PULSE-A

2024 Q1-Q2 Progress Report

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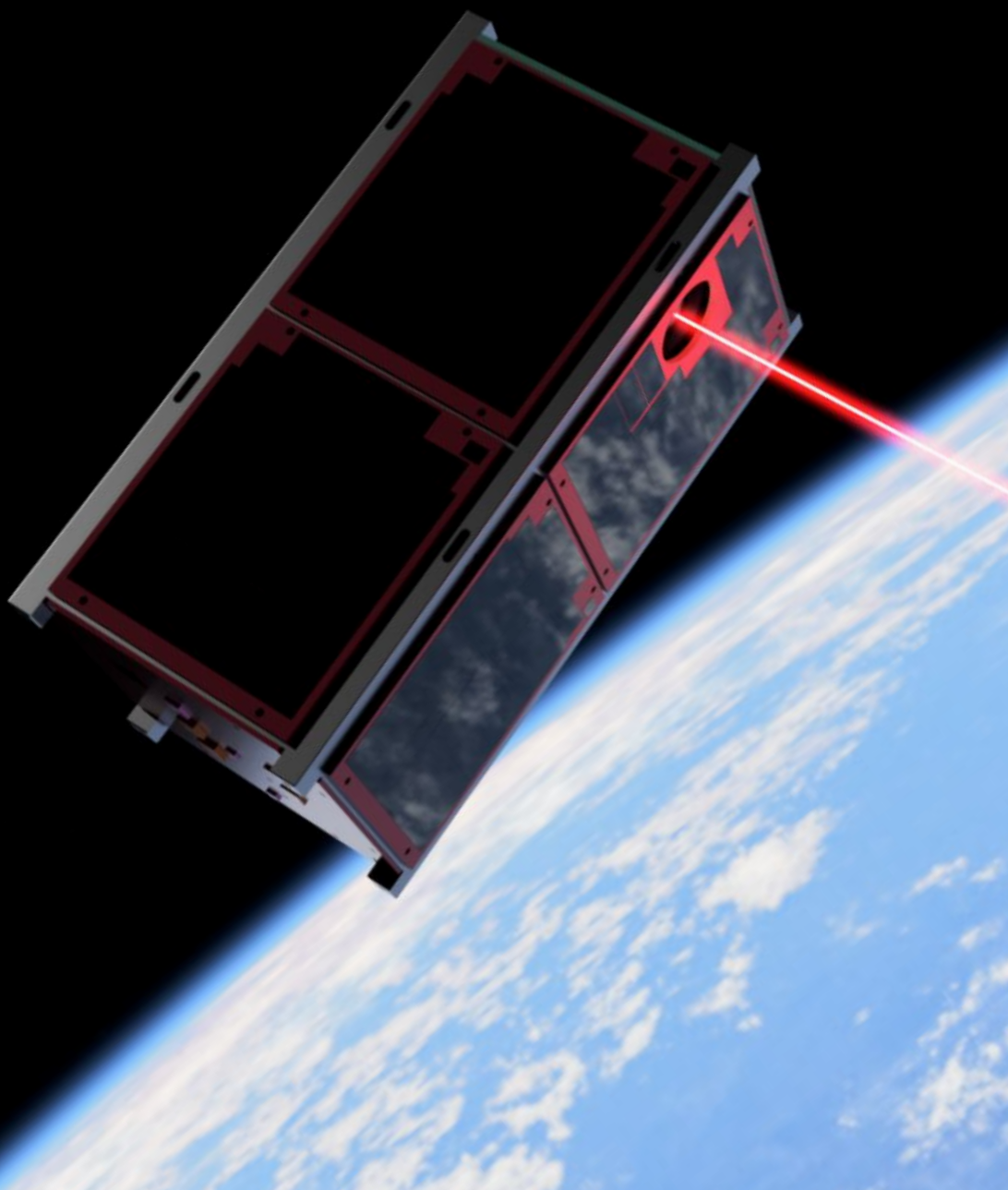

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Project Mission

The principal mission objective of the PULSE-A CubeSat is to demonstrate satellite-to-ground laser communications using circular polarization modulation at a rate of 10 Mbps, thereby developing and testing key systems that will be used in a later space-to-ground Quantum Key Distribution experiment, PULSE-Q.

If you would like to receive a 1-pager on the mission, please contact Seth Knights.

