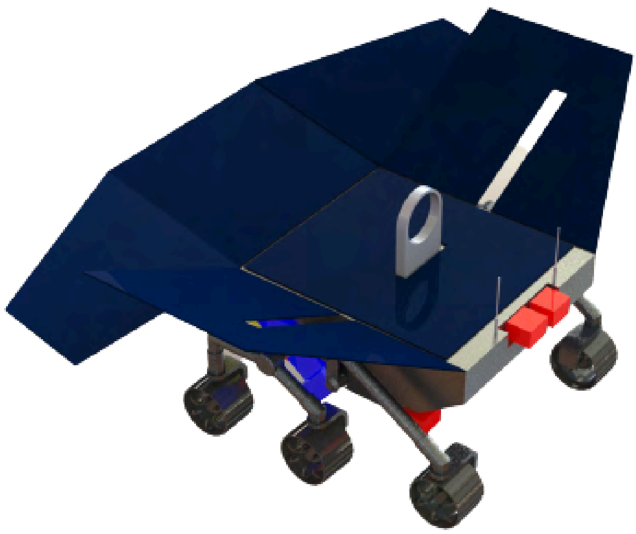
Preliminary Design Review

Poli'ahu - Mars 2026 Exploration Mission



Team 8

(Team Aegir)

Aprille Joie LeBaquin
Jonathan Mickelson
Jake Granone
Celise Vaughan
Estefany Ocegueda
Arathy Rengith
Ali Uysal
Lori Huang
Saja Alallao
Corey Lisemby
Marco Barajas
Robert Smith

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1. Introduction and Summary

1.1 Team Introduction

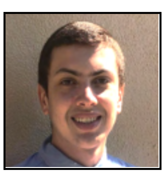
Saja Alallao:

Saja is a junior at San Diego State University, studying Computer Engineering. While her focus is on electricity, robotics, and hardware, she is very interested in artificial intelligence, graphic design, management, and astronomy. Saja has been coding, designing cir

cuits, and building electrical circuits and currently working as an Electrical Engineer Student Assistance at Caltrans under close supervision of professional engineering in the electrical design department. Saja is an Electrical Engineer and part of the leadership at SDSU Mechatronics.

Joshua Banks:

Joshua is a first-year Computer Science undergraduate student at Reedley College. He hopes to transfer to a UC or California State university within the next few years. He hopes to pursue a career in software development. He has an interest in game development, cybersecurity, and machine learning. Over the summers, he has been involved with the school cybersecurity club, providing him insight into the importance of security in development. He is excited to be part of the engineering team as a Materials Engineer and a Payload & Instrument Specialist.



Marco Barajas:

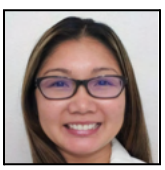
Marco is a Third Year Mechanical Engineering student at the University of California, Riverside. His biggest interests are in Robotics/Control Systems and he aspires to become an I&C Engineer in Oil/Gas or in Aerospace/Defense. Marco also has a strong interest in the Management Consulting Sector and hopes to go into it after completing his MBA. At UCR he is involved with his school's drone team, UCR UAS where he assists his team in the Design, Testing, and Deployment of UAVs. He is also currently serving as his school's ASME Secretary and Professional Development Chair for the Society of Hispanic Professional Engineers.

Jake Granone:

Jake is a senior at California State University, Long Beach, earning his BS in Aerospace Engineering with an emphasis in Astronautics. He is fascinated by in-space technologies and planetary science and is pursuing a career in the aerospace industry, possibly as a propulsion engineer. Jake has participated in both the Experimental Sounding Rocket Association (ESRA) and Long Beach Rocketry teams while at CSULB, and has completed the NASA L'SPACE NPWEE academy in summer 2021. Jake is excited to contribute to the future of space exploration.

Lori Huang:

Lori is a second-year student at University of California, Berkeley. Though she is currently majoring in mechanical engineering, she hopes to take an interdisciplinary approach in her studies exploring the intersection between mechanical and electrical designs. Lori is currently involved in undergraduate research with the Berkeley FLOW lab, designing and developing an x-ray collimator intended for use within the lab's research.



Aprille Joie LeBaquin:

Aprille is a sophomore at Glendale Community College in Glendale, California. She is majoring in Chemistry and pursuing a career in the Research and Development field as a Materials Scientist. Aprille has participated in the Organic Chemistry Undergraduate Research Summer 2019 Program, with a focus on researching natural herbs that contain high levels of antioxidant and antibacterial properties. She has participated in the NASA Community College Aerospace Scholars (NCAS) Online Program in January 2021 and the Virtual NCAS Mission 2: Engage Experience in September 2021. Aprille has also participated in the NASA L'SPACE Proposal Writing and Evaluation Experience Academy (NPWEE) in Summer 2021. She is the Project Manager of Team 7, and they were selected as one of the three NPWEE recipients. NASA has granted $10,000 seed funding to begin the prototype development stage of their proposal. Aprille is participating in the Fall 2021 L'SPACE Mission Concept Academy (MCA) and is the Project Manager for Team 8.

Corey Lisemby:

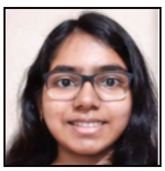
Corey is a freshman at De Anza College in Cupertino, California studying Aerospace Engineering. He has been passionate about astronomy and planetary science since his first telescope at the age of 4, and recently discovered a new interest in meteorology. As a high school student, he held several leadership positions and was a recipient of the Seal of Biliteracy in Spanish and the Gold Presidential Volunteer Service Award. He also began taking up astrophotography as a hobby and conducts observations of comets, eclipses, planets, and moons in his backyard. In the future, he plans to pursue student government and volunteer opportunities at De Anza, apply for internships, and raise monarch butterflies while studying to transfer to the University of California system. Corey aspires to work at NASA and is excited to see the success of future missions such as *DAVINCI+*, *Dragonfly*, the *Europa Clipper*, the *James Webb Space Telescope*, *JUICE*, *Lucy*, *Rosalind Franklin*, and *VERITAS*.

Jonathan Mickelson:

Jonathan is a senior at Humboldt State University, earning his BA in Leadership Studies, with a minor in Geospatial Analysis. He is passionate about planetary science, astronomy, and space exploration. Jonathan is an entrepreneur with 20+ years of experience in corporate leadership, managing technology teams, product development, and software engineering. He is actively pursuing workforce experience to learn NASA policies, programs, and operations through academies like the NASA Proposal Writing and Evaluation Experience (NPWEE), where he was a Principal Investigator and the L'SPACE Mission Concept Academy as a Deputy Project Manager. Jonathan plans to obtain his Master's degree in a space-science-related field while pivoting his career to utilize his experience in leading technical teams to further the U.S. space exploration missions.

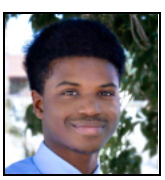
Estefany Ocegueda:

Estefany Ocegueda is a recent transfer student at California State University, Long Beach. She is majoring in Mechanical Engineering and hoping to pursue a career in the space industry. Estefany participated in the 2021 MUREP Innovation Tech Transfer Idea Competition (MITTIC) where her team was a finalist and had the opportunity to be involved in the Johnson Space Center Immersion Experience. She also participated in NASA's California Space Grant Consortium where her team created a prototype. Estefany also participated in NASA L'SPACE Proposal Writing and Evaluation Experience Academy (NPWEE) in summer 2021 where her team was one of three winners. Her team is being funded by NASA to develop their product.



Arathy Rengith:

Arathy is a second-year student at the University of Washington. She is currently majoring in Civil Engineering but hopes to explore and transfer to mechanical engineering if it is a better fit. She has experience coding in Java, making CAD models using Fusion 360, using TinkerCAD, and setting up basic circuits. She is passionate about space explorations and dreams to work in the space industry one day, making impacts that inspire people to think beyond what is thought to be possible. She is especially interested in topics such as black holes, wormholes, space travel, and life beyond Earth. Moving forward, Arathy hopes to join the L'SPACE (NPWEE) program and explore more about NASA and the space field.



Robert Smith:

Robert is a Sophomore at the University of Nevada, Reno studying Computer Science and Engineering. While his primary career goal is software engineering, he is equally interested in business (finance in particular), artificial intelligence, politics, and anything to do with space exploration and space robotics. He is the current Director of Programming for his school's chapter of ACM, as well as treasurer for Film Club and a member of Astronomy Club. As for the technical side, Robert has been coding for about 4 years now and is always making time to create projects that bridge his interests into functional, visually appealing software applications.

Ali Uysal:

Ali is a junior at California Polytechnic State University in Pomona, California. He is majoring in Aerospace Engineering focusing on astronautical emphasis. Aviation has always been his passion and he's been even more fascinated with the recent space exploration efforts in the last decade. He has been building model rockets on the side and flying them at local model rocket gatherings and recently obtained his Level 1 High Power Rocketry Certificate. Ali is aiming to improve his vision and skill sets in the next few years and find himself a place at JPL when he receives his engineering degree.

Celise Vaughan:

Celise Vaughan is a third-year student at California Baptist University in Riverside, California. She is majoring in mechanical engineering and intends to pursue a career in the aerospace industry. She has experience working with Solidworks and AutoCAD as well as experience managing deadlines through involvement in course projects. Celise is also involved with the Society of Women Engineers organization at CBU.

1.2 Mission Overview

Poli'ahu - One of the four Hawaiian goddesses of snow. According to tradition, Poli'ahu frequented the snowy slopes of the Mauna Kea volcano and participated in sledding races with humans. This mission was named after Poli'ahu to highlight Mars' volcanic past, our search for frozen water on Mars, and humankind's preparations to reach into the heavens to visit another planet.

1.2.1 Mission Statement

Poli'ahu shall quantify the volume of water ice within the vicinity of Phlegra Dorsa, a flat region on Mars. Using ground-penetrating radar, the Poli'ahu rover will travel across the Martian surface detecting subsurface geologic layers, including areas that contain water ice. Data obtained from this mission will allow for the quantification of available water ice and the characterization of the surface region above it. These results will provide future mission planners with In Situ Resource Utilization (ISRU) data that can be applied to future manned missions on Mars, namely with determining ideal sites for the extraction of water ice. Ultimately, Poli'ahu will help determine if a sustainable human presence is possible on the red planet.

1.2.2 Mission Requirements

ID	Type	Requirement
1	System	System shall be able to survive in transit and Martian environments
2	System	System shall engage in 2-way communication with the primary lander system
3	System	System shall maintain a continuous powered state throughout the operations phase(s)
4	System	System shall take measurements to quantify and characterize ice resources
5	System	System shall semi-autonomously navigate on Mars.
6	System	System shall be capable of moving on the surface of Mars
7	System	System shall be capable of performing autonomous science tasks.
8	System	System shall not exceed a mass of 30 kg
9	System	System shall have a volume fully constrained by a cube of 100cm on each side in its stowed configuration
10	System	Mission shall not exceed a $300 million budget
1.1	Functional	System shall maintain components in their operating temperature ranges
1.2	Functional	System operations shall not be affected by dust/debris
1.3	Functional	System shall survive vibrations of up to 2000 Hz
2.1	Functional	Communications subsystem shall receive radio signals from the main lander system
2.2	Functional	Communications subsystem shall transmit science data to the main lander system
3.1	Functional	Power subsystem shall generate power during charging phases
3.2	Functional	Power subsystem shall distribute current to all powered components at their nominal voltage
3.3	Functional	Power subsystem shall store energy during charging phases for use in times of shade

3.4	Functional	Power subsystem shall sustain the vehicle in a low power state while stowed, from liftoff until the Vehicle is deployed on the Martian surface
4.1	Functional	Remote sensing system shall measure the volume of subsurface ice resources
5.1	Functional	Navigation system shall autonomously image the local environment
5.2	Functional	Navigation system shall navigate from waypoint to waypoint minimizing risk to the vehicle.
6.1	Functional	Movement subsystem shall be capable of traversing over uneven terrain
6.2	Functional	Movement subsystem shall be capable of maneuvering the vehicle
7.1	Functional	Command and Telemetry subsystems shall command the other subsystems.
7.2	Functional	Command and Telemetry subsystems shall regulate the flow of data from subsystems to storage to transmission.
1.1.1	Performance	Thermal system shall maintain a minimum temp of -5 C inside the Warm Electronics Box
2.1.1	Performance	Communications system shall receive transmissions in the VHF range
2.2.1	Performance	Communications system shall transmit up to 16km (10 Miles)
2.2.2	Performance	Communications system shall transmit in the VHF range
3.1.1	Performance	Solar arrays shall charge at 165.5 watts.
3.3.1	Performance	Batteries shall maintain a depth of discharge no greater than 70 %.
4.1.1	Performance	Ground Penetrating Radar shall identify layer boundaries to a depth of 10 m with a resolution of 15 cm.
4.1.2	Performance	Neutron Spectrometer shall differentiate between layers with and without H_2O in the first 1 meter of the surface
5.1.1	Performance	Navigation subsystem shall take stereoscopic imagery of its surroundings with resolution (insert from Navcam)
5.1.2	Performance	Navigation subsystem shall image the area of contact between the wheels and the ground
6.1.1	Performance	Movement subsystem shall propel the vehicle a total distance of 27,000m

		(5 miles)
6.1.2	Performance	Movement subsystem shall be capable of propelling the system uphill at 10% grade
6.1.3	Performance	Movement subsystem suspension shall have a vertical clearance of 20 cm.
6.2.1	Performance	Movement subsystem shall be capable of rotating in place

1.2.3 Mission Success Criteria

ID	Criteria
MR 1	Identify if the explored area contains the needed mass of water ice for future human Mars missions (>100 metric tons)
MR 2	Obtain scientific data for a region of Mars not previously explored by a rover/lander
MR 3	Successfully relay all scientific data collected.
MR 4	Successfully collect necessary data in the 100 Sol timeframe of the mission.
MR 5	Radar will operate with a range resolution of 15cm to 30cm.
MR 6	The spacecraft lands on the specific landing site determined before the mission starts.
MR 7	MR 8: Data will be delivered within 30 sols of collection.

1.2.4 Concept of Operations

The following diagram shows the main phases of the Concept Of Operations (COO) for Poli'ahu:

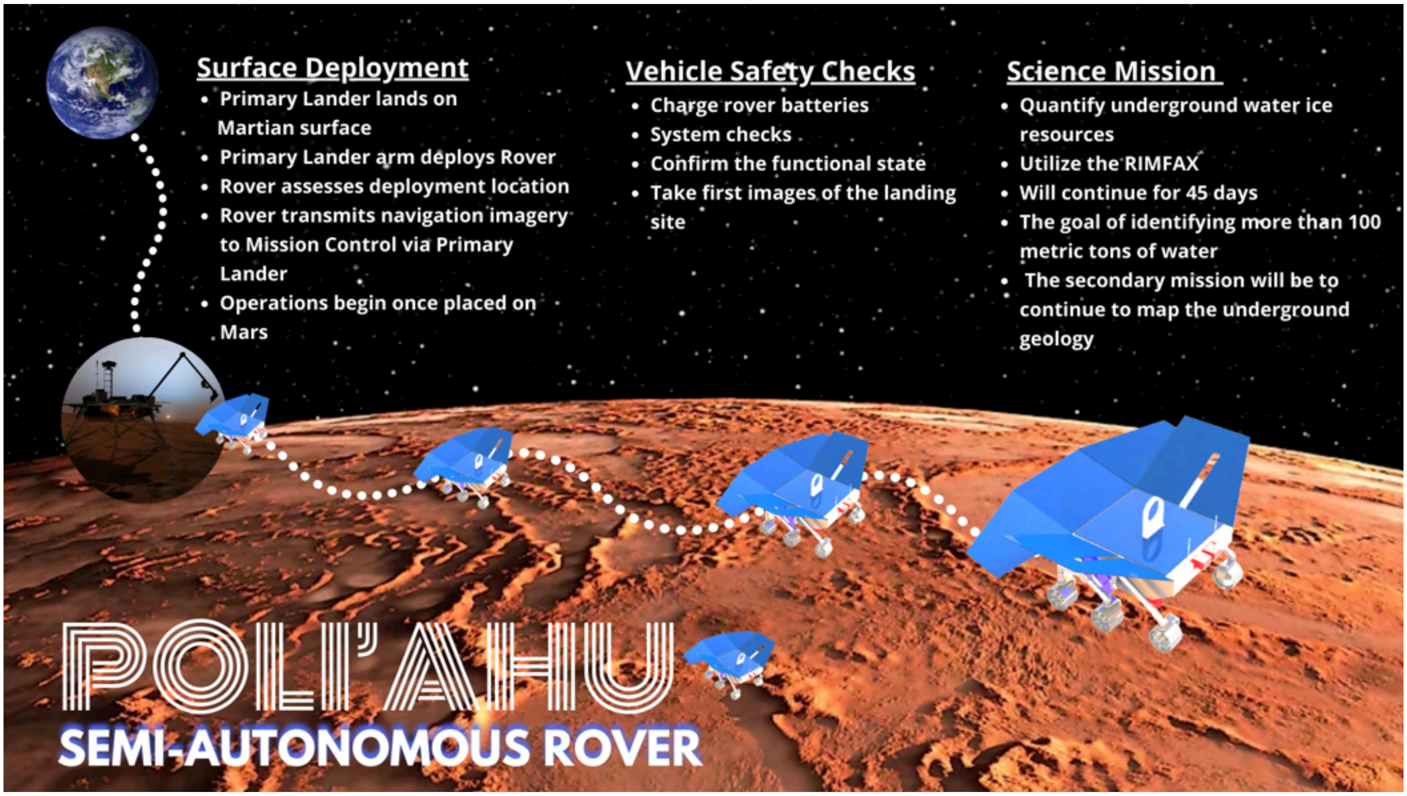


Figure 1.2.4-1: Poli'ahu Concept of Operations (COO) Diagram.

1.2.4.1 Surface Deployment

The Poli'ahu mission is a semi-autonomous rover that will be a secondary payload on a primary lander sent to Mars. As a ride-share mission, Poli'ahu will begin its mission and science operations once it is lifted from the primary lander and placed on the Martian surface. Once the mission begins, the rover will communicate with the primary lander as it conducts deployment tasks.

1.2.4.2 Vehicle Safety Checks

The rover's first autonomous tasks will be to assess its location relative to the primary landing platform, while relying upon its remaining battery power. If the rover determines that it has been placed as intended, facing the lander, and has sufficient clearance from the lander or other obstacles, it will attempt to safely deploy it's rear solar panels and begin charging its batteries.

If the rover is not within this "safe-margin," it will autonomously transmit a series of images taken by hazard and navigation cameras via the primary lander and await directives from mission operators while remaining in a low-power mode. If communications or other failures occur, and power consumption estimates for an approaching martian night or solar obstruction due to the lander shadow indicate the the rover may not survive the night, it will make its best attempt to autonomously move clear of the lander and deploy its panels while there is still sunlight, before its onboard batteries reach a low power state.

Upon successful deployment of its solar panels, the rover will fully charge its batteries and analyze the state of the power system. Once full battery power has been confirmed, Poli’ahu will conduct a series of onboard system checks. Upon confirming the functional state of all critical and science subsystems. The rover will then take its first images of the landing location, including images of the primary lander and it’s environment.

1.2.4.3 Science Mission

The primary science mission is to locate and quantify underground water ice resources in preparation for future human exploration missions to the red planet. The rover will utilize multiple instruments to accomplish these goals by remote sensing. This will be accomplished by utilizing ground-penetrating radar to identify buried layers of sediments or rock, along with a neutron spectrometer that detects hydrogen indicating the presence of underground water ice deposits as depicted in Figure 1.2.4-2.

Poli’ahu will approach this remote sensing campaign by systematically and autonomously traversing Phlegra Dorsa to an initial science location based on pre-launch satellite imagery and extrapolated geologic features expected in this region of Mars. Mission planners will analyze incoming data to determine if they should guide it towards higher-value targets by sending additional commands or changing its mode of operation. This surface operations approach will maximize the potential for locating large ice deposits such as underground frozen or liquid aquifers, buried glaciers, and permafrost. Upon identification of scientifically promising results, the rover will transition into a higher detailed mapping mode following the deposits in an attempt to identify their boundaries so that ice volume calculations can be made.

Stereoscopic three-dimensional images of the surface terrain will be gathered along with subsurface radar and neutron spectrometer data. This data will be used by mission scientists to generate three-dimensional maps of the terrain, including the subsurface layers, and highlight ice deposits or layers. Future missions will use these findings to develop equipment and extraction methodologies to enable the collection of these water resources via ISRU.

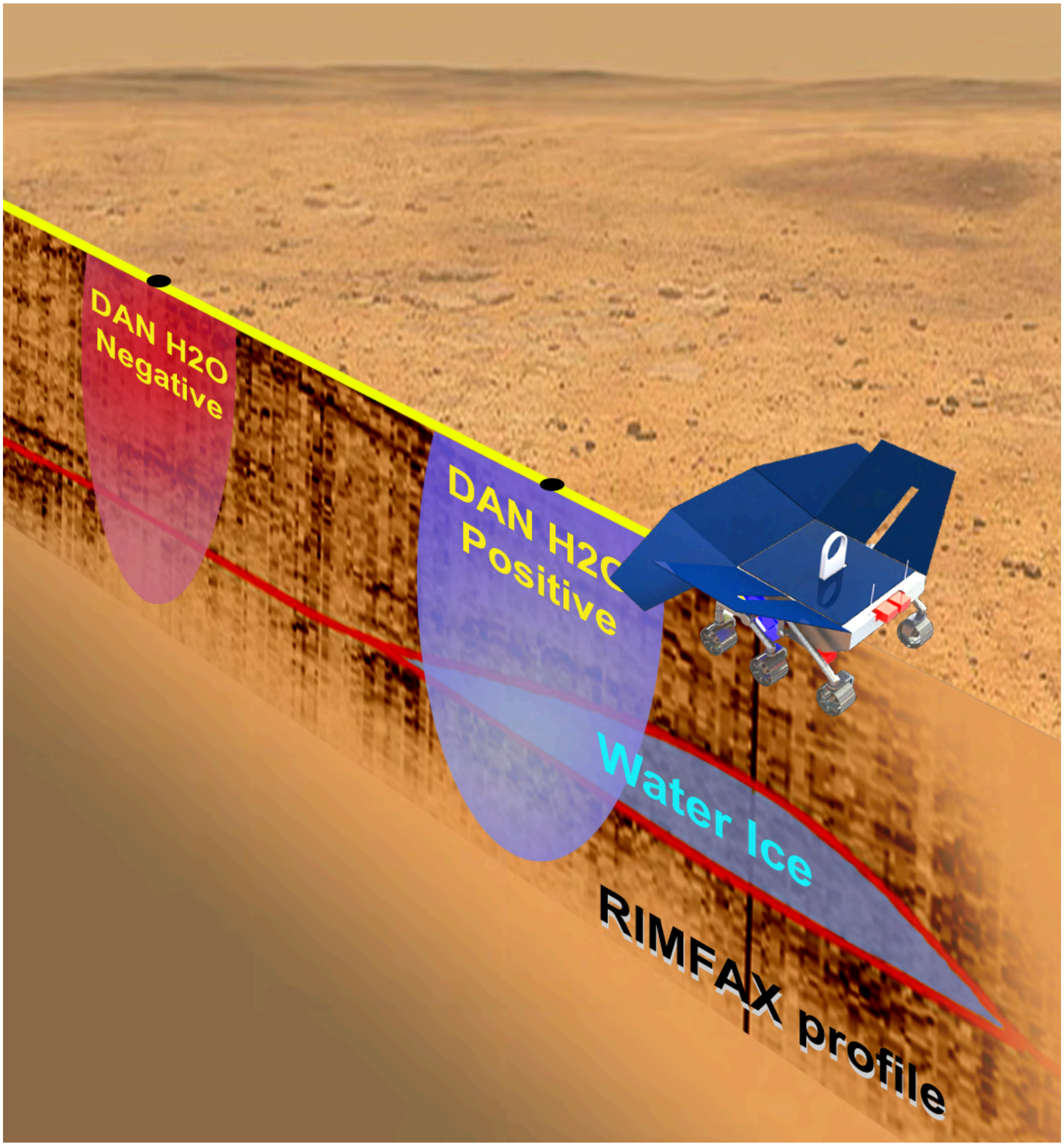


Figure 1.2.4-2: Poli'ahu Surface Science Concept of Operations.

The primary science phase will last 100 sols. The primary goal is to identify more than 100 metric tons of water ice, especially focused on deposits that are easily accessible and a good fit for automated mining activities. If Poli'ahu receives an extension to its primary science mission, the secondary mission will be to undertake mapping the underground geology around the landing site and continue to search for additional water-ice reserves. Finally, Poli'ahu mission scientists will attempt to investigate geologic features which may be correlated to the presence of underground water-ice reserves, potentially allowing likely water ice sites to be identified directly from satellite imagery in the future.

1.2.4.4 Surface Operations

The rover's autonomous movement and science plans allow for fully autonomous operation and mode switching based upon detected events, as well as manual commands to be sent from mission operations, to redirect the rover to new science targets and change its mode of operation.

In autonomous mode, the rover will prioritize safe traversal of terrain towards a target location. While it does this, it will simultaneously gather science data during brief science pauses, using RIMFAX and DAN. Routine measurements will also be taken by other payloads like cameras, IMU, and atmospheric sensors, with all data being geo-metadata tagged during the traversal.

During rover science operations the autonomous traversal paths when DAN detects a significantly high subsurface hydrogen signal it will change modes into a field mode which moves forward until the signal returns to background levels. The rover then will turn around a set amount and map in the opposite direction doing the same mapping, with turns to repeatedly traverse the potential ice field, mapping it's rough bounds. Once this field mapping is completed and detailed measurements are taken, the rover will move towards another location searching for a new ice field. More detail regarding the rover science plan is detailed in Section 4.2.4.

1.2.5 Major Milestones Schedule

Pre-Phase A: Concept Studies

Pre-Phase A involves developing mission concept ideas from which new projects can be determined. Possible mission concepts were provided by the client, these were either a Mars astrobiology mission or human exploration mission, both entailing experiments and mission goals related to the presence of Martian water ice on the planet. Near the end of this phase, the Mission Concept Review (MCR) will establish the needs of the mission.

Phase A: Concept and Technology Development

In Phase A, the mission concept was narrowed down to one goal: quantifying water ice on Mars in preparation for future human exploration. Requirements for the mission concept are drafted and the design portion of the project process begins. The System Requirements Review (SRR) ensures that requirements are drafted properly and completely for the system. The Mission Definition Review (MDR) accounts for the mission architecture in addition to the drafted requirements to evaluate the mission concept.

Phase B: Preliminary Design and Technology Completion

Phase B defines the mission concept in further detail. It continues the design process as the preliminary design is developed. In addition to the holistic design of the systems and the mission concept, Phase B identifies and analyzes risks through Phase D. The Preliminary Design Review (PDR) presents the preliminary design of the vehicle and details the systems and subsystems to determine if the developed concept is executable (Hirshorn, 2007).

Phase C: Final Design and Fabrication

Phase C completes the design process as the system and subsystem are designed in more detail. In this phase, the fabrication of hardware for the system also begins. The Critical Design Review (CDR) evaluates if the design will meet the necessary requirements within the known constraints and also evaluates whether the final design is ready to undergo fabrication and manufacturing. The Systems Integration Review (SIR) establishes the readiness of the design for systems integration. It also reviews the components, subsystems, and proposed integration procedures to determine integration readiness (Hirshorn, 2007). In this phase, the rover chassis, suspension, and wheels would undergo manufacturing, and electronics fabrication would begin.

Phase D: System, Assembly, Test, Launch

In Phase D, manufacturing is worked on and completed, allowing for the assembly and integration of the system and its components. After assembly, verifications and validations are performed to ensure the system meets the necessary requirements before launch. Comprehensive testing is also performed to better ensure mission success. The Systems Acceptance Review (SAR) evaluates the system's validations and assesses the completeness of the system. Test Readiness Reviews (TRR) evaluate the established test procedures in terms of safety and methods to determine if they are adequate. At the end of Phase D, the Operational Readiness Review (ORR) evaluates the system and procedures to ensure that it is ready for normal operation (Hirshorn, 2007). The current launch date is in July 2026, allowing for a landing in April 2027.

Phase E: Operations and Sustainment

In Phase E, the system has launched, which means a Post-Launch Assessment Review (PLAR) is used to review performance. The Critical Event Readiness Review (CERR) is also conducted to determine if the system is ready to perform the critical processes for arrival to the destination and data collection. When the system reaches its destination, analysis of the mission data occurs as the system collects and sends back the desired information. In preparation for the end of the mission, the Decommission Review (DR) verifies the decommission of the system as well as verifying the decommissioning requirements and plans (Hirshorn, 2007).

Phase F: Closeout

Analysis on the collected data continues in Phase F. Once data collection is complete, the system undergoes the determined decommission processes. Data is archived and a final mission report is drafted. The Disposal Readiness Review (DRR) determines readiness for final disposal and decommissioning operations. It takes into account the defined requirements, environmental factors, and planetary protection laws. The end of Phase F marks the end of the mission (Hirshorn, 2007).

Table 1.2.5-1: Major Milestones Schedule

	Start Date	End Date
Pre-Phase A: Concept Studies	03/06/23	06/28/23
MCR	07/17/23	06/28/23
Phase A: Concept and Technology Development	07/31/23	12/01/23
MDR	09/06/23	09/20/23
SRR	11/15/23	12/01/23
Phase B: Preliminary Design and Technology Completion	12/04/23	06/28/24
PDR	06/12/24	06/28/24
Risk analysis	02/14/24	05/24/24
Phase C: Final Design and Fabrication	07/01/24	05/30/25
CDR	10/09/24	10/23/24
Fabrication and Manufacturing	10/24/24	02/21/25
SIR	04/14/25	04/30/25
Phase D: System, Assembly, Test, Launch	06/02/25	07/22/26
Integration	07/23/25	03/27/26
TRR	06/23/25	07/08/25
Verification and Validation	7/9/25	05/22/26
SAR	04/07/26	04/21/26
ORR	04/22/26	05/03/26
Launch	7/26	7/26
Phase E: Operations and Sustainment	07/23/26	07/30/27
PLAR	07/27/26	08/12/26
CERR	08/13/26	09/02/26
Landing	04/27	04/27
DR	07/19/27	07/30/27
Phase F: Closeout	08/02/27	09/15/27
DRR	08/02/27	08/18/27

1.3 Descent Maneuver and Vehicle Design Summary

Deployment Scheme

The Poli'ahu rover will land on Phlegra Dorsa aboard a larger NASA mission as a secondary payload. After landing, the primary lander will use its robotic arm to grab the Poli'ahu vehicle. This attachment point will be a six-inch ring positioned on the top of the rover, over the center of mass. The robotic arm will remove Poli'ahu from its stowed position within the payload area of the primary lander and place it gently on the Martian surface. The rover will be placed facing forward, toward the primary lander, with a clearance of no less than 10 cm from any part of the primary lander.

Once on the ground, Poli'ahu will send a test message to the primary lander system to verify the performance of the communication subsystem. The rover will turn on its cameras to verify proper operation, its position relative to the lander, survey the hazards behind the rover and move to a location where it can safely deploy the solar panels. After the deployment, the battery will undergo a complete charge for the remaining sol. The rover will activate its IMU and internal sensors to verify the proper functioning of critical components.

Vehicle Design Summary

The Poli'ahu vehicle is a rover designed with wheels, suspension, and a maneuvering mechanism. When coupled with carefully designed clearances in the undercarriage, will allow the rover to safely traverse the Martian landscape. The rover will also utilize hazard navigation cameras along with internal maps of safely traversable terrain that is processed and loaded by mission control throughout the mission. These hazard navigation tools will enhance vehicle safety while operating in autonomous navigation modes.

Poli'ahu's science instruments will utilize this mobility to map the Phlegra Dorsa Exploration Zone's overland and subterranean layers in high definition, building a robust geologic model combined with the efforts to locate and map buried reserves of water ice. In order to build this robust geologic model, the rover will attempt to systematically traverse the local area in a grid-like pattern. Computer modeling will create local terrain models, providing the rover with a geolocated position that can update and communicate back to mission control as it travels around the terrain.

