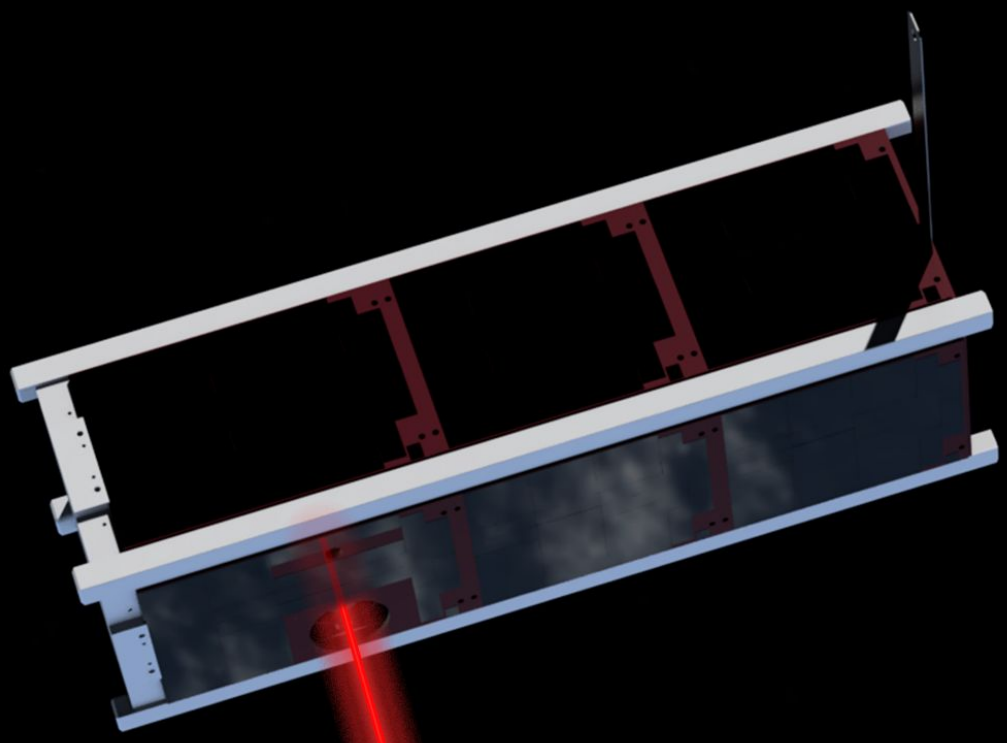
PULSE-A

2024 Q3 Progress Report



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PROJECT SPONSORS & PARTNERS

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PROJECT MISSION

PULSE-A's primary mission objective is to demonstrate space-to-ground circular polarization-modulated optical communications at 10-25 Mbps. Secondarily, PULSE-A's payload, optical ground station, and pointing, acquisition, and tracking sequence are developed to be repurposed in the future quantum key distribution demonstrator, PULSE-Q, with minimal modifications.

If you are interested in receiving a 1-page overview of the PULSE-A mission, please contact Logan Hanssler or Seth Knights.

2024 Q1–Q2 RECAP

- January – March: Concept development
- March 18th: Announcement of NASA CubeSat launch Initiative proposal success
- March – May: System requirement composition and system design
- April 29th: $8,000 secured from annual allocations for registered student organizations
- May 3rd: Announcement of $7,500 award for PULSE-A's 2nd place victory in the SEDS-USA Space For All Challenge
- June 2nd: Systems Requirements Review
- June: Beginning of Preliminary Design Phase

I. PROJECT DEVELOPMENTS

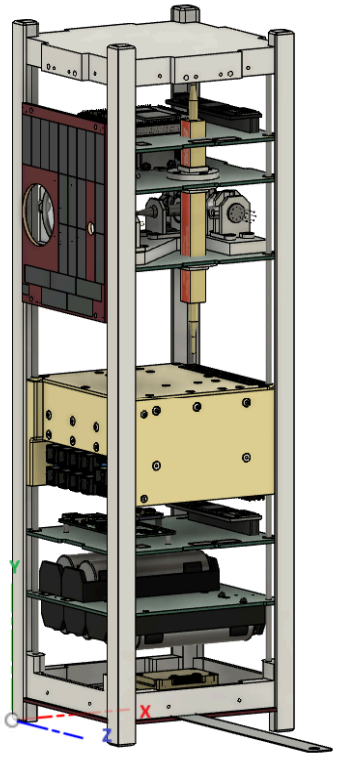
A. PRELIMINARY DESIGN PHASE

Since PULSE-A's successful System Requirements Review on June 2nd, the team has been hard at work on the project's Preliminary Design Phase. Building off of early system design work completed in the former half of 2024, our engineers have been researching the best components, layouts, manufacturing processes, and subsystem architectures to meet the mission's system requirements at minimal cost. Using industry-standard simulation software provided by Ansys, our team is ensuring the design's feasibility as we progress toward our Preliminary Design Review, scheduled for November 23, 2024. We have also made significant progress in contacting component manufacturers to help ensure we are well suited for component procurement and testing, including those necessary for design validation.

