Spring 2024
16.831 Assignment HO-3
Final Draft of Proposal for Flight Demonstration

CASCADE

Cryovolcanism Analog-Sensing Cubesat And Drop Experiment

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Version 2

Due March 22, 2024

Nomenclature

CAD	Computer-Aided Design
CASCADE	Cryovolcanism Analog Sensing CubeSat And Drop Experiment
CDH	Command & Data Handling
CONOPS	Concept of Operations
EOL	End-of-Life
FEM	Finite-Element Model
FSW	Flight Software
GEORGE	Going to Europa for the Orbital Recovery of Geyser Emissions
L-C	Likelihood-Consequence
OBC	On-Board Computer
SC	Spacecraft
TOF	Time-of-Flight

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1 Executive Summary

1.1 Motivation

Europa—Jupiter's second-closest Galilean moon—has been recognized as an attractive target for scientific study for decades. There is strong evidence of a subsurface ocean and cryovolcanic-emergent plumes that may carry salts and other molecules necessary to sustain life [3, 9]. CASCADE (**C**ryovolcanism **A**nalog-**S**ensing **C**ubesat **A**nd **D**rop **E**xperiment) is a CubeSat-based mission designed to carry out small-scale scientific objectives analogous to those proposed by the Europan reconnaissance orbiter developed by the MIT AeroAstro Space Systems Development course: GEORGE (**G**oing to **E**uropa for the **O**rbital **R**ecovery of **G**eyser **E**missions).

1.2 Technical Overview

1.2.1 High-Level Summary

The CASCADE mission involves detecting a cryovolcanic activity hotspot analog, simulated by a kiddie pool of liquid water, water ice, and dissolved salts; releasing a probe into the identified hotspot analog; and measuring the conductivity and temperature of the water via equipment onboard the deployable probe (refer to Section 2). The probe will relay to the satellite the temperature and conductivity of the water, and the satellite will relay this information to the ground. The team will use this data to identify the concentration of dissolved salt. Each of these technology demonstrations simulates an objective of the GEORGE mission, as detailed in Appendix A).

1.2.2 Key Features

The CubeSat will employ the 10 cm $\times$ 10 cm $\times$ 20 cm bus and associated avionics provided for all GEORGE missions with a minor modification to the panel facing the ground to incorporate a different release mechanism for the deployable probe. On the bottom face of the CubeSat resides an infrared camera and a TOF sensor to identify a target location in which to drop. The deployable probe is equipped with a separate 1.2-volt battery, a thermometer, and two copper wires connected to a microbit to measure the conductivity of the solution. Furthermore, the deployable probe will incorporate a radio to relay data to the CubeSat.

1.2.3 Key Risks

In addition to the standard and expected risks of CubeSat operation (e.g., communication issues, sensor errors, etc.), there are two primary risks associated with this mission. First,

because the demonstration involves dropping a payload into the water, there is a significant risk of water leakage and damage to the electrical components of the deployable probe. Secondly, the goal of deploying a probe into a targeted region while the CubeSat is in motion involves the pairing of sensor data with onboard computation of parabolic motion to land at the point of interest. Without proper testing and design of the deployment system, there is a considerable risk of the probe missing the simulated hot spot of cryovolcanic activity.

1.2.4 Testing

The team will conduct the tests outlined in Table 1 below.

Table 1: CASCADE Mission Tests and Expected Results

Test Code	Test Type	Expected Result
T-1	Communications	Pass/fail of reception of commands and data between bus, probe, and ground station
T-2	Flight Software and Electronics Test	Calibration of all sensors and pass/-fail of power cycling
T-3	Probe Release Test	Mechanism is deployed correctly, both landing within a 3-foot radius of a specified point while in transit
T-4	Centrifugal	No yield of structural elements, deformation, or disassembly
T-5	Vibration	No yield of structural elements, deformation, or disassembly
T-6	Cold Environment	Successful communication and electronic performance while subjected to a 0° Celsius environment (ice-temperature)
T-7	Probe Shock Test	No yield of structural elements, deformation, or disassembly
T-8	Water-Tight	No internal change in humidity detected (+/- 5 percent accuracy)
T-9	Remote Temperature Measurement Test	Accurate remote temperature reading confirmed with readings from a ground thermometer (+/- 5 percent accuracy); corroboration of ultrasonic distance readings with meter stick
T-10	Water Temperature and Conductivity Measurement Test	Agreement with a multimeter to measure the change in resistance due to solution (+/- 5 percent accuracy)

Tests T-8 and T-10 will serve to address the risks associated with dropping in water, while T-3, T-7, and T-9 address the concerns associated with dropping the probe. For a more in-depth look at the risks addressed by each test, please refer to Section 4. Each of these tests will ensure the independent functionality of mission-critical capabilities, allowing ample time for iteration and improvement to deliver a robust system architecture.