2023 Recap

January – June: Concept Selection
June – September: Early concept development & design meetings
September – November: Proposal writing & early funding acquisition round
November 17th: NASA CubeSat Launch Initiative proposal submission

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I. NASA CSLI SELECTION

The PULSE-A team is proud to announce that the National Aeronautics and Space Administration (NASA) accepted our proposal for Call 15 of their annual CubeSat Launch Initiative (CSLI) in March 2024.

With this selection, NASA has granted PULSE-A a launch opportunity no earlier than 2026, covering integration and launch costs up to $300k. This means that once the PULSE-A team has successfully constructed and tested the satellite, the costs and logistics of launch will be handled by NASA.

Our mission marks an important milestone for engineering at UChicago, as PULSE-A will be the first satellite developed, built, and launched by undergraduates at the university. As part of our acceptance, the PULSE-A team also provided a project update to NASA, including important work on specifications for our to-be-determined launch provider.

As a part of the grant, the team has signed a Cooperative Research and Development Agreement with NASA. This requires PULSE-A to submit progress reports, similar to this one, to NASA and to update them on our work. It also dictates certain development milestones, such as those described in the System Requirements Review and Preliminary Design Review, which are discussed in greater detail later in the report.

For more information on our acceptance, view the NASA press release for our selection.

II. FUNDING & OUTREACH

A. SEDS-USA GRANT

In early Q1, the PULSE-A team submitted to Students for the Exploration and Development of Space–USA's "Space for All" challenge, sponsored by Starfield and Xbox.

We are excited to share that PULSE-A won second place in the challenge, earning $7.5k towards R&D for the project. As part of the challenge, UCSP will further our outreach efforts on the south side of Chicago, using our telescope to hold observation nights and host space-related events.

Read more about the Space for All challenge here.

B. ANNUAL ALLOCATIONS

As a Registered Student Organization (RSO) at UChicago, UCSP submits a request annually to the Center for Leadership and Involvement (CLI) for funding. After submitting our proposal and presenting it to a panel, UCSP won $8k in funding for the PULSE-A project and separate funds for the rest of the organization.

C. NEW PARTNERS

Swabian Instruments kindly offered us their Time Tagger 20 hardware to test our ground station hardware. Information on our new testing campaign is included in section IV.

Read more about the device and Swabian Instruments here.

D. BUDGET UPDATES

PULSE-A's budget is currently $144,610.03, including a 20% contingency, an increase of approximately 100% since PULSE-A's CSLI submission. The budget includes both items that have already been bought and items that will be needed in the future, all scheduled for purchase between Q3 2024 and Q2 2025.

PULSE-A's budget has increased dramatically to better account for a rigorous testing regime and in-space redundancy:

- Full flatsat and engineering model have now been accounted for in the budget.

- Higher quality space-rated solar panels, GPS, radio, etc.
- Greater accuracy in component pricing, including development model costs.

$72,500 in funds have already been obtained, with the remaining being acquired through grants and additional fundraising. Our current aim is to close the budget, as it stands, by the end of 2024.

UCSP is presently eligible for multiple grants offered by the National Science Foundation (NSF) and other STEM-based research and education programs, such as the Astronomy and Astrophysics Research Grants, and the Experiential Learning for Emerging and Novel Technologies (ExLENT) program.

PULSE-A's Department of Funding and Outreach is focused on leveraging the University of Chicago's alumni network and other contacts to develop and maintain relationships with external and internal contacts.

E. CLUB REBRANDING

SEDS-UChicago has rebranded to the UChicago Space Program (UCSP). We decided to transition to UCSP in light of the recent achievements of PULSE-A and our upcoming appearance at the Spaceport America Cup.

Our goal with the branding change is to bring more recognition to the team both inside and outside the university, better reflecting the legitimacy of our program.

We are, of course, still a chapter of the national SEDS organization, so if you still see our classic phoenix SEDS logo, that's why!

Right: UCSP's new logo! *Credit: Graydon Schulze-Kalt*

F. RESEARCH SYMPOSIUM

In April, two groups of three PULSE-A members presented our research at the 2024 Undergraduate Research Symposium held by the UChicago College Center for Research and Fellowships.

The first group, consisting of Seth Knights, Vincent Redwine, and Graydon Schulze-Kalt, presented on the Optical Payload and the mission ConOps. (See full poster)

The second group, consisting of Logan Hanssler, Juan Prieto, and Alex Dennis, presented on the Optical Ground Station.
(See full poster)

G. PUBLICITY

Thanks to a recent article by the Pritzker School of Molecular Engineering on PULSE-A, the project has now been featured in several notable Chicago-area publications, such as the Sun-Times, WGN, WBBM, and ABC7 Chicago.