When stowed during the flight to Mars, the rover will have the dimensions of 38.47 cm tall, 108.33cm long, and 97.01 cm tall. When fully deployed the rover will be 125cm long and 195 cm wide and will have a weight of 29.7kg.

Chassis/Shell Design

The chassis/shell was designed with five main openings: one being the top which is enclosed by its lid. The lid has a six-inch ring for picking up the main system and placing it on the surface of Mars. The following four openings are located at the bottom for the wheel and suspension system. The chassis has no further features inside as it is meant for a storage facility for the instruments.

1.4 Payload and Science Instrumentation Summary

Radar Imager For Mars Subsurface Experiment (RIMFAX)

RIMFAX is one of the primary science gathering instruments. It is a ground penetrating Radar (GPR), which has been flown on the Perseverance rover. It is composed of two distinct instrument assemblies that are attached to separate areas of the rover. The antenna is located in the rear underside of the rover. The system transmits a selected range of low or high-frequency waves through the ground below it. RIMFAX's antenna detects subterranean layers and transitions. This data will be used alongside other instruments to identify any layers of water ice via their characteristic radar signatures. When this data is coupled with positional data, mission scientists will generate 3D maps of the region and subsurface layering to determine the water volumes in a target region.

The RIMFAX instrument uses an antenna to transmit, with a transmitter (TX) to send radar pulses into the Martian subsurface. The instrument's receiver (RX) which will measure the time it takes for the radar pulses to be reflected back to the system. Low frequency waves can penetrate through more layers of regolith and determine the volume of ice in a targeted region. The radar system will also have the ability to adjust the wave frequency to improve its chances of detecting the water ice.

Dynamic Albedo Neutron Spectrometer (DAN)

The DAN instrument's purpose is the detection of hydrogen atoms, indicative of the presence of water or ice within the first meter of the Martian surface. This instrument has two components: a pulsing neutron generator that shoots high energy neutrons to the ground in short pulses of 2-3 microsecond intervals and a detector and electronics unit that detects the colliding interactions of hydrogen isotopes (Mitrofanov et al., 2012). This results in measurements of the percentage (%) of hydrogen detected in the region. While the DAN instrument is operating, it continually refines its measurements. The longer duration uses reduce the uncertainty of the measured percentages ("Spectrometer Finishes Calibration-Target Reading," 2012).

The DAN instrument is an integral science instrument for this mission. Its measurements allow correlations with RIMFAX's layer data to identify potential layers of water ice and their characteristic signatures in RIMFAX's measurements.

Temperature Sensors

Temperature sensors are included with various components. The rover will also house internal temperature sensors at critical component locations, this information is used by the thermal control system and the primary Rover control system to monitor and regulate the system's internal temperature, assist in system safety checks and mitigating any malfunctioning equipment, as well as being used to infer the atmospheric temperatures of the location.

Pressure Sensors

Pressure Sensors will be used to detect the pressure of the atmosphere surrounding the rover. The barometric pressure will be collected using a sensitive pressure sensor since the Martian atmosphere has very low pressure of around 1% of Earth's average pressure of 14.7 lbs/sq.inch.

The barometric pressure data will help measure changes in elevation and annual weather cycles on Mars. The system will use a pressure sensor similar to a Tavis magnetic reluctance diaphragm sensor used in the Pathfinder mission. This instrument will also collect pressure data during entry, descent, and landing (EDL).

Power Subsystem

The rover will use a solar array to generate power to carry out the science phase of the mission. The arrays capture sunlight during the "day" of each day/night cycle, which is called a sol. Sol is the name for a "martian day," which is approximately 40 minutes longer than a day on Earth.

The solar array is made up of separate solar panels which are themselves covered in arrays of individual solar cells. These panels are hinged and are placed externally on the top of the rover, also known as the deck. The solar panels are designed to extend and unfold after the primary lander sets the rover on the Martian surface. The unfolding process will be orchestrated to safely extend to the sides and back of the rover. The rear panels are designed to actively articulate, allowing the rover to maximize the sunlight captured when the sun is low on the horizon. This innovation is beneficial due to the rover's relatively high-latitude landing site at Phlegra Dorsa.

The solar panels are connected to an energy management subsystem that will control battery charging, as well as voltage control when discharging the batteries. The solar energy collected by the panels will be used to charge batteries, which in turn will power all the rover's systems. This will ensure that the vehicle has the energy it requires to perform mission objectives while also maintaining the operational temperatures during Martian nights.

Thermal Control System (TCS)

To protect the rover during cold nighttime periods on Mars, the rover will manage its internal temperatures, similar to previous NASA rovers. This is accomplished through a combination of passive thermal protection layers, capturing excess electronics heat, and active electrical heaters. Passive thermal protection techniques such as Multi-Layer Insulation (MLI), aerogel insulation in a Warm Electronix Box (WEB), and thermal plates & pipes, will help preserve incidental heat and distribute heat from hot components to other areas where heat is desired. Since the rover's electronics generate heat during operation, it is both cost-effective and prudent to preserve this heat to keep the rover warm.

Active Heating:

Internal heaters protect the "vitals" of the rover by keeping them warm when the external temperature is too low. The heating system will work with temperature sensors to activate only when internal temperatures drop nearing critical temperatures. The heaters will be turned off when not needed. The rover will also have a number of Radioisotope Heater Units (RHUs) that use the radioactive decay of Plutonium-238 to provide small amounts of constant heat to specific components in critical systems. Active electrical heaters will be used sparingly, due to their power requirements, when they are needed to maintain minimum desired temperatures during extended cold periods.

Temperature Sensors:

Temperature sensors will be used to monitor the temperatures of system components. They will help regulate and maintain the temperature of the system. Thermocouples will be used to measure atmospheric temperature during descent and after landing. There will be three thermocouples which will be placed at varying distances above the surface during the landed mission.

Navigation Subsystem

The Poli'ahu rover is designed to move semi-autonomously on Mars. To accomplish this autonomy, its computer runs purpose-built rover software created by JPL, which has been improved upon with each subsequent Mars rover mission. The software works with hazard camera data to determine the location of hazards and select a least-cost and safest path towards its intended drive target. Thus, it will avoid obstacles as it travels, gathering images to look for a safer path prior to movement.

In the event of an error in this system (for example, the failure of a sensor if the rover cannot determine a path), it will communicate the situation with mission operators. Mission engineers shall send manual instructions to guide it on the safest path towards a science goal.

The rover will have two stereoscopic navigation cameras (Navcams) near the top front of the rover. Stereoscopic camera configurations place cameras at a specific distance (typically around 4-6 inches) from one another with overlapping fields of view. This orientation allows image processing software to use parallax distance calculations to generate third-dimensional (3D) models of the terrain and obstacles. The Navcams are the primary high resolution imaging sensors of the rover, as well as providing color imagery for use in science tasks.

The rover also contains hazard cameras (Hazcams) which are strategically mounted around the chassis, with a view of the ground areas around the wheels. These are used to detect rocks or other surface details, such as sandy potholes, or other hazards which might affect the wheels or path of the rover.

Inertial Measurement Unit (IMU)

The Inertial Measurement Unit (IMU) is mounted inside the rover chassis. The purpose of the IMU is to capture and report positional telemetry such as the position and orientation of the rover. The unit contains a number of different sensors like accelerometers and gyroscopes which measure specific gravity, angular rotation rates, and specific acceleration forces on the rover. The IUM communicates with the CPU to help inform navigation decisions.

Gyroscopic Sensors: Gyroscopic sensors detect rotational motion which are caused by changes in orientation. It detects angular measurement in a spherical coordinate system including the roll in the x-axis, pitch in the y-axis, and yaw in the z-axis. These data values provide a way to derive other positional factors, for example whether or not the rover is on a flat or inclined surface.

Communications Subsystem

Poli'ahu's communications systems use an antenna which sends and receives data to and from the primary lander. The rover will be able to communicate with the primary lander as it traverses the martian surface. This system ensures that the necessary communication signal is maintained as the distance between the primary lander and the rover increases. The antenna works by using a radio frequency modulator needed to encode data into the transmission signal, and by using an amplifier, which amplifies the signal. The communications system will connect to an external antenna on the rover.

There are two aspects of communication that this subsystem manages. One is used for command and control of the rover, communicating with mission operators via relays on the primary lander, through the Deep Space Network (DSN). The second is for storing, chaching, and managing the error-free transmission of payload data collected by the rover.

2. Evolution of Project

2.1 Evolution of Mission Experiment Plan

Team Aegir began the mission planning phase by researching both human exploration and astrobiology concepts. After discussing two possible mission concepts, the team selected a human exploration mission as their primary mission concept. Human exploration on Mars is perceived by NASA as a crucial step in the exploration of the solar system. The Poli'ahu mission planning team believes this mission is critical to performing fundamental in situ research which will directly enable future manned-missions to Mars.

The first iteration of the Mission Poli'ahu featured instruments that would characterize water ice. A trade study was conducted to evaluate which types of instruments would best reflect the goals of the mission: drilling, ice coring, radar, and sample collection.

The second iteration featured a more complex set of science instruments that were capable of locating underground water ice reserves with a prioritization of radar systems. Among the systems selected were the Dynamic Albedo of Neutrons Spectrometer (DAN), Infrared Spectrometer for ExoMars (ISEM), Miniature Thermal Emission Spectrometer (Mini-TES), Radar Imager for Mars' Subsurface Experiment (RIMFAX), Rover Neutron Spectrometer (RNS), the Rover Environmental Monitoring Station (REMS), and Water Ice Subsurface Deposit Observation (WISDOM). These additions were selected to reflect the science goals established for Mission Poli'ahu. The aforementioned trade study evaluated radar systems to be the most effective method for achieving the team's science goals. These instruments are capable of analyzing the surrounding Martian subsurface via ground-penetrating radar.

The third iteration underwent significant changes, ruling out instruments with many instruments being removed from the design. Mini-TES was considered for the final design but was ruled out. It did not satisfy the science goals and only detects the mineralogy of sediment on the surface. REMS measures the environmental temperatures, atmospheric pressure, ultraviolet (UV) radiation, and humidity ("REMS," n.d.). This science instrument will have a significant impact on future manned-missions to the landing site. Due to the total mass constraints, REMS was also removed from the final design iteration. DAN and RIMFAX were ultimately selected to be aboard the rover. The final iteration focused on the complementing abilities of DAN and RIMFAX to study the environment, the distribution, and possible presence of subsurface water ice. These two instruments were included because they were best capable of doing so through extensive mobile mapping. DAN measures subsurface water by detecting and quantifying the amount of hydrogen up to 1 meter underground ("DAN For Scientists," n.d.). RIMFAX characterizes the composition of the Martian subsurface up to 10 meters in depth and map the images of the geological layers in the subsurface (Hamran et al., 2020).

2.2 Evolution of Deployment Scheme and Vehicle Design

2.2.1 Summary

Before selecting the initial design for the Poli'ahu vehicle, the team carefully reviewed three vehicle concepts. The one concept was a rover which can traverse along the Martian terrain and perform science functions at multiple locations. The second vehicle concept was a lander which could provide similar science functions; however, this design could limit the types of exploratory science that can be done from its stationary platform. As a stationary platform, surface hazards may also be a concern since a stationary lander will only have a limited range within which it can place the rover. The third concept design was a drone-type vehicle which is a relatively new technology and has only recently been proven by the Ingenuity helicopter in a demonstration mission in 2021. This vehicle has specific benefits such as its ability to traverse rough terrain by aerial flight, obtaining local aerial photographs, and scouting prospective exploration areas. However, a drone design is limited in payload weight due to the tenuous Martian atmosphere and has a limited power battery capacity.

The Poli'ahu vehicle was selected by the team through a trade study which highlighted the best vehicle for the design (Table 2.2.1-1). In terms of cost, a drone would have been the most expensive because of the low tolerance technology required to stay airborne in the thin atmosphere of Mars. The necessity to build large propellers to lift any significant mass for instrumentation, a drone design would need a larger volume than the established constraint for the mission concept as a whole. In contrast, both the lander and rover are able to be more compact.

Table 2.2.1-1: Vehicle Concept Trade Study

Criteria list	Vehicle Concept Trade Study			
Instrument Name/Example		**Rover**	**Lander**	**Drone**
Cost	3 = least costly 1 = most costly	3	2	1
Volume/Dimensions	3 = smallest volume 1 = largest volume	3	2	1
Mass	3 = least added mass 1 = most added mass	1	2	3
Power Requirements	3 = least power usage 1 = most power usage	2	3	1
Data Return	3 = most data return 1 = least data return	3	1	2
Technology Readiness	3 = most ready 1 = least ready	3	2	1
Totals:	**Winner: Rover**	**15**	**12**	**9**

From a weight perspective, the rover was likely to be heavier than the other vehicle concepts due to the need for wheels and suspension, followed closely by the lander, then the drone being the lightest. The drone is more likely to consume most of its power to sustain its flight, whereas the rover can be more power conservative followed by the stationary lander. The data return of the rover was estimated to be the greatest as it offered a balance between mobility and instrumentation load, whereas the lander and drone concepts offered more specialized data returns. Lastly, the least technology-ready vehicle concept was the drone due to relatively recent validation of the technology, contrasted by the tried and true history of both rovers and stationary lander platforms.

Following the decision to develop a rover, the team began developing initial concept designs, and concepts of operations.

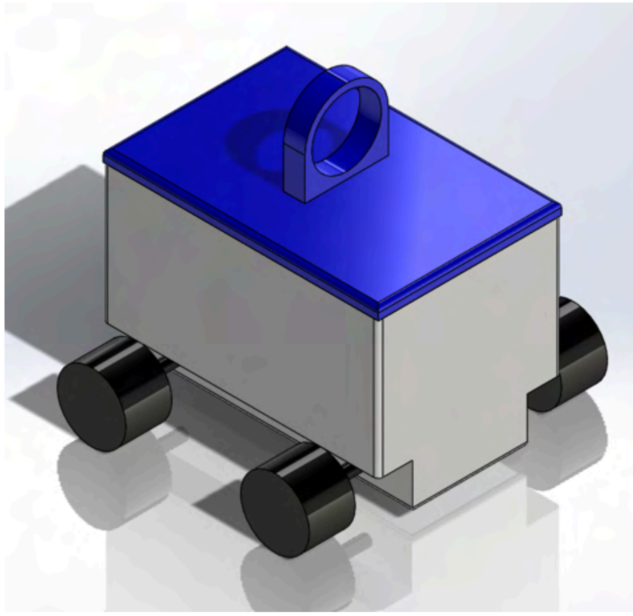


Figure 2.2.1-1: Poli'ahu First Design Iteration

The first design for the Poli'ahu rover included the following systems: a main chassis, a lid, and a 4-wheeled suspension system. The chassis was designed to be compact and fit the necessary instruments required for the mission. The lid was specifically designed to fit its purpose in being the point of contact between the robotic arm of the primary payload and the rover, which is seen through the 6'' ring mounted on top the chassis.

Structurally, the bottom of the Body had very little clearance with the martial soil which would pose a hazard towards the mission in restricting the terrain that Poli'ahu could traverse. Additionally, the body's interior was also too small to hold much relevant instrumentation. These faults were taken into heavy consideration in later iterations.

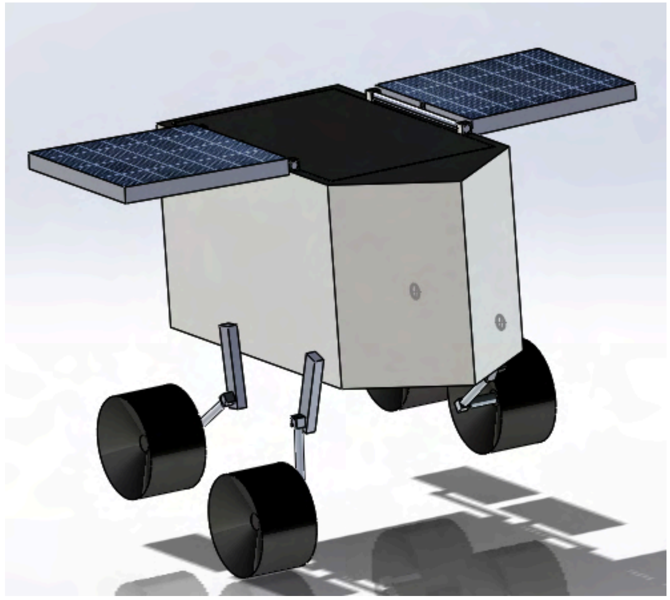


Figure 2.2.1-2: Poli'ahu second design iteration, with an initial solar panel concept.

Integration of solar panels on top the chassis was discussed in later iterations, as well as chamfered chassis edges for better fit within the volume and mass constraint. The addition of solar panels entailed considerations into the placement of external payloads, including cameras and antennas.

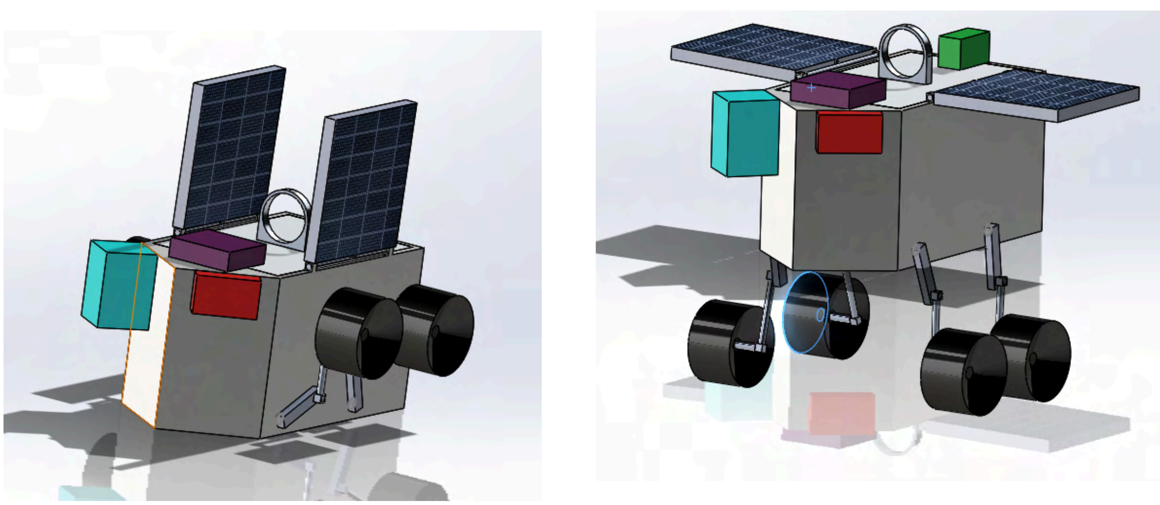


Figure 2.2.1-3: Poli'ahu while stowed on lander (left), Poli'ahu fully deployed (right)

The Second design for the Poli'ahu rover included the following large systems: body, movement, power, and the science instrumentation system. Following up from the first iteration, the Body of the rover was designed with two parts: the chassis and main lid. The main lid would be the main point of contact between the interior instruments and the outer chassis, which would have to be properly secured to prevent any outer contamination.

The movement subsystem consists of the wheels and the legs. The leg system allows the rover to be flexible in order to fit the entire rover on the transport module. The legs also give the rover a clearance over martian soil. The power system is made up of mostly the two panels which are able to fold and provide solar power to the entire rover. Evolving from the previous iteration, the rover body will be able to house the instrumentation subsystem comprising of the Neutron Spectrometer (DAN), Infrared Spectrometer for ExoMars(ISEM), Ground Penetrating Radar (RIFMAX), and the Miniature Thermal Emission Spectrometer (MiniTes).

However, this design had a number of major faults. The first was having a very heavy weight. The Poli'ahu 2nd iteration's chassis alone weighed in the 160-170kg region due to a miscalculation of the material's reliability and had thick walls which, although useful, went against the mission's goals. To address the issue of mass constraint, the third rover iteration included a lightweight chassis only large enough to house the warm electronics unit and additional internal components. This iteration also included a flatter and tapered chassis to better mount the RIMFAX antenna towards the back end, and provide some clearance from the antenna tip to the ground. A four-wheel independent suspension was considered due to concerns over wheel mass exceeding its allocation. However, a six-wheeled rocker-bogie suspension system was later implemented due to concern over its stability and reliability over the terrain with the trade-off of having the legs exceed its mass allocation. With mass being a recurring concern in the design, the final iteration of the Poli'ahu was conceptualized with this constraint kept in mind.

2.3 Evolution of Payload and Science Information

2.3.1 Primary Science Gathering Method Selection

The team conducted research on various methods for the quantification of water ice within the selected landing site of Phlegra Dorsa. These methods include drilling, ice and regolith sample collection, ice coring, and radar imaging to quantify the ice at the desired area. After reviewing each system, the team evaluated these techniques and a score was given to each technique based on the cost, volume, dimensions, mass, power requirements, and technology readiness. These criteria were chosen based on the designated budget and volume constraints, as well as characteristics that the team believes will be the basis to mission success.

After conducting this trade study, each team member assigned an individual score to each proposed method for science data collection. The scores were totalled yielding the values of 7 for drilling, 9 for ice coring, 12 for radar, and 10 for ice/regolith sampling (Table 2.3.1-1). Upon completion of the trade study, the team selected radar systems as the main science instrumentation to quantify the water ice on Mars. Major advantages of this system included its lighter mass, small volume, and lower power requirements. The radar system is determined to be the optimal method out of the four within the required constraints for the mission concept.

Table 2.3.1-1: Instrumentation method trade study.

Instrumentation Trade Study					
Criteria list	**Scoring**	**Drill**	**Ice Coring**	**Radar**	**Sampling**
Cost	3 = least costly 1 = most costly	2	2	2	2
Volume / Dimensions	3 = smallest volume 1 = largest volume	1	1	2	2
Mass	3 = least added mass 1 = most added mass	1	2	3	2
Power Requirements	3 = least power used 1 = most power used	1	2	3	2
Technology Readiness	3 = most ready 1 = least ready	2	2	2	2
Total		**7**	**9**	**12**	**10**

2.3.2 Landing Site Temperature Environment

The rover will be deployed at Phlegra Dorsa mid Martian-summer, between Ls 118 and will operate for 100 sols, until Ls 218. Average operating temperatures will range form 277K for approximately 50 sols, until temperatures begin to drop to 252K, near mission's end. See annual average surface temperatures curve for Phlegra Dorsa in Figure 2.3.2-1.

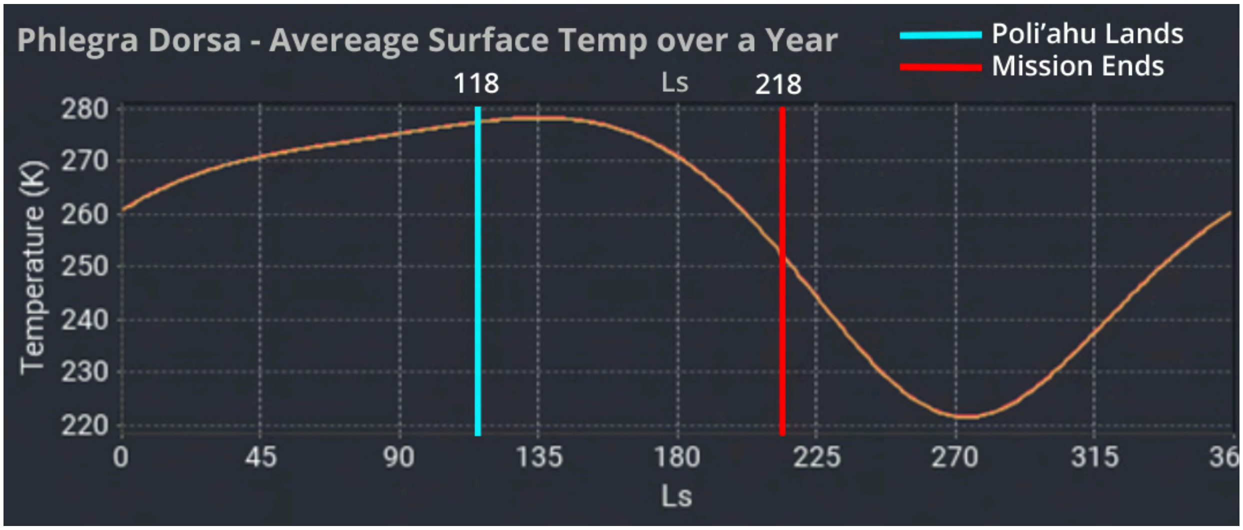


Figure 2.3.2-1: Phlegra Dorsa Exploration Zone Landing Site - Annual Average Surface Temperatures. High temperature in Summer (Ls 136) is 278K (41°F/5°C) and low temperature in winter (Ls 272) is 221K (-62°F/-52°C).

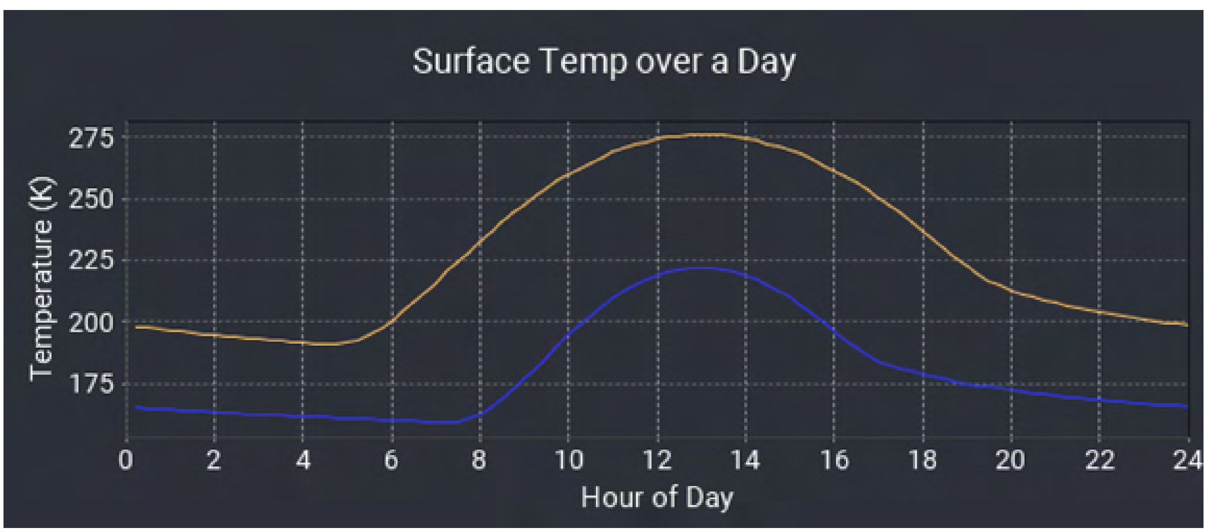


Figure 2.3.2-2: Phlegra Dorsa Exploration Zone Landing Site - Daily Surface Temperatures during Summer (orange) and Winter (blue) months.

Table 2.3.2-1: Daily Maximum and Minimum Temperatures at Phlegra Dorsa landing site, summer/winter.

	High (Noon:13:00)	**Low** (Summer:4:30, Winter:7:30)
Summer Temp (Ls 100)	276K (37°F/3°C)	191K (-116°F/-82°C)
Winter Temp (Ls 280)	222K (-60°F/-51°C)	159K (-174°F/-114°C)

Through the use of THEMIS instrument observations and the KRC tool within JMARS, The team expects daytime temperatures to reach around 276K (37°F/3°C), with nighttime temperatures near 191K (-116°F/-82°C), see Table 2.3.2-1.

2.3.3 1st Payload and Science Instrument Iteration

Science Instruments

The first payload iteration included many instruments that the team found were

This initial radar system will be modeled after RIMFAX, the ground-penetrating radar science instrument currently onboard the Perseverance rover.

The Rover Neutron Spectrometer measures the lateral distribution of hydrogen plotted by its energy and its flux per unit. The results will vary during the mission but will be considered most successful by its balance of flux per unit and neutron energy (top-right portion of the graph). The higher hydrogen content will be a clear indication to Poli'ahu of areas that should be further surveyed to search for possible signs of Water-Ice.

Command and Control

Two on board CPUs, the RAD 750 and the DragonBoard 410C, are currently being considered. The functionality of these components will be compared to mission requirements and instrumentation to determine if additional hardware is needed.

Solar Panels

The initial iteration used a generic concept of a single panel on top of the rover.

2.3.4 2nd Payload and Science Instrument Iteration

This initial radar system will be modeled after RIMFAX, the ground-penetrating radar science instrument currently onboard the Perseverance rover.

The Dragonboard 410c was selected as the CPU, and the team began research to determine the types of software which would be utilized, including open source software like ROS-2, and JPL authored software used on the Mars Exploration Rovers (MER) and Mars Science Laboratory (MSL) rovers.

2.3.5 3rd Payload and Science Instrument Iteration

The payload changes that were made within the 3rd iteration were: removal of the Mini-TES, due to non-priority for science goals, and the weight considerations. REMS was taken out of the design since it increased the total mass of the rover past the set limit. The solar panels design was finalized, and optimized for the payload power requirements. This decision was made with a trade study.

Final payload components that were kept in this iteration are: RIMFAX, DAN< HazCams, NavCams, Internal Heating Systems with RHUs and small Heater, Communications System, IMU, Thermal System Payload, White paint, Heaters, RHU.

2.3.5.1 Solar Panel Design Selection

A solar panel design sub-group evaluated a number of different solar panel design configurations. The four options selected as finalist designs drew from successful flight proven Mars solar panel designs, as well as a novel umbrella-like design similar to one used on the moon for communication antennas and on the lunar buggy. The team developed a set of criteria seen below in Table 2.3.5.1-1.

Table 2.3.5.1-1: Poli'ahu Solar Panel Criteria Descriptions

Criteria	Definition
Area & Solar Cell Packing Density	The highest area and density of solar cells per unit of area. The combination of these criteria will result in the largest amount of solar power generated for a given area. Solar cell coverage over an area is dependent on the shape of the individual solar cell (generally rectangular) and the array shape, ie. round edges or seams limit placement of cells in those locations.
Simplicity / Reliability	The most simple design that accomplishes the intended results is desired. Simple mechanisms are easy to control and/or be done autonomously. If an error does occur, it could be easier to fix compared to complex designs. A higher TRL level should also be scored higher.
Hazard Clearance / Sturdiness	High hazard clearance and sturdiness of solar power elements ensure that the solar array is not damaged during rough travel, large rocks in the path of the rover, and any atmospheric turbulence, if any occurs during the mission.
Low Mass	Low mass is desired to preserve mass for other science instruments and subsystems and reduce mobility power costs due to the lighter load. Factor in support elements like supports, backing for the panels, powered hinges, or motors (if used for articulation) etc...

Small Storage Dimensions	Small storage dimensions when the solar arrays are closed and stored for transit aboard the primary lander. When less space is consumed, more room will be left for other components.
Adjustable Angle	It is desirable, but not required, that adjustable solar panels are able to change their angle to match a sun that is lower on the horizon during Mars' winter months, or while sitting on an inclined surface. This capability would increase energy available during winter, which could open the door for an extended mission.

Following the criteria definition, the subteam scored each option and the scores were tabulated into a matrix to aid selection of the best design that meets mission goals (Figure 2.3.1-1).

Based upon the selection matrix scores, the solar panel sub-group selected Option #4. This design is a set of folding flat panels which includes a tail section with 2 articulating hinges, allowing the tail panels to raise and lower to track the sun. This design was ranked highly by the team due to it's high TRL, as this style of solar arrays has been used on many previous Mars rover missions. It also scored well as it is a simple design which can be accomplished with very simple mechanisms like springs and latches, with the exception of the articulating solar panel.