1.3 Project Plan Overview

1.3.1 Team Member Roles

Pablo Arroyo will be the team's lead sensor calibration and communication engineer. He will develop his skills by calibrating each sensor, establishing communication protocols, and taking point in directing the ground station. Joseph Hobbs will serve as the team's lead programmer, doing so after expressing a sincere desire to develop flight software after not having done so previously. He will exercise this skill by developing code for the avionics and actuation of the probe. Tomás Cantú will serve as the chief safety and testing engineer. By leading the execution and design of each test, Tomás will develop his skills in testing and validation. Finally, Cesar will serve as the main electrical engineer, developing and implementing the power distribution and wiring of the probe and the CubeSat to develop this desired skill.

1.3.2 Working Plan

The team expects to allocate between five to ten hours of work each week for five weeks until the final demonstration in May. The team will not require any special training but may require a special space to test the conductivity sensor. Currently, the team hopes to use the first floor of building 31 to test both the conductivity system and the drop-test survivability of the probe due to its isolation from the external environment, spacious facilities, and two-story balcony (for drop testing).

1.3.3 Additional Requisitions

The team will require the purchase of a small kiddie pool, including bags of ice and salt (NaCl) for testing and the final demonstration. Furthermore, the team will require epoxy and copper wiring. Finally, as a contingency to measure water leakage inside the probe, the team will need to source an Adafruit temperature and humidity sensor, which doubles as the onboard thermometer.

2 Concept of Operations

2.1 Primary CONOPS

2.1.1 Overview

This primary CONOPS enumerates the five phases of the CASCADE mission: prelaunch safety checks, launch and transit to the hotspot, probe deployment, data collection and transmission, and EOL operations. During each phase, a robust communication system, OBC, SC bus, and electrical infrastructure will ensure reliable operation within nominal behaviors.

2.1.2 Background

Improvements in the astronomical sciences have revealed the presence of liquid water on other celestial bodies in our solar system. This suggests the presence of salts, sugars, amino acids, and possibly even life. CASCADE simulates conceptually a mission that would detect the concentrations of these organics on another celestial body.

2.1.3 Mission Description

The CASCADE SC will travel along a zipline suspended approximately 1.5 meters above the MIT Aero/Astro lawn using a motorized tram until it identifies a probe target. After the target is identified, it will release a probe at the correct time to ensure the probe lands on the target. The probe will then collect scientific data and transmit it to the SC. The SC will subsequently conduct a second pass to receive the transmitted scientific data. The SC will perform data analysis, if necessary, and transmit the data back to the ground station. After the second pass, the SC will conduct EOL operations.

2.1.4 Phase 0: Prelaunch

Phase 0 will consist of safety checks and automated software diagnostics to ensure that the CASCADE SC is prepared to launch. Phase 0 will contain at least one scheduled hold as prescribed by the mission timeline, during which any issues will be resolved. If any issues are identified, the CASCADE team will perform diagnostics again to ensure mission robustness. When all diagnostics and safety checks are GO, Phase 0 will succeed and the mission will proceed to Phase 1.

2.1.5 Phase 1: Launch and Transit

Phase 1 will consist of the launch and transit of the SC. The SC will travel along the tram while maintaining all subsystems and searching for the probe target. When the probe target

is identified, Phase 1 will succeed and the mission will proceed to Phase 2.

2.1.6 Phase 2: Probe Deployment

Phase 2 will consist of the SC probe deployment. After identifying the probe target, the SC will release the probe to land on the target. The probe will then begin collecting scientific data as the SC continues to move along the tram. When the probe confirms successful deployment, Phase 2 will succeed and the mission will proceed to Phase 3.

2.1.7 Phase 3: Data Collection

Phase 3 will consist of scientific data collection. The CASCADE team will ask the 16.831 staff to reset the tram to its original position for a second pass. When the SC passes within range of the probe, it will begin receiving scientific data. The SC OBC will perform any necessary analysis before transmitting data to the ground station. When the ground station receives sufficient scientific data, it will notify the SC of successful Phase 3 and the mission will proceed to Phase 4.

2.1.8 Phase 4: EOL Operations

Phase 4 will consist of EOL operations. The SC will notify the probe of EOL, which will then perform a full shutdown. The SC will then perform a full shutdown. When the ground station ceases to receive communications from the SC, Phase 4 will succeed and the mission will terminate.

2.1.9 Mission Objectives

P-OBJ-1 CASCADE will deploy its probe at the proper time to land on its intended target during Phase 1.

P-OBJ-2 CASCADE probe will collect & relay necessary scientific data during Phase 2.

P-OBJ-3 CASCADE will collect scientific data from the probe via communication protocols during Phase 3.

2.1.10 Spacecraft Modes

The CASCADE SC will have a number of modes (as managed by the OBC and FSW) to control the various processes onboard the SC. Reference Appendix B for a detailed description of the SC modes.