For more information on the team's preliminary design developments, please see Section V. Engineering Updates.

B. SPACECRAFT FORM FACTOR

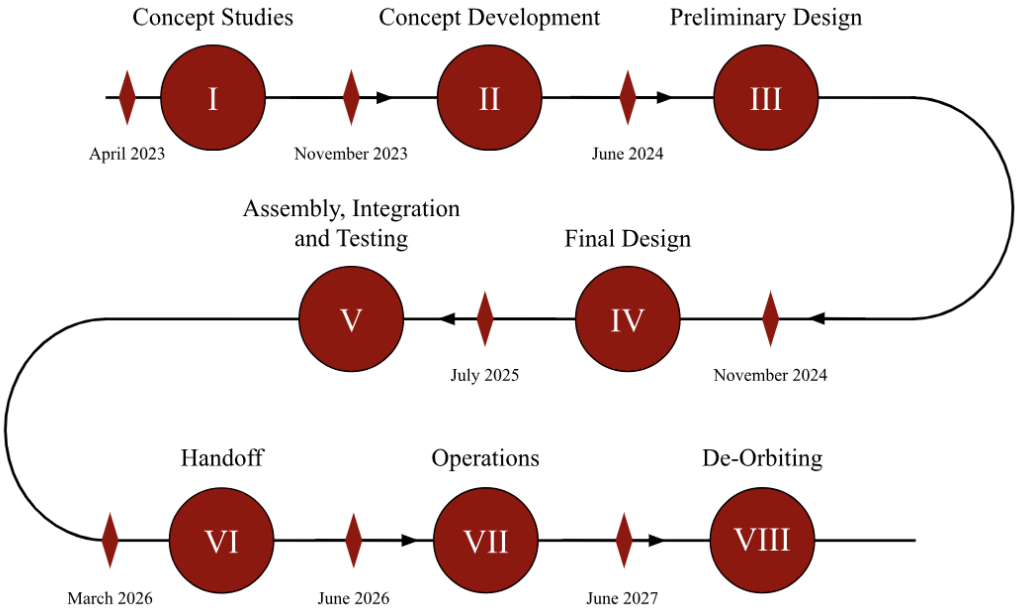
Thanks to new work from the Engineering Division on PULSE-A's volume budget, including significant revisions to the spacecraft's internal configuration, we have found that increasing the size of PULSE-A's chassis would significantly reduce risks and provide for safe and necessary margins. As a result, **PULSE-A's form factor has been increased from 2U to 3U**.



The form factor increase has resulted in less stringent requirements on the avionics stack's size and the payload's orientation. Therefore, our engineers have more creative freedom in their designs and a greater ability to modify the internal configuration according to simulation and test results. Importantly, PULSE-A's increased volume contingency greatly reduces the chance of failure during the spacecraft's assembly and allows room for minor modifications during system integration. The form factor change has also increased the spacecraft's estimated mass, which significantly extends the projected mission life and thereby allows for an improved chance of mission success.

Right: CAD rendering of new 3U form factor configuration. *Credit: Robert Pitu.*

C. PROJECT TIMELINE



Above: PULSE-A development timeline. *Credit: Juan Prieto, Logan Hanssler, Rohan Gupta.*

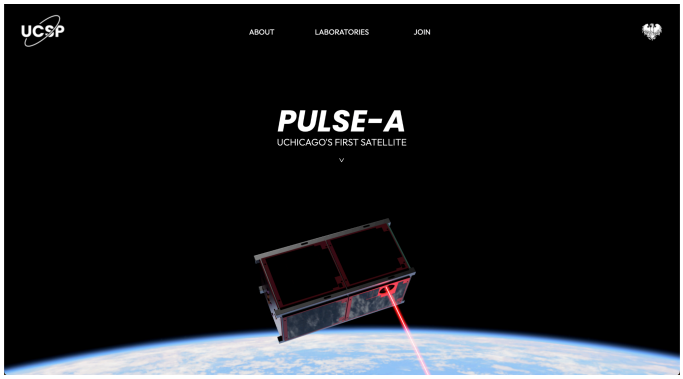
The project's timeline has been revised! We have allotted additional time to our Preliminary Design and Final Design Phases, which will end in November 2024 and July 2025, respectively. In particular, we have extended our Final Design Phase to ensure the mission's risks are minimized before we begin assembling the CubeSat's flight model. We plan for PULSE-A to launch in approximately June 2026 with handoff in March 2026.