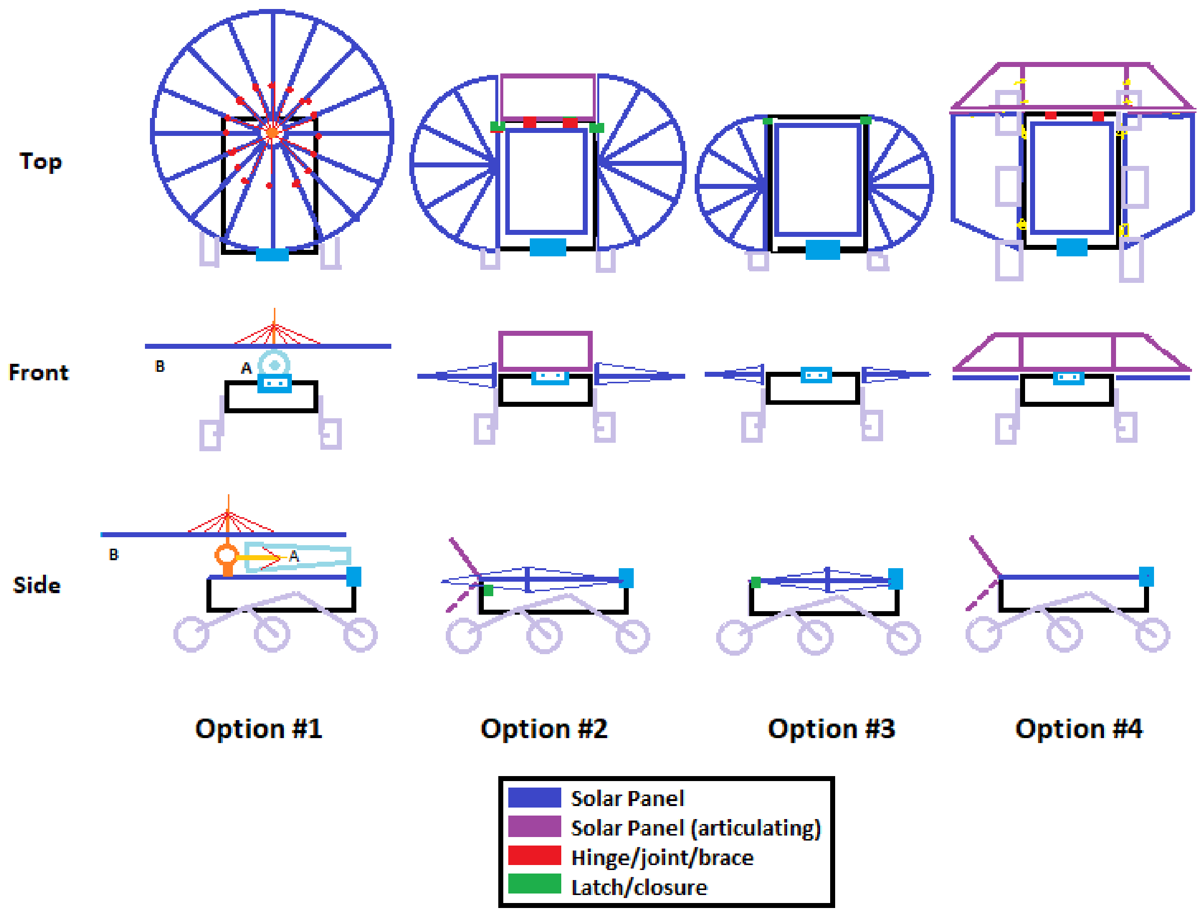


Figure 2.3.5.1-2: Poli'ahu solar panel trade study options.

Table 2.3.5.1-1: Poli'ahu Solar Panel Decision Matrix

Criteria	Option #1	Option #2	Option #3	Option #4
Area & Power Density	4	4	3	4
Simplicity / Reliability	3	3	3	4
Hazard Clearance / Sturdiness	2	3	3	3
Low Mass	2	3	3	3
Small Storage Dimensions	3	3	3	3
Adjustable Angle	3	3	3	4
Total	**17**	**19**	**18**	**21**

3. Deployment Scheme and Vehicle Design

3.1. Selection, Design, and Verification

3.1.1. System Overview

The Poli'ahu vehicle is a compact 6-wheeled surface rover that is equipped with remote sensing instruments designed to locate and quantify subsurface water ice deposits on Mars. The vehicle subsystems include structures, movement, and payload subsystems. While the Poli'ahu is stowed for transit during launch and subsequent EDL stages, it fits within a size constraint of 1-meter cube volume. The vehicle is also designed to fit within a 30 kg mass constraint as shown in table 3.1.2-4. The rovers will operate semi-autonomously, yet also be directed through instructions from mission control. It is capable of collecting data throughout its initial mission area using predetermined mission parameters and communicating with the primary lander that brought it to Mars. The primary lander is responsible for relaying rover and mission control communication.

A rover vehicle was selected as the mission concept due to its balance between quality and quantity of data returned as well as technology readiness and other factors as described in section 2.2.1. Quantifying and characterizing the ice resources for future manned missions requires access to the 100 metric tons of water needed for proposed missions. A rover design with remote sensing instruments was selected to obtain meaningful ice resource measurements, over an appreciable access area.

The movement subsystem will propel and maneuver the rover across the Martian surface. The movement subsystem is composed of a rocker bogie suspension, drive motors, servo motors, and wheels. The rocker-bogie suspension stabilizes the chassis during motion and allows the wheels to roll over obstacles/uneven surfaces while maintaining contact on all wheels. The rocker-bogie design was selected due to its simplicity, performance characteristics, and technology readiness. The drive motors will power the wheels, and the servo motors will be used for steering.

The structure's subsystem consists of the main chassis body, which has mounting interfaces for the other subsystems. The main chassis body is a thin walled structural member that houses the payload subsystems and interfaces the movement and navigation subsystems.

The navigation and control subsystem will image the rovers local surroundings, keep track of the rovers location, and allow the rover to determine its path of motion. The navigation and control subsystem will consist of two navigation cameras, to hazard detection cameras, and an inertial measurement unit (IMU). The navigation cameras will be used to create three-dimensional stitched images of the rover's surroundings, which will be used for navigation decisions. The hazard cameras will be used to detect obstacles in the immediate path of motion of the wheels of the rover.

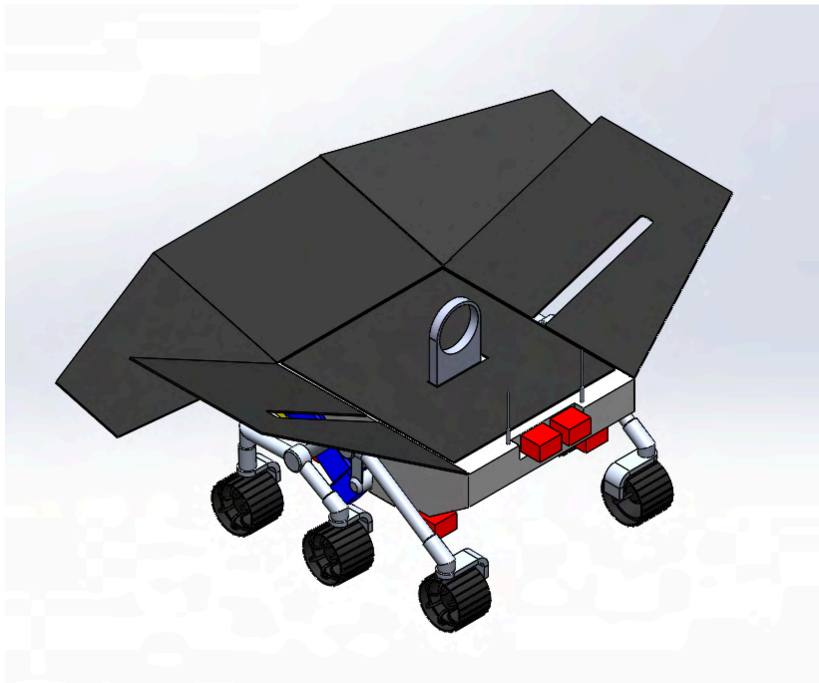


Figure 3.1.1-1: Isometric CAD model of Poli'ahu rover during solar panel unfurling.

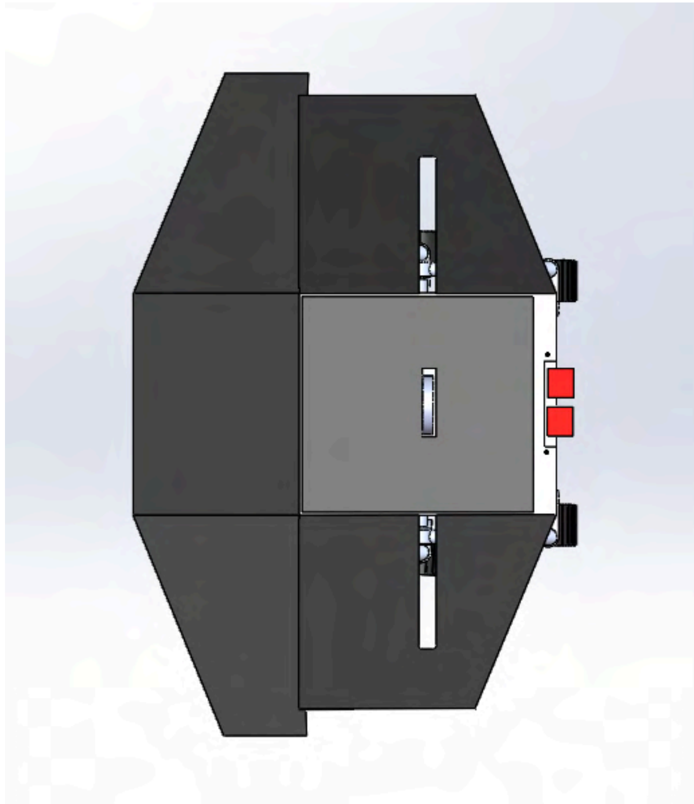


Figure 3.1.1-2: Top View CAD model of Poli'ahu rover during solar panel unfurling.

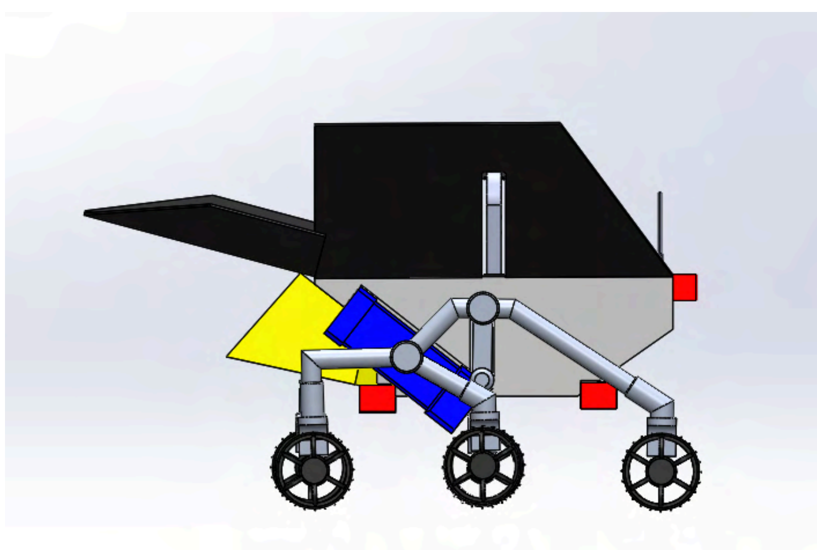


Figure 3.1.1-3: Right side view CAD model of Poli'ahu rover during solar panel unfurling.

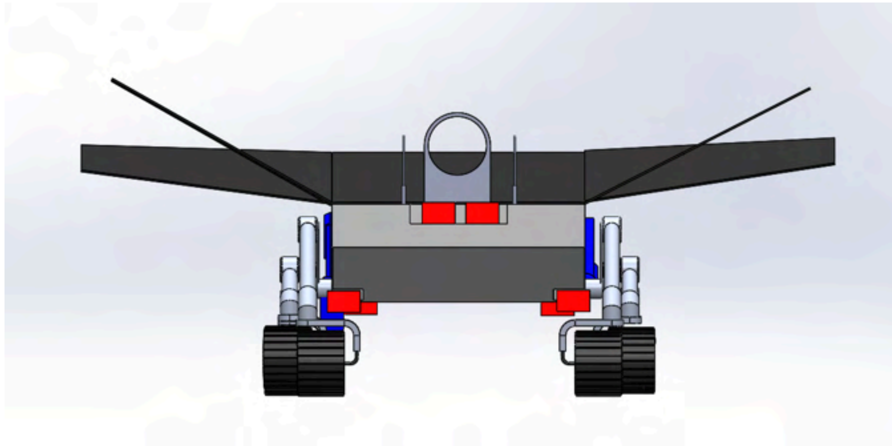


Figure 3.1.1-4: CAD model of Poli’ahu rover in front view during solar panel unfurling.

Deployment Scheme

The deployment sequence of Poli’ahu will begin when the primary lander system receives command from mission control. The lander’s robotic arm will first secure a connection with the 6 inch deployment ring. The coupling mechanism that interfaces the lander and the rover will then engage, decoupling the two from each other. The arm will then place the rover vehicle on the Martian surface. After placing the rover, the lander will send a message to the rover to begin its start up sequence. The rover will power on all its subsystems and perform a system check and diagnostics. Confirmation of successful start up and the contents of the diagnostics will be sent to mission control via the lander relay. The solar panel deployment sequence will commence next. The panels will be uncoupled from their stowed away positions, unfolded, and secured into their charging positions. The deployment sequence for the rover vehicle concludes with the successful solar panel deployment message.

3.1.2. Subsystem Overview

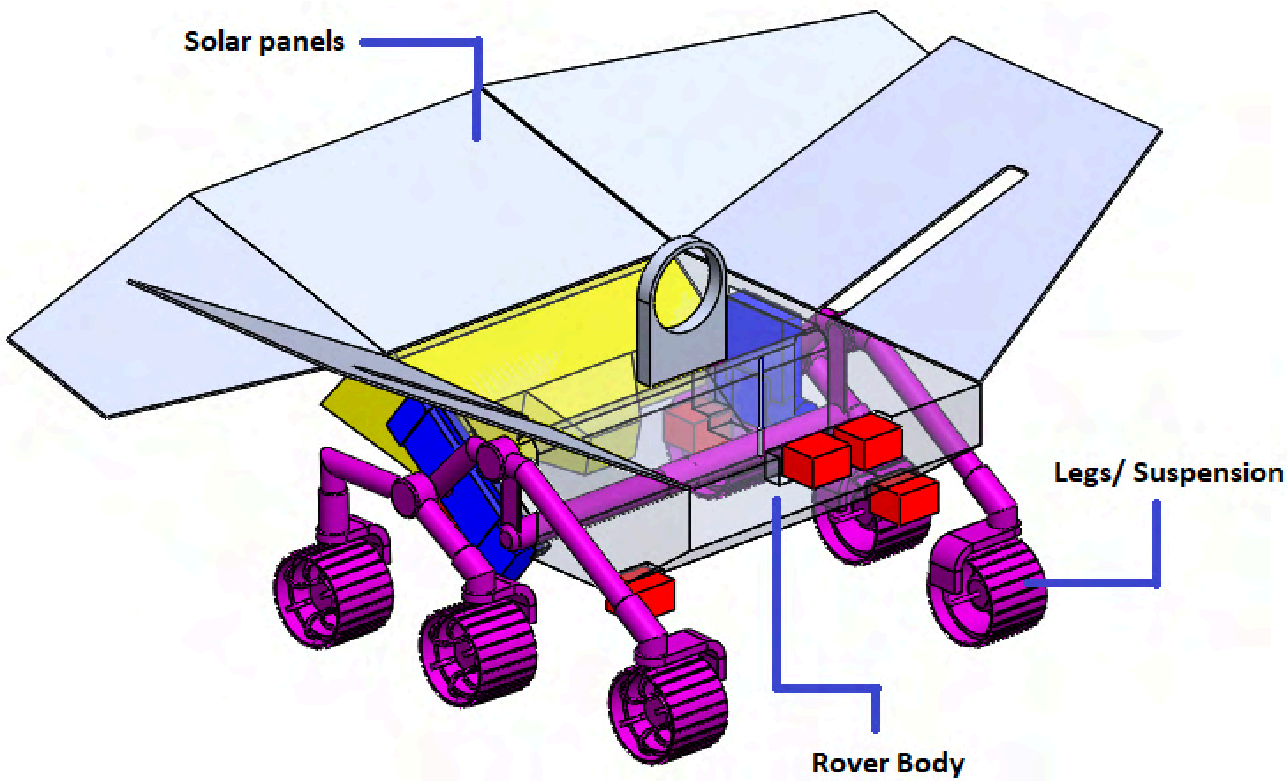


Figure 3.1.2-1: Subsystem Overview

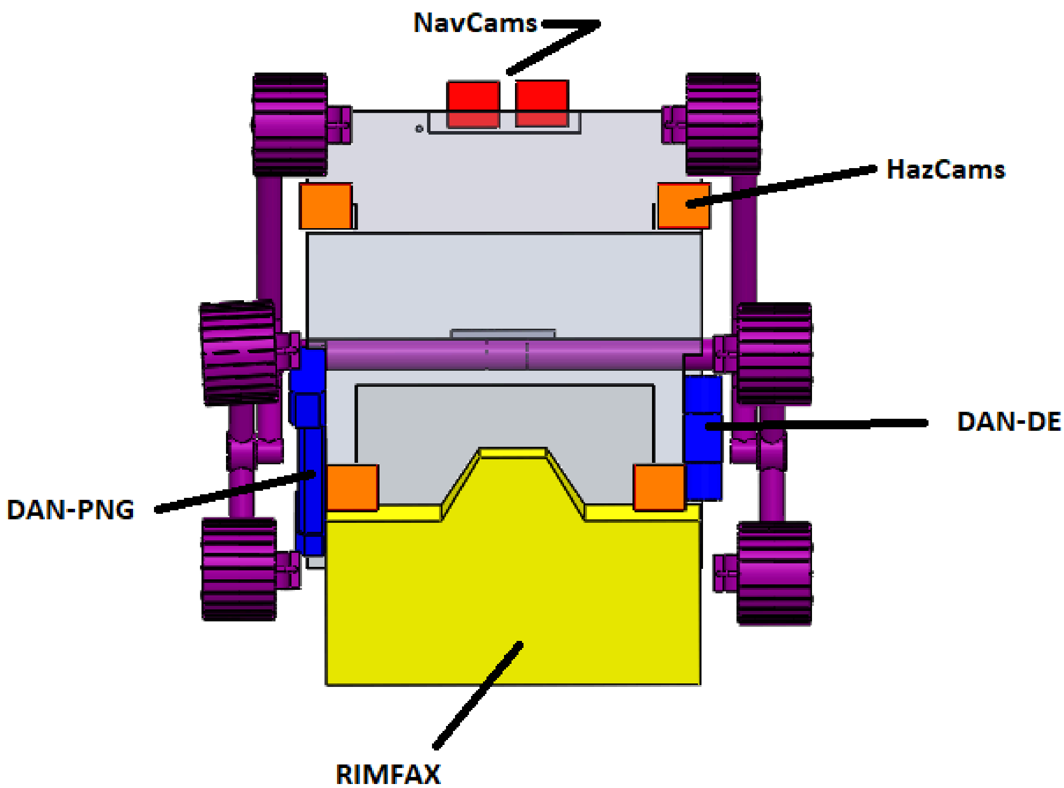


Figure 3.1.2-2: Subsystem Overview (bottom view)

Structure

The structure sub system is designed and fabricated to meet mission requirements and consists of a main chassis body and mounting interfaces. The structures system will provide structural integrity to the rover and mounting locations to interface the main components including the rocker-bogie suspension system, a 6-inch deployment ring, warm electronics box (WEB), RIMFAX's bow-tie slot antenna, and cameras. Aluminum 7075 was selected as the material for the chassis body based on its material properties such as density and yield strength, as well as cost as seen in Figure 3.1.2-3. The mass of the chassis body is 7.8 kg.

Table 3.1.2-3. Chassis Material Trade Study

Criteria list	Chassis material			
Material Name		Titanium	Aluminum (7075)	Steel (321)
Cost	5 = least costly 1 = most costly	$35-$50 per kg **1**	$3 per kg **5**	$10-$60 per kg **2**
Yield Strength	1 = smallest 5 = largest	880 MPa **4**	460 MPa **2**	206 MPa **1**
Density	5 = least dense 1 = most dense	4.43 g/cm3 **2**	2.81 g/cm3 **3**	7.5 g/cm3 **1**

Movement

The rover's movement subsystem is built around a 6-wheeled rocker bogie suspension which will enable the rover to traverse varied and potentially rocky Martian terrain. This movement subsystem is composed of its suspension system, motors, servos, and wheels.The movement system will interface with the structure system as well as the data handling and telemetry system for motor control.

The suspension of the rover uses a 6-wheeled rocker-bogie design that is attached to the rover body through an internal differential gearbox.This allows for either side of the suspension to swivel while maintaining wheel-contact with the ground. One benefit to this design is that it allows the wheels to traverse obstacles up to twice the diameter of the wheels. This suspension is best used at relatively low velocities that are less than 10 cm/s. This will limit the vibration and shock throughout the vehicle body and attached instruments, which aligns with rover terrain traversal plans. Maneuvering will be coordinated through the use of servo motors embedded in the wheel legs, which will allow the rover to steer itself. The wheel diameter is 16cm, and the vertical clearance from the ground surface is 22 cm.

Navigation

The guidance navigation and control subsystem will be designed as a semi-autonomous system on the rover. The navigation subsystem will consist of 4 Hazard Cameras (HazCams), 2 Navigation Cameras (NavCams), and an Inertial Measurement Unit (IMU). The navigation subsystem will interface the data handling, thermal, and structures subsystem. Cameras will be taking real-time photos of the surface and its surroundings while the rover is moving. The system will determine if there are any obstacles along the path of the rover, and map out a path of motion. Data from navigation cameras located about the rover's chassis will be sent to mission scientists for generation of 3D digital terrain, which will subsequently inform future mission planning. Low latency is a key point in this system to prevent restriction of the rover's speed. In the case there is an error in the system that prevents the rover from deciding whether it is safe to keep moving, a manual intervention will be done by the engineers who will make decisions based on data and images received from the rover.

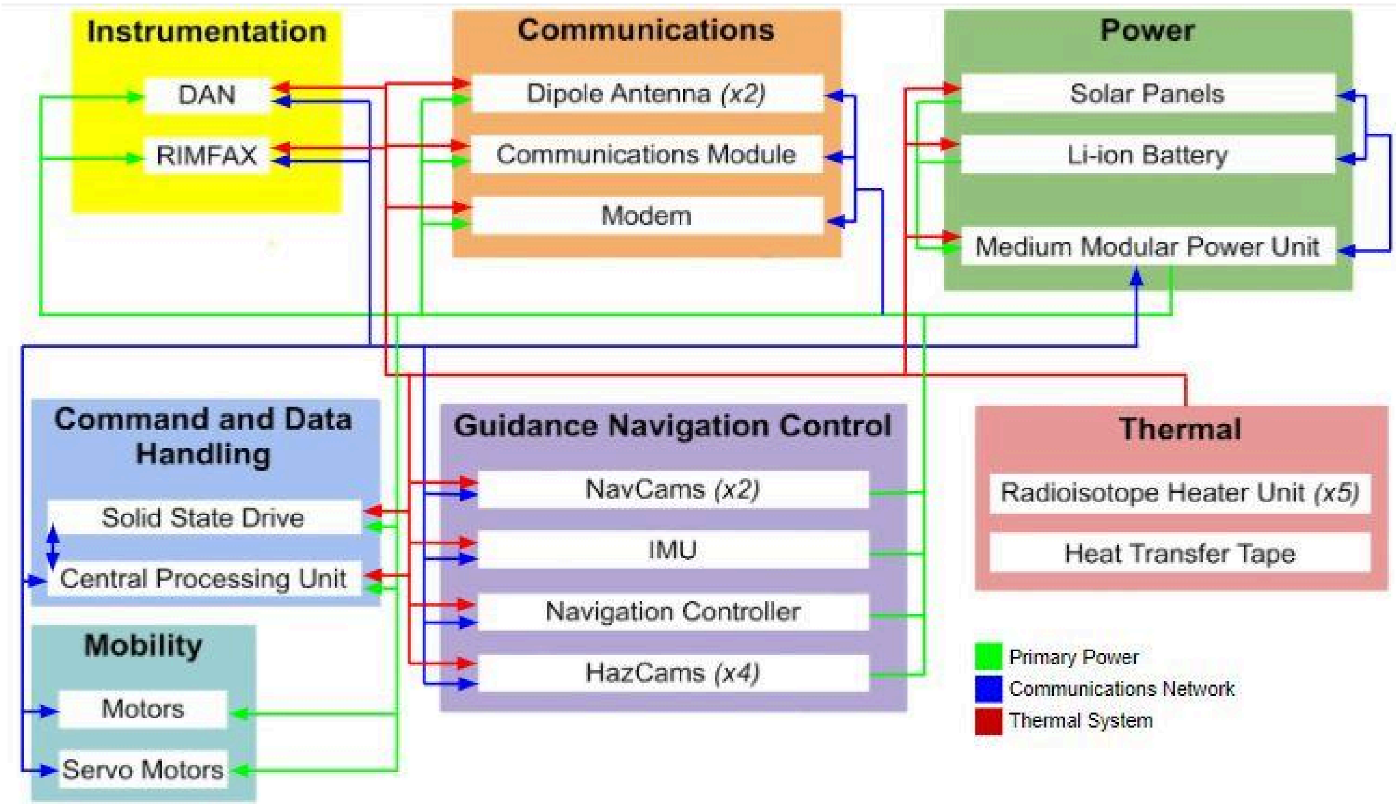


Figure 3.1.2-3: Poli'ahu Subsystem Block Diagram.

Table 3.1.2-4: Poli’ahu Itemized Mass Breakdown.

	Quantity	Mass	Total Mass	
Structures		(kg)	(kg)	
Chassis	1	7.796	7.796	
Mobility				
Rocker-Bogie Suspension	1	1.267	1.267	
Motors (EC-i 30 Ø30 mm, brushless)	8	0.153	1.224	
Wheels	6	0.4	2.4	
Science & Instrumentation				
RIMFAX	1	3	3	
DAN	1	2.6	2.6	
Communications				
Antenna (half-wave dipole)	2	0.018	0.036	
Communications Module	1	0.005	0.005	
Grove Development Board	1	0.015	0.015	
Modem	1	0.13	0.13	
Data Handling & Control				
CPU	1	0.166	0.166	
Solid State Drive	1	0.75	0.75	
Thermistor	2	0.0016	0.0032	
Pressure Transducer	2	0.015	0.03	
Power				
Solar arrays	1	1.7	1.7	
Battery (LP 33037 60A-hr Space Cell)	1	1.6	1.6	
Equipment Power Distribution Module	2	0.57	1.14	
Shunt Regulator Module	1	0.48	0.48	
Battery Charge/Discharge Module	1	0.55	0.55	
Medium Modular Power Unit	1	1.08	1.08	
Actuator	2	0.2	0.4	
Thermal Control				
Radioisotope Heating Units (RHU)	5	0.17	0.85	
Wire Heater	6	0.033	0.198	
Navigation				
HazCam	2	0.25	0.5	
NavCam	4	0.25	1	
Inertial Measurement Unit (IMU)	1	0.75	0.75	
TOTAL			**29.6702**	**kg**

3.1.3. Dimensioned CAD Drawing of Entire Assembly

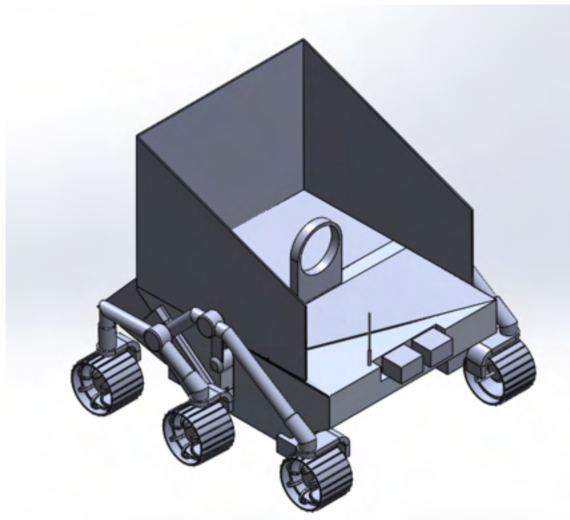


Figure 3.1.3-1: Isometric shaded model of Poli'ahu rover in stowed configuration.

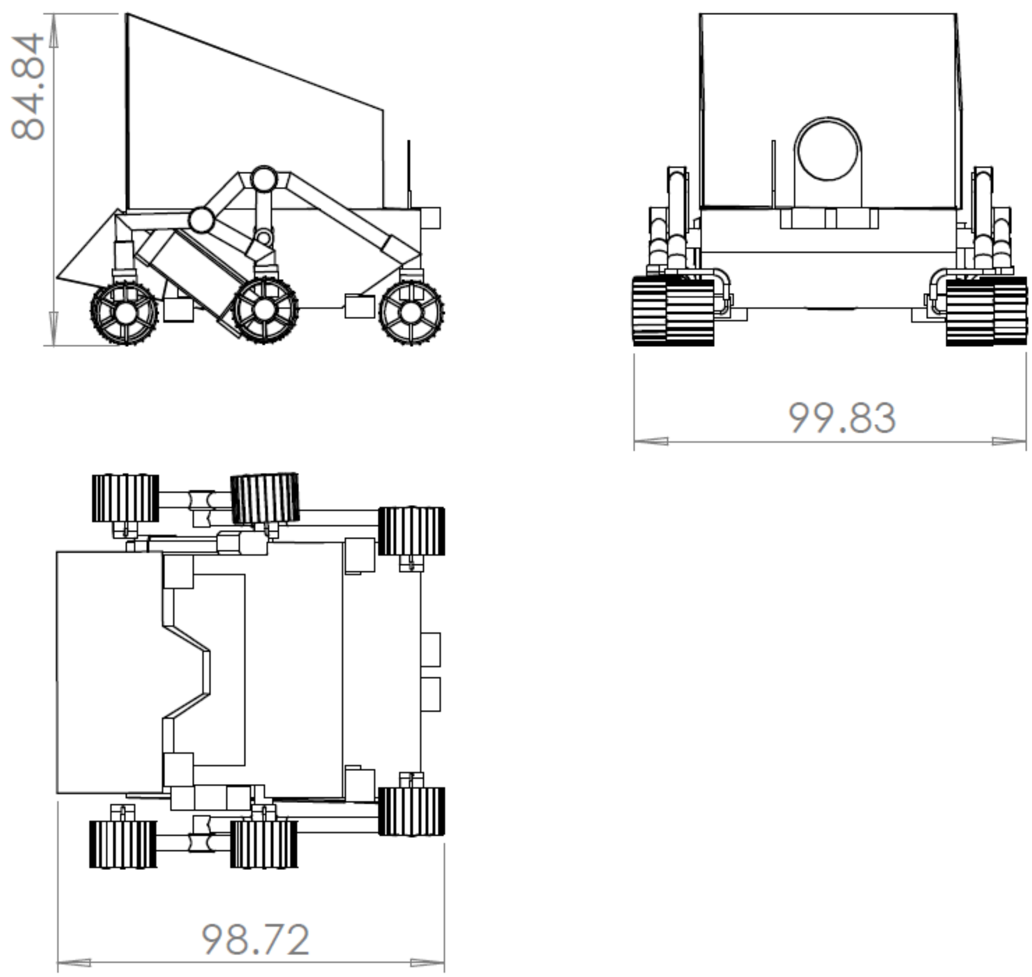


Figure 3.1.3-2: Dimensioned (mm) CAD Model of rover in stowed configuration.

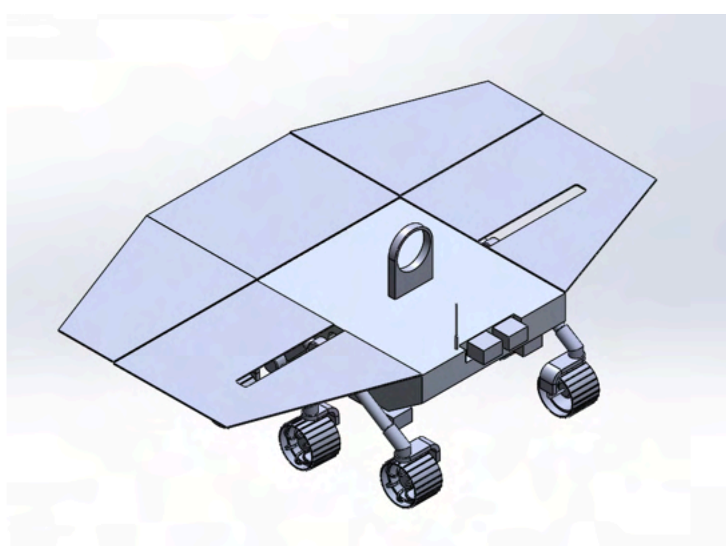


Figure 3.1.3-3:: Isometric shaded model of rover with extended solar panels.