2.2 Contingency CONOPS

2.2.1 Overview

This contingency CONOPS focuses on the survival of the CASCADE SC in the case of an unintended interface or subsystem failure.

2.2.2 Mission Description

In the case that CASCADE's primary mission is compromised by an unintended internal or external interface or the failure of one or more subsystems, CASCADE resources will, in order of precedence, ensure (1) the safety of all personnel and equipment and (2) survival of the SC. In accordance with safety directives from the 16.831 staff, the mission engineer will direct the mission to ensure safety and SC survival.

2.2.3 Mission Objectives

C-OBJ-1 CASCADE will ensure the health and safety of all project team members, 16.831 course staff, and passers-by.

C-OBJ-2 CASCADE will ensure the survival of the CASCADE space system, except when the spacecraft's survival risks health or safety (see C-OBJ-1).

3 Risk Analysis

3.1 Consequence Description

Table 2 describes the severity of consequence levels 1 through 5 (abbreviated as C1–C5).

Table 2: Consequence Score Definitions

Score	Definition
C1	An issue that can be solved remotely within the same run.
C2	An issue that affects one of the science objectives.
C3	An issue that affects most of the science objectives.
C4	An issue that poses a threat to the current test.
C5	A substantial challenge to the next test.

3.2 Likelihood Description

Table 3 describes the severity of likelihood levels 1 through 5 (abbreviated as L1–L5).

Table 3: Likelihood Score Definitions

Score	Definition
L1	0-20% chance of occurring.
L2	20-40% chance of occurring.
L3	40-60% chance of occurring.
L4	60-80% chance of occurring.
L5	80-100% chance of occurring.

3.3 Risks

Table 4 enumerates the risks outlined in the L-C Matrix above.

Table 4: Risk Description

Risk Code	L-C Score	Description
SLA	L2-C5	Structural failure during launch
SCO	L1-C4	Freezing electronics during eclipse
SDR	L3-C5	Structural failure in probe while dropping to the surface
WOR	L3-C2	Landing in an undesired orientation
WLE	L2-C5	Water leakage in probe insulator shell
WCO	L1-C4	Condensation of water vapor inside probe
PRM	L2-C3	Probe does not release
COM	L2-C3	Communications failure
FCM	L4-C2	Fluid Conductivity Measure failure
TEM	L2-C2	Temperature probe does not capture data
IMG	L1-C4	Imaging system does not provide enough data for probe deployment

3.4 L-C Matrix

The L-C Matrix for our risk analysis is shown in Table 5.

3.5 Risk Legend

Table 6 relates risk levels to colors in Table 5.

3.6 Risk-Test Map

Table 7 describes the tests we will perform in order to mitigate the risks outlined.

Table 5: Likelihood-Consequence Matrix

	C1	**C2**	**C3**	**C4**	**C5**
L5					
L4		FCM			
L3	WOR				SDR
L2		TEM	PRM, COM		SLA, WLE
L1				IMG, WCO, SCO	

Table 6: Risk Level Legend

Risk Level	Low Risk	Medium Risk	High Risk

Table 7: Risk-Test Map

Risk Code	**Solution**	**Test Type**	**Success Criterion**
SLA	Make strong structure	Vibration test	Structure does not fail
SCO	Make heat insulation	Cold test	Critical electronics intact
SDR	Add compliant structure to probe	Drop test	Structure does not fail
WOR	Create a shape that will always have on side point down	Dummy CoM test	Self-orienting on land and on a liquid surface.
WLE	Plastic box around probe with epoxy surrounding sensors	Water-tight test	No water inside box.
WCO	Seal shell while very cold and dry. Add silica packet.	Cold test	No water condensation drops.
PRM	Safe release mechanism	Mechanical test	Probe releases from main bus.
FCM	Clean electrodes	Component Test	Agreement with multimeter readings.
TEM	Mount sensors to an edge	Subsystem Test	Temperature agrees with external thermometer.
IMG	Indicator LEDs to relate function	Subsystem Test	Relays poor image capture failures.

4 Testing

4.1 Mission Requirements

4.1.1 Communications

REQ-COM-1 Must reliably send simple commands from the control computer to the bus, and from the bus to the probe. Tested and measured qualitatively.

REQ-COM-2 Must reliably send data from the probe to the bus and from the bus to the control computer. Tested and measured qualitatively.

4.1.2 Flight Software & Electronics

REQ-FSW-1 Must perform all the commands needed for the mission, in order and time. Tested and measured qualitatively.

REQ-FSW-2 Must release the probe at the desired time without getting stuck. Tested and measured with distance relative to the target.

REQ-FSW-3 Must take calibration measurements on command. Tested and measured qualitatively.

4.1.3 Probe Shock Survival

REQ-SHK-1 Probe must withstand higher shocks than the bus. Must be tested by dropping several times from a height of at least 2 meters.

4.1.4 Launch G-Force Survival

REQ-LGF-1 Must be subject to centrifugal g-force test.