D. RECRUITING

With UChicago's academic year beginning on September 30th, we are now recruiting new team members! We are particularly looking to onboard enthusiastic underclassmen who intend to support the team for years to come. By targeting underclassmen, we hope to mitigate knowledge loss as older students near graduation. We anticipate the team growing to about 70 members after this recruiting season. With 7,600 undergraduates at UChicago, the PULSE-A Team will account for almost 1% of the undergraduate student body.

PULSE-A's leadership is drafting documents detailing each role on the team, beginning with roles that are not yet filled by existing members. These documents will include achievable bi-quarterly deliverables to guide development and teamwide progress. Prospective members will apply to specific roles described by these documents to streamline the onboarding process.

E. WEBSITE PUBLISHED



The UChicago Space Program's website is now online, and we expect to have it fully finished and functioning within the next month. Thanks to design work from the team, along with the UChicago Space Program's Webmaster Geralyn Chong, we have been able to publish a draft. While formatting and content are not yet final, feel free to visit us at uchicagospaceprogram.org.

Left: Homepage for the UChicago Space Program's website. *Credit: Geralyn Chong, Seth Knights.*

II. COMMUNITY OUTREACH

A. VISITING STUDENTS 3D MODELING INTRO


Above Left: Participants with their custom-designed 3D prints; Above Right: Participants following along with the Fusion 360 tutorial. *Credit: Robert Pitu.*

In July, PULSE-A Structures Lead Robert Pitu hosted an introductory course in 3D modeling and printing for high school students taking summer classes at UChicago. High schoolers with little experience working with CAD programs learned the basics of Fusion 360 and designed jewelry, buildings, and keychains. The participants then 3D printed their custom designs for personal use.

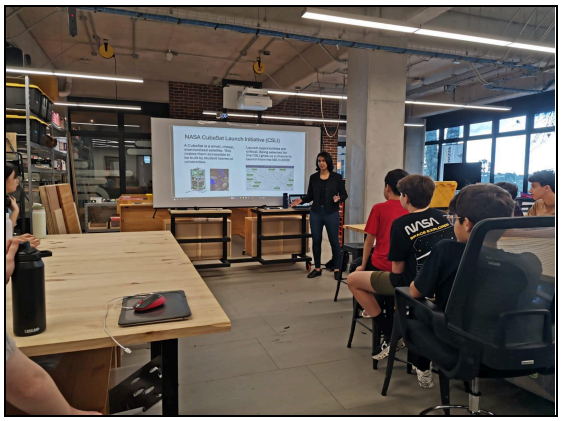
B. GUATEMALA WOMEN IN STEM

In August, PULSE-A Payload Lead Maya Shah McDaniel gave an hour-long talk to a women in STEM group at La Universidad del Valle Guatemala (UVG). UVG launched the first central American CubeSat called Quetzal-1 in 2020, and they are currently building a follow-up mission, Quetzal-2. The talk focused on PULSE-A's novel optical communication scheme, covering details of the optical payload, optical ground station, and pointing, acquisition, and tracking sequence. There was also discussion around how to navigate being women in a male-dominated field.


Upper Right: Maya explaining optical communication to the audience; Lower Right: Maya with makerspace coordinator Cecilia Marsicovetere and female engineers from UVG. *Credit: Maya S. McDaniel.*

C. HIGH SCHOOL ROBOTICS

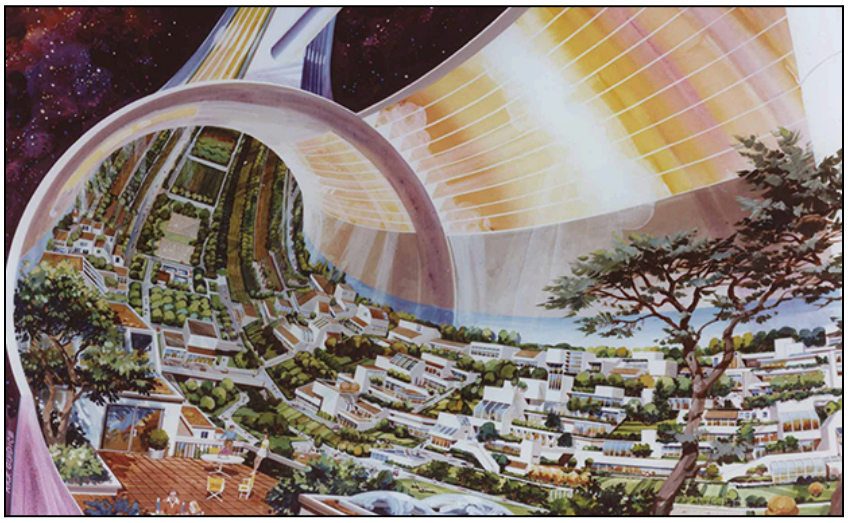
In August, Maya also taught a class of middle-and high-school robotics students at Colegio Maya, an international school in Guatemala. The aim was to inspire the next generation of engineers to begin making a tangible impact as early as high school and college. The concept of a CubeSat was used to highlight how achievable it is to create functional technologies that can travel to space, even at an undergraduate level. The mission goals and transmission scheme of PULSE-A were explained at an age-appropriate level, along with tips for being a successful STEM student in college.