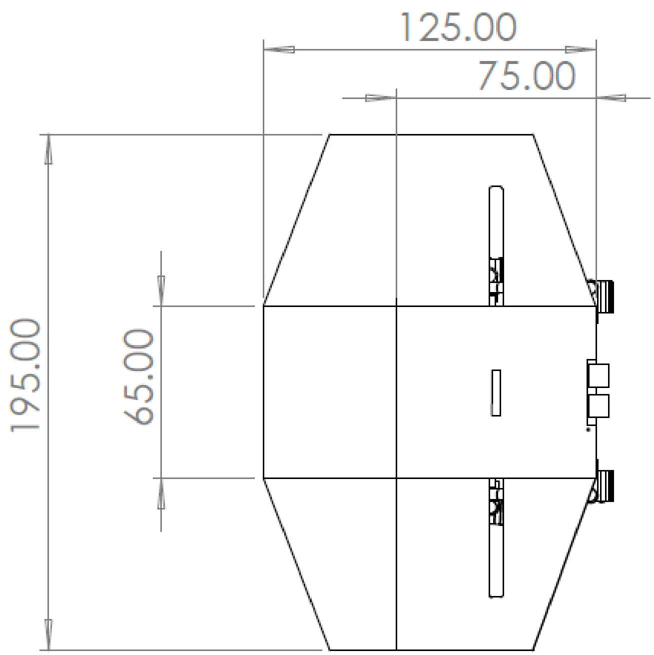


Figure 3.1.3-4: Dimensioned (mm) drawing of the Poli'ahu rover with solar panels in full extension.

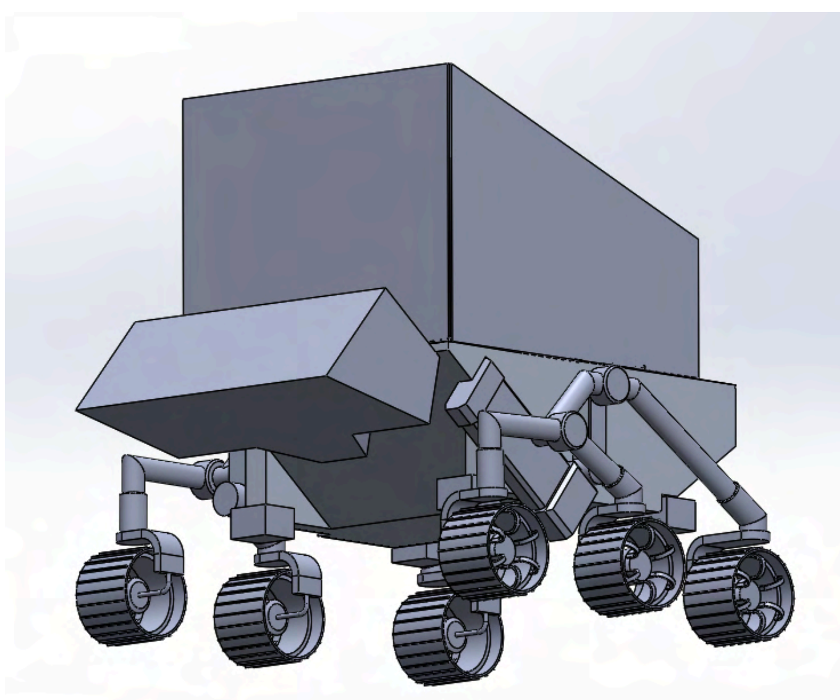


Figure 3.1.3-5: Isometric shaded model of the rover suspension and RIMFAX in full extension, prior to extending solar panels.

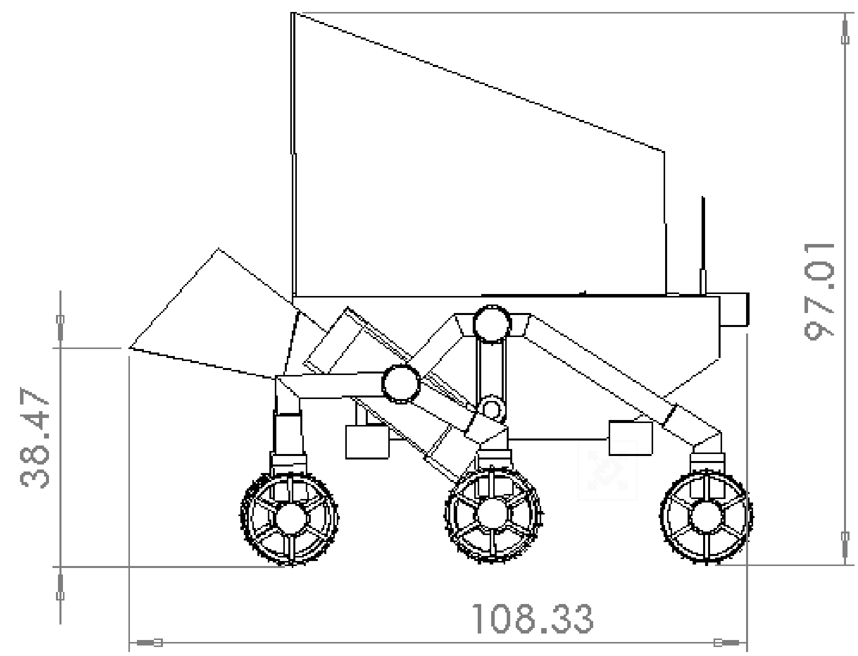


Figure 3.1.3-5: Dimensioned (mm) CAD model of the rover suspension and RIMFAX in full extension, prior to extending solar panels.

3.1.4. Manufacturing and Integration Plans

The main manufactured components of the Poli'ahu Rover are its chassis, Warm Electronics Box, Suspension and Wheels. The manufacturing of these components will be outsourced to a specialized machine shop with 4-axis milling capabilities, as several components, such as the wheel axle and spokes, have complex, non-planar geometry. Manufacturing for these components and tolerance verification should take no more than 2 weeks to complete.

Chassis

The chassis will be made out of 7075 Aluminum 1/16th inch stock sheet metal, due to its low cost and rigidity. 4 square meters of this material will be sourced from McMaster-Carr. (Aluminum Catalog, n.d). Once the raw material is acquired, the chassis panels will be CNC-machined according to the design and connected on the edges with brackets. Welding was initially considered for connecting the panels, but further research revealed that the welding zones for the alloy are prone to cracking and corrosion under high stress and may also compromise precision. The use of brackets as a mounting method for the chassis is more cost effective and provides better long term structural reliability. According to Blackstone Advanced Technologies, it's safer to go this route instead of using a welding method for the whole process because when this material gets heated by a welding machine, it creates micro cracks as it cools and these cracks have a serious impact on the tensile strength of the material.

Suspension and Wheels

The wheels are designed for a moderately rocky environment with medium soil-cohesion to better navigate the terrain of Phlegra Dorsa. It will be capable of rolling over rocks up to 32 cm in height, and will provide a 22 cm clearance between the rover body and its contact point on the ground. Like the chassis, the wheel and treads will be manufactured with 7075 Aluminum, with the wheel thickness of 4 mm and tread thickness of 2 mm. Twenty-four 1 cm tall treads will be machined perpendicular into the wheel. As 16cm diameter Aluminum tube extrusions are difficult to source, the wheel will be manufactured through sheet metal rolling, with edges joined together through friction stirring.

Suspension and motor housing will be likewise manufactured from 7075 Aluminum, with the suspension tubing sourced from TW Metals. (7075 Aluminum Tubing, n.d). 300 cm of 4 cm-diameter tube extrusions will be acquired and machined for the suspension, including the differential bar passing through the chassis. Wheel axles and spokes will be manufactured and machined from the same material due to its light-weight nature. As the suspension utilizes a rocker-bogie design, each side of the suspension will be attached to the body via an internal differential gear box located at the rover's center.

Assembly

Each individual manufactured component will undergo coordinate measuring-machine verification to determine if the part is within tolerance. Once assembled into position, an additional CMM check will be done to ensure that each component is positioned within tolerance with neighboring parts.

Warm Electronic Box

The Warm Electronics Box (WEB) will be made out of Aluminum and aerogel layers and has a solid cover attached to a hand for easier removal works like a lead. The dimensions of the box will be 42 x 20 x 16 cm. This box is designed to keep the electronics and certain components of the rover kept warm in the nighttime temperatures, which may fall under -140 degree Celsius.

Final Integration

This takes place before launch and ensures that everything is working sufficiently from development unit testing through final integration testing. Each subsystem will be integrated into the rover, starting with the power subsystem. Systems will go through a series of stages of testing, including electronics testing and power cycling. Integration and assembly will take place at the Arizona State University Interplanetary Initiative Lab clean room.

3.1.5. Verification and Validation Plans

After manufacturing the parts, it is crucial to go through the verification and validation process. First, Team Aegir will be doing a verification process which involves verifying that the material or part functions as expected and is designed and manufactured as planned in order to integrate it with other parts and systems. The team's main criteria would be the mission requirements for the system. For validation, the team shall validate these parts and systems to test if it is functioning as stated in the expected environment.

The rover needs to meet the specified volume and mass constraints defined in the requirements. The vehicle will be measured and weighed. Length, width, and height measurements will be used to determine volume, and the mass will be measured using a scale. Measurements of the rover can be completed in the clean room after assembly, while the weight measurement must be made in the Kennedy Space Center where Perseverance Rover also had these measurements done (NASA Jet Propulsion Laboratory, 2020). This testing center will also provide for the verification of the center of mass. The weight verification of the vehicle is referred to System Requirement 8 and volume verification is referred to System Requirement 9.

As it searches for subsurface ice on Mars, the rover will be exposed to low temperatures and a thinner atmosphere. To ensure that all systems will operate reliably in such conditions, the rover will be tested in a thermal vacuum chamber at Arizona State University. Here, the rover will be put into a vacuum environment simulating the atmospheric pressure on Mars and will also be exposed to temperatures as low as -90 C to observe how the vehicle behaves in these conditions. The integrated systems can then be tested remotely to validate that the rover operates as expected. With a rate of $2500/hr and an estimated testing time of up to 2 weeks. This test is referred to in System Requirement 1.

Dust storms are something that are expected during the beginning of the mission. To validate that the rover survives these conditions, environmental testing will be conducted to ensure desired rover function. Environmental testing will ensure that there are no areas of entry for dust that could reach important internal components. This testing will be completed at Kennedy Space Center in Florida where the same procedure is performed for the next Moon mission. Team Aegir has determined that this facility has the right resources and experience to conduct dust testing for this Mars Mission as well (Tabor, A, 2020). This is referred to by Performance Requirement 1.2.1.

When conducting surface operations, the rover is expected to traverse up to a 10% grade at Phlegra Dorsa. To verify that the rover can successfully manage traveling at varying sloped ramps. The rover will be driven up, down, and to analyze slipping. This can be accomplished in the clean room. This refers to Performance Requirement 6.1.2.

The rover is also expected to be able to travel over obstacles completely and safely without causing damage to the rover. Varying obstacle heights will be used to complete tests that will determine the height of obstacles so that the rover can no longer continue to travel over the obstacle. Time taken to completely and successfully clear the obstacle will also be recorded. This is referred to by Performance Requirement 6.1.3.

Once all these verifications are confirmed with system requirements, the next step is the integration of these components. Team Aegir shall validate if the components work all together when they're integrated. The team plans to conduct a mobility test to validate the vehicle's functions when integrated with all vehicle components.

3.1.6. FMEA and Risk Mitigation

Failure Mode and Effects Analysis											
Item / Function	**Potential Failure Mode**	**Potential Effects of Failure**	**S E V**	**Potential Causes / Mechanisms of Failure**	**Current Design Controls Prevention**	**O C C**	**Current Design Controls Detection**	**D E T**	**R P N**	**Recommended Actions**
Deployment	Rover fails to deploy	Mission is unable to continue	10	-Deployment mechanism damaged during takeoff. -Deployment mechanism damaged during entry, descent or landing.	Deployment mechanism will be tested under several stress conditions before launch.	2	Rover will send out signal when it is deployed.	8	160	Watch

Figure 3.1.6-1: Deployment FMEA

ID	Summary	L	C	Trend	Approach	Risk Statement	Status
1D	Rover fails to deploy	1	5	→	W	Rover can be damaged during launch, entry, descent or landing. This risk will be watched.	Testing deployment mechanism will mitigate some damage if risk shall occur.

Figure 3.1.6-2: Subsystem Risks.

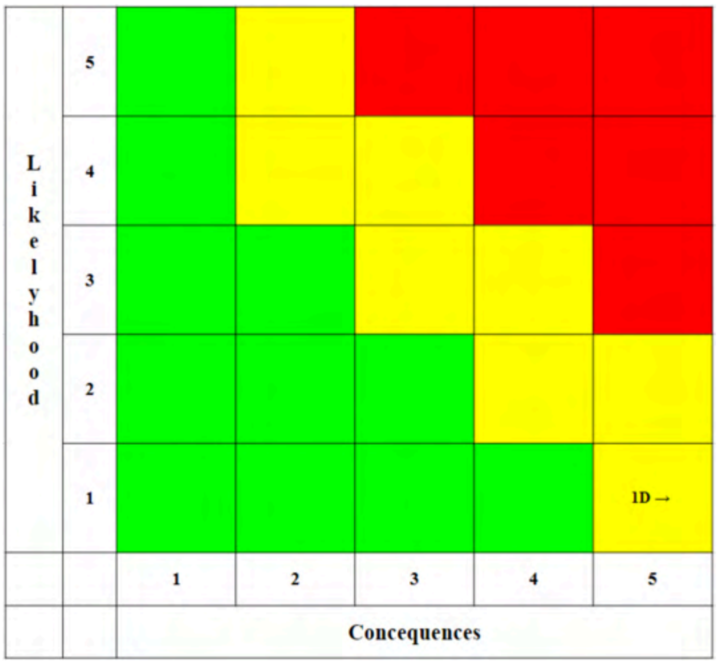


Figure 3.1.6-3: Subsystem Risk Matrix.

Approach	Criticallity	LxC Trend	L = Likelyhood (1-5)
A - accept	HIGH	↓ - Decreasing (improving)	1 = not likely
M- mitigate	MED	↑ - increasing (worsening)	5 = extremely likely
W - watch	LOW	→ - unchanged	**C = Consequence (1-5)**
R - research		**NEW** - added this month	1 = low consequence
			5 = high consequence

Figure 3.1.6-4: Subsystem Risk Matrix Legend.

3.1.7. Performance Characteristics and Predictions

Navigation

The navigation system will image the rover's immediate surroundings to provide a basis to make guidance decisions. The navigation subsystem includes two NavCams and four HazCams. The NavCams have a 45 x 45 degree horizontal/vertical field of view with a field depth spanning from 0.5 meters and above.The resolution of NavCam images is 1024 x 1024 pixels. The nominal exposure for an image on Mars at noon is 0.25 seconds. This exposure time is determined to ensure the image signal is much greater than the image smear acquired during frame transfer. The NavCams have an operating temperature range of 218 to 278K, and contain a built in resistance heater. Surface operations call for these resistance heaters to be active throughout data gathering modes to ensure that the NavCams are maintained inside their temperature range.

The HazCams will be used to view obstacles directly in the path of the rover wheels. The HazCams use f-theta fish eye lenses with a 124 x 124 degree horizontal/vertical field of view. The quality of the HazCam images is 1024 x 1024 pixels. Similar to the NavCams, the HazCams have a nominal exposure time of 0.25 seconds, an operating temperature range of 218 to 278K, and a built in resistance heater.

Mobility

The functions of the mobility subsystem include maneuvering and propelling the rover across the Martian surface. The mobility subsystem will be capable of propelling the rover at 2.5 cm/s while in ordinary surface operations. The rover will be capable of turning around in place. The rover will be able to traverse a 6% incline while on the surface of Mars. Verification will be done on a 10% incline on earth to account for the possibility of slip and imperfections of the regolith. The rover has a 22 cm vertical clearance from the ground to the bottom panel of the chassis. The rocker bogie suspension is estimated to be able to roll over a 20 cm obstacle based on the wheel diameter.

3.1.8. Confidence and Maturity of Design

The use of RIMFAX as a ground-penetrating radar instrument has proven to be very valuable on Mars by exposing layered deposits as well as identifying layers that may show signs of water . Unfortunately, in-ground ice layers and highly porous sediment layers have very similar dielectric properties, so it is difficult to differentiate with radar measurements alone.

In the second iteration, Team Aegir researched additional instrumentation which could be employed in synergy with the RIMFAX instrument to characterize the underground layers it identifies as bearing hydrogen bearing, as found in H_2O. This led to the search for neutron mass spectrometers. The team located a number of instruments, such as the Neutron Spectrometer System (NSS) which will be used on VIPER, a rover that will search for ice on the Moon. Though it is a valuable instrument, its technology readiness level (TRL) would likely be lower when applying to a Mars mission. The team discovered a similar neutron spectrometer, which has successfully been used on active Mars rover missions, called the Dynamic Albedo of Neutrons (DAN), used on the Curiosity Mars rover.

To ensure the rover design will perform reliably in a Mars environment, it must go through a number of tests to verify that the systems will function reliably in different conditions. The rover will be operating in an environment with extreme low temperatures and a low atmospheric pressure, making it necessary to conduct testing in a thermal vacuum chamber to verify that the rover subsystems continue to work and that the thermal system works sufficiently. RIMFAX along with other instruments and subsystems will be tested in this environment to validate that they operate correctly.

In terms of communication, there is a system in place in which Poli'ahu will make use of a radio relay system to accurately communicate with the primary lander, which communicates with the spacecraft. Ultimately, the data will be received by mission control. This information will include science/housekeeping data collected over the duration of the mission that can then be analyzed by mission control.

3.2. Recovery/Redundancy System

A number of measures have been taken to ensure as much redundancy as possible throughout the mission design. The landing site was chosen to accommodate several areas of interest, lessening the need for a small landing ellipse. Launch date will be scheduled to allow for up to 3 weeks of delays without missing the launch window. The solar panels will be sized with a margin of 30% for the power budget. The movement system will be designed to work in the event of a failure in 1 wheel motor on level ground. The onboard CPU will have remote download/reboot capabilities in the event of an unknown software error.

Due to mass restrictions, it is not feasible to include backups for science instruments on a mission of this scale. The contingency plan in the event of an instrument failure will be to proceed on a mission architecture that best utilizes the remaining, functioning instrument. In the event that all three instruments fail, the navigation cameras may still be used to collect photographic data.

3.2.1 Low-Power Recovery Modes

The rover control system and power management boards will manage the rover's power levels to ensure that it maintains a 30% power reserve during normal surface operations. The rover will have a pre-programmed protective mode, which is automatically triggered when the rover's battery is depleted below a safety level. Mission controllers will also have the ability to issue commands helping manage the low power states to prioritize specific systems and performance parameters. These capabilities will help the team maintain more active control of the rover to hopefully avoid the extreme-low-power protective mode, which presents increased risk that the rover may not be capable of autonomously recovering from.

The rover will be programmed to autostart upon return of power generation capacity. To accomplish this, when the rover reaches extreme-low power mode, it will set the power generation board into a constant trickle-charge of the batteries from the solar panels. The power board will be designed to trigger restart of the primary computer upon a 15% charge held on the batteries. This power-first startup sequence will make the rover resilient to unexpected or long-term dust storms.

3.3. Payload Integration

Navigation

The Navigation and Control subsystem will be integrated into the rover strategically to meet mission requirements and constraints. Components of the Navigation and Control subsystem include two

NavCams and four HazCams. The two NavCams have the function of collecting stereoscopic imagery to create three-dimensional terrain maps. These maps will be used to infer a path of motion. The placement of these NavCams was chosen to be the center of the top-front edge of the rover as seen in Figure 3.3-1.

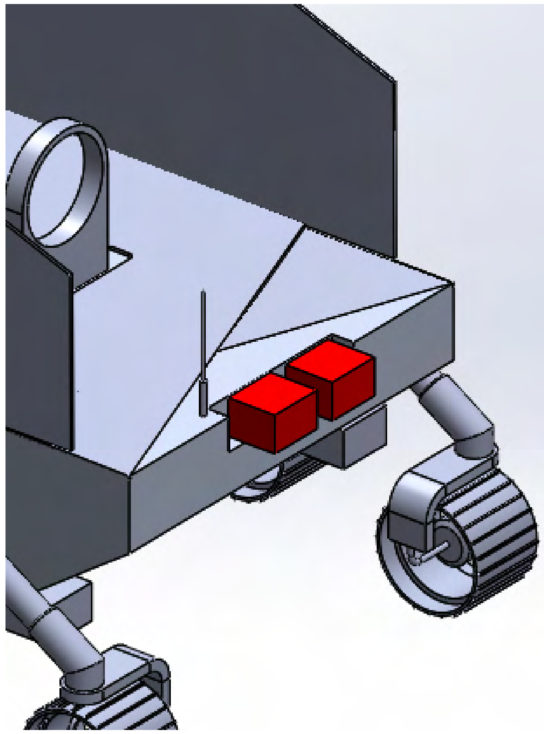


Figure 3.3-1: NavCam Placement on front of Rover

The center of the top-front edge was chosen for the NavCams because it faces the direction of motion, maximizes the useful field of view, and is in close proximity to the Warm Electronics Box. The four HazCams will be used to image the ground in and around the path of motion of the wheels. To best meet this functionality, the four HazCams are mounted to the bottom four corners of the main chassis body as seen in Figure 3.3-2.

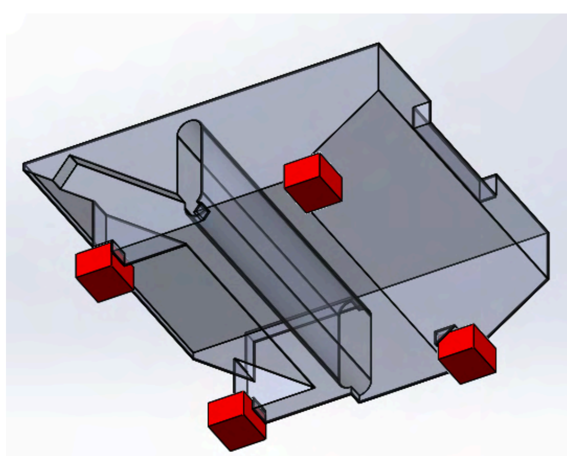


Figure 3.3-2: HazCam placement on Chassis

The HazCams will be oriented at 45 ° offset from the front and back faces, pointing outward. The orientation of the HazCams will allow the rover to get an up close 360 ° view of the martian surface.

Data Gathering

The proper integration of the data gathering system is key for mission success. The data gathering systems main components are the RIMFAX instrument, the DAN spectrometer, and the IMU. The RIMFAX instrument has two subcomponents, the electronix box and the bow-tie slot antenna. These two subcomponents have separate locations within the overall system. The bow-tie slot antenna is mounted to an inclined plane on the exterior of the aft side of the rover as depicted in figure 3.3-3.

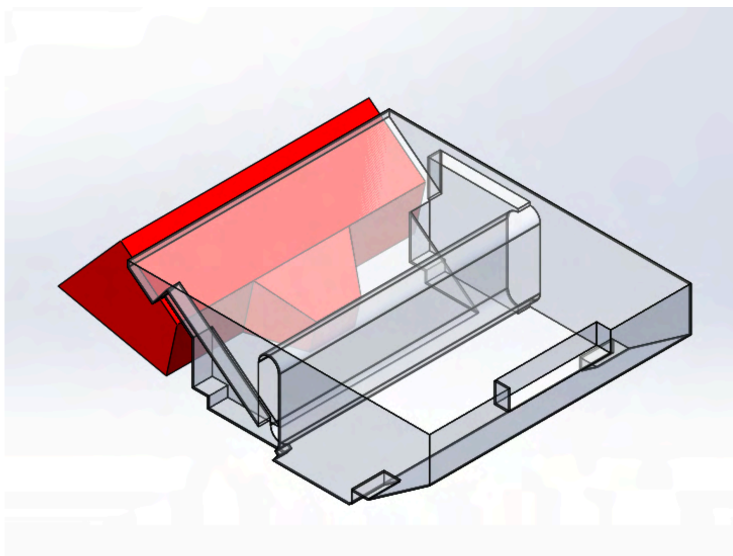


Figure 3.3-3: RIMFAX Bow-Tie Slot Antenna Location

The placement of the antenna was constrained by its functionality. Operation of the antenna requires it to be on the exterior of the rover to prevent interference and maximize the quality of data. The orientation of the antenna is also limited, as the transmitting/receiving face must be parallel to the martian surface. The inclined plane mounting was selected as a way to satisfy both of these constraints. The RIMFAX electronics module will be secured within the Warm Electronics Box, as seen in figure 3.3-6. The electronics module was placed inside the WEB in order to meet its operating temperature requirements.

DAN contains 2 components on opposite sides of the rover's stern, as shown in Figure 3.3-4.

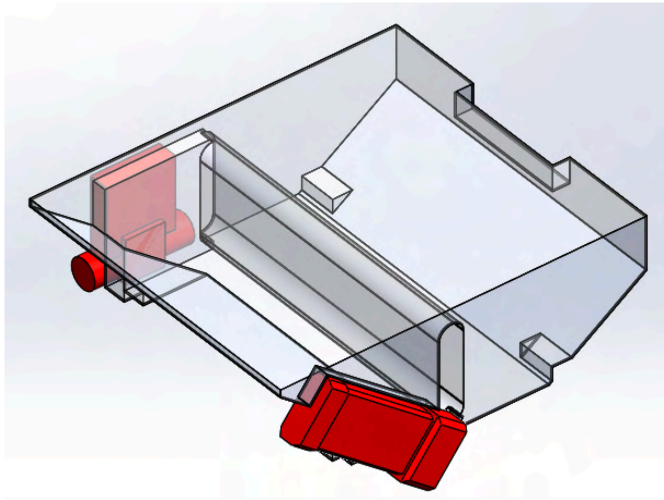


Figure 3.3-4: Location of the DAN components

The pulsed neutron generator (DAN-PNG) is located on the starboard side of the rover. It is a small particle accelerator that shoots short pulses of neutrons into the Mars soil. If there are hydrogen atoms in the subsurface, the excited states of the neutrons will collide off of them and reflect back out of the soil. The detectors and electronics unit (DAN-DE) will measure the reflected neutrons' rate and delay time. The DAN-DE is located on the port side of the rover. This science instrument is necessary to search and identify the ice region of Phlegra Dorsa because if the DAN-DE measures a high quantity of hydrogen atoms or hydroxide ions, this will likely be an abundance of water for astronauts to use for future manned missions. If there is a low quantity, this may possibly be identified as carbon dioxide in a solid state (dry ice).

Thermal Control

The thermal system will consist of a Warm Electronics Box (WEB), Radioisotope Heating Units (RHU's), exterior insulation, and electronic wire heaters. Figure 3.3-5 below shows the location of the WEB in the chassis body.

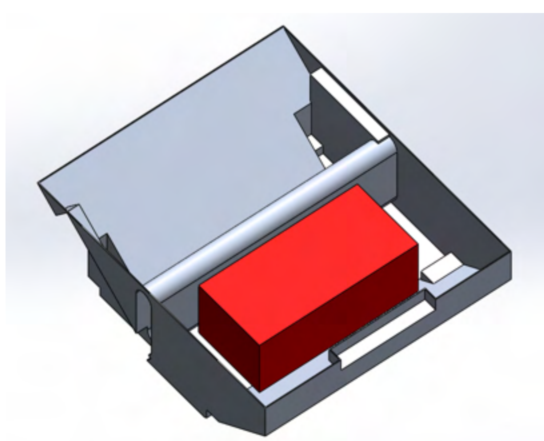


Figure 3.3-5: Warm Electronics Box Location

The integration of the thermal control system is critical for mission success as all of the other subsystems rely on temperature control to operate on Mars. Many of the electronic components are especially susceptible to cold temperatures. The WEB will be mounted in the center of the rover. This location was selected because it allows for short transmission lines from the interior electronics to the exterior sensors/antennas. The RHU's will be located inside the WEB to heat the electronics and the wire heaters will run through the legs of the rover to reach the motors near the wheels. The external insulation will be made of gold paint and will be applied to all exterior faces on the rover except the solar panels.

The interior layout of the WEB is described in figure 3.3-6. The locations of the individual components were determined iteratively with the goal of minimizing the overall volume while allowing space for connecting cables between components. The final dimensions of the WEB will be 42 x 20 x 16 cm. The shell of the WEB was hidden to show the layout in this figure.

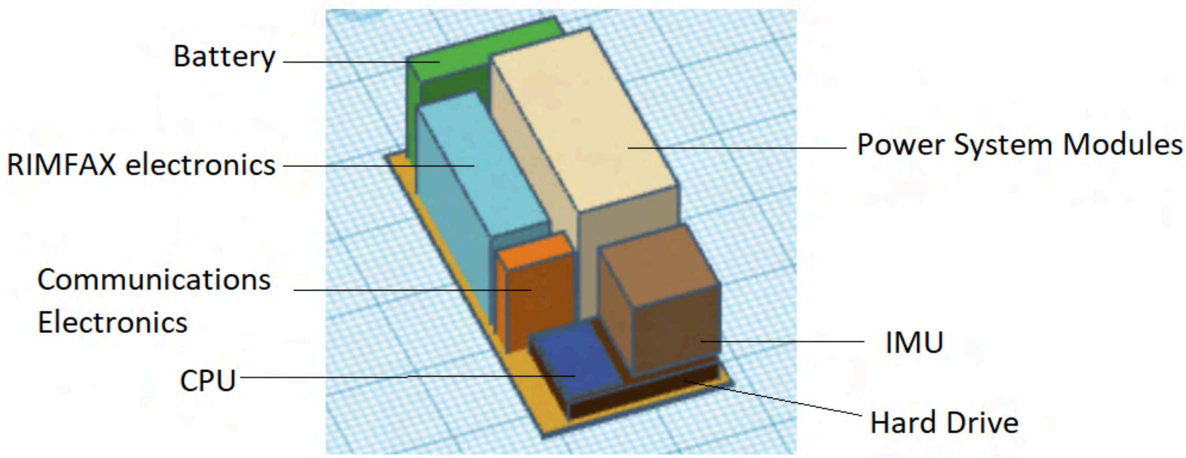


Figure 3.3-6: Interior layout of WEB

Communications

The main components of the communications subsystem are the communications module, development board, modem, and the two half-wave dipole antennas. The communication module plugs into the development board directly through electrical pin connectors. Similarly, the development board plugs into the interior of the modem such that the module and board are completely circumscribed by the modem outer shell. The position of the modem within the WEB can be seen in Figure 3.3-6 above. The two half wave dipole antennas will be mounted through the top panel of the chassis.

Data Handling and Control

The components of the data handling and control system include the Dragonboard 410c development board and the solid state drive. Both components will be housed inside the WEB, their locations can be seen in figure 3.3-6. The data handling components are located within the WEB because it is critical that they stay relatively warm, within their operating temperature ranges. Extra space has been allocated inside the WEB near the interfacing ports for cables.

Power

The power subsystem will have a modular design, with several functions being accomplished by individual modules that integrate together to make the power subsystem. The power subsystem has four specialized modules including: two equipment power distribution modules, a battery charge/discharge module, and a shunt regulator module. All four of these modules are plugged into the Medium Modular Power Unit (MMPU), which houses and interfaces the modules. The modules are made with a common baseplate, which screws directly into the MMPU's backplane motherboard without any internal wiring. Wiring is needed, however, for the MMPU to interface the solar arrays and the battery within the power subsystem. The MMPU is located within the WEB in order to meet operating temperature requirements of its components.