4.1.5 Vibration Survival

REQ-VIB-1 Double-check that all the natural frequencies of our elements are higher than expected vibrations.

REQ-VIB-2 Must be vibration tested.

4.1.6 Cold Environment Survival

REQ-CLD-1 Insulation must be rated for temperatures expected in orbit and in contact with Europan ice.

REQ-CLD-2 Must be tested in an artificial cold environment. Electronics must work nominally while in it.

4.1.7 Probe Submersibility

REQ-SUB-1 Must have a water-tight case. Tested by submerging.

REQ-SUB-2 Must be sealed while in a cold and dry environment to prevent condensation of water vapor from humidity inside the shell. Can be done in the same cold environment.

4.1.8 Accuracy of Remote Temperature Measurement

REQ-TMP-1 Must be able to detect differences in temperature in a far-away surface with the on-board temperature sensor. These can be tested and compared against ground truth measurements with a thermometer.

4.1.9 Accuracy of Water Temperature and Conductivity Measurements

REQ-TAC-1 Must be able to always fall on one of the sides that has the sensors (or have sensors in all sides). Tested by drop test.

REQ-TAC-2 Must perform accurate readings with all sensors. Can be tested against a ground truth from prepared water environments.

4.2 Pre-Demonstration Testing Plan

To ensure that we are meeting the requirements above before the final demonstration, the following tests will be performed, in the following (flexible) order (Communications and electronics tests will be performed once after every other test).

4.2.1 Communications Test

This test will consist of sending commands to the bus and then the probe (in series) and ensuring that the computer is getting a response in the expected time. Validates REQ-COM-1 and REQ-COM-2.

4.2.2 Flight Software & Electronics Test

First, conductivity and power will be tested with a multimeter in the bus. Then, every sensor in the bus and probe will perform and send calibration readings. Next, all commands needed for the demonstration mission will be performed, in order, including releasing the probe. Addresses risk FCM. Validates REQ-FSW-1 and REQ-FSW-3.

4.2.3 Probe Release Test

Ensure that the mechanism that releases the probe does not get stuck. Addresses risk PRM. Validates REQ-FSW-3.

4.2.4 Centrifugal Test

This test produces centrifugal forces to simulate high g-forces on the satellite during launch. It must be able to replicate the highest expected g-load. Addresses risk SLA. Validates REQ-LGF-1.

4.2.5 Vibration Test

During this test, the satellite must be clamped to a machine that produces vibrations in all directions and frequencies expected during launch. Addresses risk SLA. Validates REQ-VIB-1.

4.2.6 Cold Environment Test

This test will subject the entire system to temperatures as low as expected in orbit. Communications and electronics testing will be conducted first in the "ground" environment and then again in the "cold" environment. Addresses SCO, and validates resistance to WCO. Validates REQ-CLD-1, REQ-CLD-2, and REQ-SUB-2.

4.2.7 Probe Shock Test

Drop from at least 2 meters and assess structural damage. Addresses risks SLA, SDR, and WOR. Validates REQ-SHK-1.

4.2.8 Water-Tight Test

Submerge probe in water as deep as its largest dimension. Use an internally built hygrometer in the probe to determine if there is water leakage. Addresses risk WLE. Validates REQ-SUB-1.

4.2.9 Remote Temperature Measurement Test

Create a surface with a different temperature compared to its surroundings using ice. Compare the long-distance temperature sensor readings with the readings of a ground truth thermometer. Compare height readings with height ground truth measurements. Addresses risks IMG and TEM. Validates REQ-TMP-1.

4.2.10 Water Temperature and Conductivity Measurement Test

Create water environments with different values of conductivity and temperature by filling our kiddie pool (PR-1) with water, ice (PR-2), and sodium chloride (PR-3) (see 12). Compare probe readings with ground truth readings. Addresses risks FCM and TEM. Validates REQ-TAC-1 and REQ-TAC-2.

4.3 Integration Test

The demonstration run will consist of the following steps. First, the imaging and temperature sensor in the bus will look for the hottest spot on a surface of ice/water that will be beneath the zipline. When it identifies the spot, it will turn on an LED indicator. Then, it will navigate until it is right above said spot and will drop the probe. The probe will then send a signal to the computer, indicating that it has been dropped. It will now measure the temperature and conductivity of the water beneath it and send it to the computer for analysis. A random untested sample of water with a random value of conductivity will be set during the test so that we validate that the probe can read and understand previously unknown data. See Figure 1.