Above: Maya teaching a class of middle and high school robotics students at Colegio Maya in Guatemala. *Credit: Maya Shah McDaniel.*

D. SPACE SETTLEMENT DESIGN COMPETITIONS

The PULSE-A Team and the UChicago Space Program are hosting 2 Space Settlement Design Competitions (SSDCs) at UChicago this academic year! SSDCs are day-long, intensive industry simulation events. Students are sorted into teams structured like engineering companies and given a request for proposal (RFP) modeled on calls issued by NASA. Each team then designs a space settlement according to the RFP's specifications and presents it to a judging panel who selects a winning team. We will host the Great Lakes SSDC for high school students on March 16th, 2025 and the first ever pilot Collegiate SSDC for UChicago undergraduates on January 11th-12th, 2025. We expect 30-50 students from the Chicago area to compete in the Great Lakes SSDC and 100-150 undergraduates to compete in the Collegiate SSDC.



Upper Right: Space settlement similar to what students design in SSDCs. *Credit: Contest Watchers post for the 2016 NASA Ames Space Settlement Contest: https://www.contestwatchers.com/nasa-ames-space-settlement-contest-2016/.*

This past quarter, we have carried out a number of preparatory tasks instrumental to the events' success:

1. We entered into a partnership with UChicago's Department of Astronomy and Astrophysics. The department has graciously provided us with the facilities required to host the events. Students will work in the department's conference rooms, while presentations and food will be held in larger presentation rooms. The department has also offered support in finding students and resources. We are very grateful for their assistance.
2. We created a full budget, schedule, and record of required materials for each SSDC. We estimate the competition for high school students will have a total cost of $3,800, while the competition for college students will have a total cost of $6,150. We are continually working with the Department of Astronomy and Astrophysics as well as other UChicago departments to bring down this cost. Participants will be charged $15 per registration, but any students who feel this presents a barrier to entry will have the fee waived.
3. We have begun reaching out to high schools and STEM education organizations in the Chicago area to find teachers interested in bringing students to the Great Lakes SSDC. We are particularly targeting underserved students at local public schools, and we hope to bring this educational experience to as diverse of a group of students as possible.
4. We created promotional materials for our SSDCs and are currently drafting event materials. This includes the competitions' RFPs, program booklets, introductory and concluding presentations, technical tutorials, and event stickers.
5. We drafted a list of the volunteers we will need to run the SSDCs along with desired qualifications. We are currently creating volunteer orientation materials. Each volunteer working with high school students will be given a background check prior to the Great Lakes SSDC. We expect many volunteers to come from the PULSE-A Team, but we will also bring on more experienced professionals such as UChicago faculty or local engineers.

By the end of Q4 2024, we plan to register the vast majority of participating students, complete the drafts of event materials, begin onboarding volunteers, and recruit a guest speaker for the high school students. To learn more about SSDCs and our partners at Industry Simulation Education, please visit insimeducation.com.

E. TELESCOPE VIEWING NIGHTS

In April, we hosted the first Telescope Viewing Night using PULSE-A's optical ground station telescope. The event was held for undergraduate students in a course offered by UChicago's Department of Astronomy and Astrophysics. While we aimed to host several successive Viewing Nights for visiting high school students over the summer, the events' logistics proved unresolvable due to the long daylight hours conflicting with students' curfews. With

shorter daylight hours this fall, we plan to hold several Viewing Nights in the upcoming quarter. Our next Viewing Night will be held in late October and will use a new telescope received from a private donor. This telescope can be used in a hand-held position or on a mount, and its smaller size compared to the optical ground station's telescope makes it far more accessible for events.

F. UPCOMING OUTREACH PLANS

We have many other upcoming outreach initiatives, planned and staffed by the PULSE-A Team's dedicated Outreach Department. The department's current goal is to coordinate at least one new outreach initiative per month in conjunction with the UChicago Space Program, thus promoting space education in the Chicago area. More events will be held in months where UChicago's academic year is not interrupted by a scheduled break.

We are also in the process of partnering with minority-serving STEM organizations on campus. As partners, we are actively planning to host both speakers and social events designed to encourage underrepresented involvement in the areas of science, engineering, and industry that the UChicago Space Program and PULSE-A represent.

