PULSE-A
Systems Engineering Management Plan

University of Chicago Space Program

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Change Log

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1.0 Introduction

This Systems Engineering Management Plan (SEMP) is intended to document the activities to be performed by the PULSE-A Project's Systems Engineering Team and Program Management Team in support of the University of Chicago Space Program (UCSP) PULSE-A Mission throughout the overall program lifecycle phases. The Systems Engineering Team and Program Management Team review and update this document as necessary. At a minimum, the document is reviewed and re-evaluated at the end of each mission lifecycle phase in order to ensure that the SEMP remains updated, accurate, and relevant to the ongoing systems engineering effort that remains to be completed. This SEMP provides the technical approach to organizing the UCSP mission. This includes the people, products, and processes that put into operation the program within technical, cost, schedule, and other applicable constraints.

This SEMP documents how the UCSP mission is organized to accomplish essential Systems Engineering and Integration (SE&I) activities over the life cycle. This SEMP provides the communications medium, and provides a communications impetus, for the Program Management team and the technical implementation teams. All mission documents and resources are organized in this central document. Those with change authority and responsibility for maintaining this SEMP are the Principal Investigator, the Project Director, the Chief Engineer, the Lead Systems Engineer, and the Lab Manager.

2.0 Documents

The applicable documents for the PULSE-A Mission include specifications, models, standards, guidelines, and handbooks. The documents include the CAD model, thermal model, and mission analysis model; the Payload optical model and Optical Ground Station optical model; NASA mission and launch services standards; System Requirements Document; PDR; CDR; CubeSat Standards; and SEMP guidelines. Reference documents include the NASA CubeSat Launch Initiative (CSLI) Proposal, the Merit Review, the Feasibility Review, and the Pre-Procurement Readiness Review (PPRR).

In the event of conflict between/among plans, policies and guidelines, the following precedence shall exist when not specifically identified. First, the PULSE-A SEMP, then the remaining PULSE-A pertinent documents as equal importance. The SEMP spawns all other engineering plans on the project. The PULSE-A Project Director, or designee, shall have authority to resolve any conflict between/among guidelines/direction.

3.0 Technical Summary

The PULSE-A Mission aims to demonstrate space-to-ground optical communications using circular polarization modulation. The demonstration shall be characterized by an uncoded downlink data rate of 1 Mbps to 10 Mbps and coded bit error rate of 1e-9 to 1e-3, with the downlink to be sustained for a consecutive period of 5 seconds to 150 seconds. The 3U CubeSat uses a commercial off-the-shelf (COTS) attitude determination and control subsystem (ADCS) with flight heritage and a high degree of accuracy along with a micro-electromechanical system (MEMS) mirror in the Payload to achieve sufficiently accurate pointing to the ground station. In addition to a radio frequency ground station (RFGS), the PULSE-A Mission necessitates the construction of an Optical Ground Station (OGS) to receive, detect, and interpret the transmission beam. The OGS employs a telescope for coarse pointing and a MEMS mirror for fine pointing.

The cost of this mission is projected to be $529,963.72 in the current Itemized Financial Budget; the mission cost will be finalized by CDR. The current schedule calls for PDR in November 2024, CDR in June 2025, PPRR in September 2025, AIT in September 2025 through September 2026, and launch no earlier than January 2027. In accordance with the PULSE-A Team's NASA CSLI award, launch may be no later than December 2028.

3.1 System Description

The principal architectural elements of the PULSE-A Mission include the 3U Satellite, the Ground Station, NASA Launch services, and the Deployer. The Satellite is compliant with the most recent revision of the CubeSat Design Specification (rev. 14.1) and will be compliant with the TBD Launch Provider requirements and TBD Deployer Provider requirements after the Launch Provider and Deployer Provider have been selected. The Satellite is capable of continuous operations after deployment, generates detailed log files during operations, transmits log files to Ground Control, and accepts commands uplinked from Ground Control. The Ground Station will be situated in a remote location (tentatively Yerkes Observatory) so as to not violate the FAA's laser safety regulations.

