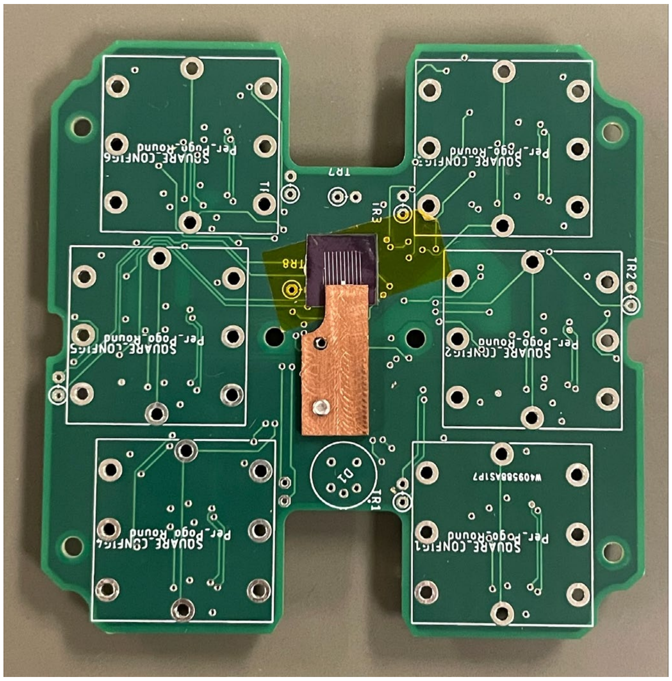
1. 10k Ohm 8085 resistors
2. 470 Ohm 8085 resistors
3. .1 microfarad 8085 capacitor
4. 1 microfarad 8085 capacitor
5. Molex 60-conductor connector
6. Pogo pins
7. Multiplexers
8. Analog Switches
9. Custom Sun Sensor

Assembly of the AMU board requires 2 different kinds of components:

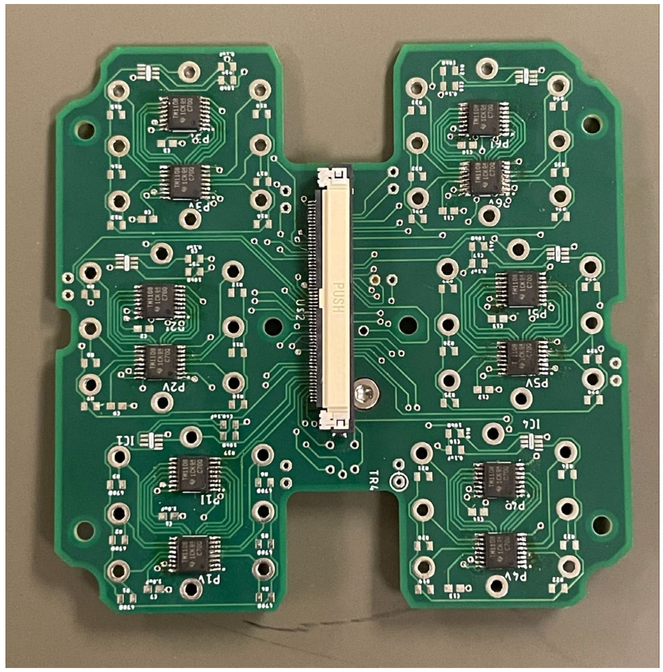
1. Aerospace Measurement Units
2. CSKB connectors

Once assembled, the completed top plate-pogo PCB apparatus must be tested. To do this, we 3D print different jigs to hold and turn the apparatus and measure data from the sun sensor, CIGS cell, and perovskites, and test to make sure we can properly connect and control the AMUs. The sun sensor will be calibrated using a 1000W incandescent light bulb placed closely to mimic the sun's intensity. The sun sensor will then be measured facing the bulb at different angles, which will allow us to match the sun sensor's output to an angle. The CIGS cell is tested in the same way to characterize its performance.