Mobility

The mobility subsystem contains wheels, motors, and a rocker-bogie suspension system. The rocker-bogie suspension system is mounted to the rover with one set of legs attached to either side of the chassis body and attached to the body through an internal differential gearbox. The front and back wheel on both sides of the rover will each have two motors mounted in the legs, one for driving the wheels and one for precision control of the wheel angle for steering.

4. Payload Design and Science Instruments

4.1. Selection, Design, and Verification

4.1.1. System Overview

Poli'ahu's payload and science instrumentation has been designed to meet the mission goals of quantifying Martian water-ice deposits for in-situ resource utilization. The science payload consists of a multi-instrument remote sensing subsystem that takes measurements and acquires data, and supporting systems including power, communication, command and data handling, navigation, and thermal control.

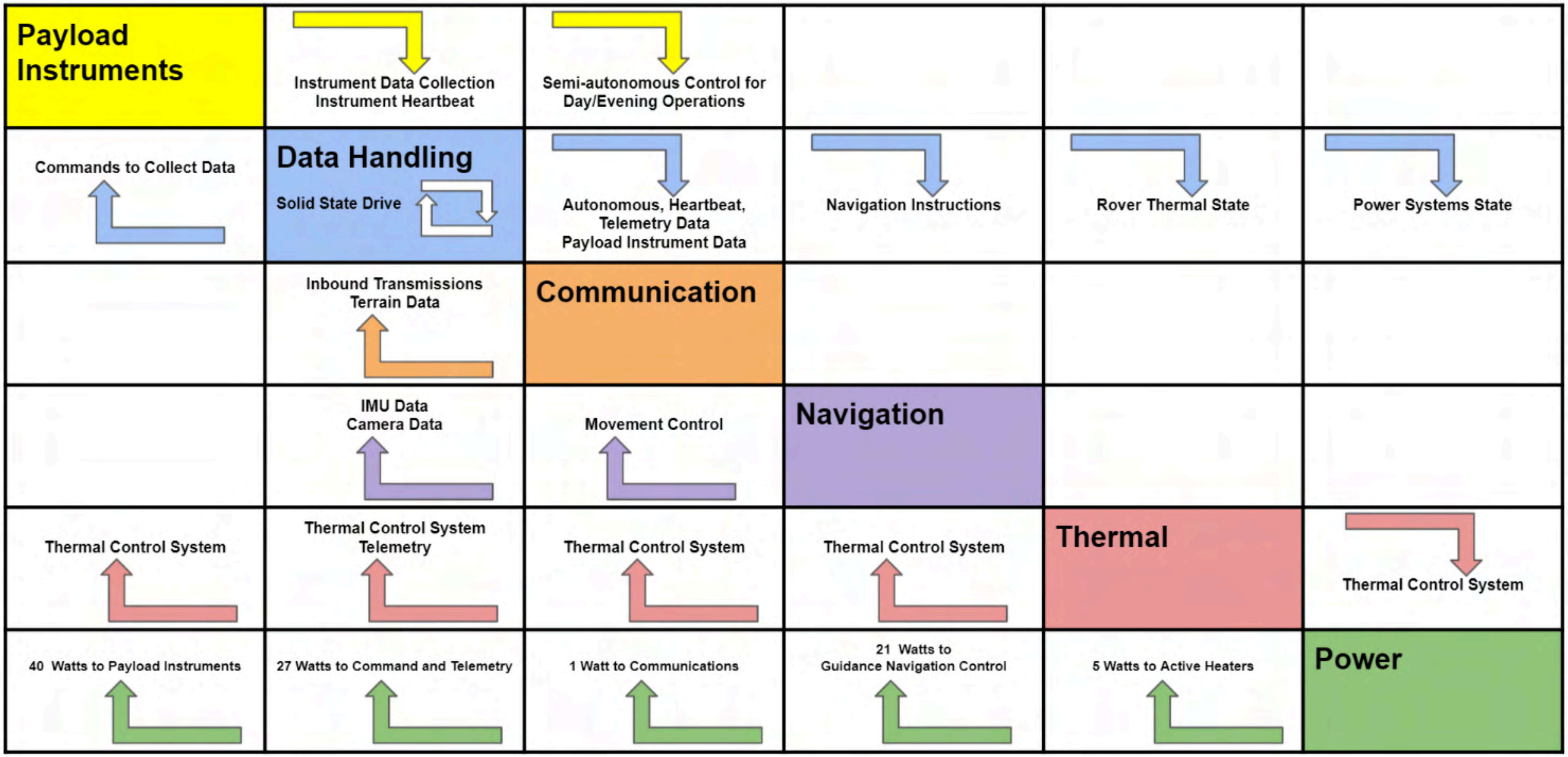


Figure 4.1.1-1: N² Chart

4.1.2. Subsystem Overview

The RIMFAX and DAN instruments have been selected because their data sets complement the quantified findings of the subsurface ice deposits.

4.1.2.1 Radar Imager for Mars' Subsurface Experiment (RIMFAX)

The Radar Imager for Mars' Subsurface Experiment, or RIMFAX, is a ground penetrating radar that assembles profiles by stacking successive radar soundings to create a two-dimensional subsurface image.

The radar profiles can be used to map out subsurface layers and narrow down their possible composition. RIMFAX pulses every 10-20 centimeters and collects 5-10 kilobytes of data per sounding location at a vertical resolution of 15-30 centimeters. The functional maximum depth of RIMFAX measurements is 10 meters (30 feet) below the surface, though may allow deeper measurements depending on the properties of the layered material (Alanis et al., 2021).

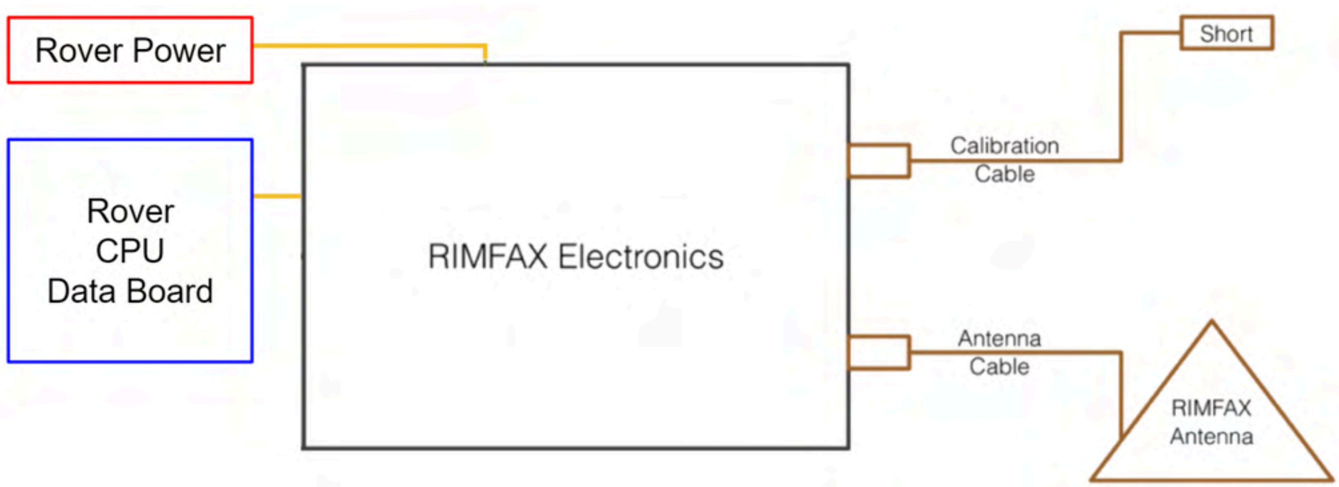


Figure 4.1.2-1: RIMFAX Components Block Diagram.

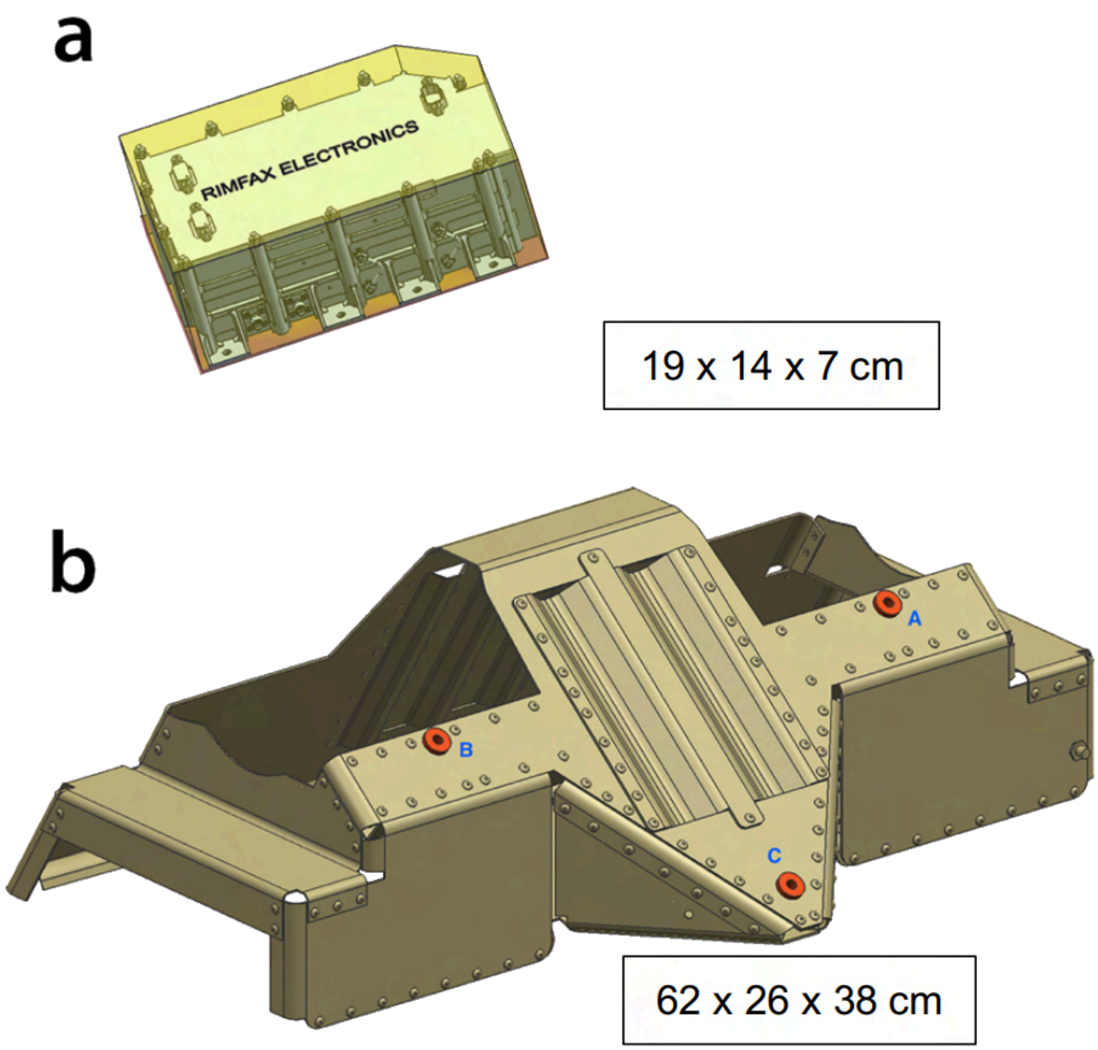


Figure 4.1.2-1: RIMFAX Component Parts, (a) Electronics, (b) Antenna. (Source: JPL/NASA)

4.1.2.2 Dynamic Albedo of Neutrons Spectrometer (DAN)

The Dynamic Albedo of Neutrons Spectrometer (DAN) is a remote-sensing science instrument located on the side of the rover. This neutron spectrometer detects the presence of hydrogen and hydroxide ions while quantifying their abundance up to 1 meter (3 feet) below Martian regolith. This data detects the presence of water ice or salty brines in the subsurface of the Mars regolith.

DAN will function as the Poli'ahu rover traverses in short ~1 minute stops to calculate a rough estimate of the water-equivalent hydrogen distribution by weight.

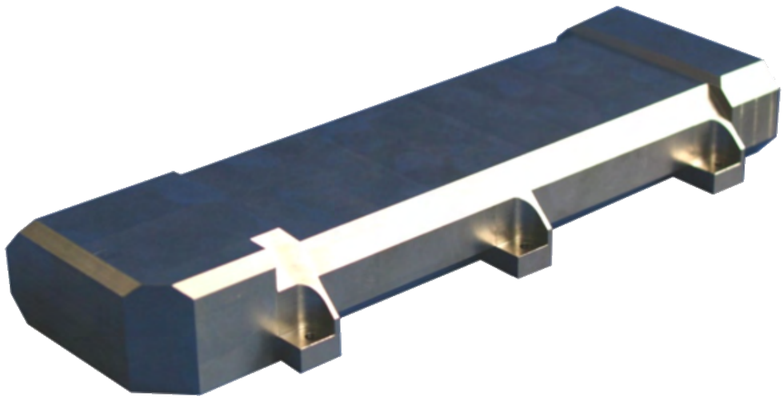


Figure 4.1.2-3: DAN Pulsing Neutron Generator (JPL/NASA)

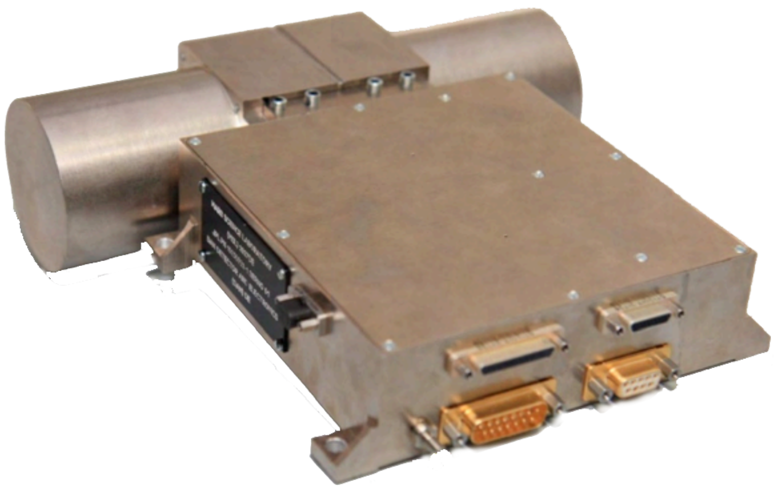


Figure 4.1.2-4: DAN Detector and Electronics (JPL/NASA)

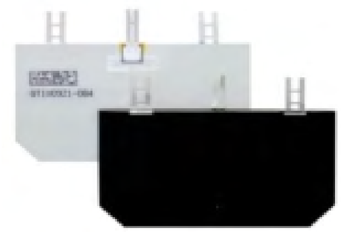
4.1.2.3 Power Subsystem

The power system will be tasked to generate, store, and distribute the necessary current and voltage to all the powered components. In order to achieve this, the system will include solar panels and the power distribution units. The distribution systems of the rover are designed to be modular, which means the system is subdivided into smaller independent units called modules. These modules can be created, modified, and replaced or exchanged with other modules. Applying this design helps to cut down on cost, as customizations can be limited, increases flexibility in design, allows unconstrained augmentation or updating and exclusion. This enables individual instruments within the rover to operate according to its specific power requirement and specifications.

Power Distribution System: The power system will consist of solar panels, a battery, two equipment power distribution modules, one battery charge/discharge module, a shunt regulator module, and the necessary cabling. Photovoltaic solar cells will generate the power required by the system. Solar panels will be able to expand to an area of 20,047 cm sq in order to accommodate the power budget with

12,529.4 cm sq margin allocated. In order to expand, each solar panel will be connected through an actuator mechanism to allow its expansion once arrived at the Mars Surface. The rear panel will have an actuator that allows it to adjust to a more favorable incidence angle with the sunlight. The battery selected is LP 33037 60 Ah Space Cell purchased from Eagle Picher Technologies. The power conditioning and distribution system will employ a modular design to allow for functionality across the solar arrays, battery, and individual components.

Solar panels: The main source of power for Poli'ahu will be solar panels. Poli'ahu will be using high efficiency space photovoltaics. These solar cells will be purchased from Spectrolab, which is a branch of The Boeing Company. These cells are highly reliable and have been used on similar Mars rover applications.



2 Per (26.6 cm²)

4.1.2.4 Communications Subsystem

Poli'ahu's communication approach is to communicate directly with the primary lander. The primary lander then will relay data to spacecraft in orbit around Mars or directly to the Deep Space Network (DSN), which delivers the communication to mission control. This same communications path will operate in reverse with the DSN communicating with the primary lander, which will relay communication to the rover.

The communication system will provide two-way radio relay communication between the rover and the primary lander system. This system is based on technologies with demonstrated technology readiness in Mars conditions. A radio relay system will be utilized to send science and housekeeping data to the primary lander and to receive commands from mission control. The system consists of a Digi XBee-PRO® 900HP RF modem and communications module, a Grove Connector Development Board - XBee, and a Half-Wave Dipole RPSMA antenna. The antenna is an omni-directional, half wave dipole, which was chosen for its favorable radiation pattern and reasonable gain. It has a range of up to 22 km, a weight of 0.64 oz, and a RF rate of 10,000 bps. This gives the chosen antenna a large range and a fast rate of data transfer for it's lightness, in comparison to other antennas with similar specifications.

4.1.2.5 Data Handling and Control Subsystem

The data handling and control system will provide the primary computational decision making for the rover, as well as process and store data from the science instruments and other subsystems.

The power management system will ensure that the vehicle is able to enter a low power state, when needed, in cases of low solar power generation. One such low power state might occur during large seasonal dust storms, or Martian winter periods. Certain instruments that are not operable under this condition will be put into idle mode. In idle mode, the unit will be provided the minimum power required to wake it up quickly after the incident.

Software for Mission Control, Navigation, and Science

Surface System Software for Rover Navigation

JPL has spent years providing software, improvement of algorithms, and technical guidance in surface system software for autonomous and semi-autonomous rovers. The highest level of software used is called Rover Flight Software (FSW) which resides on the CPU operating system of the rover, which is a specialized version of Linux. This handles commands sequences and high level control.

The on board software receives telemetry data from the IMU regarding the rover's orientation, wheel odometry, and ground-truth stereo image pairs from the Navcam, and Hazcams, at set intervals during a drive. This data is processed by the flight software which corrects the calculated rover location using the ground-truth data.

The Robot Sequencing and Visualization Program (RSVP), another software tool, has been used by the Mars Science Laboratory (MSL) rovers, the Mars Exploration Rovers (MER), and even Mars Pathfinder. This software has two components, a Robot Sequence Editor (RoSE), which is a GUI, or graphical user interface for mission operators to create command sequences to be sent to Poli'ahu. RoSE also connects to JPL's spacecraft sequence generation system (SEQGEN), which commutes resources, and validates the sequences that will be attempted.

The second component of RSVP is called HyperDrive. This software compiles and displays the 3D terrain models that are generated from stereoscopic cameras, and telemetry data (Figure 4.1.2.5-1). This tool allows operators to plan the motions of a rover and test them against the terrain in a simulation, before sending commands to the rover.

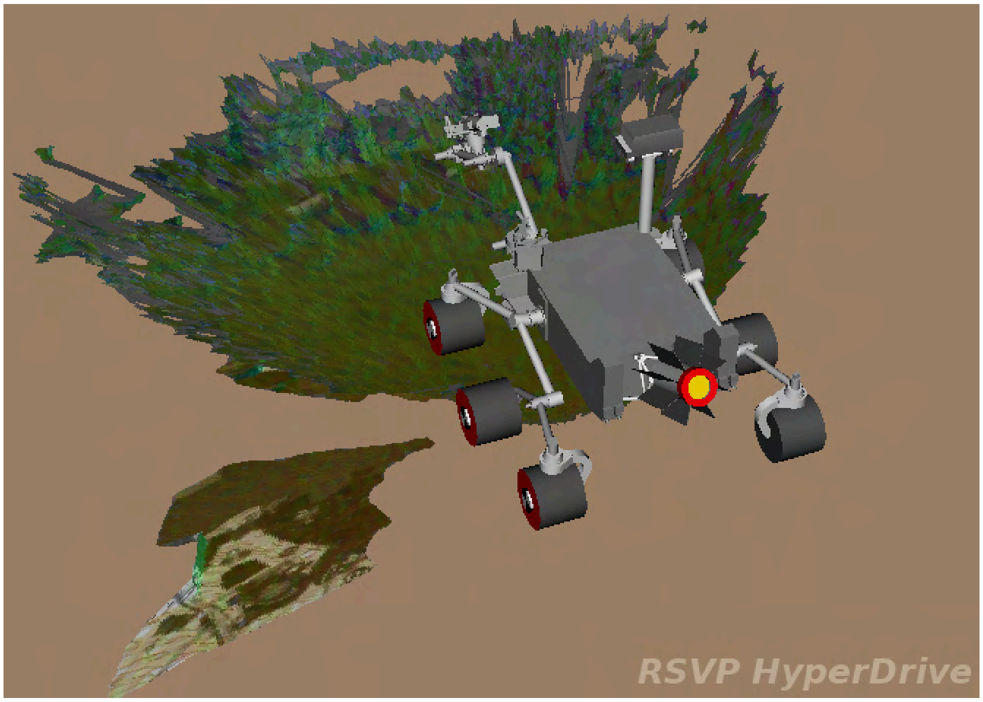


Figure 4.1.2.5-1: Example of 3D interface for HyperDrive (JPL/NASA).

Autonomous Movement

Autonomy software is used on Poli’ahu as outlined in the Concept of Operations, the rover will use the observations made by sensors and cameras to autonomously carry out it’s science mission. Software called AutoNav (which was used on the MSL rover Perseverance) creates a digital elevation model and evaluates the multiple possible least-cost paths that the rover can take based on the potential terrain types and hazards (Figure 4.1.2.5-2). This software takes potential obstacles such as rocks and steep elevation changes into account.

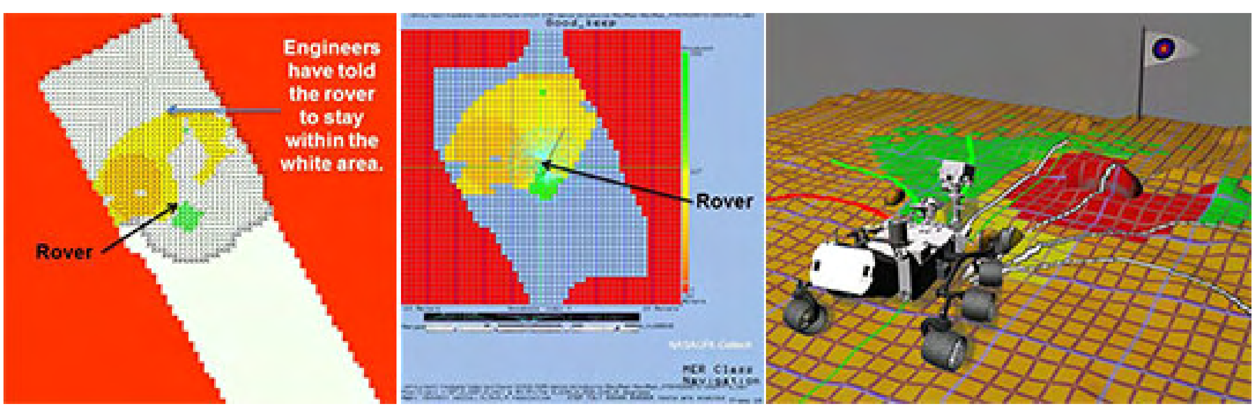


Figure 4.1.2.5-2: 3 different views inside the SMl autonomous navigation software (JPL/NASA).

Onboard Visual Odometry Software

Since there is no global GPS on Mars, it is important that the Poli'ahu rover utilize any, and all positional data available to it. While the wheels and IMU do provide telemetry and wheel revolution counts, the soft surface of Mars can introduce inaccuracies when wheels or even the rover slips back down a steep grade, or the terrain gives way.

To combat these inaccuracies, JPL created a set of software algorithms called the Mars Exploration Rover Visual Odometry software system. This software uses image data from the Hazcams and compares images taken before and after a short drive (Figure 4.1.2.5-3). After locating multiple landmarks or features in the images, it tracks their movement in the images and compares this to the 3D terrain model, to tell the rover how far it really traveled, with much more precision than just counting wheel rotations (Figure 4.1.2.5-4).

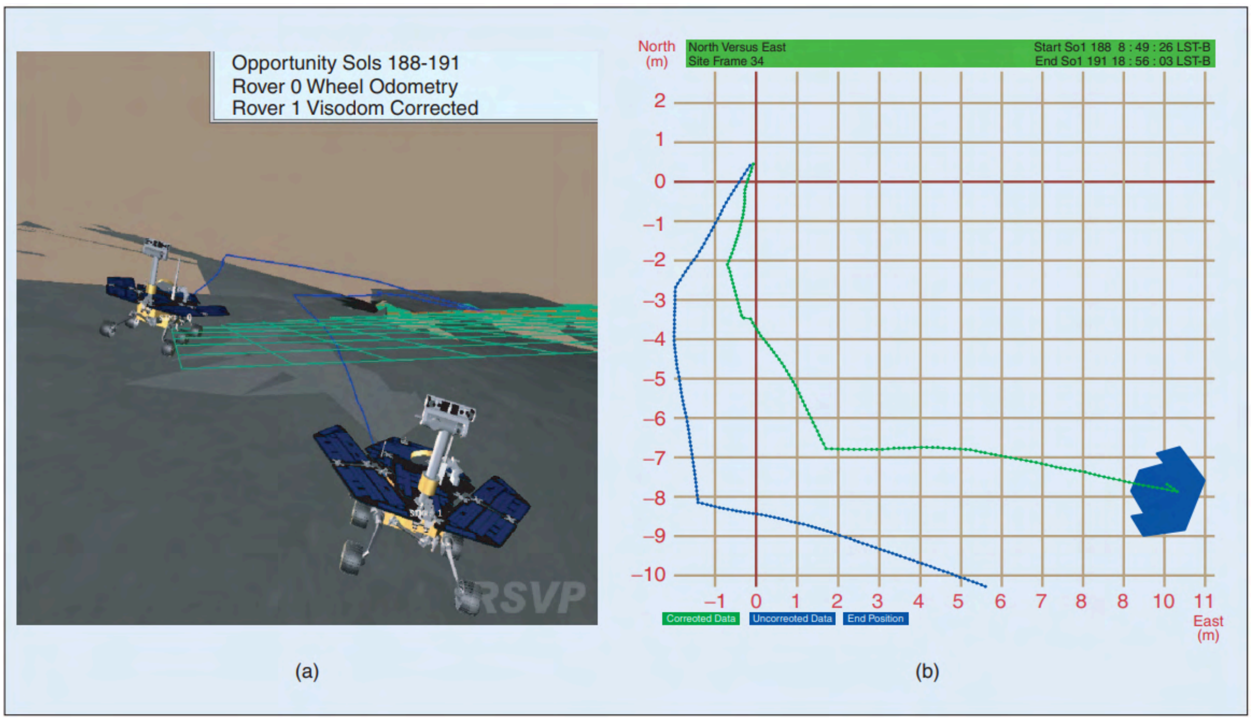


Figure 4.1.2.5-3: Opportunity drive on Sol 188-191 shows how far off the IMU/wheel predictions were (blue), compared to the visual odometer corrected path (green). Units are in m.sq.

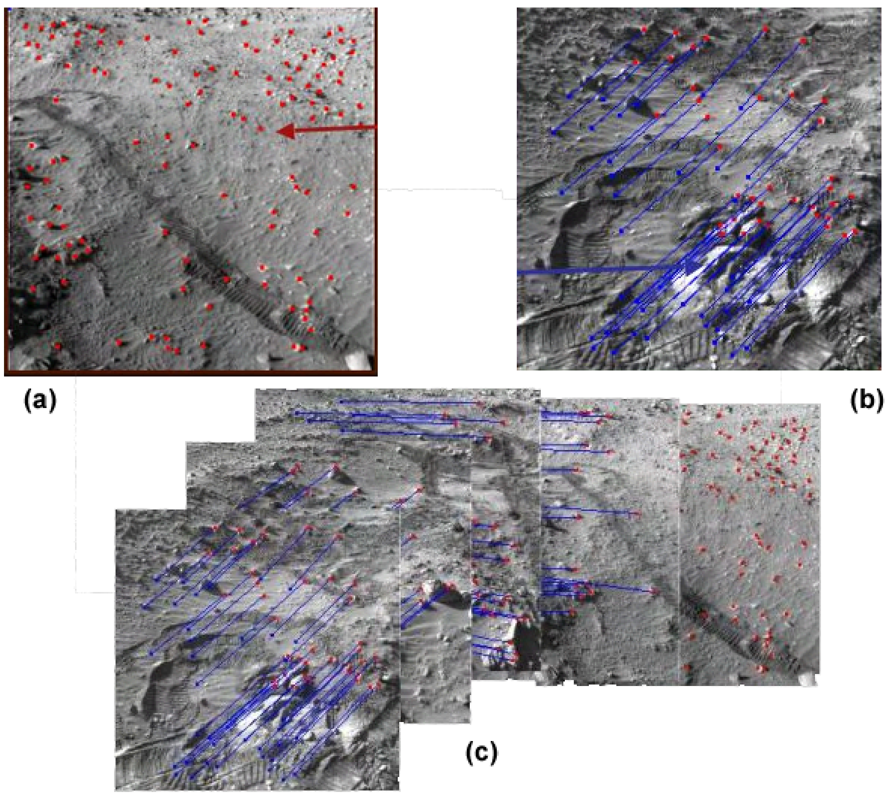


Figure 4.1.2.5-4: Visual Odometry Process, (a) onboard computer located interesting features. (b) when it has moved less than 1m, new photos are taken and processed. (c) The onboard computer measures distances and angles from blue to red dots, building a 3D vector of the movement. (NASA/JPL/M.Maimone)

Terrain-Adaptive Wheel Speed Control

The Terrain-Adaptive Wheel Speed Control flight software, developed and deployed by JPL for Curiosity will be leveraged by Poli'ahu, to reduce the forces exerted on the wheels, by terrain contours and obstacles. The algorithm "adapts each wheel's speed to fit the terrain topography in real-time, by leveraging the rover's measured attitude rates and rocker/bogie suspension angles and rates." Paired with a rigid-body kinematics model, it estimates in real-time the contact angles between the wheels and the terrain so as to command the rover to a more stable position and prevent slipping (Toupet et al., 2019).

AMMOS Mission Data Processing and Control Subsystem (AMPCS)

Poli'ahu mission science operations will utilize a NASA funded PDS data pipeline software which was created by the Advanced Multi-mission Operations System (AMMOS). Mission Science products will be processed with the AMMOS Mission Data Processing and Control Subsystem (AMPCS). This software automates the depacketization of the raw downlinked data into files with the appropriate PDS structures (Alanis et al., 2021). This software is part of a mission operations and data processing set of applications which are used by NASA, international partners and academia. It has provided low-cost, high reliability data processing services for over 50 robotic missions, utilizing an "Ops in a Box" design (Estefan, 2021). This enables teams to leverage work created by past mission funding and efforts. For data processing on the chosen computers, there should be no additional cost unless software modifications are needed, and specified in later mission plans (Benecken, n.d.).

4.1.2.6 Navigation Subsystem

The Navigation system will allow the rover to autonomously traverse the Martian terrain while carrying out its science objectives.The navigation system is designed as a semi-autonomous system on the rover.It will mainly consist of two navigation cameras, four hazard cameras, and an inertial measurement unit (IMU).

Navcam, or navigational camera, will be used to take wide angle photographs. This will allow the rover to make decisions while moving across the Martian surface. Hazcams, or hazard avoidance cameras, will take balck and white images that are used by the rover to produce a 3D map of the terrain. These cameras have a wide field of view of approximately 120 degrees horizontally and vertically. Hazcams are fixed and cannot move independent of the rover. This produces real-time photos of the surface and its surroundings while the rover is moving. These cameras will assist the rover to identify threats during its operations, avoiding damages to both the wheels and the payload. The IMU will report orientation, velocity, and gravitational forces. The IMU unit will serve as a GPS to locate the rover.