Stay tuned for additional outreach developments in the near future!

III. PUBLICITY

A. SMALLSAT 2024

In August, 3 PULSE-A team members attended the 38th Annual Small Satellite Conference at Utah State University. They heard presentations on emerging developments in small satellite technology from other universities, industry, and the private sector. After speaking with other CubeSat laboratory research teams, we eagerly anticipate future partnerships. We also plan to submit an abstract to the SmallSat 2025 Conference on PULSE-A's design.

Right: Zane Ebel, Logan Hanssler, Robert Pitu (left to right) at the SmallSat 2024 Opening Social.
Credit: Logan Hanssler.

B. UPCOMING PRESENTATIONS

6 members of the UChicago Space Program are attending SpaceVision 2024 at the University of Denver this October. We are excited to announce that 2 PULSE-A team members will present the mission at the conference alongside other projects that won the SEDS-USA Space For All Challenge!

Additionally, 2 members are submitting an abstract on the PULSE-A mission to NewSpace Chicago's 2024 Student Space Congress. If the abstract is accepted, then the students will give a presentation at the virtual conference on November 7th or 8th.

Upper Right: SpaceVision 2024 logo. *Credit: SpaceVision Instagram: https://www.instagram.com/sedsspacevision/.*
Lower Right: NewSpace Chicago Student Space Congress 2024 logo.*Credit: NewSpace Chicago website, Student Space Congress page: http://www.newspacechicago.com/student-space-congress/.*

IV. FUNDING UPDATES

A. NEW PARTNERS

We have recently entered into a partnership with Cadence Design Systems! They have provided the PULSE-A Team with a host of EDA software for the design and development of our electronics. They will also provide an electronics critical design review at the team's request. We are currently in the process of finalizing this partnership; once we are able to do so, we will begin using Cadence Allegro for circuit design and piloting the use of Cadence InspectAR for hardware analysis. We appreciate the generous support and are grateful for Cadence to join us as a sponsor.

Right: Cadence Design Systems logo. *Credit: Cadence Design Systems website, Media Resources page: https://www.cadence.com/en_US/home/company/newsroom/media-resources.html/.*

B. DONATIONS & SPONSORSHIP PACKAGES

The PULSE-A Team has received $500 in private donations this quarter! These contributions will be used for hardware prototyping costs. In an effort to support additional donors and sponsors, the University of Chicago Space Program has developed sponsorship packages for PULSE-A and other student projects. We are currently creating a prospectus containing information on the PULSE-A mission and our desired partnership opportunities. We expect the prospectus to be completed by the end of October.

If you are interested in receiving the PULSE-A prospectus or other information on partnership opportunities, please contact Aishani Mohan, Logan Hanssler, or James Passmore.

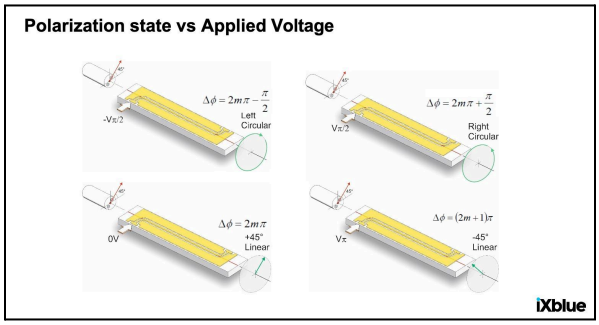
C. BUDGET UPDATE

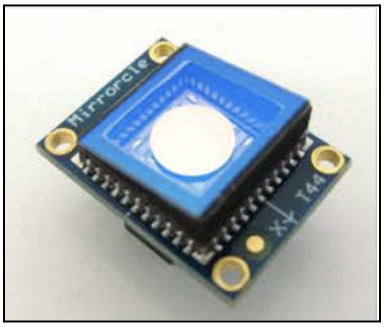
PULSE-A's procurement budget has increased to $162,098.07, largely due to the form factor increase from 2U to 3U and more accurate quotes received from manufacturers. We have also accounted for a more comprehensive testing budget, amounting to $15,000.00. Including a 20% contingency applied to the combined procurement and testing budget, the project's full budget is $212,517.68.

V. ENGINEERING UPDATES

A. OPTICAL PAYLOAD

The Payload Department completed trade studies of three critical components this past quarter. As a result, the Fast Steering Mirror (FSM), Erbium-Doped Fiber Amplifier (EDFA), and quadrant photodiode models will soon be procured. At the moment, the primary remaining component awaiting selection is the phase modulator, of which there are four potential options undergoing trade study.

