PULSE-A

2024 Q4 Progress Report

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PROJECT SPONSORS & PARTNERS

TABLE OF CONTENTS

PROJECT MISSION

PULSE-A is the first satellite to be designed entirely by undergraduate students at the University of Chicago. The 3U CubeSat's primary mission objective is to demonstrate space-to-ground circular polarization-modulated optical communications at a data rate of 10-25 Mbps. PULSE-A's secondary objective is to act as a risk reduction mission for the future quantum key distribution demonstrator, PULSE-Q. PULSE-A's payload, optical ground station, and pointing, acquisition, and tracking sequence will be repurposed in PULSE-Q following minimal modifications.

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

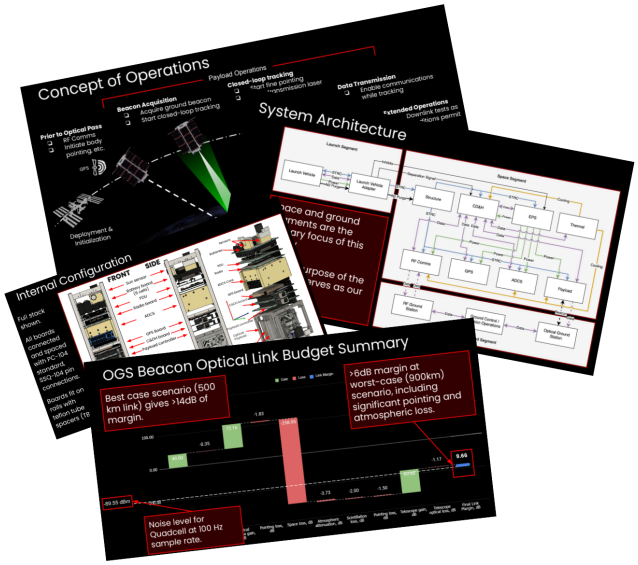
2024 Q3 RECAP

- July: Began preliminary design; Hosted 3D printing workshop for high schoolers
- August: PULSE-A guest speaker at Guatemala Women in STEM & high school robotics class
- September: Began creating materials for November's Preliminary Design Review

I. PRELIMINARY DESIGN REVIEW

The PULSE-A Team's hard work since June's System Requirements Review has culminated in this quarter's Preliminary Design Review (PDR)! On November 24th, 9 members of PULSE-A's leadership presented our preliminary design to a panel of in-person and virtual professionals. The panel encompassed diverse experience across engineering and physics disciplines from both academia and industry. Throughout the 4-hour review, we discussed component choices, system architecture, system requirements, verification and validation plans, technical documentation, and team organization. At the conclusion of the review, it was deemed successful!

PULSE-A's successful PDR represents a massive achievement in UCSP's history. The team has made significant technical, administrative, and organizational progress since our proposal to NASA's CubeSat Launch Initiative was accepted. We would like to sincerely thank everyone who has supported the project in its journey to achieving this milestone! If you would be interested in reading our PDR slide deck, we have made it available publicly on [PULSE-A's GitHub repository].



Above: Four slides taken from PULSE-A's PDR.
Credit: PULSE-A Team

Our PDR panel has provided extremely useful feedback on PULSE-A's design. As of December 2024, we have begun implementing their feedback and moving forward into the Detailed Design Phase of development. You can find more information on our engineering progress throughout Q4 in Section III.

II. OUTREACH & PUBLICITY

A. RECRUITING

In October, the PULSE-A Team completed a recruiting cycle to fill open positions across all of the team's departments. We received a total of 54 applications from interested students! After carefully reviewing the candidates, we decided to onboard 24 members and 2 student advisors. This brings our team size to 66 undergraduate members and 9 student advisors. Since the new members joined during preparation for the PDR, they have already made plenty of valuable contributions to our development!