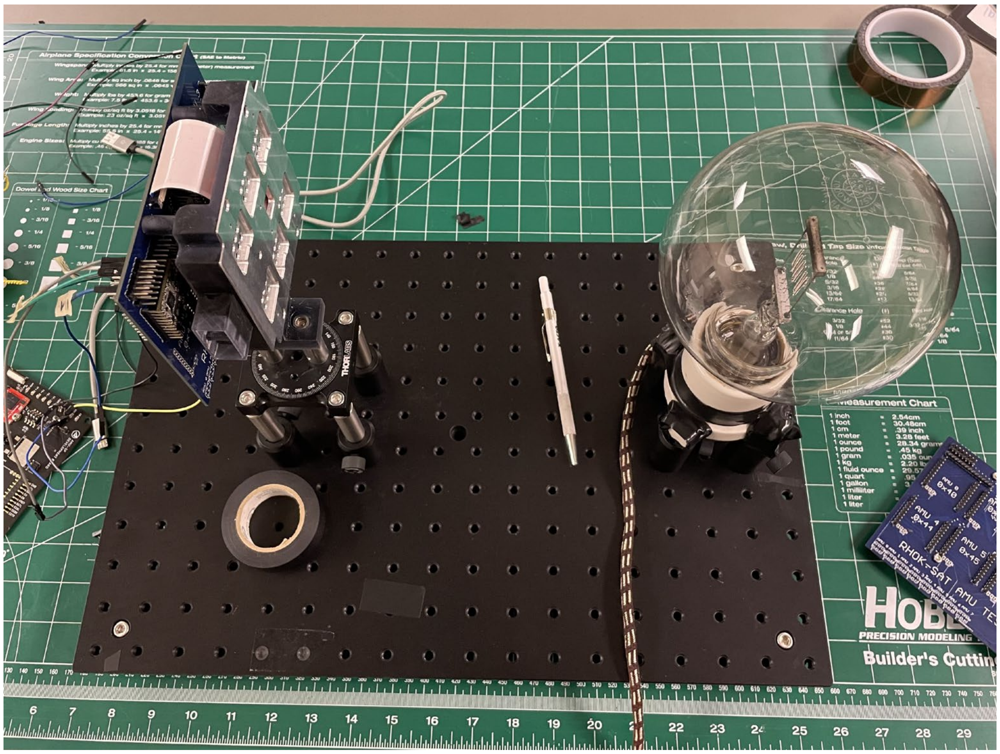
After all prototypes have been tested and everything works correctly, a flight model version must be made. This requires the PCBs from Osh Park and will include working perovskite cells. The assembly of the payload is as follows. The perovskites will each have an RTD integrated on through the use of a thermally conductive space grade epoxy. The RTD will be soldered into the pogo PCB, allowing the perovskites to be easily handled. The perovskites will then be placed onto the aluminum face plate and the pogo board will be screwed into the face plate. The measurement PCB can then be connected to the pogo board through the Molex connector and will attach straight to the CSKB.



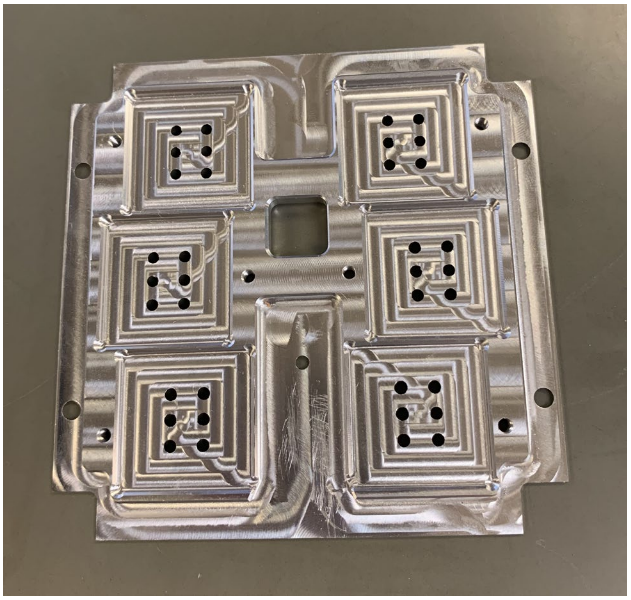
The front side of a prototype pogo PCB (CIGS cell in center)



The back side of a prototype pogo PCB (Molex connecter and multiplexers)



A prototype sun sensor testing environment (face plate-PCB apparatus with test measurement board on left)



An aluminum face plate. The square indents are where the perovskites will be placed.