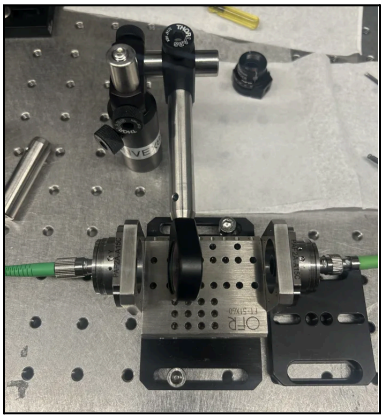




Left: An iXblue schematic of their polarization switch creating four different polarizations from different input voltages. *Credit: iXblue.*
Right: A Mirrorcle FSM. *Credit: Mirrorcle.*

The Payload Department's FPGA Engineer has procured a small, prototype FPGA and programmed it to output square waves—as required by the phase modulator—at a speed of 10 MHz. Further testing with an acousto-optic modulator is underway.

Prior to integrating optical payload components into the CubeSat frame, various components and subsystems will be tested individually on the optics bench for isolated verification and ease of troubleshooting. Much of the lab equipment needed for testing has been procured, low-loss fiber coupling has been achieved, and data collection is set to begin to test the behavior of polarization-maintaining fiber under a multitude of expected conditions. Following this, other tests include: pointing and detection testing with the quadrant photodiode and FSM, transmission testing with the modulator and FPGA, and polarization maintenance testing with fibers, collimators, and lenses.



Above Right: Fiber-free space-fiber polarization maintenance testing setup. *Credit: Maya S. McDaniel*

A team has been established with members from the Payload and Ground subteams dedicated to finalizing pointing and link budget calculations. These are being programmed into an accessible format such that they can be easily updated as components and layouts are adjusted.

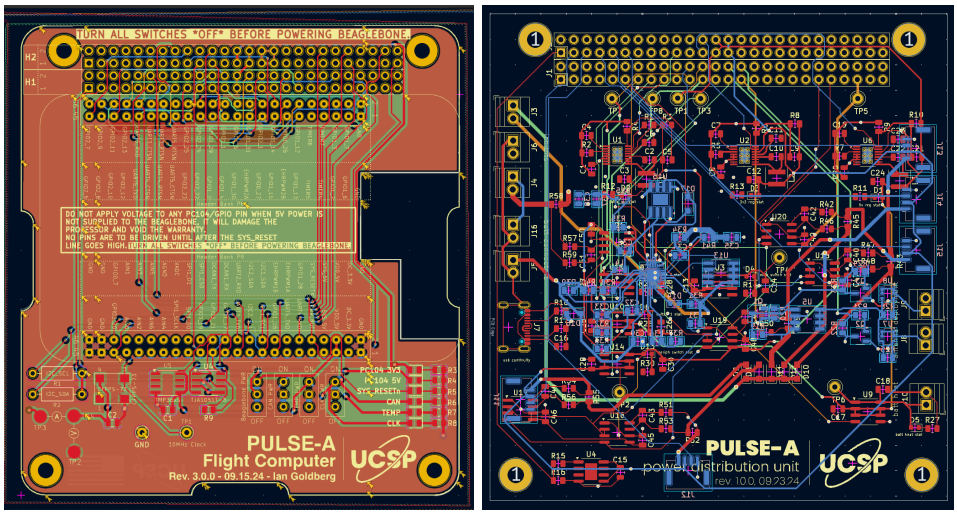
B. AVIONICS HARDWARE & SOFTWARE

The Avionics hardware subteam has made significant advances in preliminary component design within the last quarter.

We have designed and fabricated a flight computer based on the BeagleBone Black platform with integrated peripherals. The 4th revision (currently under development) includes a watchdog processor, real-time clock, digital controls for all peripherals, and voltage protection buffers for the processor to prevent damage in the case of an OBC reset.