3.2 System Structure

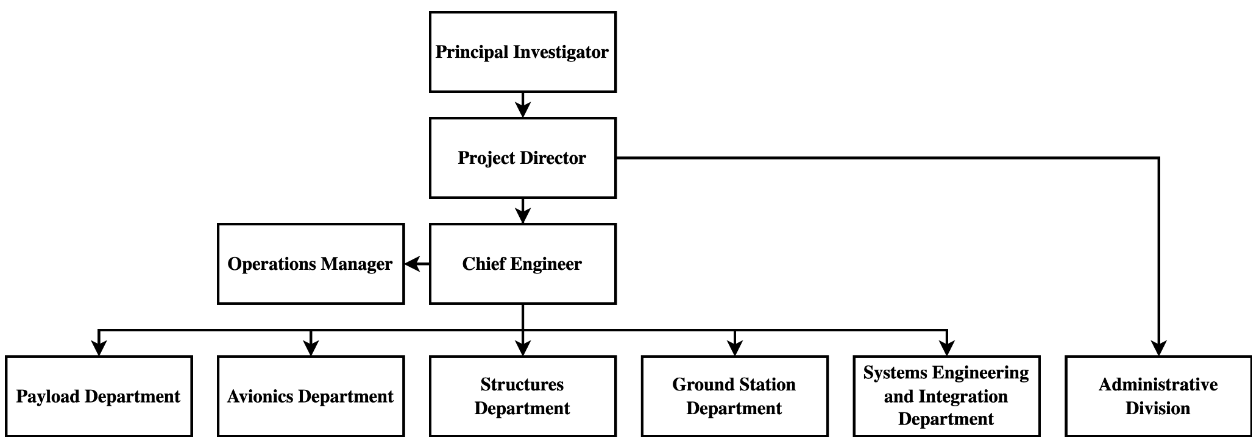
The system is organized by a Work Breakdown Structure which effectively divides technical development in support of the PULSE-A Mission across the PULSE-A Team's 5 engineering subteams (hereafter referred to as "Departments") and Administrative Division.

3.2.1 Work Breakdown Structure Key Terms and Responsibilities

Key Terms	Responsibilities
Principal Investigator	Overall mission management
Project Director, Chief Engineer, Operations Manager	Program management
Payload Department	Optical payload subsystem

Avionics Department	Electronic power, command and data handling, attitude determination and control, and RF communications subsystems; flight software
Structures Department	Structure and thermal subsystems; bus configuration; thermal analysis
Ground Station Department	OGS and RFGS subsystems; ground software
Systems Engineering and Integration Department	System requirements formulation, verification, and validation; AIT of satellite and ground station; risk assessment and mitigation
Administrative Division	Grant composition; procurement and accounting; outreach

3.2.2 Work Breakdown Structure



3.3 Product Integration

The Product Integration approach defines responsibility for both internal and external integration of the System into the overall Architecture. Internal integration within the Program produces a functional System compatible with the architecture and is the responsibility of each Department Lead assigned to a set of subsystems as organized by the WBS. External integration is the primary responsibility of the lead system integrator which is the Systems Engineering and Integration Department/Chief Engineer for the PULSE-A Mission. Spacecraft integration is arranged between the Payload Department, Avionics Department, and Structures Department. Launch integration is through a launch systems provider as arranged by NASA. Ground Station development and integration is arranged by the Ground Station Department.

3.4 External Program Integration

The lead system integrator is responsible for interfacing elements in External Program Integration throughout all program phases: Concept Studies, Concept Development, Preliminary Design, Detailed Design, AIT, Operations, and Closeout. Interfacing elements include Documentation; transportation to the launch site, test facility, and remote Ground Control location; and environmental testing. External Program Integration will be defined in further detail before the CDR.