Data from navigation cameras located about the rover's chassis will be sent to mission scientists for generation of 3D digital terrain, which will subsequently inform future mission planning. In the case of an error in the system, which prevents the rover from deciding whether it is safe to keep moving, a manual intervention will be performed by operations engineers. They will make decisions based on data and images received from the rover, and send the necessary commands to direct rover actions.

4.1.2.7 Thermal Control

The Thermal Control System will monitor and maintain the operating temperature range for all relevant components. The thermal control system consists of a Warm Electronics Box (WEB), Radioisotope Heating Units (RHU's), electric heaters, and warm-up heaters.The thermal control outside the WEB will consist of warm-up heaters that will be placed on motors and actuators to bring them to optimal operating temperature. Team will also use the white coating paint which reduces heat loss by spraying the gold metal it will reduce the energy that is radiated from the rover.

Radioisotope Heater Units are miniature devices that use radioactive decay to generate a heat constant of one watt. The Poli'ahu rover uses 5 RHUs within the WEB to maintain key electrical components at a safe temperature. In addition, RHUs are used to maintain the operational temperatures of other components, which may be substantially different from the temperature of other portions of the rover. Furthermore, the heater that will be used are simply wires. When current is conducted through a wire, it generates heat due to its resistance to the flow of electricity. The wire is glued to the portions that need to be warmed and is heated by conduction. When the temperature drops below a preset threshold a thermal switch will engage to turn on the heater. This simple circuit helps prevent any damage to the electrical components due to temperature swings. The switches will turn the heaters on and off.

Aerogel is a very light insulating material that prevents heat transfer. It can be used as a very efficient insulator. The Warm Electronics Box (WEB) will have aerogel, RHUs, and heaters to keep it warm during the night temperatures.

4.1.3. Manufacturing Plan

The first priority is to determine if it will be more accurate, time saving, and cost effective to fabricate materials used in the manufacturing phase for payload components. This effective route allows for perfect integration with minimal error in the dimensions and weight. If necessary, raw materials will be outsourced for manufacturing, which could yield some imperfections during integration with other components. It may take more time and resources to finalize this process.

The main payload components in Poli'ahu Rover are its cameras, navigation system, and electronics.

Cameras: The camera system will be outsourced to Malin Space Science Systems in San Diego, California. (MSSS Delivers Mast Cameras for MSL, Restarts work on zoom Mastcams, 2010) Malin Space Science Systems has experience in this field where they built camera systems for previous Mars Rovers. After debating between off the shelf camera systems and the camera systems manufactured by Malin Space Science Systems, the Poli'ahu team has determined that it would be the best choice to move forward with the special camera systems that are particularly manufactured for the Martian environment.

All camera systems will be manufactured at MSSS and will be delivered to Team Aegir for installation to the chassis and final integration.

Navigation System: The Navigation System in Poli'ahu is a semi-autonomous system that is powered by the Navigation and Hazard Cameras on board. The software in this system will be developed in-house by Team Aegir's software engineer to ensure an excellent integration between the navigation system and its cameras.

IMU: The Inertial Measurement Unit (IMU) is one of the most important components that will be on board to ensure all the data needed in terms of acceleration. This data is necessary to precisely navigate on the Martian surface. The IMU unit will be outsourced and manufactured by Northrop Grumman because it is the leading distributor of IMU products utilized in previous Mars rovers (LN-200 Inertial Measurement Unit, 2021). This is a standard LN-200 Unit that Northrop Grumman has in it's inventory so it will be directly ordered by Team Aegir. Once the unit is delivered to the team, it will be installed and then final integration will be done.

Temperature Sensors: Temperature sensors are vital to the mission's success and it's important to be able to monitor the temperature data of most components that are in motion. Each vital component on the Poli'ahu rover has built-in temperature sensors. Due to the mass constraint, the team has decided to rely on these built-in temperature sensors to monitor the internal temperatures of the components.

SSD Storage: Poli'ahu Rover will be taking many images and information during its journey on Mars. The team will be scheduling daily data transfers to the main lander in order to transfer all this data back to earth via the main lander. In the meantime, an SSD on board is needed to store all this data until it is transferred to the main lander. After doing some research, the team decided to outsource this component to Mercury. This company manufactures components that can survive the Martian environment. After conducting a thorough research, the team selected the RH 304 T model with 4.5 TB capacity in order to meet mission conditions. (RH304T Solid-State Data Recorder, n.d). This unit will be delivered to Team Aegir for final installation and integration.

Science Instruments: RIMFAX is a ground penetrating radar that operates as a remote-sensing instrument. It is being outsourced to the Norwegian Defence Research Establishment. Considering their expertise in this area, the team has determined it would be the best choice to go through the Norwegian Defence Research Establishment. Once the RIMFAX is received by Team Aegir, the installation and integration will be done in house.

Integration Plan

Power Cycling: Power cycling is the procedure for turning hardware off and then on again. It is used in the data center to assess the longevity and reliability of network components. It is usually done remotely by using the system management. This process will reduce the chance of data/ file corruption. Once the power is off during this process, the system will be restarted automatically.

Electronics Test & Technical Analysis: When conducting an electronics test, the team will perform tests on different sections of the electronic systems such as the wiring continuity, insulation resistance, and short test. The first test that must be performed is the continuity of circuit and earthing after wiring is completed. The team also decided to conduct an insulation resistance test which is a very important test to guard against shocks/ burns and to avoid equipment damages such as accidental discharge. The insulation resistance test will be performed to measure the whole system of conductors in this test to make sure that all the fuses are in place and all the switches are closed. Soft short test is to make sure that there is no leak through something that's partially conductive of electricity rather than a hard short for example connecting one electrical wire to another one.

Warm Electronic Box (WEB): For this test, the team decided to integrate the Warm Electronic Box by testing it under -90°C to -140°C to make sure that the warm electronic box is keeping the electrical components warm during the nighttime without getting overheated.

Aerogel: Aerogel is a thermal insulator, light weight, and easy to use (NASA Content Administrator, 2017). There is no need for any power to be performed.The team will compare the WEB with and without Aerogel then compare the differences in the resulting data. The aerogel will act as an insulating layer to protect the temperature inside the warm electronics box.

4.1.4. Verification and Validation Plan

To ensure that the rover's subsystems and science instruments perform reliably on Mars, the vehicle needs to go through a verification and validation process. This means that the subsystems and instrumentation must undergo testing to establish that the requirements are met and how they will function in the Mars environment.

To verify that the communications systems function properly, tests should be conducted to ensure that the transmitter and receiver can send and receive signals on the VHF band by sending multiple test signals. The communications system will be validated by testing if the transmitter and receivers can operate while subjected to extreme low temperatures and low atmospheric pressure in the thermal vacuum chamber. This test is referred to in System Requirement 2 and its functional and performance requirements.

The Poli'ahu Rover will be a semi-autonomous rover on Mars. Team Aegir designed a navigation system that is powered by six cameras and software being developed in-house. This system is crucial for the mission success, so it shall go through an intense verification and validation process. The team plans on testing the camera system on earth to see if it can detect and avoid obstacles. This test is referred to System Requirement R8 and its derived requirements.

Since camera systems will be taking footage of the surroundings constantly, there needs to be a data storage system to store all this data. The team selected an SSD system that is compatible with Martian environments. This equipment will be tested under low temperature and radiation to verify if it is functioning properly. This test is referred to Systems Requirement R8.4.

In order to have the most accurate acceleration data, there is an Inertial Measurement Unit (IMU) onboard that is manufactured by Northrop Grumman. This unit will be verified and validated by tilting the rover to different directions to verify that the component is working properly. This test is referred to System Requirement R8.3.

RIMFAX will be tested by using it over an area where the expected data outcome is already known. The resulting data can be analyzed to ensure the RIMFAX is working efficiently with minimal to no issues. This will also verify that the instrument identifies layer boundaries to the expected depth of 10m at a resolution of 15cm. To validate if RIMFAX will operate reliably in the Mars environment, it will be tested in a thermal vacuum chamber where it can be tested under low temperature and low atmospheric pressure conditions.

The thermal system is an immensely important system of the rover since many of the rover's components have a specific operating temperature range. Most of the rover's components will be found in the Warm Electronics Box. This box needs to be kepts at a minimum temperature of -5 °C. Testing will be done to verify that the thermal system maintains this temperature uniformly throughout the WEB by placing thermistors in key places near important components. With the thermal subsystem running, the temperature at each location in the WEB can be monitored to ensure that components are kept in their operating temperature ranges. This test is referred to by Functional Requirement 1.1 and Performance Requirement 1.1.1. Temperature sensors are very important to the other components on Poli'ahu. It is crucial to monitor temperature activities in order to make the best decisions for the mission.

4.1.5. FMEA and Risk Mitigation

Failure Mode and Effects Analysis										
Subsystem	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes / Mechanisms of Failure	Current Design Controls Prevention	OCC	Current Design Controls Detection	DET	RPN	Recommended Actions
Communications	Antenna stops working	No instrument data will be transmitted	8	Problem in the code for sending and receiving data/connecting	Test code that runs communication.	2	After rover is assembled, run the program to test for connection errors.	7	112	Mitigate Test and run program to test for connection errors
Instruments- RIMFAX Neutron Spectrometer- (DAN)	Instrument is damaged	Loss of instrument	8	Instrument is damaged during launch, entry, descent or landing.	Instruments will be assembled to protect from some damage.	3	Rover will send message if instrument is damaged.	9	216	Accept
Power	Uneven distribution of power across the system	Subsystems fail due to insufficient or too much power	7	Error in modulator.	Modulators will control distribution of power.	2	After rover is assembled, power system will be tested to ensure that it is running properly.	2	28	Mitigate
Thermal-	Subsystems overheats	-Subsystems temporarily stop -subsystems fail	3 9	Too many instruments used at once.	Thermal switches will monitor and maintain temperature.	5 3	C&DH will keep certain subsystems on/off to regulate temperature.	3 3	45 81	Mitigate

Figure 4.1.5-1: Subsystem FMEA

ID	Summary	L	C	Trend	Approach	Risk Statement	Status
1I	Instrument failure	2	4	→	A	Due to mass constraints, there is no recovery system for instruments. Data cannot be collected by other instruments.	
2T	Subsystems overheat	3	4	↓	M	Due to cold Mars temperatures, critical components need to be maintained at operating temperatures.	Thermal system is being researched and designed.
3N	Camera fails	2	2	↓	M	Cameras can be damaged.The rover will have to travel based on the feedback from the remaining cameras.	Multiple cameras have been added.

Figure 4.1.5-2: Subsystem Risks.

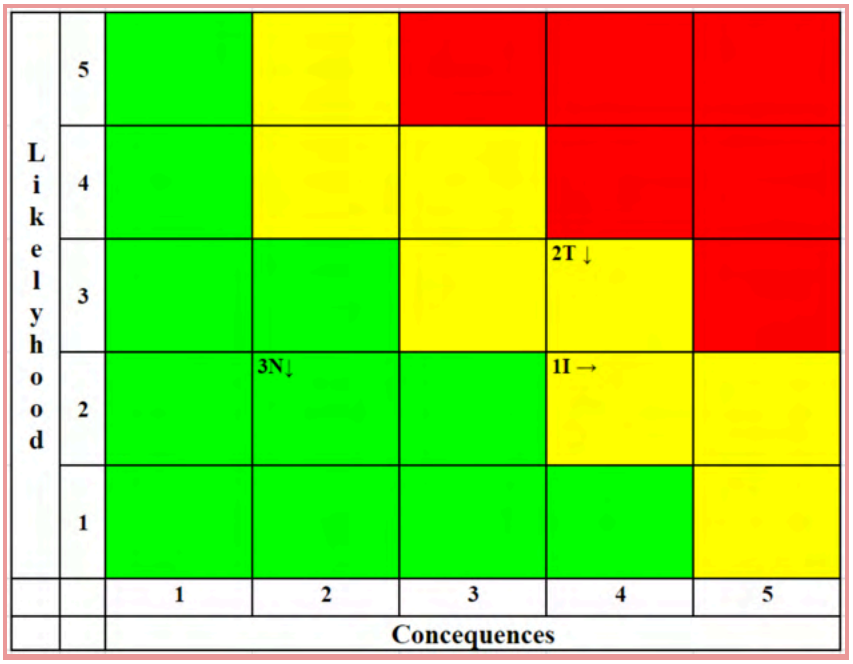


Figure 4.1.5-3: Subsystem Risk Matrix.

Approach	Criticallity	LxC Trend	L = Likelyhood (1-5)
A - accept	HIGH	↓ - Decreasing (improving)	1 = not likely
M- mitigate	MED	↑ - increasing (worsening)	5 = extremely likely
W - watch	LOW	→ - unchanged	**C = Consequence (1-5)**
R - research		**NEW** - added this month	1 = low consequence
			5 = high consequence

Figure 4.1.5-4: Subsystem Risk Matrix Legend.

4.1.6. Performance Characteristics

Power System

To determine the solar panel area, a power budget was constructed that included all powered components operating at their nominal and idle power rates for time estimates based on the surface operations plan of a standard sol on Mars. The estimated energy demand for a normal day and night were determined to be 1484 Watt-hours and 171 Watt-hours respectively for a daily total of 1655 Watt-hours. To simplify the calculations, the solar irradiance was averaged over a 12 hour daytime period according to figure 4.1.6-1.

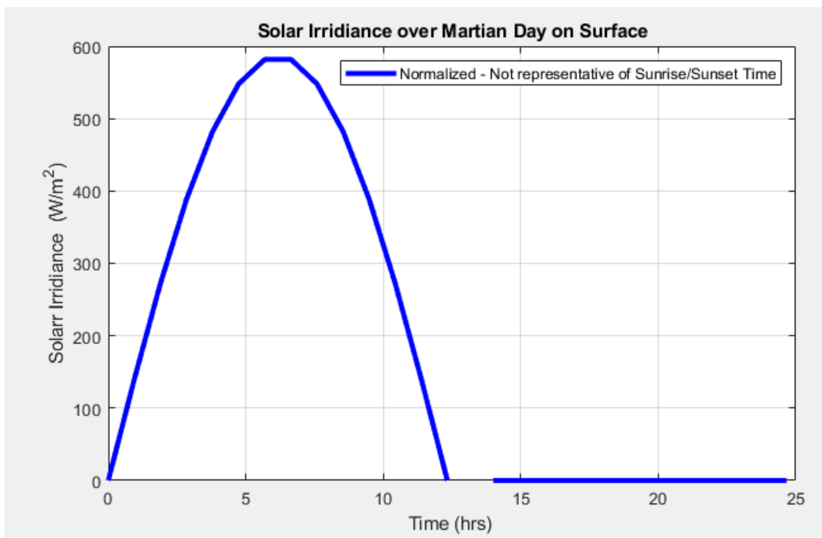


Figure 4.1.6-1: Solar Irradiance throughout a Sol.

The average solar irradiance was calculated to be 344.8 W/m^2. This value was calculated by using MATLAB code given below:

```
%Average flux throughout a Martian day
Total=0;
Theta = linspace(0,180,180/Tday);
Flux = SolarIr*sind(Theta);

for t = 1:14
Total=Flux(t)+Total;
end
average=Total/14;
```

Assuming a 10 hour charging period per sol and 30% panel efficiency, the calculated minimum solar area was 1.6 m^2.The solar array will have a final area of 2.00 m. This area gives the power system a 30% margin for daily charging. It is estimated that 30% margin will be enough to compensate for any loss of panel area due to dust/debris accumulation, as well as deviations in daily power usage.

Communication System

The communications subsystem is responsible for sending and receiving radio signals to the main lander system. The communication system will have a data transmission rate of 10 kBits/s. The system includes a half-wave Dipole RPSMA antenna. The antenna is 7 in long and has a frequency range of 900 to 928 MHz. The antenna has a gain of 2.1 dBi, and a free range rural line of sight up to 22 km. Nominal transmissions will occur in the VHF band at 900 MHz. The communications module uses the Frequency Hopping Spread Spectrum (FHSS) modulation scheme. The RPSMA is connected directly to the Modem which includes a communication module and a grove development board. The communication module connects RPSMA signal in order to send information back to ground station. The Grove Development Board is the PCB which transmits and processed the RPSMA and Communication Module interactions

Data Gathering

The data gathering subsystem has the function of quantifying and qualifying the subsurface ice deposits. RIMFAX ground penetrating radar creates profiles of the subsurface and can reach to a depth of up to 10m with a vertical resolution of 15cm to 30cm. At each sounding location RIMFAX produces 5-10 kbytes. The DAN spectrometer has the function of detecting the presence of Hydrogen, “DAN measures the time decay curve (the "dynamic albedo") of the neutron flux from the subsurface induced by its pulsing 14 MeV neutron source” (Mars Ex. Program, 2021). The DAN spectrometer has accuracy that depends on the length of the measurement. DAN has 1% accuracy for a one minute long measurement, and up to 0.1% accuracy over a thirty minute measurement. The surface operations plan calls for use of the 1 minute, short pulse mode as its primary measurement mode, only using the 30 minute pulse on command by mission control.

Thermal Control

The thermal control system functions to keep the rover’s components within their operating temperature ranges. All of the electronics will be stored inside the Warm Electronics Box (WEB). Inside the WEB there will be 5 Radioisotope Heating Units (RHU’s) each emitting a constant 1 Watt of thermal energy, and a warm up wire heater for the battery. The interior of the WEB will be maintained at a minimum temperature of -5 ° C (268 K).

Data Handling and Control

The data handling and control is to manges all forms of data that will help carry out the commands that will be received from earth; furthermore, it will manges the collection of the solar power and charging the batteries. Also, it will calculate the rover's position. Data handling will help autonomously monitor and respond to a wide range of onboard problems. The team decided to use Solid State 4.5 TB capacity. The data will be stored on a recorder until it gets sent to earth; afterwards the data will be deleted and replaced with the new data.

4.2. Science Value

4.2.1. Science Payload Objectives

The Poliahu mission's primary science objective is to locate and quantify the volume of water ice within the vicinity of the Phlegra Dorsa Human Exploration Zone. It will accomplish this through the use of remote-sensing science instruments rather than surface sampling. The rover will identify 100 metric tons of subsurface water ice deposits as an preliminary step in NASA's plans for establishing a long-term future human exploration base of operations on Mars.

These goals are important because human exploration requires significant amounts of in situ water reserves.These reserves will facilitate human consumable water in situ resource utilization (ISRU) fuel manufacture, and potentially the production of locally produced foodstuffs. By locating and quantifying the available quantity of water ice deposits that can be collected, the Poli'ahu spacecraft will enable future human exploration missions, securing a landing site that is capable of sustaining long-term human missions.

The science instruments will gather data that will identify the isotopes of hydrogen, which can help determine what type of resources they will be used for. For example, if there is an abundance of deuterium, this hydrogen isotope can be used to fuel fusion reactors that will generate electricity to power necessary laboratory equipment in future manned missions. If there is an abundance of hydrogen, it generally indicates the presence of water ice. Water can be used to produce rocket propellants, distilled potable water for human explorers, food/crop production, cooling, radiation protection, and is very useful as a solvent. The practice of ISRU will allow astronauts to live independently from Earth for long-term missions on Mars.

4.2.2. Creativity/Originality and Significance

For human exploration to occur on Mars, NASA has determined that it will require 100-metric tons of water. Ideally, this water will be extracted in situ, or on site, which is called In Situ Resource Utilization (ISRU). The Poli'ahu Mission objective and design are unique because it will locate and quantify subsurface water-ice that can potentially be mined through later ISRU missions. To accomplish this goal, this mission will deliver a rover to the surface of Mars.

The rover is designed to use active and passive electromagnetic remote sensing instruments to gather its science data. The first instrument, called RIMFAX, will detect the density differences and boundaries of subsurface layers using ground penetrating radar. The second instrument called DAN, a neutron spectrometer, will detect the percentage of hydrogen which indicates the presence of water-ice.

Mission operations staff will also combine the above data with stereoscopic surface imaging to create 3D models of the area, both above and below ground, that the rover traverses. The detailed 3D and geologic models created by the Poli'ahu mission will provide NASA and the scientific community with a detailed map of subsurface ice layers, and their volume. This information will greatly facilitate planning for future human spaceflight missions to the region, and eventually the development of an exploration base on Mars.

This mission will trailblaze several "firsts" on Mars:

1. **First mission to Arcadia Planitia**.
2. **First high latitude (39°N) rover-type vehicle.** Only two other NASA missions have landed such as high latitude. These were Viking 2 (47°N - Utopia Planitia) and Phoenix (68°N - Green Valley), and both were landers rather than mobile rovers.
3. **First articulating solar panel on a rover.** Due to the high latitude, the sun appears lower in the sky throughout the year. This low inclination will generate less solar power than previous rovers which were closer to the equator. This rover design is the first to include an articulating panel that can raise and lower to gather light closer to perpendicular to the sun's rays.
4. **First rover to test active dust mitigation techniques for solar panels**. The mission will evaluate the effectiveness of gravity and the atmosphere on a variably angled surface, to quantify the effectiveness of the "shake it off" approach to dust buildup and mitigation.

4.2.2.1. Landing Site

The team has selected Phlegra Dorsa as the planned landing site. It is located in the northern hemisphere on the southwestern edge of Arcadia Planitia, at coordinates 39°N 172°E. The primary reasons for selecting this site was:

1. Water-ices appear to be ubiquitously present at all ROIs at this site.
2. Low Elevation aids aerobraking methods of entry, descent, and landing (EDL).
3. High mineralogical diversity, especially noting the presence of hydrated minerals in one ROI and a prevalence of metals/silicate resources throughout the region.
4. Lower levels of dust than other sites.
5. Large areas of smooth terrain suitable for EDL, Civil Engineering, and ISRU processing.
6. More ROIs with good potential for highly automated water-ice, metals, and silicate mining operations.
7. Higher diversity of aeolian sediments and landforms for future geologic study.
8. ROIs with high meteorological diversity in space and time

9. ROIs showing evidence of aqueous processes.

4.2.2.2. Landing Site Selection Process

Selecting Phlegra Dorsa as the landing site for Poli'ahu was the culmination of several weeks of research and site selection trade studies. The primary component of this analysis was a comprehensive trade study of potential landing sites (Figure 4.2.2.2-1), created by the "First Landing Site/Exploration Zone Workshop for Human Missions to the Surface of Mars," held in 2014.

Workshop participants attended presentations of abstracts for the Exploration Zones (EZ) they would score. Each EZ had a number of defined Regions of Interest (ROI) to be evaluated. For example, the Phlegra Dorsa EZ, as seen in Figure 4.2.2.2-2, had 4 Science ROIs and 3 Resource ROIs sites for a total of 7 ROIs. Workshop participants then scored each ROI within the EZ with a score for each criteria, depending on their evaluation whether the ROI satisfied the criteria fully, partially, or not at all. Examples of these criteria include the potential for ice and regolith mixed in a permafrost, the potential for locating hydrated minerals at the site, or the accessibility of water-ice reserves to automated rovers. A synthesis of the workshop's results were later distributed to the public via the Mars Landing Decision Matrix.

The first step of selecting the landing site was creation of a Landing Site Selection Committee. This group created the Poli'ahu Mission Landing Site Selection Matrix, which down-selected from the original 40 sites, to the 7 with the highest likelihood of accessible and higher volumes of water-ices. The top scoring sites were: Coprates Chasma, Endeavour Crater, Deuteronilus Mensae, Eastern Hellas, Erberus Montes, Acheron Fossae, and Phlegra Dorsa (Table 4.2.2.2-1).

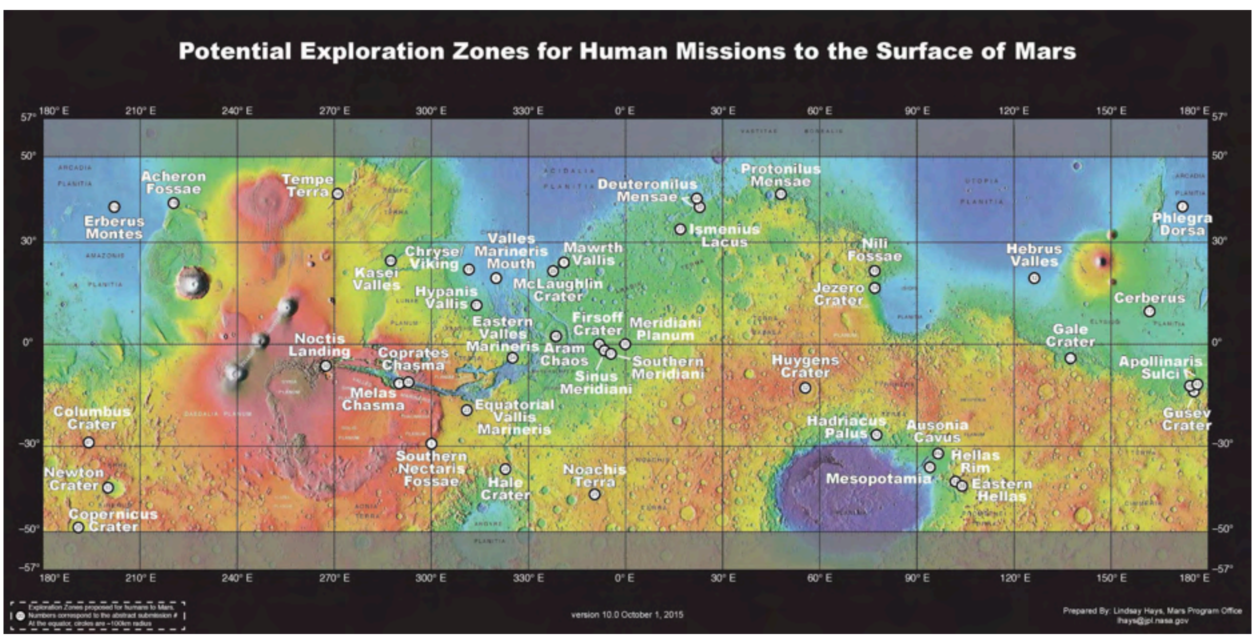


Figure 4.2.2.2-1: Potential Exploration Zones for Human Missions to the Surface of Mars.(Credit: NASA)

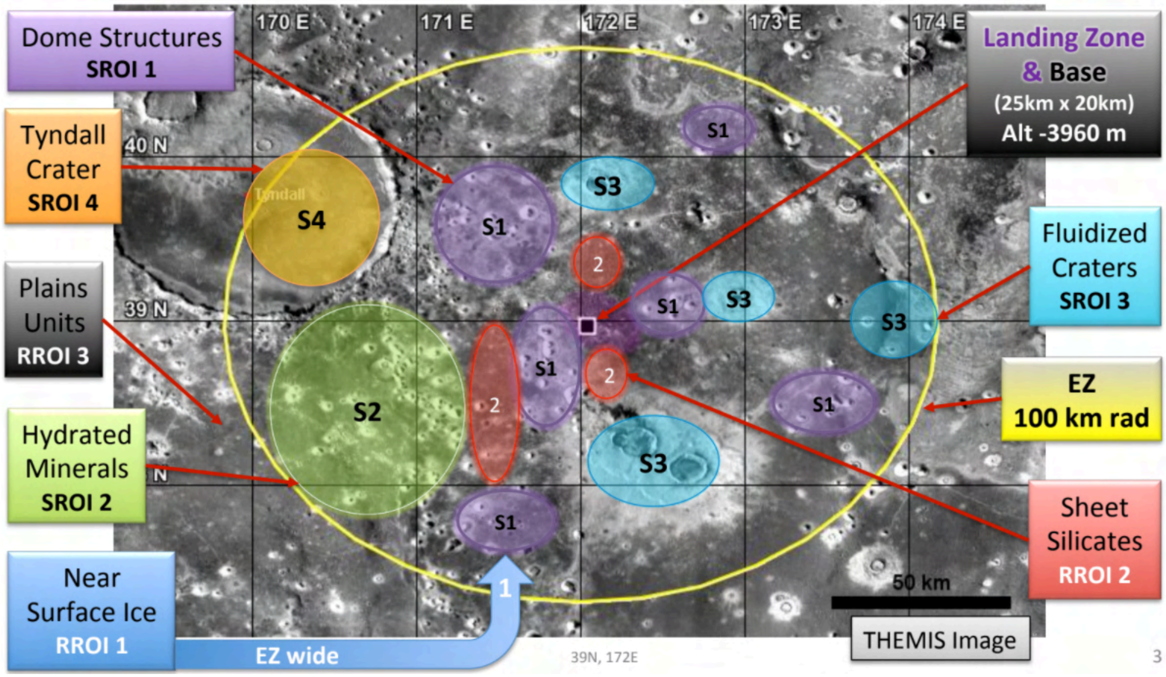


Figure 4.2.2.2-2: Phlegra Dorsa Exploration Zone with Science and Resource ROIs. (Credit: Lunar Planetary Institute, NASA)

Many of the candidate sites were at higher northern latitudes which is a favorable region for finding subsurface water-ice deposits. The team then cross-referenced the sites with research using the JMARS application, which includes NASA data layers. Some of the most helpful layers were ones for glaciation, permafrost bearing soils, Oct 2015 Proposed Exploration Zones, and glacial valley locations.

The committee members then performed detailed research on the top 3 sites: Erberus Montes, Acheron Fossae, and Phlegra Dorsa. The team held multiple meetings to discuss the sites. During this time, committee members utilized satellite remote sensing data from the JMARS application to analyze the site's geography, topology, surface temperatures, and location to other features on Mars. Additionally, some team members studied the original workshop abstracts for each site in order to present information to the committee and answer committee questions regarding characteristics of the sites .

Scoring
# of Science or Resource ROIS that:
(fully meet criteria, partially meet criteria)

Exploration Zone Location Names	Abs #	Total ROIS	Science						Resources													
			Astrobiologic		Geoscience			Qua. Crit.	Water Resources							Site Location			Civil Engineering		Metal / Silicon Resource	
			AND/OR						AND/OR													
			Potential for past habitability	Potential for present habit./refugia	Range of martian geologic time; datable surfaces	Evidence of aqueous process	Potential for interpreting relative ages	Near-surface ice, glacial or permafrost	Potential for ice or ice/regolith mix	Potential for hydrated minerals	Quantity for substantial production	Potential to be minable by highly automated Systems	Located <3 km from planned IRSU processing site	Located <3 m below surface	Accessible by Automated Systems (Low slope / Simple Terrain)	Low Latitude <30 deg	Low Elevation	Accessible by Automated Systems (Low slope / Simple Terrain)	~50 sq km region flat & stable terrain with sparse rock	No local Terrain shadowing light collection facilities	Potential for metal/silicon	Potential to be minable
Coprates Chasma	1036	8	6,1	5,2	8,0	8,0	8,0	7,0	5,3	8,0	7,1	5,3	1,0	8,0	5,3	Y	Y	/	2,0	7,1	8,0	6,2
Endeavour Crater	1057	19	17,3	8,0	18,0	18,0	19,0	3,0	14,0	10,0	10,4	14,0	?	11,0	3,7	Y	N	N	7,4	10,9	15,0	10,0
Deuteronilus Mensae	1033	6	6,0	0,6	6,0	0,6	6,0	6,0	6,0	0,6	6,0	6,0	2,0	2,0	2,0	N	Y	Y	6,0		6,0	6,0
Eastern Hellas	1038	8	8,0	8,0	8,0	8,0	8,0	8,0	8,0		6,0		2,0		8,0	N	N	Y	3,0			
Erberus Montes	1011	6	0,2	0,6	2,0	2,0	2,0	6,0	6,0	?	6,0	6,0	2,0	6,0	2,0	N	Y	Y			2,0	?
Acheron Fossae	1011	7	?	0,7	5,0		5,0	7,0	7,0	?	7,0	7,0	2,0	7,0	2,0	N	Y	Y			2,0	2,0
Phlegra Dorsa	1002	7	?	?	3,4	6,1	4,3	6,1	7,0	7,0	5,2	5,0	5,0	7,0	7,0	N	Y	Y	5,0	7,0	7,0	7,0

Table 4.2.2.2-1: Poli'ahu Mission Landing Site Selection Matrix.