B. SPACEVISION 2024

On October 3rd through 5th, six members of the PULSE-A Team attended the 2024 SpaceVision Conference hosted by SEDS-USA at the University of Denver. Our members were able to network with space industry professionals and students at other universities' SEDS chapters. As part of the PULSE-A Team's award for winning second place in SEDS-USA's Space For All Challenge, Project Director Logan Hanssler and Chief Engineer Seth Knights had the opportunity to present a slideshow on the PULSE-A mission to the conference's attendees! Additionally, Logan Hanssler received SEDS-USA's Jeff Bezos Award, an award given to one student each year for being an innovative leader in their SEDS chapter and the space industry. This award included a $500 prize, which was donated to the PULSE-A Team.

Right: Team members Lucas Glickman, Logan Hanssler, Seth Knights (left to right) at SpaceVision 2024.
Credit: SEDS-USA

C. SOUTH SIDE SCIENCE FESTIVAL

Left: Team members Vidya Suri, Sofia Cavallone, Eliana Schiller (left to right) at UCSP's activity booth.

Right: Team member Sofia Mansilla (left) showing a festival participant (right) a prototype of PULSE-A's payload.

Credit: Eliana Schiller, Juan Prieto

On October 5th, ten members of the PULSE-A Team volunteered at Hyde Park's South Side Science Festival, a hands-on learning event for all ages hosted on UChicago's campus. Elementary, middle, and high school students interested in aerospace engineering and astronomy visited our activity booth! They engaged in a laser-pointing optics demonstration, looked at UCSP's model rockets, and learned about PULSE-A and the broader field of small satellite development.

D. OBSERVATION NIGHT

Left: Observation night participants enjoying the view from Ryerson Laboratory's roof and observing the Chicago skyline with a small telescope.

Right: Observation night participants watching a demonstration of the mechanisms controlling Ryerson Laboratory's primary telescope..

Credit: Eliana Schiller, Vidya Suri

On October 26th, during UChicago's Family Weekend, the PULSE-A Team hosted our first joint-observation night with UChicago's Ryerson Astronomical Society (RAS). This event was primarily held for families of UCSP and RAS members, though it was open to the general public as well. Students and their families joined representatives from both USCP and RAS atop the Ryerson Laboratory, viewing the sunset and Chicago skyline through large telescopes. Participants learned about the various telescopes and received a hands-on introduction to astronomical observation.

E. SPACE SETTLEMENT DESIGN COMPETITION

The PULSE-A Team is hosting a Space Settlement Design Competition (SSDC) at Bennett Day School (BDS) in downtown Chicago in Q1 2025! SSDCs are typically day-long, intensive aerospace industry simulation events for high school students. Students are sorted into teams structured like companies in the engineering industry and given a request for proposal (RFP) modeled after 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. To learn more about SSDCs and our partners at Industry Simulation Education, please visit insimeducation.com.

Above: Space settlement similar to what students design in SSDCs.
Credit: Space Settlement Design Competitions: https://spaceset.org/

In an effort to innovate the SSDC format, we have partnered with two teachers at BDS to run a longer format SSDC in the students' curriculum. BDS is a small school with a class size of about 17 students; their curriculum is entirely project-based. For 7 weeks, all of the school's 11th and 12th grade students will work on a space settlement RFP every school day. This will culminate in the school's Demo Night on March 12th, 2025, where each team will present their designs to their parents and a panel of judges at the competition's conclusion.

Throughout Q4 2024, the PULSE-A Team has been completing preparations for the BDS SSDC. We have defined the competition format and timeline with the teachers, onboarded volunteers, and drafted event materials. This SSDC is the PULSE-A Team's most ambitious outreach initiative yet, and we are very excited to share its results in the Q1 2025 Progress Update!

F. UPCOMING OUTREACH & PUBLICITY PLANS

PULSE-A's dedicated Outreach Department has many other upcoming community outreach initiatives. Our goal is to coordinate at least one new outreach event per month, thus promoting space education in the UChicago community and greater Chicago area.