PULSE-A was also featured several times on UChicago social media, dramatically increasing our LinkedIn and Instagram follower counts

Right: Members present at the Undergraduate Research Symposium. *Credit: Seth Knights.*

III. NEW SPACES

A. THE CUBESAT LABORATORY

Thanks to the generosity of the UChicago Department of Physics, the PULSE-A team is thrilled to share that we now have an official CubeSat Laboratory workspace in Kersten Physics Teaching Center 318.

The CubeSat Laboratory is the first laboratory managed entirely by undergraduates at the University of Chicago. This represents yet another huge milestone for UCSP and the University in bringing more opportunities to undergraduates.

We hope that this space will allow us to develop critical Avionics and Ground Station hardware and conduct flatsat testing. This space will also serve as our home mission control in Chicago during the mission operations phase post-launch.

Left: A rendering of our eventual laboratory setup. *Credit: Graydon Schulze-Kalt*

UCSP is currently in the process of preparing the space for summer usage.

Above: Our current progress in the lab. *Credit: Graydon Schulze-Kalt*

B. ZHONG LAB

The PULSE-A Payload department has also been utilizing Zhong Lab in LL2 of Eckhardt Research Center for the development and testing of our payload system, thanks to our advisor Professor Tian Zhong. As part of this arrangement, PULSE-A is also using loaned optical hardware from the lab and will have the opportunity to use lab funds to help acquire equipment useful to the lab's own research as well as ours.

Read more about our development campaign in section IV.

IV. PROJECT DEVELOPMENTS

A. RECRUITMENT

In early Q1, the PULSE-A leadership team conducted a major recruitment cycle, bringing our membership from roughly 10 members during the proposal phase to around 60 team members in January.

Applicants had to submit a short write-up about their qualifications and interests. Top choices were then interviewed. Applicants were selected for a variety of reasons, ranging from passion to experience.

New team members were placed into either the funding division or one of five new engineering subteams: Optical Payload, Avionics & Software, Structures, Ground Station, and Systems Integration & Test.

B. NEW MENTOR

Due to the lack of Aerospace Engineering faculty and resources at UChicago, we have had to look externally for guidance on the engineering aspects of the project. Thankfully, Dr. Michael Lembeck of the University of Illinois at Urbana-Champaign (UIUC) has generously offered his time as a mentor for the PULSE-A project.

Dr. Lembeck is a Clinical Associate Professor of Aerospace Engineering at UIUC and the head of the Laboratory for Advanced Space Sciences at Illinois (LASSI). Dr. Lembeck has led and worked on multiple government and commercial spaceflight programs, including JPL's Galileo Jupiter Orbiter, Space Industries Inc.'s Wake Shield Facility, Orbital Sciences' OrbView/Warfighter commercial remote sensing programs, and the Northrop/Boeing CEV and Boeing commercial crew programs. As the Requirements Division Director for the Exploration Systems Mission Directorate at NASA Headquarters, Dr. Lembeck managed the original development of requirements for the Constellation/Orion program.

Dr. Lembeck was an invaluable asset in the development of our initial Systems Requirements and brings his many years of experience to support PULSE-A as an advisor to our engineering and development.

LASSI also has several testing capabilities which have all been made available for the PULSE-A project, courtesy of Dr. Lembeck. These include Thermal Vacuum testing, Solar panel testing, Helmholtz cages, and more.

More info on LASSI can be found here.

Above Right: Dr. Lembeck. *Courtesy of LASSI.*

C. NEW CONNECTIONS

PULSE-A has also established a connection with NASA Jet Propulsion Laboratory's Avionics System Engineering group (348A), led by Technical Group Supervisor Arby Argueta. Arby and

the Next Generation Avionics team of 348A have years of experience with Avionics systems, working on Psyche, Europa Clipper, and Mars Sample Return, among other missions.

The PULSE-A Avionics team engages in active conversation with the group, who are currently reviewing our System Requirements. Section 348 (including other groups) develops F', an embedded software framework for spaceflight used on the Ingenuity Mars helicopter, one of several frameworks the PULSE-A software team is considering. We thank Arby and his team for the wonderful advice they have given us so far.