4.2.2.2. Phlegra Dorsa Landing Site Qualities

The committee determined that Phlegra Dorsa had the highest likelihood of near-surface ice that is easily accessible for mining operations. In addition the site offers numerous geologic features of interest, namely periglacial landforms, signs of permafrost, and potential past glacial activity. Phlegra Dorsa was also found to have a very flat surface with manageable changes in elevation, as it is within the Borealis Basin (Figures 4.2.2.2-3, 4.2.2.2-4). This relatively level terrain profile makes it a safe area for the rover.

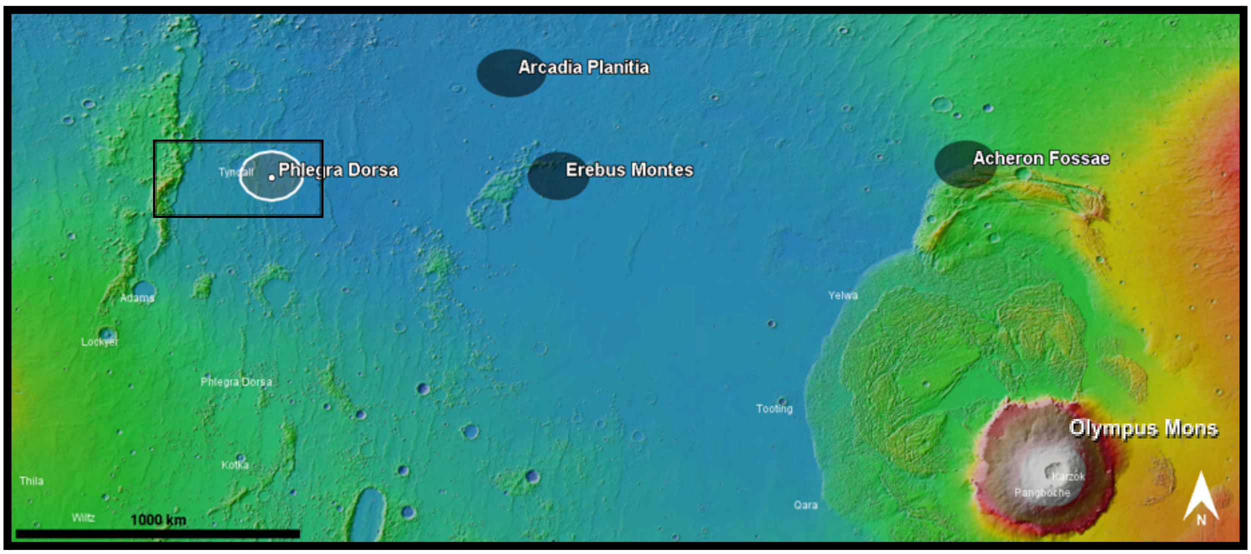


Figure 4.2.2.2-3: Phlegra Dorsa exploration zone in the northern hemisphere, within the Borealis Basin on the Arcadia Planitia. (Data Source: JMARS MOLA data, NASA)

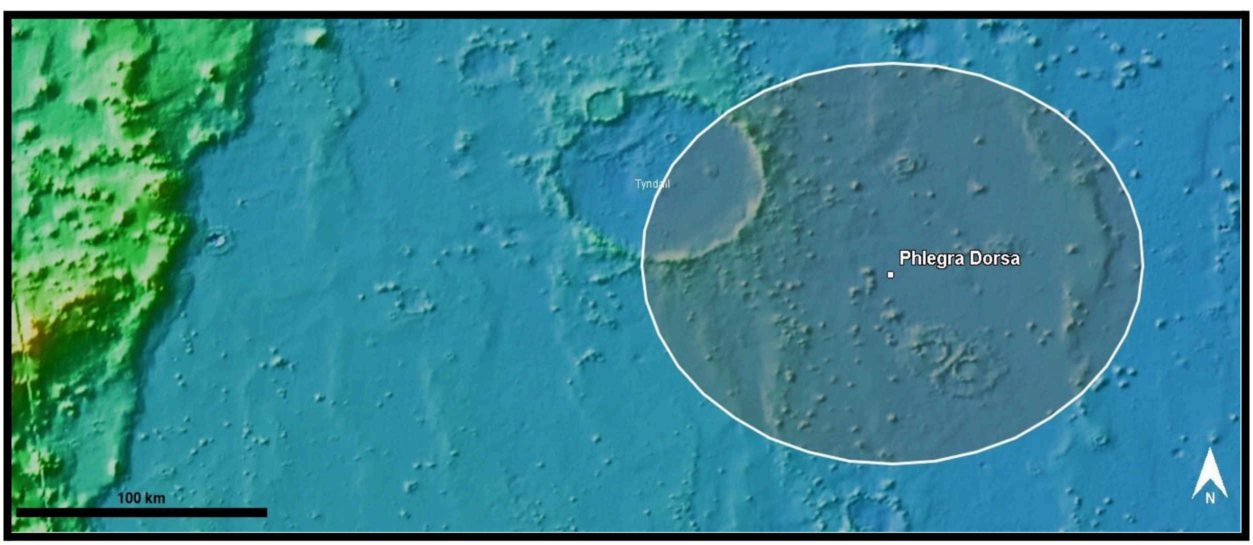


Figure 4.2.2.2-4: Phlegra Dorsa exploration zone detail view with Phlegra Dorsa mountain range to the West.(Source: JMARS MOLA Data, NASA)

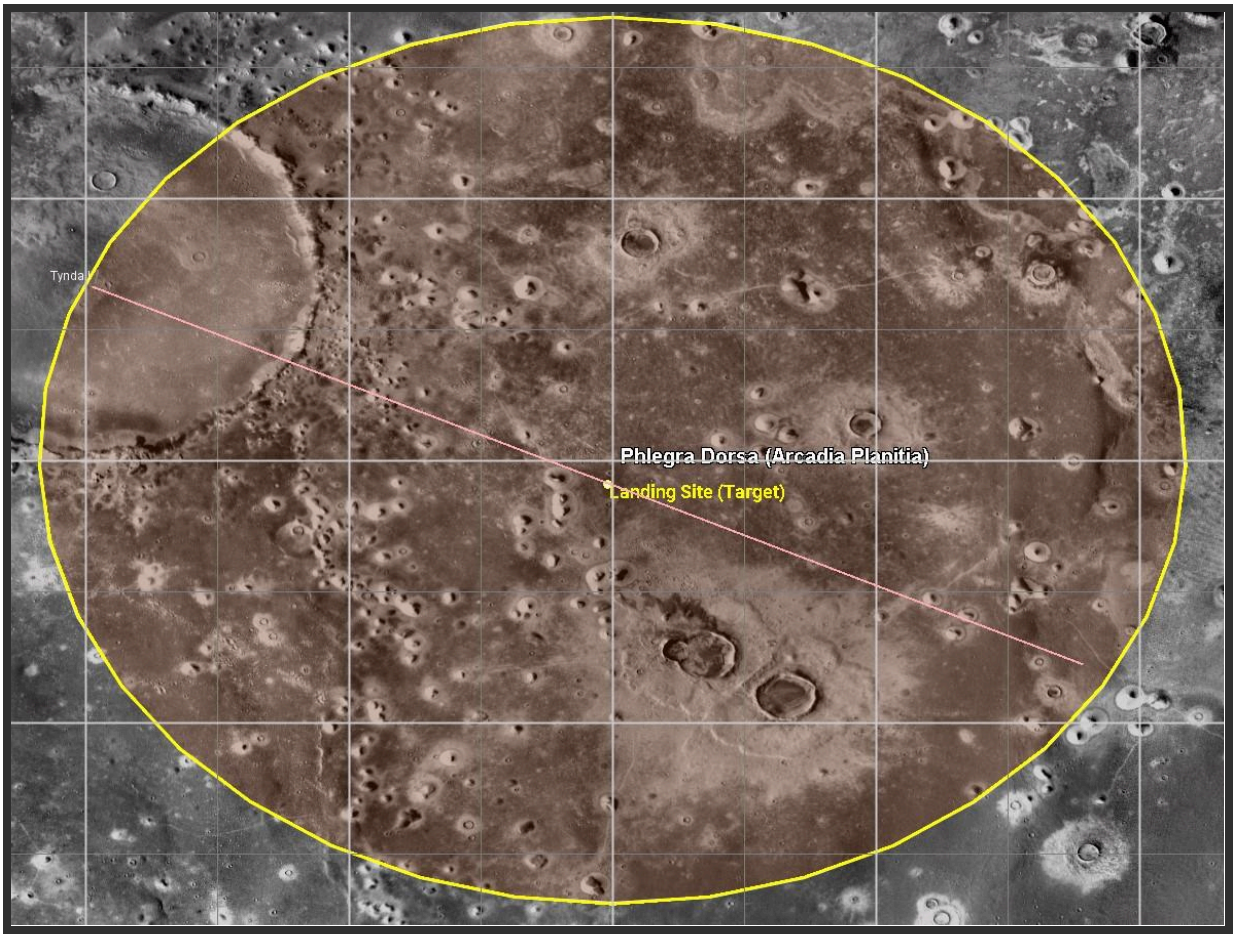


Figure 4.2.2.2-5: Poli’ahu Landing Site Elevation Profile Line

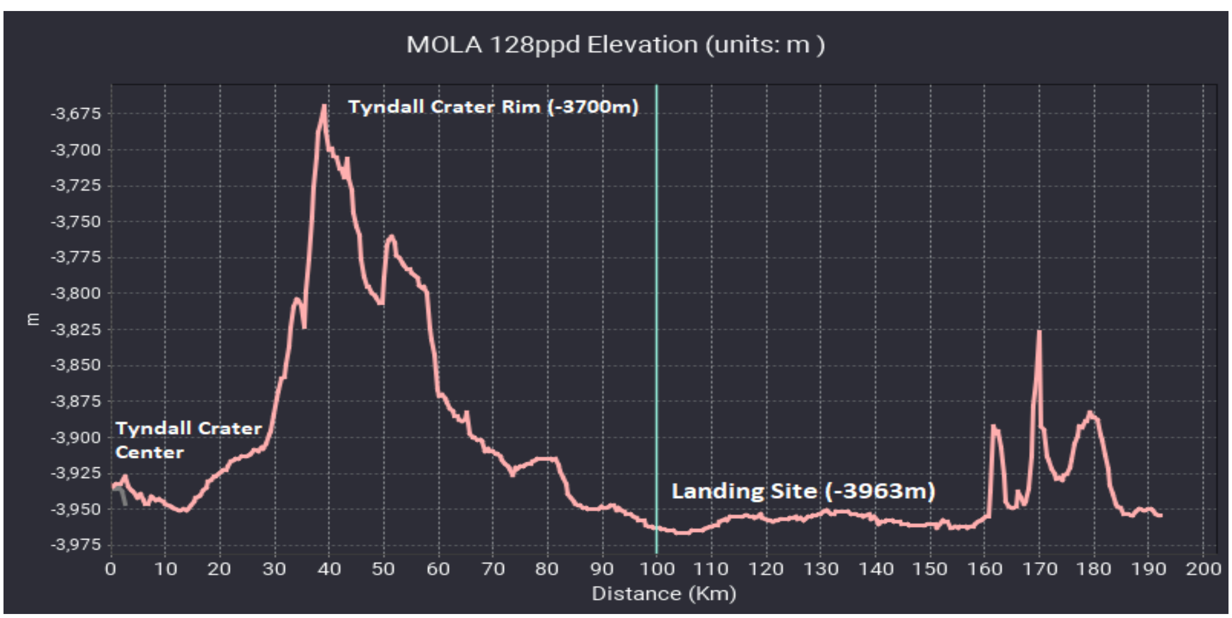


Figure 4.2.2.2-4: Poli’ahu Landing Site Elevation Profile Graph

During the selection process, the team recognized that in order to be a good location for human exploration, not only must a site have water reserves but it must be worthy of long-term investigation. Such a site must also contain compelling science and civil engineering ROIs. The Phlegra Dorsa site encompasses a large variety of scientifically interesting ROIs. Additionally, there is one exciting resource ROI, labeled RROI 2, within the region to the south-east of the landing zone that may prove to contain minable metallic and silicon resources (Table 4.2.2.2-2).

Ultimately, this site was selected because of its primary science goal suitability as well as its many other human exploration qualifying criteria, such as: low elevation for easier aerobraking of incoming spacecraft, large level and accessible landing areas suitable for an eventual base, commercial mining potential, likely water-ice reserves, and access to scientifically relevant regions of study. The combination of all these factors made the Phlegra Dorsa site stand out as a site which is able to support multiple long-term manned exploration missions.

4.2.3. Payload Success Criteria

The success of the mission will be mainly based on the success of the science payloads, where all the instruments shall collect the data necessary for research and analysis. The mission is to research and quantify the volume of water ice in the target region. This can only be achieved if the science instruments are able to acquire the necessary data. All payload components must work as planned to successfully perform the required measurements.

Cameras: The Camera system's success is based on its ability to 3D map the terrain by using the Navigation Cameras. This is crucial to achieve semi-autonomous movement on Mars. The Hazard Cameras also play a significant role in semi-autonomous navigation and shall detect incoming obstacles as the rover traverses the Martian terrain. The intent is to structure this system as it would detect and notify the navigation module once the obstacle is one meter away. It's vital to the mission that the accuracy of 3D mapping to work flawlessly. Testing and calibration will be done by the team before the scheduled launch to verify high accuracy of the 3D mapping function which shall provide a range of data out of 100 m with better than 10 cm accuracy at a distance of 10 m (Soderblom et al. 2008).

Navigation System: The importance of a navigation system is crucial to achieve a successful mission. This system shall work in harmony with the navigation cameras. The Navigation System shall receive data from cameras and make semi-autonomous decisions based on the data received. The previous semi-autonomous rovers achieved successful autonomous navigation based on previous data collected, which was measured by the average velocity per hour. Team Aegir is targeting the rover to travel at 35m/hour. (Maimone et al. n.d)

IMU: The Inertial Measurements Unit needs to work flawlessly just like all other components on the Poli'ahu rover. The accuracy of this unit shall not exceed 0.05 degrees when it comes to the reading pitch to provide accurate data to the Navigation System.

Temperature Sensors: These sensors shall read data accurately to provide the current state of the rover and its components. The team aims at achieving no greater than a 1% error in reading these values.

Each vital component on the Poli'ahu Rover has a built in Temperature Sensors in them and due to mass constraint, the team has decided to rely on these built in temperature sensors.

SSD Storage:

The team selected a 4.5 TB SSD that can survive the Martian Environment when it comes to low temperatures and radiation. The success of this SSD Storage is based on a few factors. The first one shall be able to use almost all its capacity sufficiently, which is 4.5 TB. The data speed shall meet the expectations at 3.125 Gbps, and the error correction shall not exceed 24 errors per 30 bytes.

RIMFAX: A key primary science instrument is RIMFAX, a ground-penetrating radar. This instrument shall work in unison to locate a target region of study, characterize the hydrogen composition, and quantify the subsurface water ice on Mars. Back-up systems for crucial components such as power and data recording. If some of these main components fail, backups should intervene to keep the rover alive and the mission moving forward.

The team researched and proposed various instruments that shall support the search and quantification of subsurface water ice targets. A trade study was performed (see Section 2.3) to determine the experimental method of study for quantification of sub-surface water ice. The results of this trade study showed a clear preference for using a ground-penetrating radar instrument over more sample-collecting instrument methods such as coring, drilling, and scooping. This decision was based on the low mass requirements, power requirements, and high Technology Readiness Level (TRL) of a previously flown Radar Imager for Mars' Subsurface Exploration instrument, known as RIMFAX. This instrument is currently operating on Mars aboard the Perseverance rover.

DAN: The DAN spectrometer will be used to verify and quantify the presence of Hydrogen bearing molecules in the subsurface, indicative of water ice resources. DAN will collect measurements within 1% accuracy. The mass of ice resources will be extrapolated from DAN and RIMFAX measurements. Interpreting RIMFAX data will in part rely on DAN. The ability to use DAN data to cross reference RIMFAX data is also necessary for mission success.

4.2.4. Experimental Logic, Approach, and Method of Investigation

The science instrumentation for the Poli'ahu mission has been selected to meet the science objectives of quantifying ice for human exploration at the Phlegra Dorsa landing site. RIMFAX will provide ground penetrating radar profiles of subsurface layers in the form of two-dimensional images while the rover is in motion. One of the difficulties of distinguishing between sediment layers in ground penetrating radar profiles is that the dielectric properties of highly porous sediment layers and subsurface ice are similar. The inclusion of the DAN instrument will address this issue by providing corroborating hydrogen data. This will confirm the presence of hydrogen, an indicator of water-ice within the first meter of soil.

Cross-referencing the DAN data, the RIMFAX data for the first meter can be interpreted with much greater confidence and accuracy. Having cross-referenced data for the first meter of regolith will be an invaluable resource for analyzing the remainder of the RIMFAX profiles, which will have a depth of up to 10 meters depending on soil properties.

4.2.4.1 Method of Investigation

Surface Operations Traversal Approaches

The rover will traverse the martian surface looking for elevated hydrogen levels within the subsurface, indicating that water ice lies within 1 meter of the surface. Once significant levels of hydrogen are located, the rover will use a set of turns and driving tracks to repeatedly cross the ice field, with multiple intersections across the field of study.

Each subsequent track will provide spatial plots of layers that can be extrapolated and triangulated between other tracks, to determine the area of the layers within the field. Examples of such field survey approaches for a complex subsurface ice deposit are provided in Figure 4.2.4.1-1**.** Prior to mission launch, additional analysis will be performed to quantify the efficiency of various path algorithmic patterns, to identify the best fit for the rover's constraints and goals.

Upon completion of a field survey in this manner, the rover will reset to travel a distance in a direction until it encounters a hydrogen detection, and it declares a new field_ID, and begins mapping the region using the sequence. Before it determines its next driving direction, it will consult with mission planners, determine its location, and current distance from the primary lander, and choose a driving direction that is within the range of the communications subsystem.

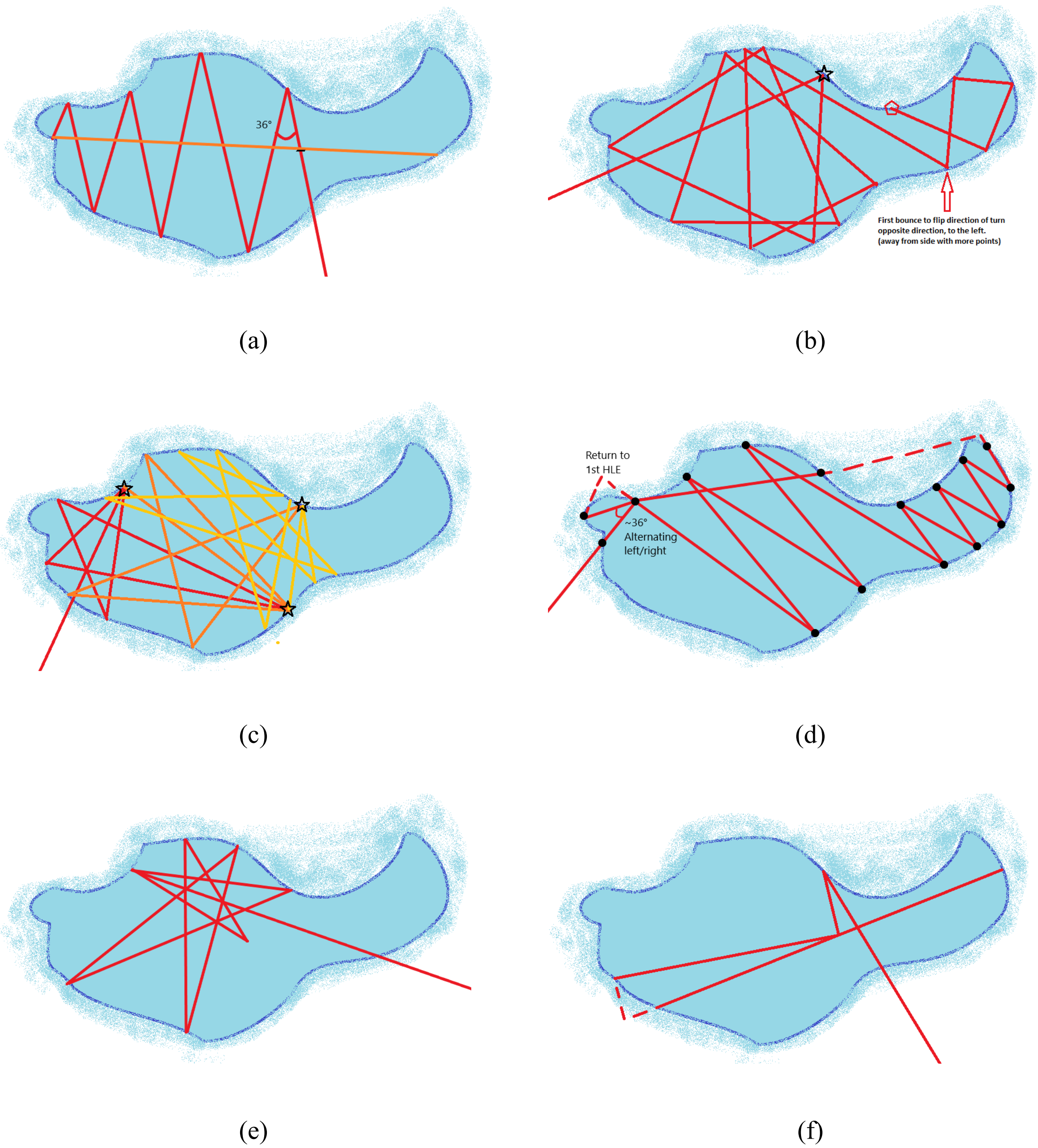


Figure 4.2.4.1-1: Analysis of approaches for algorithmic traversal paths over buried ice. Outer blue line is the hydrogen level exceeding the detection threshold. (a) 36° angle backtrack alternating left / right, (b) 60° angles until count reached, (c) 5 pointed star 36° return angles, repeated 3 times, (d) 36° alternating left/right with Loss of detection return to 1st Loss of Detection point, (e) arbitrary angle until limit, (f) right angles, trouble spreading.

Modes of Operation

To accomplish the semi-autonomous scientific study, the rover will utilize many modes of operation, each with carefully planned results and interactions with other modes (Table 4.2.4.1-2). These modes will be triggered by various events, such as an elevated hydrogen detection, low battery power, or an impending martian night as outlined in Table 4.2.4.1-1.

Primary Science Mode (PSM): The rover's movement algorithm is one of it's primary modes of operation, called Primary Science Mode, in PSM the rover will:

1) Travel in a specified straight direction, barring any detours due to obstacles of hazards.
2) Take pictures with Navcam and Hazcams at requisite intervals.
3) Continuously use RIMFAX, at short intervals during the drive, to measure the layers underneath the rover's track.
4) Use DAN to routinely sample hydrogen percentages at intervals.
5) When it detects a significantly high hydrogen percentage, known as a Hydrogen Detection Event (HDE), it will stop and change modes.

Site Capture Mode (SCT): Upon the first HDE on a track, the rover will change modes to perform a Hydrogen Site Capture Mode. SCT mode prioritizes science gathering at a single location, using an orchestrated set of turns and actions:

1) The rover will turn-around 360°, to end in the same direction of original travel.
2) While it does the turn-around, it takes a set of overlapping images with Navcam for the creation of a 3D panorama.
3) It also takes higher frequency Hazcam images.These will look for ice exposed under freshly turned-up regolith from the rover's turning wheels (**Figure 1.2.4.4-1**).
4) The DAN Instrument will also take a detailed reading of around 30 minutes to increase its accuracy of measurement.
5) The rover will attempt a high-detail measurement of its location for geotagging of the site relative to its origin.
6) If no other modes are indicated by previous mission control commands, the rover will resume Primary Science Mode (PSM) in the original direction of travel.
7) The rover will then continue along the same track until the hydrogen percentage drops below a threshold, known as a Hydrogen Loss Event (HLE), or a specified distance limit has been reached. This will trigger a mode change.

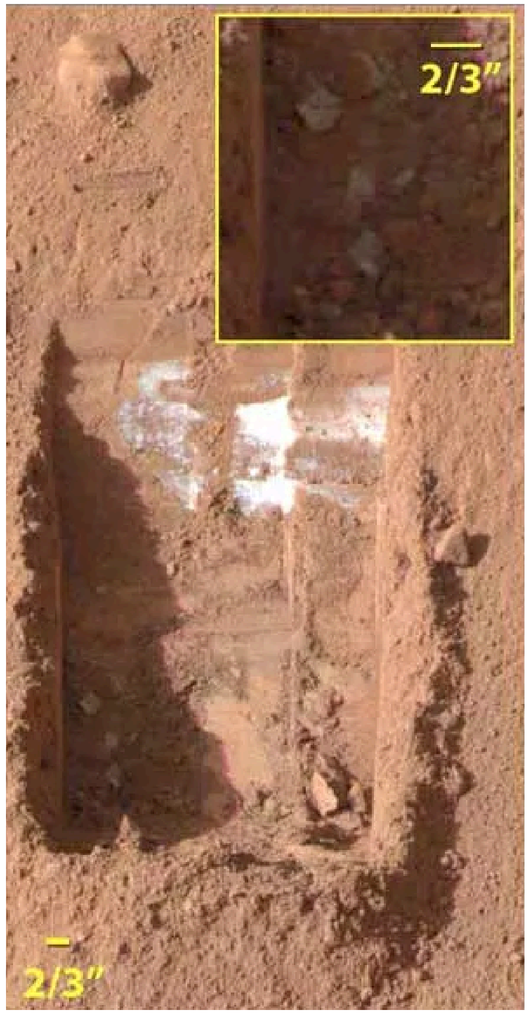


Figure 4.2.4.1-1: Subsurface Ice exposed by the Phoenix Lander on sol 2 (Dunbar, 2008)..

Return Track Science Mode (RSM): After PSM or RSM mode loses hydrogen detection or HLE, the rover will switch modes to perform an action called (RSM). This return track mode will entail a turn of a specified number of degrees, back into the general direction it came from, but at an offset. This mode will continue until it loses the hydrogen signature and will then turn again, executing a detailed site capture Mode (SCM), and then another Return Track Mode (RSM) leg. This repeats until the rover reaches distance limits, or the maximum number of turns.

Table 4.2.4.1-1: Significant Events/Triggers for Poli'ahu surface operations.

Significant Events/Triggers	**Description**
Hydrogen Detection Event (HDE)	● Acquisition of significant hydrogen signatures

Hydrogen Loss Event (HLE)	• Loss of significant hydrogen signatures
Power Low (PWL)	• Power within in low range set by Ops
Power Critical (PWC)	• Power critical / potential loss of vehicle
Solar Energy Rising (SER)	• Solar energy rising, return of sun, or less cloud/dust cover, under solar_threshold
Solar Energy Decreasing (SED)	• Solar energy rising, return of sun, or less cloud/dust cover, over solar_threshold
Command Override (CMD#####)	• New commands to gracefully end existing modes, and begin new commands from Ops

Table 4.2.4.1-2: Modes of Operation & Sequences for Poli'ahu surface operations.

Modes of Operation	**Description**

Primary Science Mode (PSM)	• Primary drive mode
	• Normal science gathering, seeking water signatures
	• If HLE occurs:
	    ○ Increment 'field_ID'
	    ○ Mode: FSM
	• If 'track_distance' > limit:
	    ○ Turn 90°
	    ○ Mode: PAM
	    ○ Mode: PSM

Site Capture Mode (SCM)	• Enter (DSM) Mode • DAN ~30 Minute Hydrogen • Captures 'field_ID' • Increments 'site_ID'
Forward-track Science Mode (FSM)	• Similar to Primary Science Mode • *Continues on previous heading* • Watch for loss of water event, HLE • If HLE, trigger RSM
Return-track Science Mode (RSM)	• Similar to Primary Science mode • *Turns around* a set angle, and drives back across the field, a minimum distance. • Watch for loss of water event, HLE • If HLE, Compare 'site_ID' count with

	'site_degrees' to stop or continue in the existing ice field: ○ If stop, mode PSM. ○ If continue, mode RSM
Panorama Mode (PAM)	● Stationary, 360° turn in place ● Create Panorama ● Resume previous Mode
Detailed Science Mode (DSM)	● Stop movement, if moving. ● Begin detailed science data capture ● RIMFAX multiple measurements, same location, for calibration and averaging. ● DAN ~30 Min hydrogen detection, for increased accuracy.
RIMFAX Calibration Mode (RCM)	● RIMFAX sends a signal to the calibration cable, instead of the antenna. ● Resume previous Mode
DAN Calibration Mode (DCM)	● DAN takes ~6 hour measurement. ● Resume previous Mode
Pause Mode (PSM)	● Stop movement. ● Save computer state to non-volatile memory (NVM). ● Power down non-essential payloads. ● Continue Communications and data uplink/downlink into Comms NVM. ● Watch for power level/solar levels, or commands.
Sleep Mode (SLM)	● Pause Mode ● Power Down all equipment except Thermal
Emergency Pause Mode (EPM)	● Sleep Mode ● Communicate Com interval clock to Ops ● Hibernation Mode for extreme loss of power. ● Set power subsystem pwr_trickle=true, for emergency startup upon recharge. ● Set auto_start_computer=true ● Extreme power saving, shutdown all systems except basic clock in NVM. ● If Power raises above threshold, power subsystem reads NVM and auto_start_computer value to trigger main CPU startup at safe power levels.

4.2.4.2 RIMFAX Experimental Method

Nominal Experiment Procedure

The nominal experiment procedure will be the predominant method of operation for the Poli'ahu rover. RIMFAX measurements will be gathered approximately every 10cm along the rover's path. The rover will briefly pause at measurement locations for about 1 second to allow for stationary measurements to be taken. Three nominal modes, Surface, Shallow, and Deep, will be grouped at each sounding location. At each measurement location, a measurement will be taken in each depth mode. A diagram of RIMFAX sounding modes can be seen below in Figure 4.2.4.2-1. The nominal experiment plan will be utilized in the Primary Science Mode, Forward-track Science Mode, and Return-Track Science Mode.

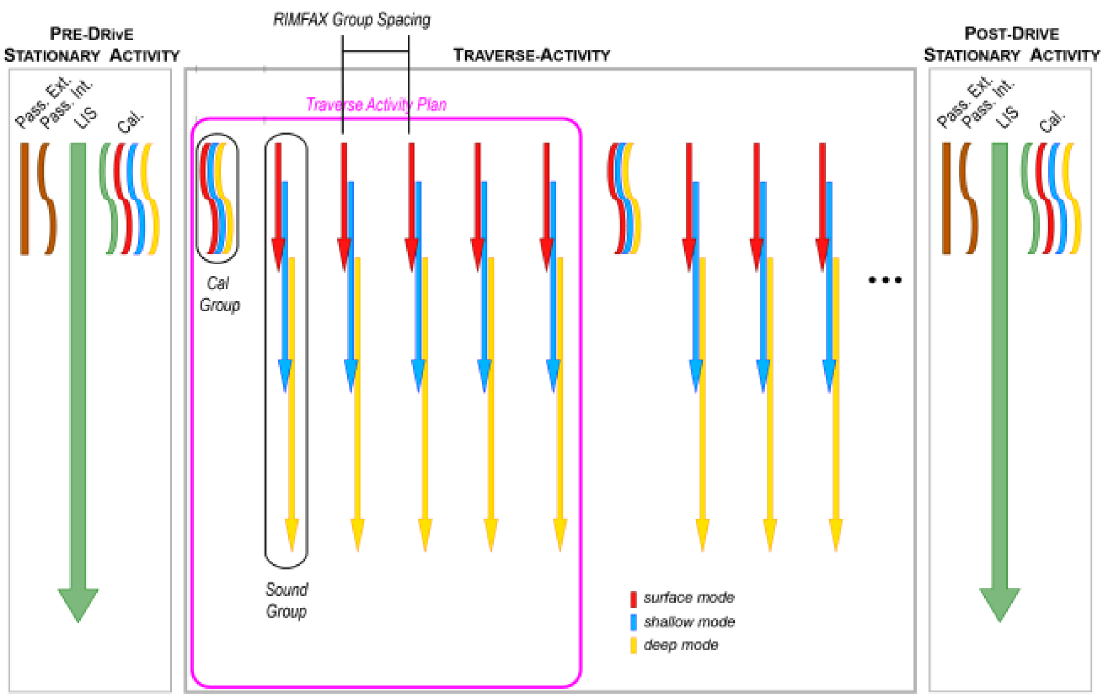


Figure 4.2.4.2-1: RIMFAX Surface Modes and Relative Depths of Radar Penetration (JPL)

Detailed Science Mode (DSM)

Detailed Science Mode will be used sparingly throughout surface operations. In DSM, the rover will be completely stationary as it gathers data. Multiple soundings will be stacked in the same location to create a more detailed subsurface profile. The surface, shallow, and deep modes of RIMFAX operation may be adjusted during DSM to aim for slightly different depths. Before returning to other science modes, the RIMFAX surface, shallow, and deep modes of operation will be returned to their nominal states.