In 2025, we will begin hosting a UCSP speaker series. Guest speakers will present on topics related to space or engineering in talks open to the public, and they will also spend time discussing with PULSE-A Team members in the design process. We plan to have 2-3 speakers per quarter from a variety of technical backgrounds. These talks will be held in collaboration with relevant student groups on campus, thus increasing the talks' reach within the Chicago community. Aside from the upcoming speaker series, we will host several other community outreach events, such as the BDS SSDC throughout Q1 2025 and the STEAM Carnival in May 2025.

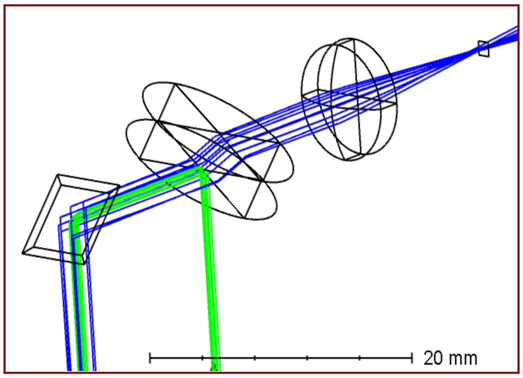
We also have further plans for team publicity in 2025. A number of members will present at UChicago's Undergraduate Research Symposium this April. An oral presentation will be delivered on the PULSE-A mission as a whole, and poster presentations will be given on PULSE-A's payload, bus, optical ground station, RF ground station, systems engineering, and optical simulation work. PULSE-A will also be featured on WHPK, UChicago's student-run radio station, and the College's Undergraduate Research Spotlight in Q1 2025.

III. ENGINEERING UPDATES

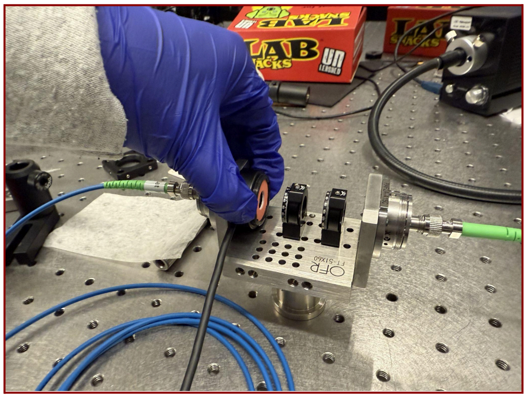
A. OPTICAL PAYLOAD

Progress in Q4 2024 focused on readying for our Preliminary Design Review. We built a Zemax OpticStudio simulation of the optical payload's beacon collection path to verify design choices, determine lens placement tolerances, and investigate various other parameters of the optical system prior to assembling it on the lab bench. Thus far, this simulation has been used to characterize the quadrant photodiode's readout in response to various angles of light introduced through the beam condenser, and further lens tolerance tests are currently underway. Many specific components were also selected prior to the design review, including filters, lenses, our Erbium-doped fiber amplifier, and beacon and transmission lasers. Other components, such as the polarization switch and the fine steering mirror (FSM) are under consideration.

The polarization switch has proved to be a difficult component to source given the space-constraints of a CubeSat, as most space-grade switches are longer than ten centimeters in length when including the fiber bend radius. However, companies such as Agiltron or Axenic may be able to adapt the components' size or orientation to make this feasible. We have also been strongly considering a two-laser design, using a fiber combiner to combine two lasers that alternate on or off inversely. The FSM manufacturer is known, but calculations must be done taking into account the finalized system layout to determine the most optimal diameter, balancing between larger surface area to capture the beam and larger range of movement to redirect it onto the detector. The power budget and pointing calculations were updated to a greater degree of certainty as specific components were selected. Additionally, laboratory testing has begun with measuring the behavior of fiber optic cables under various conditions expected in the satellite. Lastly, the quadrant photodiode circuit is being designed and assembled, and it will soon also be introduced into laboratory testing.