3.5 Internal Program Integration

The lead system integrator is responsible for organizing interfacing elements in Internal Program Integration. The lead system integrator organizes the system architecture, definition, and engineering functions including Satellite-Ground Station interface definition, subsystem interface definition, trade studies, system architecture development, and test planning. Internal Program Integration will be defined in further detail before the CDR.

3.6 Planning Context

The Planning Context is the context under which the PULSE-A program operates to satisfy the constraints placed upon the program by UCSP, NASA, and other funding partners. The Project Director updates the SEMP prior to PDR, prior to the CDR, and at the conclusion of development phases. The Project Director updates the WBS monthly. The Administrative Division tracks spending monthly, with their documentation approved by the Project Director.

3.7 Boundary of Technical Effort

The Boundary of Technical Effort is influenced by factors internal and external to the PULSE-A Team. The main external factors include the academic year schedule, undergraduate student availability during different times of each academic term, and the majority of undergraduate student team members graduating and thereby leaving the team within 4 years. The main internal factors include schedule delays due to uneven development or design anomalies.

3.8 Cross References

The primary non-technical document which cross-references the SEMP and interfaces with technical effort is the System Requirements Document. Current cross references are TBD by CDR.

4.0 System Design Process

4.1 Responsibility and Authority

The Project Director, Chief Engineer, and Operations Manager together act as the governing authority for the PULSE-A Program and are responsible for the overall Program Management. The Project Director has final authority for Program Management, the Principal Investigator has final authority for Mission Management, and the Chief Engineer has final authority for technical efforts. The Payload Department is responsible for the Payload. The Avionics Department and Structures Department are together responsible for the spacecraft bus. The Ground Station Department is responsible for the development of the Ground Station. The Systems Engineering and Integration Department is responsible for systems engineering, verification and validation, and risk assessment.

4.1.1 Project Technical Manager

The Project Technical Manager is responsible for implementing the technical processes defined in the SEMP and leading overall technical efforts. The PULSE-A Project Technical Manager is the Chief Engineer. The Project Technical Manager's responsibilities will be expanded upon before CDR.

4.1.2 Technical Authorities

The Technical Authorities, in addition to the Project Technical Manager and Project Director, are the technical Department Leads: Lead Payload Engineer, Lead Avionics Engineer, Lead Structural Engineer, Lead Ground Station Engineer, and Lead Systems Engineer. The Technical Authorities are responsible for maintaining consistent meetings and technical progress with their subordinates, titled Department Members, in accordance with the schedule created by Program Management.

4.1.3 Lab Manager

The Lab Manager is responsible for managing activities and resources in the PULSE-A Team's laboratory spaces. PULSE-A has two Lab Managers: the Principal Investigator, who manages the optics laboratory (Zhong Lab) where the Payload and OGS are developed, and the UCSP CubeSat Lab Manager, who manages the team's student laboratory space where electronics and software are developed. The UCSP CubeSat Lab Manager is an administrative authority for the student organization: either the President or Vice President of the organization.

4.1.4 Operations Manager

The Operations Manager is responsible for overseeing personnel assignment and task distribution among the technical team. The Operations Manager works with the Project Director and Chief Engineer to update and maintain the technical team's schedule, then ensures the feasibility of each Department completing deliverables by the outlined deadlines. The Operations

Manager assesses the gaps in the technical team's development and leads recruiting efforts for the technical team accordingly.

4.2 Governance

Project Governance measures are taken at regularly scheduled authority meetings, titled Leadership Meetings. The Technical Leadership Meetings occur weekly with the Project Director, Chief Engineer, Operations Manager, and 5 technical Department Leads present. The Administrative Leadership Meetings occur weekly with the Project Director, Head of Administration, Funding Lead, Finance Lead, and Outreach Lead present. Technical Leadership Meetings and Administrative Leadership meetings are chaired by the Project Director. Progress and setbacks are discussed, and goals for the next week are established for Department Leads to implement. Regularly scheduled Department Meetings occur at least weekly at each Department Lead's discretion. Department Meetings are attended by the Department Lead and all Department Members. Department Meetings are chaired by the Department Lead. Team-wide meetings occur monthly and are chaired by the Project Director.