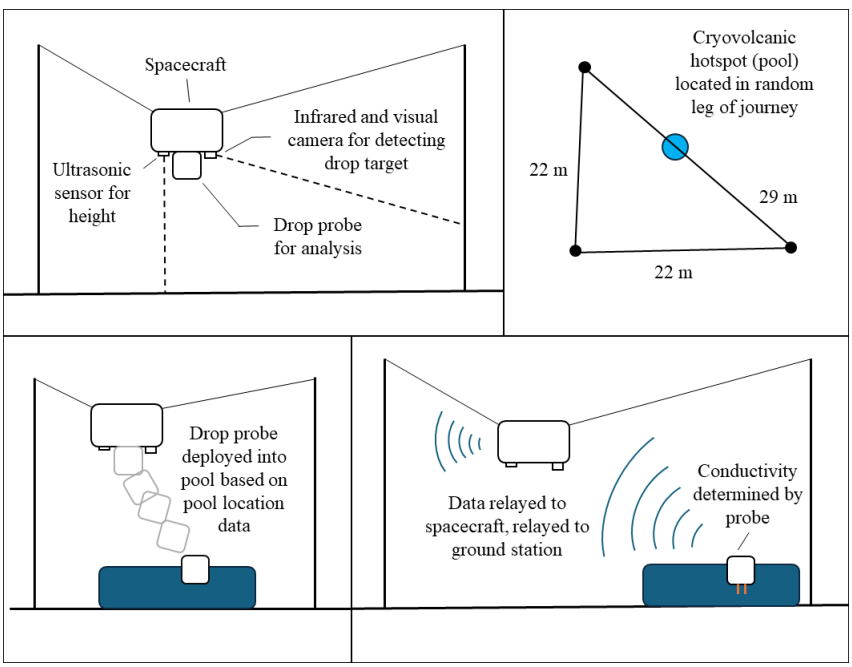

Figure 1: Integration Test Diagram [6]

5 Project Plan

5.1 GANTT Chart

The critical path on the GANTT chart flows primarily through the integration of radio communication systems as it is essential for the remote testing and sensing operations and therfore serves a potential bottleneck to using flight test opportunities productively. See Figure 2 for the project GANTT chart.