Several members of the Avionics flight software (FSW) subteam also connected with David McComas, a former flight software engineer from NASA Goddard of 34 years. Dave now works as an independent educator helping provide open-source products built around Goddard's core Flight System (cFS).

The PULSE-A FSW subteam is strongly considering using cFS as our primary software framework on the spacecraft. The subteam has already met with Dave several times, including a preliminary cFS tutorial session. In the future, Dave will be able to support the FSW team as software development begins should questions arise.

D. SYSTEM REQUIREMENTS REVIEW

The PULSE-A team spent several months developing our System Requirements for the System Requirements Review (SRR), which was held in mid-June. The SRR was the team's first major review post-submission to CSLI and marks a significant milestone in the development of PULSE-A.

After receiving feedback from our reviewers, the PULSE-A team has made modifications to the requirements. With the completion of the SRR, PULSE-A has officially entered the preliminary design phase in preparation for the Preliminary Design Review in Fall 2024.

The slides from our SRR are now published to our GitHub, which can be viewed here.

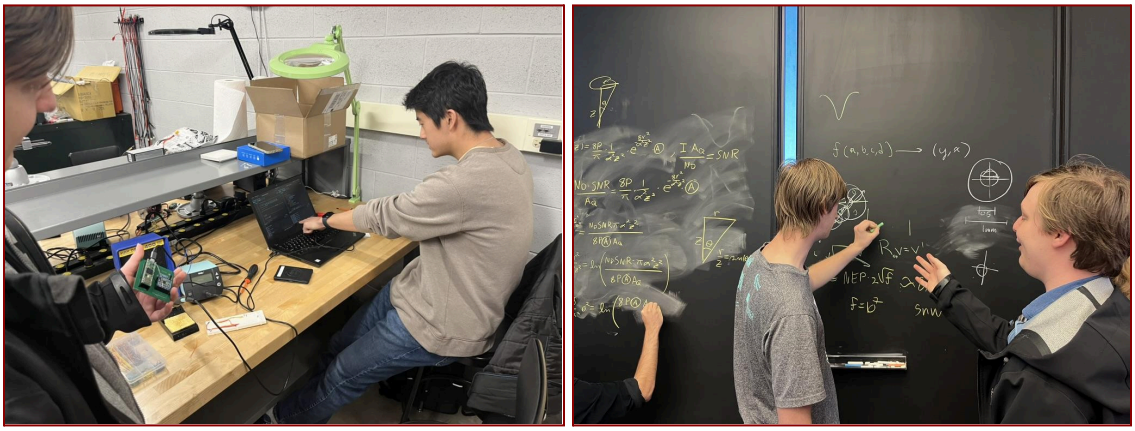
V. ENGINEERING UPDATES

The PULSE-A engineering division comprises several departments: Avionics, Payload, Ground Station, and Systems Integration. Each is responsible for a different section of the mission, including many individual requirements and subsystems. For our first quarterly report, we would like to introduce the responsibilities of each department and update readers on their current development status.

Having recently completed our System Requirements Review, we are now focused on preparing for the much more engineering-focused Preliminary Design Review, currently planned for October 2024.

A. AVIONICS HARDWARE & SOFTWARE

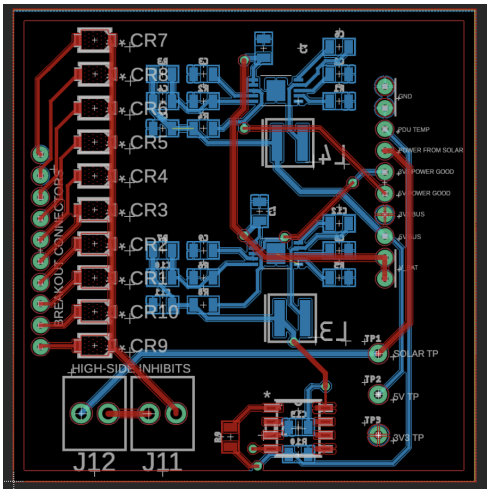
Avionics is responsible for the development of all flight hardware and software, as well as all processes relating to the operation of the satellite in space. This mainly comprises any and all onboard electrical, power, computational, and communications capabilities.



Above: Avionics department members get to work! *Credit: Graydon Schulze-Kalt*

In Q1, the Avionics hardware subteam selected our On Board Computer (OBC), the Beaglebone Black, with the guidance of Dr. Lembeck. Since then, the team has ordered several of the boards for the FSW team to begin installing both F' and cFS to compare the frameworks. Currently, the hardware team has been adapting the Beagleboard to fit into the CubeSat form factor.