Technical Decision-Making Forums are scheduled as-necessary during the design process. They are attended by the Chief Engineer, Department Leads of relevant Departments, and at least 2 Department Members from each relevant Department. Technical Decision-Making Forums are chaired by the Chief Engineer, and the result is approved by the Project Director.

4.2.1 Integration and Decision-Making

When Departments or working groups disagree based on differing perspectives on the balance among considerations of safety, quality, cost, schedule, and risk, the team discusses potential solutions between the disagreeing groups. In the event that a solution cannot be reached by standard discussion, a Decision-Making Forum is created with the relevant technical group leads (Department Leads or appointed working group lead), at least 2 Members of each relevant technical group, the Lead Systems Engineer, the Chief Engineer, and the Project Director. The Decision-Making Forum is chaired by the Project Director, who has the final authority on resolution.

4.2.2 Top Level Process Descriptions

4.2.2.1 Nominal Product Development

The nominal product development functions under several inputs, including System Requirements and the Work Breakdown Structure. The PULSE-A Project's development has already reached several significant milestones. The PULSE-A Team held a successful Merit Review and successful Feasibility Review, each in November 2023; the PULSE-A Team submitted a successful proposal to NASA CSLI in November 2023 with notification of the proposal's success received in April 2024; and the PULSE-A Team held a successful System

Requirements Review in June 2024. The PDR is in November 2024, describing the preliminary design choices made for the mission. The CDR is scheduled for June 2025 to review detailed design choices preceding final design decisions. The PPRR is scheduled for September 2025 for final design decisions to be approved and initiate the AIT phase. Systems Integration is scheduled to conclude with the Test Readiness Review in January 2026, and testing is scheduled to conclude with the Flight Readiness Review in August 2026. Handoff is scheduled for September 2026 with launch no earlier than January 2027.

4.2.2.2 Issue Resolution Process

The Issue Resolution Process during engineering design is typically handled by a Department trade study, with the result approved by unanimous decision between the Chief Engineer and Project Director. In the event that an unforeseen issue is identified during the development process, an exception to the trade study process may be made under unanimous agreement between the Chief Engineer and Project Director. The issue is instead resolved by rapid solution development from the relevant Departments.

4.3 Support Integration

Virtual workspace tools are particularly important for the PULSE-A Team's development, given the majority of undergraduate students do not remain in the Chicago area during the academic summer (late May to late September). The Team uses Discord for informal messaging and announcements; email for formal messaging; Zoom for virtual and hybrid meetings; Google Drive for file sharing, document composition, and slideshow creation; and Notion for task management. All Team members have remote access to these tools at any time.

5.0 Common Technical Process Implementations

5.1 System Design Processes

5.1.1 Stakeholder Expectations Definition Process

Stakeholders are defined by the Project Director and Chief Engineer. Stakeholder expectations are provided through formal and informal communications to the Project Director and/or Chief Engineer. The Chief Engineer and Lead Systems Engineer are responsible for ensuring the stakeholder expectations are accurately translated to requirements, with requirement approval given first by the Project Director and finally by the relevant stakeholder. The Systems Engineering and Integration Department establishes support strategies, ensures expectations for product validation are met, and defines the concept of operations.

5.1.2 Technical Requirements Definition Process

The Systems Engineering and Integration Department performs the analyses needed to transform program expectations and design constraints into functional and performance requirements. These analyses are advised by Department Leads and often collaborated on by relevant Department Members depending on the complexity of the analyses. The resulting functional and performance requirements are expressed succinctly as "shall" statements, which are individually validatable in an organized manner. The requirements are documented in the Systems Requirement Document and other relevant Documentation, including the driving requirements documented in the PDR. Appropriate measures of performance and verification are defined for each requirement by the Systems Engineering and Integration Department. Approval for requirements and validation method selection must be given unanimously by the Chief Engineer and Project Director, taking financial and schedule constraints into account. Requirements are assigned to Department Leads for implementation. The validation methods and requirement decomposition will be expanded upon prior to the CDR.