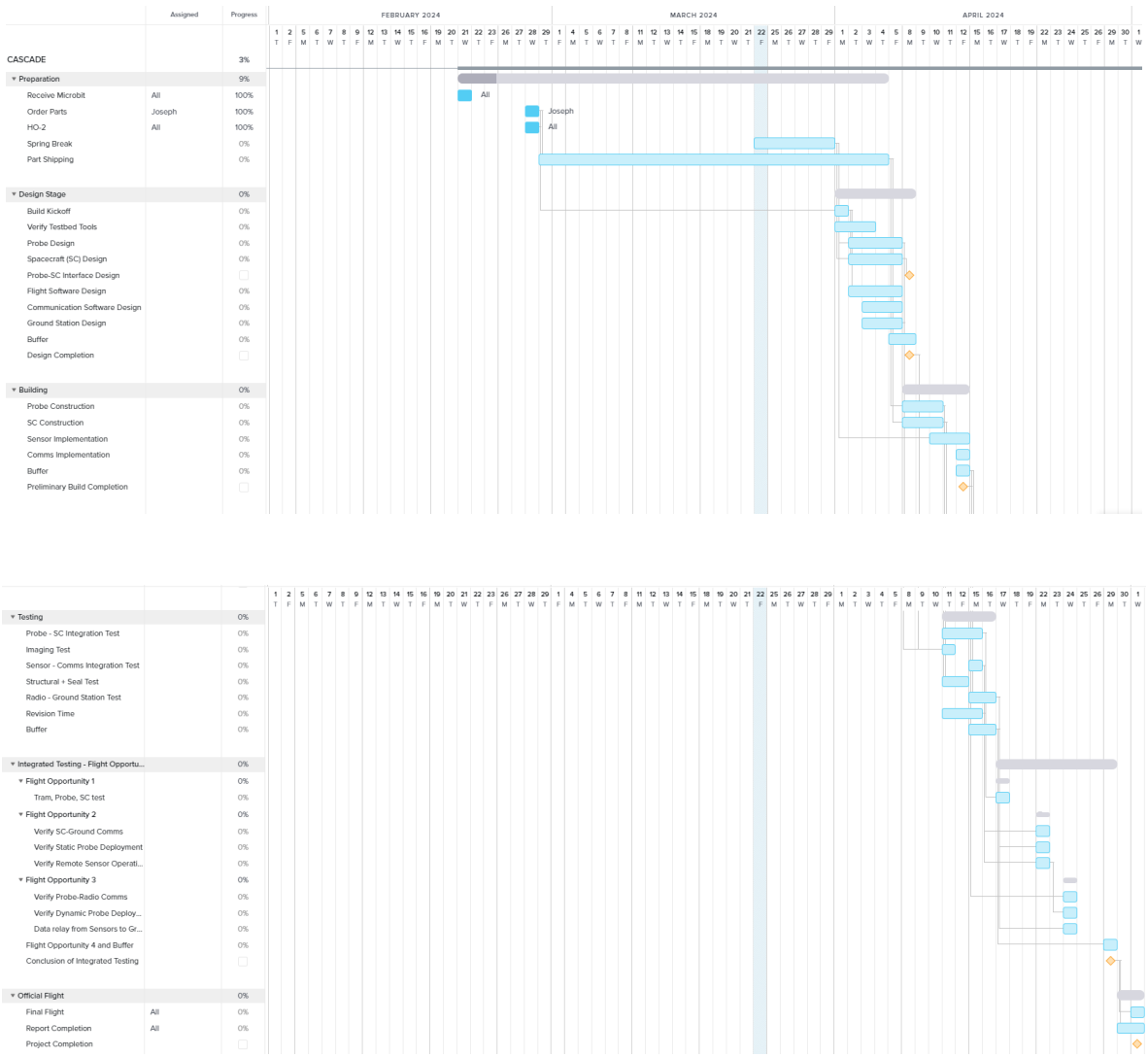

Figure 2: GANTT Chart

6 Safety Plan

6.1 Safety Plan Summary

The biggest threats to safety will potentially be soldering, drop testing, and the 10g launch test. Soldering presents a risk in the form of fumes and a burn risk and will never be conducted by two people, only before midnight, so that help can be readily obtained should it be needed. The 10g test involves rotating the spacecraft on a 3m rope and may be a threat should it come loose, so only the person spinning the rope should be in the area. The drop tests and hot/cold tests may also pose a slight danger depending on how they are conducted, with parts possibly falling on someone's foot during the drop test. All team members will ensure that nobody is in the area reachable by pieces that might fall off during a drop test. Team members performing structural tests will be wearing safety glasses at all times. More details will be provided later, such as lists of relevant PPE and instructors to seek help from.

7 Division of Labor

7.1 Proposal Phase

Table 8 provides the division of labor for the proposal phase, which consists of the development and revision of this document.

Table 8: Proposal Phase Division of Labor

Task	**Leader**
Write Executive Summary	Cesar
Write Concept of Operations	Joseph
Write Risk Analysis	Pablo
Write Testing	Tomás
Write Project Plan	Pablo
Write Division of Labor	Joseph
Write Individual Skill Plans	Each student
Write Resource Support Requests	Joseph
Write Conclusion	Cesar
Conduct Document Formatting	Joseph
Develop Sketches	Cesar [8]

7.2 Design Phase

Table 9 provides the division of labor for the design phase of our mission.

Table 9: Design Phase Division of Labor

Task	**Leader**
Supervise Team Progress	Cesar
Supervise Safety	Tomás
Develop CAD Model	All
Conduct FEM Analyses	Cesar
Develop Testbed	Tomás
Develop Scientific Instruments	Joseph
Supervise Risk Management	Pablo
Develop Communications	Pablo
Develop Sensor Calibration Protocol	Pablo
Conduct Resource Support Requests	Joseph

7.3 Build Phase

Table 10 provides the division of labor for the build phase of our mission.

Table 10: Build Phase Division of Labor

Task	**Leader**
Supervise Team Progress	Cesar
Supervise Part Fabrication	Cesar
Develop FSW	Joseph
Integrate Avionics	Joseph
Integrate Scientific Instruments	Joseph
Supervise Power Management	Cesar
Supervise CubeSat Integration	Cesar
Supervise Tests	Tomás
Supervise Safety	Tomás
Calibrate Sensors	Pablo
Integrate Communications	Pablo
Obtain Resource Support	Joseph

8 Individual Skill Plans

8.1 Overview

The following section details the individual skill plans of each team member. For reference, each self-assessment results graph has each of the eight skills labeled on a scale from one to five: 1 = no knowledge, 2 = some knowledge, 3 = average knowledge, 4 = substantial knowledge, 5 = expert. The abbreviated skill codes are as follows

1. FS = Flight software development
2. PE = Power electronics
3. OE = Other electronics
4. RC = Radio communication
5. SC = Sensor configuration and calibration
6. CAD and mechanisms
7. Prototyping and machining
8. Testing and diagnostics

8.2 Cesar Meza

Cesar would like to gain more experience with systems-level thinking and testing/diagnostics for two reasons: because the student would like to pursue space-systems development in graduate school (where testing and diagnostics are critical) and since he has not had exposure to designing robust architectures in the past given that most of his experience has been in the realm of rapid prototyping. This project will involve a great deal of systems thinking, primarily in the development of procedures and contingencies in the event of communication issues or a failure to deploy the probe, and also in testing the system rigorously to mitigate mission-critical risks. By taking point in developing these aforementioned satellite trouble-shooting procedures and designing the high-level architecture, Cesar will gain substantial exposure in this skill with the hopes of being able to apply it independently on personal projects and in graduate-level research. The second skill Cesar would like to develop is that of electronics and wiring since he has not had the opportunity to develop these skills beforehand. Particularly, he would like to take point on developing the power distribution system for the deployable probe and its constituent instruments with the hopes of gaining sufficient familiarity to develop circuits and electronic devices for his usage.