The hardware subteam has also been developing the Electrical Power System (EPS) by adapting boards from the University of Hawaii's Artemis and Stanford's PyCubed. Several boards have been completed, fabricated, and delivered, and will undergo testing as soon as possible. Additionally, the photodiode amplification array for the Payload has been designed and fabricated, with testing beginning when a testbed has been completed.



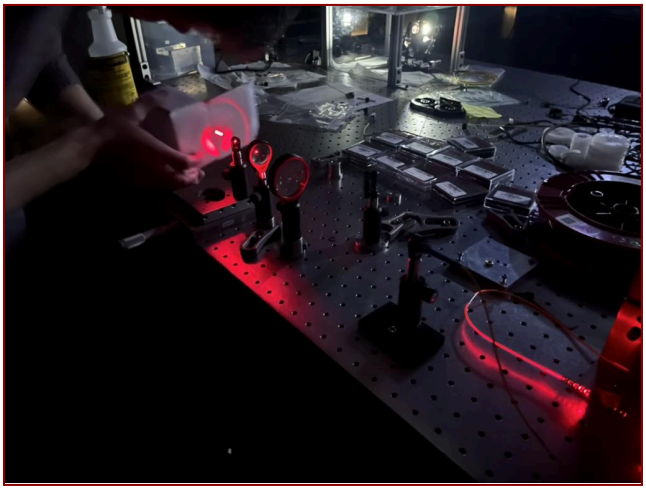
The FSW subteam is currently frameworking the Pointing, Acquisition, and Tracking sequence and developing algorithms for detecting the ground station

beacon. A development model for the Attitude Determination and Control System (ADCS) has been procured and is scheduled for imminent delivery. The FSW is planning on developing simulation software based around the ADCS dev kit.

Above Right: An example of Avionics' power system development work. *Credit: Graydon Schulze-Kalt*

B. OPTICAL PAYLOAD

Payload is responsible for the design and development of the optical payload. This represents the largest portion of our mission and is the subsystem that will facilitate laser communication with the ground. The department focuses on opto-mechanical engineering, including simulation and analysis of our designs. With Ground Station, the department is also working on designing experiments to help grow the team's experience and give us methods of validating and demonstrating our abilities.



Currently, the team is working on finalizing major aspects of our design. Simultaneously, we have begun preparing laboratory setups for validating the physical properties of the optical system (think focal points, collimation, field of view, etc.), taking them out of simulation and into the real world. So far, we have been successful in working with Structures to establish our first physical prototype of the lens system. During the coming months of summer, we are excited to test the nature of transmitting circularly polarized light through fiber (in the hope of helping us choose the best type for our mission) and to plan out a long-distance transmit and receive test, to see whether the team can successfully conduct optical communications.

Above Right: Payload begins arranging their optical setup in Zhong Lab. *Credit: Graydon Schulze-Kalt*

C. GROUND STATION

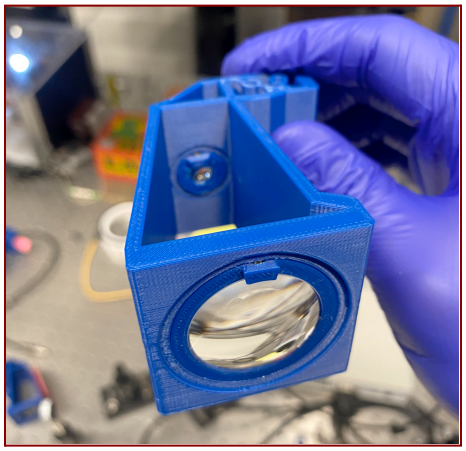
Ground Station is responsible for the optical and radio ground stations. The first will be the receiving end of our optical link, enabling us to collect and decode the data transmitted from the satellite, while the radio ground station will help us manage spacecraft operations and telemetry communication.

Right: Testing our brand new Celestron telescope. *Credit: Seth Knights*

The ground station department procured the telescope, began testing it, and started determining methods and protocols to control it with a feedback loop and tracking software. The FPGA was procured and has achieved tagging rates higher than 10 MHz in simulations. Many design choices were revisited, including the APD choice, which led to a large redesign of the detection system to lower the noise to achieve an acceptable SNR. A preliminary RF link budget was completed.