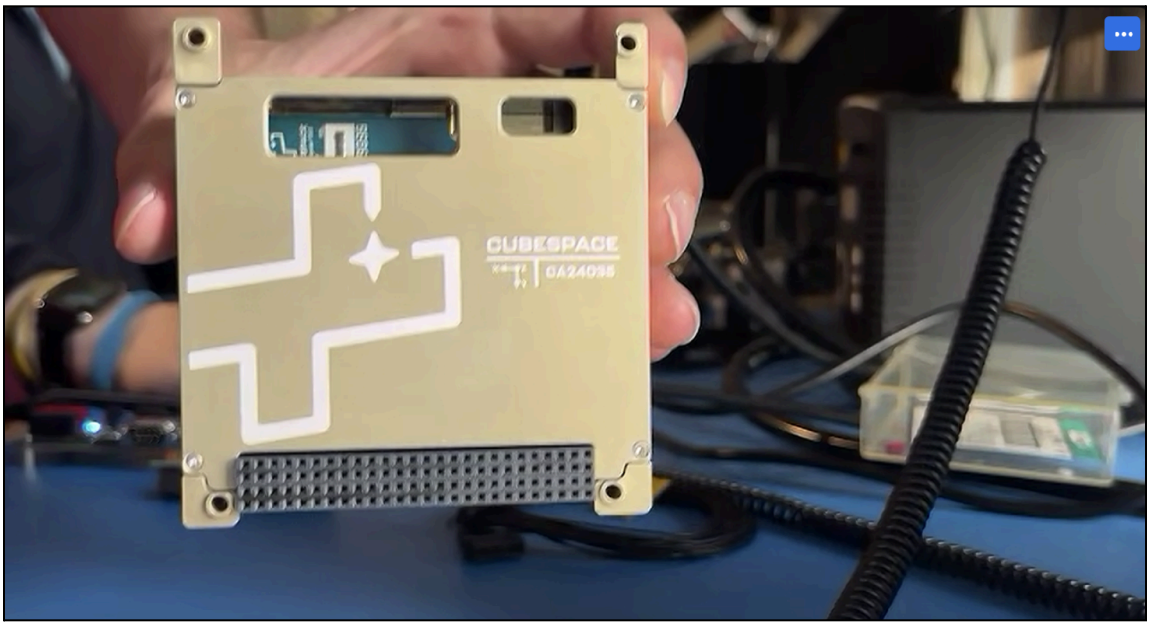
The team has also designed the first revision of the power distribution unit based on Stanford's PyCubed and the Hawai'i Space Flight Laboratory's Artemis kits, suited to our Payload's power requirements. Revision 1.0.0 will undergo its initial testing phase early in Q4, with 2.0 to follow soon after.

Revision 1.0.0 of the Battery Pack has been designed and fabricated, with revision 2.0.0 soon to follow to address concerns with the quality of the initial design.



Above Left: OBC revision 3.0.0. *Credit: Ian Goldberg.*
Above Right: PDU revision 1.0.0. *Credit: Graydon Schulze-Kalt.*

The software team was able to get their hands on the Attitude Determination and Control System (ADCS) development model from CubeSpace in early July!



Above: ADCS Development Model upon receipt in July. *Credit: Graydon Schulze-Kalt.*

The development model has enabled the team to gain initial familiarity with the CubeSpace platform as we prepare to write PULSE-A's flight software. We are currently working with CubeSpace to acquire the D2S2 simulator, which will allow us to run Hardware/Software in

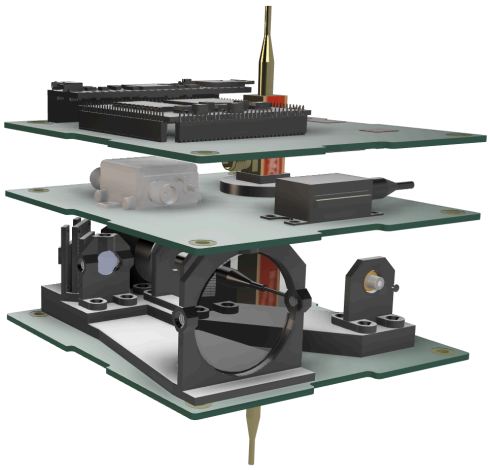
the loop testing with the ADCS development model. The hardware allows us to interface our Avionics stack directly with a mock-ADCS in a flat-sat environment.

The software team also held a workshop with mentor Dave McComas on the cFS software framework. Moving forward, the team will continue to hold these workshops to better understand how to write effective flight software.

C. STRUCTURES & MANUFACTURING

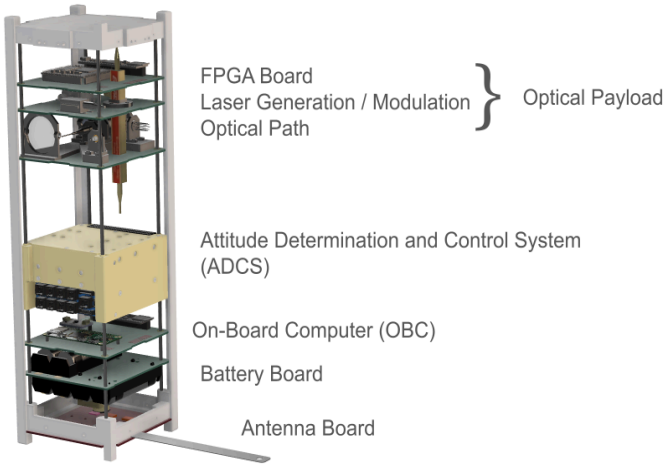
Over the course of this quarter, the Structures and Manufacturing Department continued the development of both the scientific payload's mounting hardware and the CubeSat bus frame.