5.1.3 Logical Decomposition Process

The Systems Engineering and Integration Department uses the Logical Decomposition Process to derive technical requirements from top level goals, objectives, and expectations. The derived requirements are allocated to system modules and conflicts resolved. The derived requirements are then added to baseline documentation, including the System Requirements Document, which shows parental requirement flow.

5.1.4 Design Solution Definition Process

The Design Solution Definition Process begins with each Department defining alternative design solutions in accordance with the technical requirements. Full analyses are conducted of each alternative solution to determine which solutions satisfy the requirements. Trade studies are completed, and the selected solution must be unanimously approved by the Lead Systems Engineer, Chief Engineer, and Project Director. A data package is developed to describe the selected solution, with the package documented in support of technical reviews and future design efforts.

5.1.4.1 Requirements Analysis Cycles (RACs)

The PULSE-A Project's primary RAC was used to support analyses and trade studies performed early in the PULSE-A Project's lifecycle in developing and validating technical requirements. In support of the System Requirements Review, the following types of supporting assessments were conducted:

- System Requirements Analysis
- Feasibility Assessments
- Life Cycle Cost Analysis
- Requirements and Technical Trades assessments
- Technology Risk Assessment

- ❖ Risk Analysis
- ❖ Operations Concept Trades

5.1.4.2 Design Analysis Cycles (DACs)

The PULSE-A Project's first DAC was performed in support of the PDR in demonstrating that the preliminary design is expected to meet the functional and performance requirements, that the design is verifiable, and that risks have been identified, characterized, and mitigated where appropriate. The following types of supporting assessments were conducted in preparation for the PDR:

- ❖ System Requirements Analysis
- ❖ Preliminary System Design Analysis
- ❖ Operational Assessments
- ❖ Cost and Schedule Analysis

Further information on the second DAC, which will be performed in support of the CDR, will be added immediately following the PDR.

5.2 Product Implementation Process

The Product Implementation Process is used to generate a specified product through buying, making, or reusing in a form that satisfies the design solution definition specified requirements. The Systems Engineering and Integration Department collaborates with Program Management to determine and implement the Product Implementation Process. The Product Implementation Process will be described in further detail before the CDR.

5.3 Product Realization Processes

5.3.1 Product Integration Process

The Product Integration Process transforms the design solution definition into the desired end product. During the process, all generated data is recorded as data products for analysis, communication in internal reviews, and communication to the Launch Provider. The PULSE-A Product Integration Process is as follows:

1. Lower-level modules are assembled and validated.
2. Lower-level modules are integrated to yield individual subsystems (the Payload, the Structure, the OGS, and the RFGS) and the Avionics Stack. The individual subsystems and Avionics Stack are then validated.
3. The Avionics Stack and Structure are integrated to form the spacecraft bus. The Payload is integrated to form the integrated Satellite system, which is then validated.
4. The OGS and RFGS are integrated to form the integrated Ground Station system, which is then validated.

5.3.2 Product Verification Process

During the assembly and integration process, all generated data is recorded as data products for analysis. The Systems Engineering and Integration Department performs analyses on the data products to verify that the product conforms to the requirements which guided the design process, as defined in the System Requirements Document. A Product Verification report is generated and analyzed for review by the Chief Engineer, Project Director, and Principal Investigator.

5.3.3 Product Validation Process

The Systems Engineering and Integration Department conducts Validation testing with realistic or simulated conditions. Qualification testing is designed to test the system against the worst case loads and environmental requirements in which the system is meant to perform and survive. Environmental testing specified for qualification includes thermal cycling, bakeout, vibrational testing, and EMI/EMC.

5.3.4 Product Transition Process

The Product Transition Process will be documented prior to the CDR.

5.4 Technical Management Processes

5.4.1 Technical Planning Process

The Technical Planning Process will be documented prior to the CDR.