Above: Visualization of a subsection of the optical collection path as simulated in Zemax OpticStudio. From left to right, optics are: FSM, dichroic, bandpass filter, quadrant photodiode. Varying FSM angles impact the readout of the simulated photodiode.
Credit: Daniel Lee, Maya Shah McDaniel, Seth Knights



Above: Examining the severity to which misaligned PM fiber affects our coupling using a half-wave plate and a linear polarizer.
Credit: Sofia Mansilla, Maya Shah McDaniel

B. AVIONICS HARDWARE & SOFTWARE

In Q4 2024, initial development efforts concentrated on finalizing preliminary component selection. The Hardware and Flight Software subteams collaborated to confirm that components satisfied requirements laid out in the Systems Requirements Review.

Once the PDR was completed, the Hardware team shifted towards iterating on existing designs, in particular the Onboard Computer (OBC). The OBC board, the brains of the satellite, went through several design iterations to solve issues that popped up in earlier revisions (particularly with respect to I2C and CAN bus configurations) and to add functionality. The most recent version is currently undergoing testing before it is integrated with the rest of the bus (notably the Power Distribution and Battery boards).

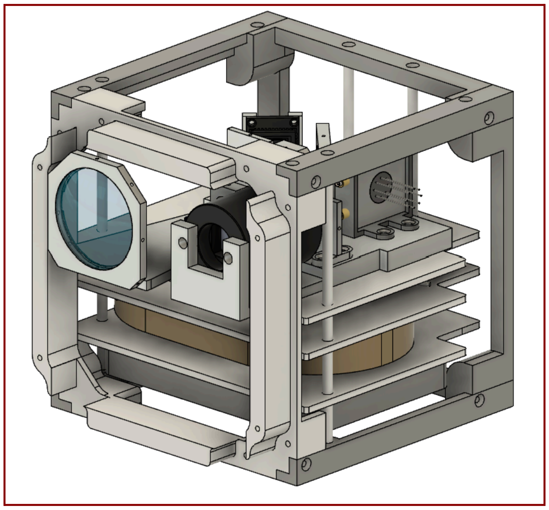
The Power Distribution Unit v2 was procured and assembled and underwent initial testing, and v3 began development in late Q4. The second revision of the Battery Board was also completed. The team is now working towards finalizing board designs before integration testing planned for early Q2 2025.

C. STRUCTURES & MANUFACTURING

In Q4 2024, work within our department was split between 4 main areas of focus: thermal modeling, optical payload design, bus configuration, and manufacturing opportunities. Members worked together to develop all of these areas concurrently, with the Preliminary Design Review serving as our effective deadline.

Thermal modeling: As a team, we decided to make use of the licenses provided by our industry sponsor, Ansys, by integrating Thermal Desktop into our workflow. Members then gradually learned how to properly and effectively make use of the software to achieve a realistic thermal model of our CubeSat. Our initial attempts of importing the CAD model with a very high feature count and then trying to simplify down did not help us converge on a sensible, useful model. Instead, we opted to create a model from the ground up with the thermal surfaces provided in Thermal Desktop, and from there increase the specificity until desirable results were met. By PDR, we were able to run certain simulations and get some very preliminary results, however, time constraints and a steep learning curve for the software required us to re-develop our thermal model. As Q4 came to a close, the thermal team converged on the study of several research papers pertaining to CubeSat thermal modeling.

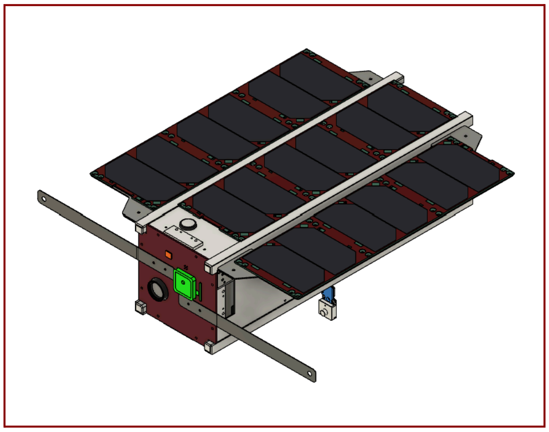
Optical Payload Design: The primary design constraint for the development of the optical payload was the sizing of the selected components. We integrated previous design decisions and converged to the current solution of a payload box which houses all relevant parts of the payload and interfaces with the satellite bus both mechanically and electrically.