Figure 3: Cesar Meza [7]

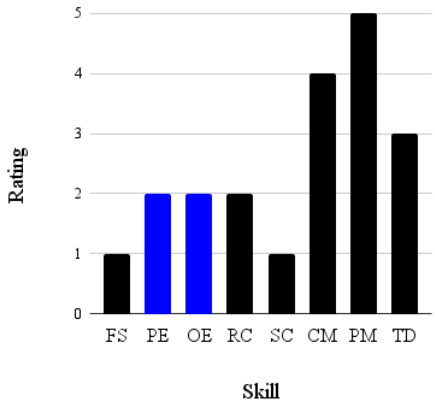

Figure 4: Cesar's Self-Assessment Results [5]

8.3 Tomás Cantú

Tomás has informal experience in systems-level thinking, electronics, and mechanical systems, but all his projects have been designed through rough trial and error; he has never done planned and formal experiments to test and validate his designs. Tomás wants to learn more about testing, validation, and risk prevention and is excited to work on the testing side of the project. Since his main area of interest is space robotics and science, he wants to be able to better understand and plan for unknown events beforehand. This project, since it heavily relies on preliminary testing and risk management, will help Tomás develop this skill. Another skill Tomás would like to develop is the use of sensors to take scientific data. Although he has used sensors before, he has never performed rigorous scientific analysis with the data taken. Finally, Tomás wants to continue improving his manufacturing and computer designing skills, which is a very strong area of interest that he wants to pursue as a career.

Figure 5: Tomás Cantú [2]

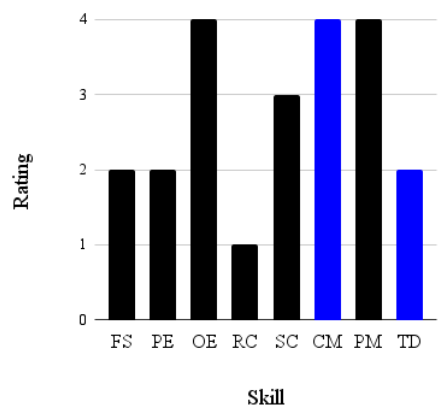

Figure 6: Tomás' Self-Assessment Results [5]

8.4 Pablo Arroyo

Pablo has limited experience in sensor configuration and calibration and no experience in radio communication. Pablo has skills with CAD, prototyping, and testing, so integrating sensors and remote information will make him a more well-rounded engineer. His work in this field is also beneficial as some of his other teammates can help him if he needs help with this. Remote operations, enabled here by radio communication, are a key part of the lab as the spacecraft and probe need to relay valuable science information back to the operators to fulfill the science objectives. Radio communications are not very useful to us if we collect no data, so Pablo hopes to incorporate thermal, electrical, and image sensors into the mission. Pablo is also working on a personal project that would benefit from being able to close the loop on chemical concentrations using Adafruit and Arduino-style sensors, so this experience is a valuable opportunity for him.

Figure 7: Pablo Arroyo [1]

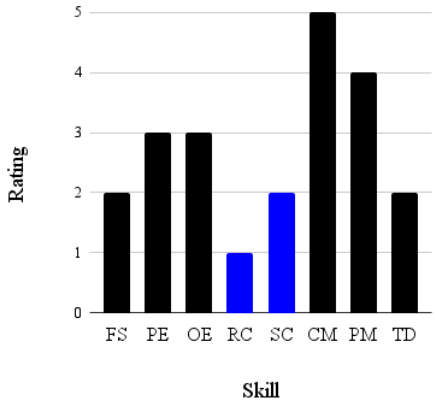

Figure 8: Pablo's Self-Assessment Results [5]

8.5 Joseph Hobbs

Joseph has moderate experience in software development but no experience in interfacing with flight hardware. He also has a great interest in but a limited understanding of system automation and decision-making. Furthermore, he would like to learn more about flight diagnostics. As the FSW developer and diagnostics engineer, Joseph will gain valuable experience in the development of robust flight software to interface with existing flight hardware. Additionally, Joseph seeks to refine his CAD and fabrication skills as well as his teamwork and systems engineering ability.

Figure 9: Joseph Hobbs [4]

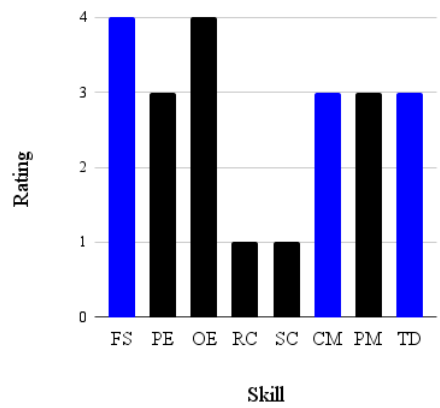

Figure 10: Joseph's Self-Assessment Results [5]

9 Resource Support Requests

9.1 Testbed Configuration Requests

Table 11 outlines our testbed configuration requests.