D. STRUCTURES & MANUFACTURING

Structures & Manufacturing is in charge of developing mounts for and integrating all hardware components of both the Bus and optical payload, including framing, lenses and optical elements, PCBs, solar panels, and access ports. The main mechanical constraints of our satellite are size constraints and the resistance to 10 g's of acceleration, set by the launch provider. In addition to the design of components, we are also responsible for their manufacturing, either in-house (especially for prototypes) or through external service providers across the US.



In Q1, Structures was responsible for selecting the Bus frame for our satellite, ultimately settling on Gran Systems' 2U frame. In addition to that, we laid the groundwork for the optomechanical mounting strategies we would eventually end up developing, as well as coupling all other components of the bus in a cohesive CAD file, from which we were able to extract rough mass estimates and Moment of Inertia values, both used in progress reports. We also collaborated with the ground station department to help in its design, especially for the OGS (Optical Ground Station).

In Q2, our department continued the development of the satellite payload, with the added step of 3D printing components to help validate test fit, tolerancing, and alignment of the system. We are currently trying to add thermal and vibration simulation within our design loop. On the Bus side, we are actively working with the avionics department to figure out the placement of PCBs and access ports.

Above Right: A 3D printed iteration of the payload optical mounting. *Credit: Robert Pitu*

E. SYSTEMS INTEGRATION & TEST

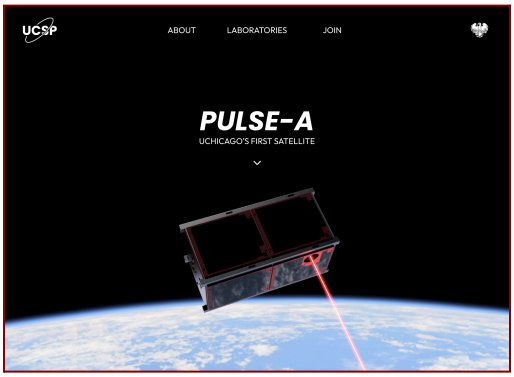
Systems Integration and Test is responsible for managing vital interfaces between other subteams, and will soon manage the organization and planning of any and all testing. The department also helps to keep everyone on top of their requirements to help ensure we have a successful mission.

In Q2, the department played a pivotal role in preparing the team for our SRR this past June, not only helping to define the important interfaces for the mission (where requirements are often most necessary) but also taking charge of the assembly, integration, and testing requirements which will only become increasingly necessary as the project progresses. To help with this changing need, the department has also been working to reorganize itself over the summer, with the goal of being better prepared to facilitate testing regimes and to ensure other department interfaces are attended to with the proper care they deserve.

VI. PROJECT GOALS

A. WEBSITE

UCSP recently onboarded a new webmaster who has begun building a new website for the RSO and PULSE-A. The PULSE-A website, once built, will allow for further outreach and act as some much needed promotion of the project to larger audiences.



Right: A first look at the main page of our website. *Credit: Seth Knights*

B. SPACEVISION

SEDS-USA is hosting its annual SpaceVision conference this November in Denver, CO. UCSP is currently planning to send nine team members, supported by UChicago's Center for Leadership and Involvement.

PULSE-A will use this opportunity to network with other student organizations and industry professionals. Additionally, as part of the 'Space for All' grant, we will present a technical project update at the conference with a demo of any engineering hardware assembled by that point.

C. SMALLSAT

PULSE-A is sending several members of leadership to the SmallSat conference from August 3-8th in Utah. Individual team members are currently paying for registration, hotel, and flight fees until further funding is acquired.

This opportunity will allow us to connect with manufacturers and industry leaders, growing the support network of PULSE-A.

D. Q3 ENGINEERING GOALS

The biggest challenge and driving force of Q3 will be preparing for our preliminary design review (currently scheduled for October 2024). This is a major step in the development plan, where we will be forced to present arguments for each and every design decision. The goal of such an exercise, especially for our team, will be to receive expert feedback on all aspects of our CubeSat development.

While we hope to present compelling reasons for our decisions, including evidence collected during our Q3 experimentation, finding the inevitable flaws or overlooked possibilities that are discovered during this review process will be vital. Given we are a new team, and at a school that lacks engineering resources in the relevant fields, constant feedback is key to creating an iterative environment in which the team can learn. If we can execute this correctly, then we know we are trying our best to ensure mission success.

– Seth Knights
PULSE-A Chief Engineer