Above: PULSE-A optical payload configuration as of the PDR.
Credit: Robert Pitu

Bus configuration: Apart from implementing all of the PC-104 boards into the bus, we also fashioned mounts for the relevant sensors needed by our ADCS. Externally, team members designed a deployable butterfly solar panel configuration, as well as the deployable antennas and magnetorquer needed. Choices for port holes were made and the final layout is still to be determined. We kept in touch with our frame provider, Gran Systems, to verify that progress is still on-going, and received helpful advice for deployment schemes.

Manufacturing opportunities: While our frame will be produced externally, for testing purposes we explored potential ways to rapidly manufacture our design for the additional sensor mounts, payload box and optomechanical lens mounts. With input from our university's engineering department, we were informed that our current estimates for required tolerances could be achieved in our on-campus machine shops. This came as a relief, since it allowed us to plan our prototyping stage in Q1 2026 much more easily. We also got in touch with other CubeSat teams to discuss what choices they made for manufacturing, and also took into consideration online services such as Xometry.



Above: PULSE-A external configuration design as of the PDR.
Credit: Robert Pitu

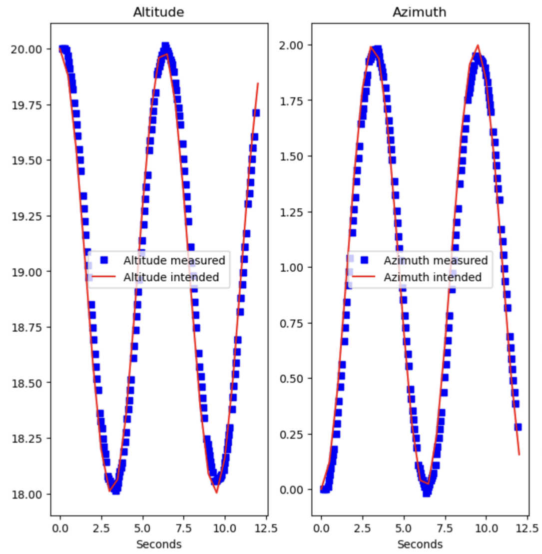
D. OPTICAL & RF GROUND STATION

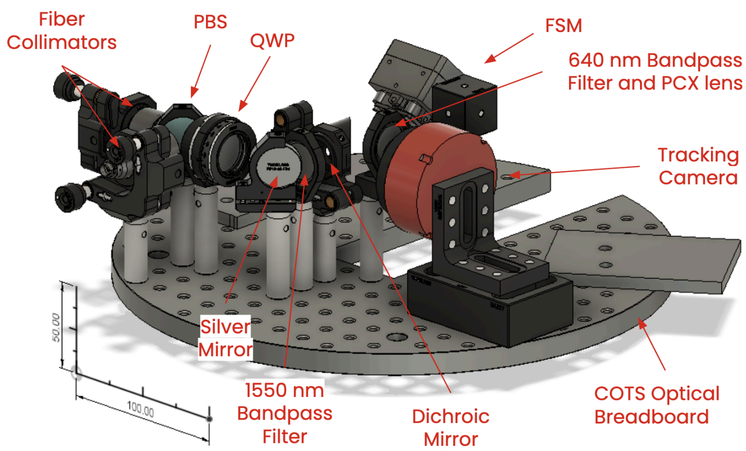
Optical Ground Station (OGS):