In conjunction with the optical payload's team selection of components, we created CAD models for the different layouts for polarization generation, ultimately deciding on one using an EDFA. Ultimately, the size of the phase modulator, alongside the additional space needed to accommodate fiber bend radii and splicing ultimately made us, as a team, decide on the expansion of our satellite from 2U to 3U. Additionally, we are considering nadir-pointing of our optical payload as the next step in our design iteration, again motivated by the dimensions of the phase modulator as well as passive pointing techniques.



Right: Current CAD model of the optical payload, with FPGA board (Top), seed laser and amplification (Middle), optical path (Bottom). Phase Modulator embedded vertically through boards. *Credit: Robert Pitu.*

The switch to 3U required a quick redesign of the bus frame and of the component placement onto the rails. Thus, both mass and MOI estimates had to be updated, alongside new dimensions. All changes were then communicated to the other departments to facilitate efficient testing of effects in orbit such as slew rates.



Right: Current CAD model of Bus layout, with panels and front corner rail removed for better visibility.
Credit: Robert Pitu

Our department has continued to learn more about the thermal requirements that the mechanical design must satisfy. Online resources are invaluable toward this task, and our next steps consist of expanding our Thermal Analysis and Simulation subdivision, which will primarily use Thermal Desktop to validate our design and inform required changes.

Lastly, with two members of our department having attended the SmallSat Conference in early August, we expanded our search for adequate industry partners for high-precision manufacturing of optical components. We will have updates on potential partnerships soon!

D. OPTICAL & RF GROUND STATION

Optical Ground Station (OGS):

Throughout this past quarter, the OGS engineers focused on developing the telescope's tracking software and FPGA communication protocols. Our engineers managed to command the telescope through one of our laboratory computers, and we are currently working on directing the telescope to move along a calculated trajectory simulating the pass of a satellite. With our electronics modulation and detection setup ready in the lab, we have been working on establishing a communication protocol to deliver the digitized data to a script for data rate and error analysis.

RF Ground Station (RFGS):

RFGS development has focused on setting quantitative requirements for our RF communications subsystems following PULSE-A's System Requirements Review in June. As such, the RFGS team collaborated with the Avionics Department to choose a suitable communications subsystem for the satellite and is using it to set requirements for the RFGS. This trade study has narrowed down our options to the Gomspace AX100 or the LTM-1 module by AMSAT.

To successfully operate with RF communications, PULSE-A must obtain FCC licensing, which requires frequency coordination with the IARU. In Q3, the team began preparing to request frequency coordination with the IARU, which is expected to happen in the next few months. Allowing for a year to obtain our FCC license, we predict having FCC licensing with a sufficient margin before our handoff to NASA.

E. SYSTEMS ENGINEERING & INTEGRATION

Since PULSE-A's successful Systems Requirements Review, the Systems Department has been diligently updating the mission's system requirements according to the feedback we received. We are continually taking input from other departments' mathematical predictions and simulation results to update quantities dictating performance requirements. We are also

planning the method and timeline for ensuring each requirement is met; we expect to have this plan completed alongside PULSE-A's Systems Engineering Management Plan (SEMP) by the Preliminary Design Review.

We are tracking risks to the mission throughout development, and we are working to form mitigation plans with engineers from other departments. Additionally, we are drafting a comprehensive plan for PULSE-A's Assembly, Integration, and Test Phase. We are looking into partnerships with assembly and test facilities that would allow us to carry out construction and analyses with acceptable risks and minimal expenditures.

VI. Q4 OUTLOOK

We expect the last quarter of 2024 to be a significant time for the team. As we transition back into working together on campus and in-lab, we hope to establish a solid pace for our development and uphold it as best we can through our PDR this coming November. At the same time, we are excited to welcome new students at UChicago both to the UChicago Space Program and to the PULSE-A Team. Our fall recruitment schedule should have us onboarding new members between the 3rd and 4th weeks of the quarter. We aim to bring on a group of mostly underclassmen for the team's longevity, and maintaining a diverse student base for the student organization is one of our top priorities. We are taking additional precautions to ensure both stable attendance and a stable future for the team in general.

Besides design work, the new school year is also a principal time for renewing our commitment to effective university and community outreach. We are prioritizing the use of PULSE-A as a platform to involve as many communities as possible in space science and development. We are continuing to develop partnerships with minority serving organizations on and near campus, and we are planning on hosting speakers and events to promote underrepresented communities' involvement in the areas of space science and technology relevant to PULSE-A and the UChicago Space Program.

Lastly, assuming successful completion of our PDR, the project will begin its transition from our Preliminary Design Phase to the Final Design Phase in December. Accomplishing this next step will mean we have outlined how we expect our designs to meet all necessary systems requirements (as finalized through our System Requirements Review), and we will turn toward experimentation and iteration to confirm our technical capabilities.

We hope to update you all more on this front in the next quarterly report!

— The PULSE-A Team