Plan for Carrying Out Proposed Project

The plan for the proposed project will continue until approximately the end of the Rhodes College 2024 spring semester. All required parts are in stock and can be shipped from the manufacturer with minimal lead time. PCBs will be ordered and may take a few weeks to be fabricated. The payload team students will be in charge of the final assembly of the PCBs and the testing of all components of the payload with oversight from the physics department faculty and staff. Currently, all the payload students are active SPS members.

Students involved in PCB assembly and testing are as follow:

- Damian Nguyen: a class of 2025 Physics major and the current Rhodes All Engineering Club President. Damian is responsible for rapid prototyping of payload parts, developing test devices, and 3D design.
- Jasper Scherz: a class of 2026 Physics major and current Rhodes All Engineering Club demo officer. Jasper is responsible for design and implementation of electronic hardware, and the assembly of PCBs.
- William Butler: a class of 2026 Physics major and current Rhodes All Engineering Club secretary. William is in charge of testing the sun sensor and other components.
- Other students involved with the flight software aspect of the project are: Kairos Wong '24 (SPS Member), Marouf Mohammad '24, and Anas Matar '25

Physics faculty members involved with the project include:

- Dr. Bentley Burnham, Assistant Professor of Physics and RHOK-SAT project manager. Dr. Burnham oversees the progression of the project and handles administrative communications between the Rhodes team, the University of Oklahoma, NASA, and other outside collaborators.
- Dr. Ann Viano, Associate Professor of Physics, Sigma Pi Sigma (SPS) chapter advisor, and Rhodes Physics department chair.
- Dr. Brent Hoffmeister, Professor of Physics and SPS chapter advisor.

RHOK-SAT payload development has a dedicated laboratory on the fourth floor of Rhodes Tower. The assembly of the PCBs is done on the fifth floor, in the electronics laboratory. These spaces have all the necessary equipment, computers, and resources to carry out the proposed project except for those requested in the budget.

Project Timeline

- **December 2023:** Order all required parts needed. Receive the flight model from ISISPACE (hardware provider in The Netherlands)
- **Jan 2024:** Assemble all PCBs.
- **Feb-May 2024:** Test all parts, finalize any last pieces.
- **May 2024:** Integrate payload with flight model and hand flight model over to NASA**.** Write the interim report, detailing the project's progress of the flight model's completion and integration of payload into flight model, and changes that happened.
- **September 2024:** RHOK-SAT gets launched!
- **December 2024:** Write the final SPS report of the year.

Budget Justification

Soldering connections for missions in space requires accuracy and precision. This process can be aided by a proper imaging system. A microscope for looking closely at the solder point will enable students to make precise solders with more accuracy than a magnifying glass. A new soldering station and soldering equipment are needed to ensure the PCBs are assembled well. Over time and through heavy use, soldering irons may start to heat up incorrectly, creating an unstable solder joint. It is critical that the PCBs and payload are assembled well so they will survive the trip to space. Other soldering supplies are needed and 63Sn/37Pb solder is used to reduce the chance of tin whiskers in space (1).

Testing the components requires a very bright light, which can only be turned on or off. Looking directly at the light can harm the eyes, so a voltage regulator is needed for easy use of the lightbulb. This would create a safer testing environment and would make testing the components much easier.

As we are nearing the final launch date of the satellite, it is important for us to save time where we need to. One such area is 3D printing wait times. As new tests are being done, new testing apparatus have to be made. Our current resin printer is slow and has an issue curing the products. A new resin printer would be much faster, allowing us to increase our efficiency and waste less time waiting, and would create better 3D prints of the testing apparatus.

To attach the RTDs to the payload, a special thermally conductive space grade epoxy is used. Our epoxy that we have in house has expired since the RTDs have last been integrated. The epoxy must meet NASA outgassing requirements, and is made specially to order by a MasterBond, an epoxy manufacturer. The RTDs are necessary in characterizing the perovskites, and new epoxy is required to attach the RTDs.

Any additional costs associated with the assembly of PCBs will be covered by the Rhodes College Department of Physics and the CubeSat program budget.

Bibliography

(1) NASA. “NASA Technical Standard: Soldered Electrical Connections.” https://nepp.nasa.gov/docuploads/06AA01BA-FC7E-4094-AE829CE371A7B05D/NASA-STD-8739.3.pdf