Over the course of Q4, the OGS subteam focused on completing our designs and analyses in preparation for the PDR. Our team polished our link budgets and noise analysis in order to support our design decisions on detection components. Furthermore, we developed a preliminary outline of the ground control scheme, as well as developed our telescope control software by making our commands to the telescope more reliable, as well as completing tests with changing slew rates that prove smooth tracking of a satellite pass (like the ISS) is possible in the near future. Our optical design also changed over the course of the quarter, as we added multiple lenses to our system to help collect and condense the incoming laser light, as well as creating a better image for our tracking system. A full preliminary optical simulation was created and proved our optical system can reliably track and detect the incoming beacon and transmission lasers from the payload. We also designed a data structure, and we worked towards selecting an initial error correction scheme tailored to our detection setup and nature of optical transmissions. This also prompted work on a comparator circuit, which functions as an analog component of this error correction scheme. Future work in the OGS will adapt our designs from feedback received during the PDR, as well as further our development with major goals including tracking the ISS with our telescope, developing and testing FPGA communications protocol, testing our optical setup in lab, simulating and experimentally determining the noise in our system, and finalizing the location where the OGS will operate.

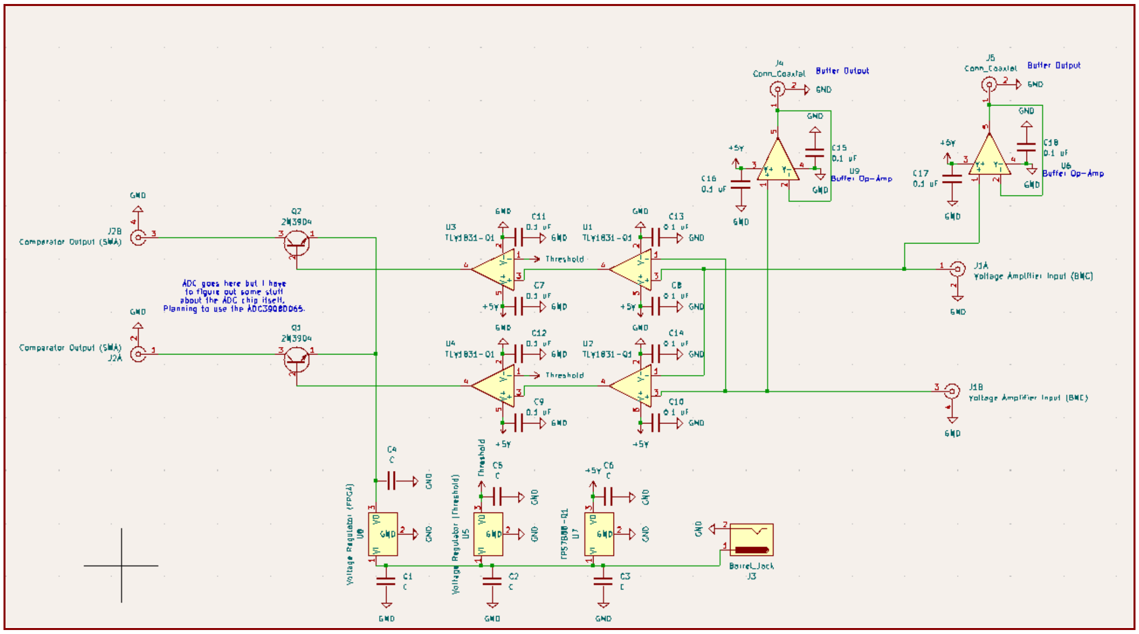
RF Ground Station (RFGS):

The RFGS team determined our component choices to finalize our design in preparation for the PDR. We remade our link budgets in order to account for multiple potential radio choices that could be used in the CubeSat, and we used the budgets to determine our ground station design to be feasible. Furthermore, we began looking into software to control the RFGS and communicate with both the satellite and the OGS, as well as track the satellite (with less accuracy than the OGS), as our system includes a directional antenna. We were also able to detect telemetry from beepsats in LEO towards the end of the quarter. This will enable us to make further decisions on radio components, including those going on the satellite, as well as working on acquiring our licensing for radio operations.