Table 11: Testbed Configuration Requests

Request Code	Description	Quantity
TB-1	Freezer for T-6	1

9.2 Purchase Requests

Table 12 outlines our purchase requests.

Table 12: Purchase Requests

Request Code	Description	Quantity	Source
PR-1	Kiddie Pool (for cryovolcanic analog)	1	Amazon
PR-2	Ice	1	DoorDash
PR-3	Iodized Salt	1	Target
PR-4	Structural Adhesive	1	McMaster
PR-5	Multi-Purpose Copper Wire	1	McMaster
PR-6	Adafruit BME280 Temperature & Humidity Sensor	1	Adafruit

9.3 Training Needs

Table 13 outlines our training needs.

Table 13: Training Needs

Request Code	Description
TN-1	Radio Communications Development Training

9.4 Workspace Access Requests

Table 14 outlines our workspace access requests.

Table 14: Workspace Access Requests

Request Code	Description
WA-1	Access to Building 31 Balcony for Drop Test

10 Conclusion

In fine, the CASCADE mission attempts to recreate, on a small-scale several of GEORGE's mission objectives. Namely, the mission will consist of deploying a probe into an identified region of interest (a pool full of ice water) while in transit. The probe will subsequently measure the conductivity of the water to determine the concentration of salt dissolved in the solution. There will be a total of ten tests conducted to validate the functionality of key components such as the conductivity sensor, infrared sensor, time-of-flight sensor, and probe release mechanism, in addition to the structural integrity of all the included components. Each team member will tackle a previously undeveloped skill, namely those of data handling, flight software development, testing, and power distribution. In fine, the complexity of the CASCADE mission renders the demonstration a challenging yet feasible demonstration of robust system architecting that will prove edifying to the team and engrossing for the teaching staff.

References

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[4] Joseph Hobbs. *Original Work*.

[5] Cesar Meza. *Compilation of Self-Assessment Survey Data*.

[6] Cesar Meza. *Integrated Test Sketch*. Microsoft PowerPoint.

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[8] *Microsoft Copilot*. 2024. URL: https://copilot.microsoft.com/.

[9] NASA. *Why Europa*. https://europa.nasa.gov/why-europa/ingredients-for-life/.

A GEORGE Mission Analog

Table 15: CASCADE–GEORGE Mission Analogies

CASCADE Capability	**GEORGE Analog**
Infrared Detection of Hot Spot	InSAR and Imaging Reconnaissance
Deployment of Probe	Hohmann Transfer to Collect Plume
Conductivity Test of Water	Mass Spectrometry of Plume Sample
Temperature Readings	Thermal Imaging by Orbiter

B Spacecraft Modes

This section outlines the modes available to the SC.

B.1 Mode Descriptions

Safe The SC will automatically enter this mode when the power is switched on, or on recovery after a software error. Safe mode disables all non-essential subsystems, including the zipline motor.

Pre-Launch The SC will enter this mode after the launch command is given. The launch countdown begins and the spacecraft conducts diagnostic tests of all essential subsystems. Pre-launch mode also disables the zipline motor.

Transit Nominally, the SC will enter this mode after the launch countdown expires. The SC will also enter this mode after completing the objectives of another mode. During Transit mode, the SC will travel along the zipline. The SC camera will also scan the surface below it for cryovolcanic activity.

Science The SC will enter Science mode after detecting cryovolcanic activity. The SC will release the probe into the hotspot and begin receiving scientific data from the probe.

Comms The SC will enter Comms mode after the successful completion of Science mode. The SC will format probe data and relay it to the ground station.

Diagnostics The SC will enter Diagnostics mode after detecting a fault. The SC will disable all non-essential subsystems except for the zipline motor and conduct its full battery of software diagnostics.

EOL The SC will enter EOL mode after receiving the EOL command from the ground station. The SC will relay the EOL command to the probe, which will conduct a full shutdown. The SC will then disable all subsystems and conduct a full shutdown. After the completion of EOL mode objectives, the SC will be disabled and the mission will terminate.

B.2 Mode–Subsystem Map

Table 16 relates SC modes to enabled and disabled subsystems.

Table 16: SC Modes and Subsystems

Mode	**Power**	**Comms**	**CDH**	**Propulsion**	**Telemetry**	**Science**
Safe	Enabled	Enabled	Enabled	Disabled	Disabled	Disabled
Pre-Launch	Enabled	Tested	Tested	Disabled	Tested	Tested
Transit	Enabled	Enabled	Enabled	Enabled	Enabled	Disabled
Science	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
Comms	Enabled	Enabled	Enabled	Enabled	Enabled	Disabled
Diagnostics	Enabled	Enabled	Enabled	Enabled	Tested	Tested
EOL	Disabled	Disabled	Disabled	Disabled	Disabled	Disabled