5.4.2 Requirements Management Process

The Requirements Management Process will be documented prior to the CDR.

5.4.3 Interface Management Process

The Interface Management Process will be documented prior to the CDR.

5.4.4 Configuration Management Process

The Configuration Management Process will be documented prior to the CDR.

5.4.5 Technical Planning Process

The Technical Planning Process will be documented prior to the CDR.

5.4.6 Technical Data Management Process

The Technical Data Management Process will be documented prior to the CDR.

5.4.7 Technical Assessment Process

5.4.7.1 System Requirements Review (SRR)

The SRR ensures that the higher-level requirements have been properly translated into unambiguous design requirements. It provides project management assurance that tradeoffs between conflicting requirements have been performed and properly resolved. It confirms that the System Requirements Document requirements are allocated to the hardware and software specifications and that the design concepts presented are sufficient to meet the Program objectives.

5.4.7.2 Preliminary Design Review (PDR)

The PDR is a technically-focused design review intended to demonstrate that the preliminary system, module/element, and subsystem design of the integrated system, its concept of operations, associated processes, and applicable technical plans meet all system requirements with acceptable risk and within cost and schedule constraints. The PDR establishes the basis for proceeding with the detailed design and provides evidence that the correct design options have been selected, interfaces have been identified, and verification methods have been described.

Following the PDR, the specifications and drawings should be under configuration control to support the manufacturing of engineering hardware. This will allow the program to better track changes for the as-built hardware. If these changes are not properly captured, required hardware changes may not be incorporated into the flight hardware drawings and specifications.

5.4.7.3 Critical Design Review (CDR)

The CDR verifies that the design has proceeded in accordance with that authorized by the PDR; changes (if any) are assessed in the plans, requirements, and design that have occurred since PDR; and the integrity of the design is verified by assessing analyses and test data. The review establishes the initial “build-to” configuration. A CDR Process Plan describing CDR products, processes, and participants is published consistent with the CDR schedule.

Following the CDR, the specifications and drawings are updated and put under configuration control for release to manufacturing. The CDR confirms that the design is of sufficient detail to initiate hardware manufacturing, integration and testing, and represents acceptable risk. All open PDR actions and Review Item Discrepancies (RIDs) must be closed prior to the CDR, unless express written direction is received from Program management.

5.4.7.4 Pre-Procurement Readiness Review (PPRR)

The PPRR determines the readiness of the system developers to efficiently carry out the AIT phase. The PPRR ensures that the production plans; fabrication, assembly, and integration-enabling products; and personnel are in place and ready to begin production. A successful PPRR marks the beginning of the NASA CSLI manifestation process through which a Launch Provider is selected.

5.4.8 Decision Analysis Process

The Decision Analysis Process will be documented prior to the CDR.

5.4.9 Technical Margins Management

The Technical Margins management will be documented prior to the CDR.

6.0 Technology Insertion

A Technology Insertion Process is not applicable for the PULSE-A Mission.

7.0 Additional Systems Engineering Functions and Activities

7.1 Safety and Mission Assurance (S&MA)

The S&MA plan will be documented prior to the CDR.

7.2 Engineering Methods and Tools

The Engineering Methods and Tools have not yet been selected. Details are expected to be added prior to the CDR.

7.3 Specialty Engineering

No Specialty Engineering functions have been identified at this time.

8.0 Integration with the Program Plan and Technical Resource Allocation

8.1 General Approach

The general approach for resource allocation in the PULSE-A Mission lies within the authority of the Program Management and Principal Investigator. The Program Management Determines the roles and responsibilities of all other members and groups in the PULSE-A Team. Funds are allocated directly to engineering Departments by the Administrative Division in collaboration with Program Management, and the schedule is allocated by Program Management in collaboration with the Systems Engineering and Integration Department. Staff are allocated by Program Management, primarily by the Operations Manager, advised by discussions with Department Leads.

9.0 Waivers and Tailored Requirements

There are no approved waivers or tailored requirements to report in the SEMP at this time.