Left: Graphs depicting the variance between intended and measured positions as commanded to our telescope. *Credit: Rodrigo Spinola e Castro.*
Right: Excerpt from the PDR showing off the physical layout we expect to construct on the back of the telescope. *Credit: Kevin Zamudio, Juan Prieto*



Above: First version of the comparator circuit schematic for the optical ground station's signal detection assembly.
Credit: Juan Prieto

E. SYSTEMS ENGINEERING & INTEGRATION

In preparation for the PDR, we dramatically overhauled our system requirements, building on our work for the System Requirements Review by streamlining and clarifying requirements. We designed a preliminary timeline for verifying and validating each requirement by analysis, demonstration, inspection or testing. The next steps are to continue refining system requirements and implement a method to document requirement verification and validation.

To prepare for assembly, integration, and testing (AIT), we determined which tests we would perform and what levels to test to, and we designed a preliminary AIT process flow and testing sequence. Next quarter, we plan to finalize our testing procedures and procure facilities and equipment needed for AIT. We also added several new engineers solely focused on risk analysis and mitigation who prepared a risk square quantifying the likelihood and severity of the most significant risks we will face. In the future, we will design and implement more full risk mitigation plans.

Finally, we designed a Systems Engineering Management Plan (SEMP), which will be implemented team-wide starting next quarter.

IV. 2025 OUTLOOK

As we dive into the new year, we have some exciting prospects! With the successful completion of our PDR, we have moved into our Detailed Design Phase which will last until the completion of our next major milestone: the Critical Design Review (CDR). We are currently planning for this review to take place in Q4 of 2025, assuming that progress is made at our expected pace through Q2 and Q3. We are hopeful that with the growth of our team this past fall, we can host a variety of members throughout the summer months and continue our work without significant interruption.

To help prepare for this, and to continue getting these new members up and running, we have decided to pursue independent, small group projects for the majority of Q1 2025. The goal of these projects will be to give all members the opportunity to work hands-on with problems that should be more easily managed and allow each member to experience the entire process from conception, design, construction, and through to testing. Ideally, these projects are relevant to the concepts the members have been learning, or for longer term members present a timeline for completing a smaller section of their current work. We know that allowing students to complete (or at least to attempt) such projects gives the team skills that they can take advantage of over the next year, without having to worry about understanding any unnecessary complexities that may come with active satellite hardware. It also is a major chance for students to show that they can both be independent and operate with self-initiative from the start to end of a project, something that is not always taught in the classroom. Members will be expected to present the outcome of these projects to their departments by the end of Q1.

Following these projects, we will enter officially into work for the CDR. While we are still outlining a clear plan—including timeline, monetary budgets, and incoming leadership transitions—we hope to be in full swing by the end of Q2. Primarily, this will look like transforming ideas that have yet to be built, especially for the Payload and Ground Station Departments, into minimal viable products that can undergo basic testing regimes and serve as proof-of-concept for any CDR-related purposes. In terms of satellite hardware, we hope to have an entire flatsat completed before the CDR, meaning all major subsystems have undergone basic integration testing. Our desire is that preliminary hardware for the avionics, structures, and payload can successfully be operated via the on-board computer, the same manner in which it will be operated while in space. For our ground hardware, we hope to run proof-of-concept testing with the use of prototype, lab-based subsystems in conjunction with prototype payload components. We will also begin the licensing process for our RF ground station (and onboard transmitter), while procuring components for the RF station itself, much of which can be tested by receiving existing satellite signals. Importantly, given the feedback from our PDR and reflection over the last quarter, we have extended our schedule to align with an expected handoff date in late Q3 to early Q4 of 2026, with launch planned for very early 2027 with operations following that summer.

All in all, 2025 looks to be the most impactful year yet for the future of our project. We know that making consistent progress is extremely important, and are deeply grateful for the continued interest and dedication from each of our members, both new and old.

— The PULSE-A Team

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