RIMFAX Calibration Mode (RCM)

RIMFAX Calibration Mode is planned to be a regular part of surface operations. Every 10 meters of rover distance traveled or every hour, whichever comes first, the rover will enter RCM. In RCM, RIMFAX will be used while the rover is stationary. Instead of sending the signal to the bow-tie slot antenna, RIMFAX will send a signal to the calibration cable, to be read and referenced across calibration data. RIMFAX has functional flexibility that allows its multiple sounding modes (surface, shallow, and deep) to be reprogrammed/updated remotely by mission control. During RCM, the three sounding modes can be focused to meet the needs of the local regolith parameters if commanded by mission control (Alanis et al., 2021).

4.2.4.3 DAN Experimental Method

Nominal Experiment Procedure

The nominal experiment procedure is the main method of operation for the DAN spectrometer, and will be used in the Primary Science Mode, Forward-Track Science mode, and Return-Track Science Mode. On every twentieth RIMFAX measurement (every 2 meters of rover distance traveled) the rover will stop to take a short pulse measurement. The short pulse measurement will last for 2 minutes. Measurements taken over 2 minute periods will provide a rough estimate of the water distribution with an accuracy of 1% (Litvak et al., 2008).

Detailed Science Mode (DSM)

In Detailed Science Mode, the rover will take longer measurements to improve the quality of data for a single location. A 30 minute, long duration pulse will be performed in order to estimate the water distribution to a greater accuracy of 0.1% - 0.3% (Litvak et al., 2008).

DAN Calibration Mode (DCM)

DAN Calibration Mode will be used one time before science operations begin, and again if commanded by mission control. In DCM the DAN spectrometer will perform a long duration measurement. The measurement will last about 6 hours. The 6 hour measurement will be compared to existing calibration data from ground tests performed on Earth and other existing DAN data sets from previous MARS missions.

4.2.5. Testing and Calibration Measurements

Navigation System

The Navigation system components will be outsourced to Malin Space Science Systems in San Diego and once they deliver the camera components, Team Aegir will install them on the rover and calibrate their angles and locations. Navigation cameras shall be positioned at a 43 degree angle which will allow imaging software to map the terrain in 3D. Laboratory tests will ensure that the manufacturing and integration of the cameras were performed correctly and the data return is nominal.

Hazard Cameras will be calibrated by installing them and checking their view angle. A simple rolling test in a sandbox of simulated Mars regolith will be conducted to ensure the integration process was successful and the HazCams field of view is appropriate for viewing wheel obstacles.

IMU

The Inertial Measurement Unit (IMU) is one of the most important components that will be on board. Once the IMUs are installed, calibration data will be obtained by conducting a test where they are moved to different directions. Before data gathering operations begin on Mars, the IMU will be calibrated by replicating the pattern of motion used to obtain the calibration data. This IMU data will be cross-referenced with data from the visual odometry software as well as the telemetry data from the wheel motors turn count in order to determine calibration equations to correct any IMU drift.

Temperature Sensors

Temperature sensors are very important in the mission and the team will monitor the temperature data of most components that are in motion. During integration testing, temperature sensors will be tested against other reference temperature sensors to confirm their operation and margins of error. If a temperature sensor fails laboratory testing, instead of calibrating the sensor it will be replaced due to the relatively low replacement cost.

SSD Storage

The SSD will be calibrated on Earth to ensure it’s performance in Martian temperature environment. Because the SSD will be located inside the WEB, it will be tested at the internal requirement temperature of the WEB, -5° C. The upload and download rates will be measured in the simulated Mars environment. Rather than attempt to manage the SSD transmission rates, surface operations will be adjusted to meet the SSD needs in these temperatures.

RIMFAX

Calibration of RIMFAX will ensure that the ground penetrating radar profiles obtained will be of the highest quality for later analysis. Quality of these subsurface radar profiles is crucial because they must be interpreted to assign meaning to the layers. The RIMFAX calibration plan will be extensive and ongoing throughout the mission. A primary calibration will take place before the first data gathering operations begin. To calibrate RIMFAX, a signal is sent to the calibration cable instead of the antenna. The calibration cable is used to detect gain variations in the transmitter and receiver, and correct for temperature sensitive variables in radar amplitude and timing (Alanis et al., 2021). The three sounding modes of RIMFAX can also be individually calibrated. Mission controllers will remotely fine tune these three modes to better fit to the local environment, during the primary calibration. Only slight adjustments will be made to the sounding modes after the primary calibration, if at all. Short calibrations will be performed every 10 meters of distance traveled or every hour, whichever comes first, during normal surface operations. Short calibrations will only engage the calibration cable once, and the sounding modes will not be changed unless commanded by mission controllers (Alanis et al., 2021).

DAN

Calibration of the DAN spectrometer will ensure that verification of Hydrogen content is accurate. The DAN spectrometer will undergo a primary calibration before the data gathering operations begin. Follow up calibrations are planned in the event of a software reboot, or as commanded by mission control. To calibrate DAN, the PNG emits a long duration pulse lasting about 6 hours. The calibration lasts this long because the accuracy of the DAN measurement depends on the time duration of the measurement. The primary calibration data will be cross referenced with calibration data obtained on Earth. Ground-testing was performed at the Joint Institute for Nuclear Research facility (JINR) in Dubna, Russia (Shvetsov et al., 2017). Field testing was performed at the dry regions of Atacama Desert in Chile, the dry regions in Antarctica, and the permafrost regions of eastern Russia (Litvak et al., 2008) to simulate the extreme weather of Mars.

4.2.6. Precision of Instrumentation, Repeatability of Measurement, and Recovery System

4.2.6.1 Precision, Accuracy, and Repeatability of Measurement

RIMFAX

RIMFAX ground penetrating radar has a vertical resolution of 15cm - 30cm, and reaches to a depth of up to 10 m. Surface clutter can affect the accuracy of the top 30 cm of the subsurface radar profile. Surface clutter refers to reflections off of various surfaces or objects above the ground surface. The wheels and suspension system are potential sources of surface clutter. The post-processing and interpretation of the data can help mitigate the error introduced by surface clutter. The constant recalibration of RIMFAX throughout surface operations will help increase the precision of the data gathered. Measurements will be repeated by RIMFAX when in Detailed Science Mode. Several subsurface profiles will be stacked in the same location allowing for comparisons between internal data sets (Alanis et al., 2021).

RIMFAX will be taking measurements every 10-20 cm while driving, as well as at long-duration stops, where it can take multiple soundings. RIMFAX is highly repeatable, surface operations and field study tracks will result in multiple passes over the same location in occasionally crisscrossing patterns that enable repeated measurements at the same location. Additionally, the rover may return to a location and perform repeated soundings to verify previous data.

DAN

The DAN spectrometer has accuracy as a function of how long the measurement was taken. Dan has 1% accuracy for a one minute long measurement and 0.1% accuracy for a measurement over 30 minutes (Litvak et al., 2008).The precision of DAN spectrometer's measurements will be assessed by comparing values acquired in the same ice patch. All of the measurements taken in between a Hydrogen Detection Event and a Hydrogen Loss Event are assumed to be within the same ice patch. The traversal pattern of the rover will allow for measurements taken in similar regions of the ice patch which can be compared. The repeatability of DAN data sets can be evaluated while the rover is in Detailed Science Mode. The short pulse data obtained at the start of DSM can be referenced to the long pulse data obtained in the same location.

The DAN instrument will take measurements at routine stops during a driving track. This will occur approximately every 2 meters. DAN is also able to take multiple repeated measurements at a location to ensure the data is reliable. This ability, coupled with the crisscrossing tracks of measurement and multiple long-duration exposures, increase the accuracy and reliability of the instrument.

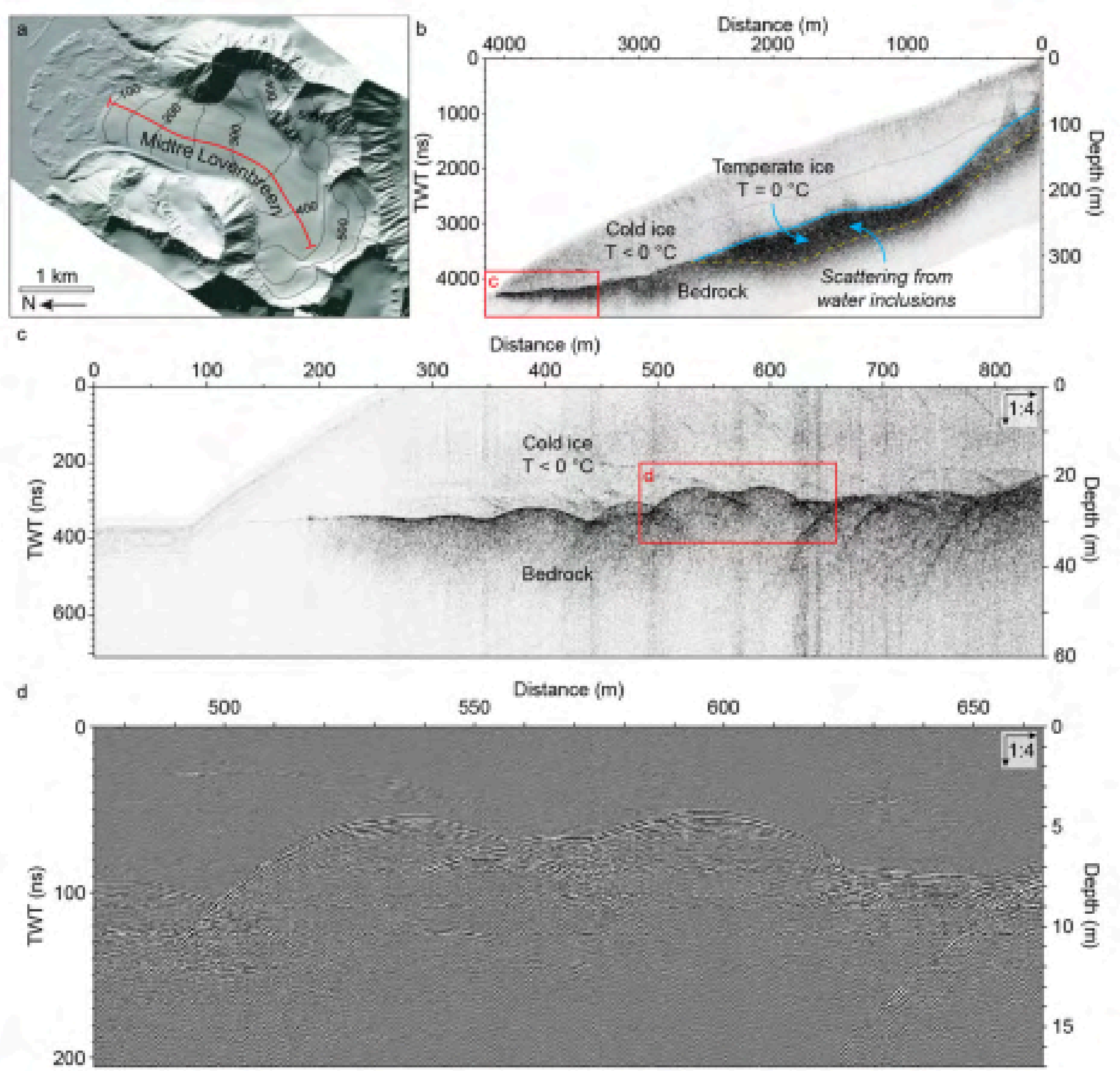
4.2.6.2 Recovery System

Due to the mass constraints, full recovery/redundancy of systems is not feasible for this mission. Certain measures have been taken to ensure the success of mission goals. Precautionary measures are mainly focused on preventing problems rather than fixing them. Emergency Pause Mode (EPM) will be triggered if the battery depth of discharge reaches the emergency threshold, or if the internal temperature sensor within the WEB reaches an overheating danger threshold of (X) K. Variable wheel speed software will be implemented to mitigate uneven wear and tear of the wheels. Operating software will also have reboot capabilities that can be commanded remotely by mission controllers. The antenna selected in the communications subsystem had a low enough mass to include a backup antenna in the event of a failure of the primary. Should one of the instruments fail, the other instrument is still available to collect data. The data collected can then be analyzed alongside information already collected from satellites.

4.2.7. Expected Data & Analysis

4.2.7.1 RIMFAX Ground Penetrating Radar Data

RIMFAX produces two dimensional ground penetrating radar profiles in the form of cross sectional images, see figure 4.2.7.1-1. It creates the profiles by stacking successive soundings aimed at different depths. This enables the Rover to detect underground water, ice, and salty brines on Mars. As RIMFAX is an advanced frequency modulated continuous wave (FMCW) radar, it is capable of operating in the 150–1200 MHz band.



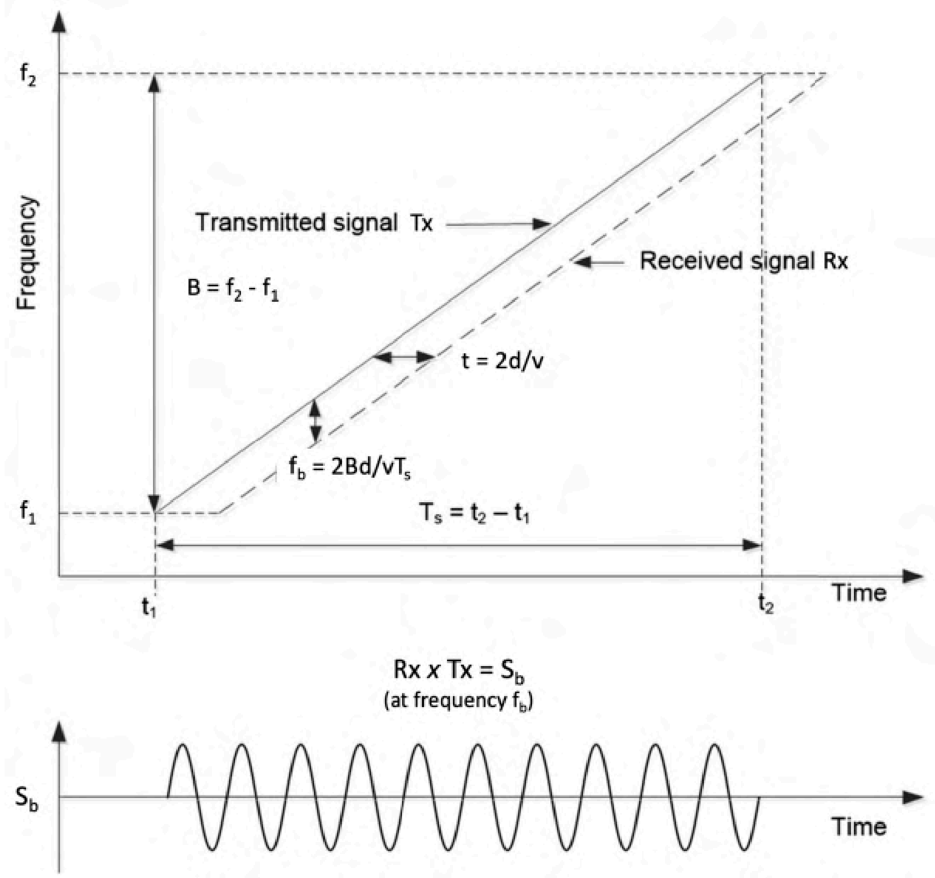
4.2.7.1-1: RIMFAX calibration data gathered at Midtre Lovénbreen (a). The radargrams (b-d) visualize the detection of layers of cold and temperate ice zones against bedrock. (NASA/JPL)

The principle of FMCW radar is illustrated in Figure 4.2.7.1-1. The following quote outlines the data gathered by the RIMFAX system: “A signal, Tx, is swept through the full bandwidth, B, of frequencies (from f1 to f2) over the time span, Ts (from t1 to t2), and is transmitted through the antenna (as represented by the solid line Tx). A signal reflected from a distance, d, is received by the antenna delayed by the two-way travel time, t, equal to 2d/v, where v is the wave velocity in the material. This delayed received signal, Rx, has a different frequency than the signal currently being transmitted (represented by the dashed line Rx).

Multiplying the received signal with the signal currently being transmitted gives a baseband signal, Sb = Rx x Tx. At any point in time, this baseband signal has a frequency equal to the frequency difference between the transmitted and received signals. For a stationary reflector this frequency difference is constant over the sweep. The frequency of this constant baseband signal, called the beat frequency, fb, is proportional to the delay time, t, and thereby to the distance range, expressed as 2d/v, to the reflector. The proportionality constant is given by the ratio between the sweep bandwidth and the duration of the sweep, or B/Ts. The frequency of the beat signal is thus:

$$f_b = \frac{2Bd}{vT_s}.$$

Measuring the beat frequency thus yields the range to the reflector. The amplitude of the received sine-wave signal gives the reflection strength. If several reflectors are present the baseband signal will be a summation of all the different reflected signals. Spectral estimation techniques like Fourier transforms can calculate the reflected signal” (Alanis et al., 2021).



4.2.7.1-2: RIMFAX Signal generation, with beat frequency and the signal amplitude (JPL).

4.2.7.2 DAN Neutron Spectrometer Data

The Dynamic Albedo of Neutrons (DAN) tool is an active/passive spectrometer that measures the die-away time profiles for two types of neutrons, thermal and epithermal. By comparing the time intervals of the various neutrons, a profile will expose differences that correlate to the percentage of hydrogen in the first meter of the Martian subsurface as simulated in Figure 4.2.7.2-1. Complex algorithms such as a Monte Carlo simulation are needed to relate these die-away emission profiles with the correct layered structure within the hydrogen-bearing soil.

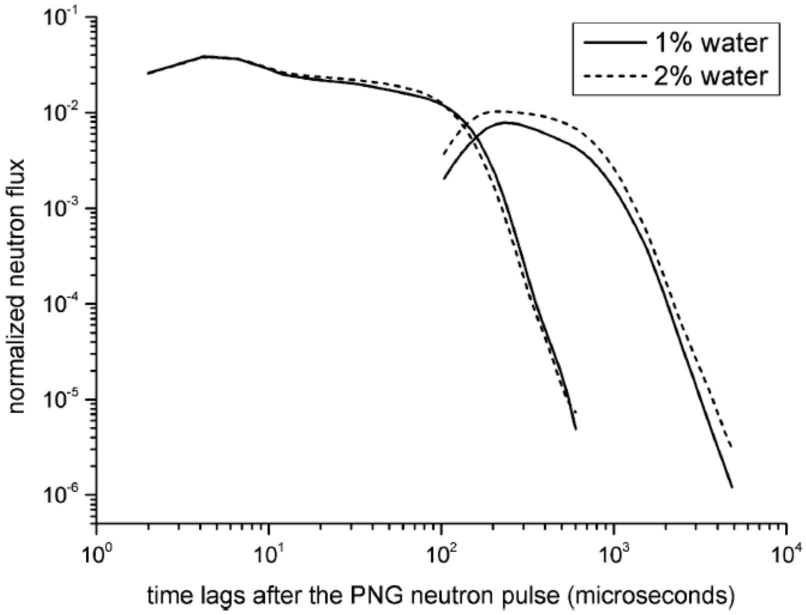


Figure 4.2.7.2-1: simulated die-away curves of epithermal and thermal neutrons, displaying the signatures of 1% vs 2% water content in Martian subsurface (Mitrofanov et al., 2012).

Active Mode: DAN's will begin active observations when stationary between stretches of driving and while the rover is parked. The instrument uses a Pulsing Neutron Generator (PNG), which is "actually a miniature nuclear fusion reactor, which produces α-particles with an energy of 3.5 MeV and neutrons with an energy of 14.1 MeV in the classical nuclear fusion reaction of hydrogen isotopes 2H+ 3H→4He+n"(Mitrofanov et al., 2012). In it's primary active mode, it estimates distribution of water-equivalent hydrogen present at a location for a short duration, usually around two minutes. This length of measurement will provide an accuracy around 1% by weight. Since die-away profile shapes differ depending on the depths the hydrogen is distributed within, longer experimentation periods will improve the accuracy of estimates of the vertical distribution of the same region, see Figure 4.2.7.2-2 . It is expected that when DAN operates for around 30 minutes or longer the data accuracy will improve to within 0.1-0.3% by weight.

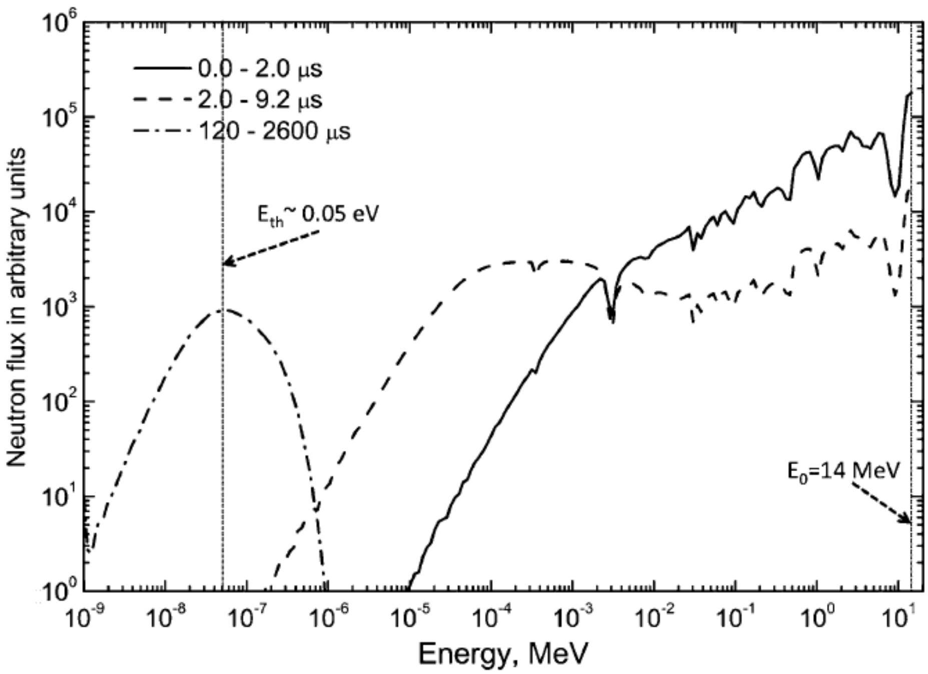


Figure 4.2.7.2-2: calculated Martian subsurface neutron spectra (energy) when irradiated by a E_0=14 MeV neutron pulse. (Source: Mitrofanov et al., 2012)

Passive Mode: Dan can also enter a passive mode where it does not use the PNG, and instead measure the background neutron flux values of the Martian surface. This passive mode will map the spectral albedo of counts gathered for fixed exposure times, usually around 20 seconds. This mode can also be used while the rover is driving, allowing the mapping of passive neutron albedo over time and distance.

The analysis of the DAN data against the more highly detailed RIMFAX data will allow the detection and location of subsurface hydrogen deposits. Since the Martian soil is very low in hydrogen bearing minerals and the atmosphere is so low, any detections of significantly high percentage are most likely to be subsurface water in the form of ice or permafrosts.

4.2.7.3 Post-Mission Science Data Storage

All mission data will follow NASA's Planetary Data System (PDS4) archival standards. PDS4 is an image and data-file labeling and metadata standard which is designed to guide engineers and scientists who gather, prepare, and organize planetary science experimental data. NASA's Planetary Data System is also a vast repository of planetary science data that spans missions, and domains.

Before the mission begins, mission data scientists will activate a PDS account, gain approval, and organize an archive/repository within PDS for all Poli'ahu science data.Data scientists will analysis the instruments on Poli'ahu, and develop a PDS compatible xml schema to be used for each instrument. This includes characterization of all possible fields and expected values in a reference document (PDS, 2021).

Raw files, calibrated files, and processed/derivative files will all be stored within PDS as soon as possible during the mission. Files will be named according to their respective PDS schemas, using the data captured at the time the data was recorded. The timely upload of mission data to the PDS is critical to mission scientists, as well as the public, to access mission data in a timely manner.

```
XML Declaration and Schema Reference
Root Tag
        Identification_Area
                Alias_List
                Citation_Information
                Modification_History
        Observation_Area
                Time_Coordinates
                Primary_Result_Summary
                Investigation_Area
                Observing_System
                Target_Identification
                Mission_Area
                Discipline_Area
        Reference_List
                Internal_Reference
                External_Reference
                Source_Product_Internal
                Source_Product_External
        File_Area_Definition
                File
                Data_Object_Definition
End Tag
```

Figure 4.2.7.3-1: Example of a simple PDS label structure & schema reference (JPL).

RIMFAX & DAN Data Processing Flow

Incoming data that is processed by AMPCS data software will be tagged with appropriate PDS tags and label structure. The resulting data product will then follow setup files created by the RIMFAX & DAN science team matching it to the correct instrument and mission. Both the data product and the metadata files are uploaded by AMPSC into the Operations Cloud Store (OCS) which will be ingested by

IDS's EDR generator software called "m20edrgen," and will be processed with a data product dictionary and other dictionary metadata provided by Rover Flight Software (FSW) Figure 4.2.7.3-2. this procedure is shown in Figure 4.2.7.3-3.

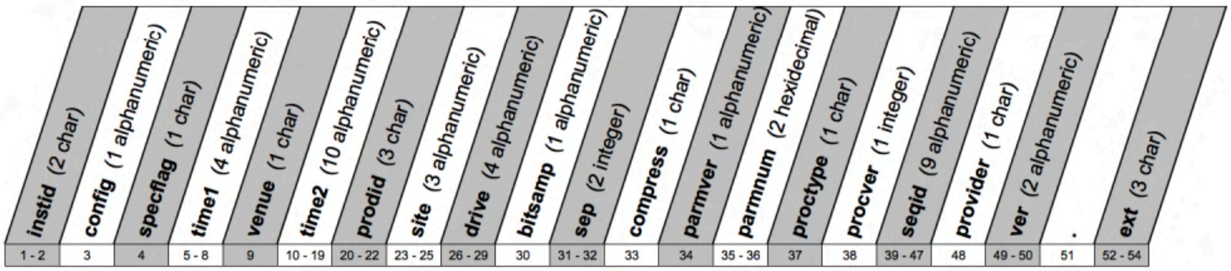


Figure 4.2.7.3-2: Poli'ahu RIMFAX EDR filename convention (Alanis et al., 2021).

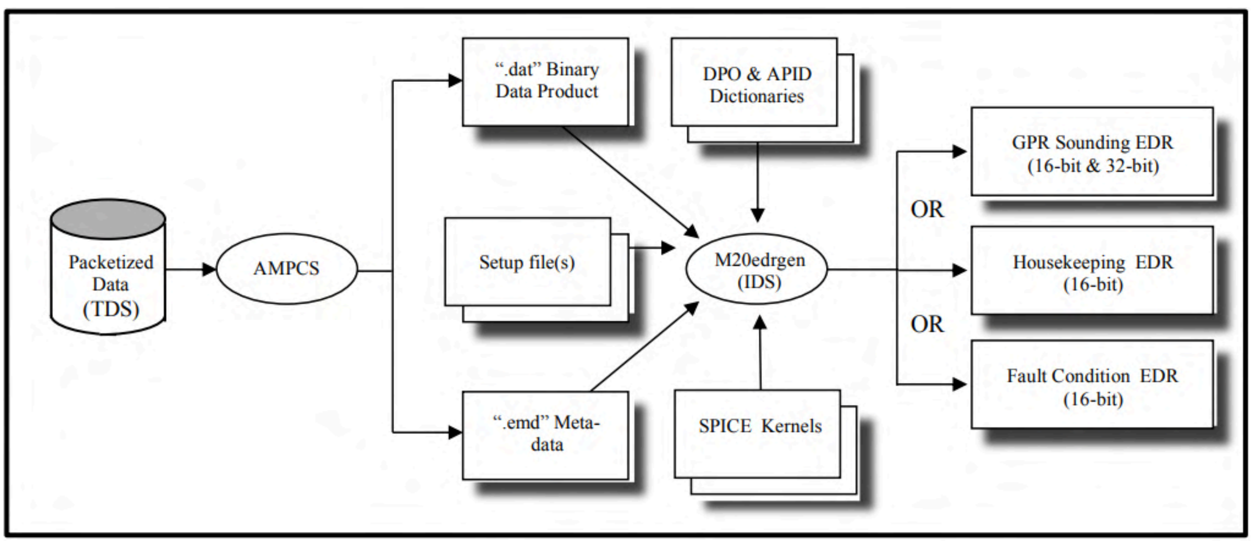


Figure 4.2.7.3-3: Example simple PDS label structure & schema reference (Alanis et al., 2021).

5. Safety

5.1. Personnel Safety

5.1.1. Safety Officer

The Safety Officer is Estefany Ocegueda. She will be responsible for ensuring that mission safety requirements are followed throughout the design, development, manufacture, integration, and operation of the spacecraft. These safety procedures will be followed for the duration of the mission to guarantee that personnel, equipment, and budget are protected from loss.

The Safety Officer will work with sub-team leads, facility managers, and laboratory staff to ensure they follow all safety guidelines related to the type of work being undertaken. For example, science and laboratory staff will be required to follow facility and equipment guidelines that are specific to the location. Such criteria will include recommendations from various departments such as the Department of Health and Human Services, Centers for Disease Control and Prevention, and National Institute for Occupational Safety and Health.

The team will be fully implementing NASA standards for safety within laboratories and manufacturing facilities outlined within directive NASA NPR 8715.1B (OSMA, 2021). These standards will be applied to all subteams and enforced throughout the duration of the mission. In addition to these safety guidelines, all staff will adhere to federal, state, and NASA-specific Human Resource, Department of Health, and Human Services laws that protect workers. Examples of these policies include equal opportunity employment protections, non-discrimination policies, establishment of reasonable working hours, and ensurance that workers have necessary support equipment and team member support during critical tasks for their safety.

5.1.2. List of Personnel Hazards

It is inevitable that hazards will be encountered by personnel during the course of the mission. The goal of mission planners is to minimize the impact to personnel when these situations arise. Below is a list of anticipated hazards that have been organized into categories and their phases of work based upon NASA directive NPR 8715.1B (OSMA, 2021). These will be used by the Safety Officer to develop Hazard Mitigation Strategies, many of which are provided in Section 5.1.3.

Transport

- Injury from Lifting Heavy Objects
- Injury from Vehicles or Machinery
- Driving while tired
- Vehicular accidents
- Accidents due to dangerous weather conditions

Manufacturing

- Cuts, lacerations, crushed limbs from Machinery
- Injury to Hearing

Testing Labs & Research Facilities

- Radiation Exposure from leaking RHU's
- Fire or Explosion
- Chemical burns from leaking batteries
- Cryogenic burns

Office Work

- Mental health/stress, upper body pain, carpal tunnel syndrome, eye strain, migraines, (musculoskeletal discomfort, in general)

Launch

- Injury from Rapid Unscheduled Destruction
- Injury from Harmful Propellants

Health

- Pre-existing conditions, mental health.

5.1.3. Hazard Mitigation

The health and safety of mission personnel is of utmost importance to the accomplishment of the mission goals. The safety officer will oversee the implementation of a robust safety campaign that encompasses all phases of the mission. The safety officer will gather safety and injury data, and work with sub-team leads to ensure that safety practices are followed and refined as new risks are encountered.

Below is a list of anticipated hazards and the planned mitigation strategies (OSMA, 2021):

Transport

- **Injury from Lifting Heavy Objects** - Staff will not lift heavy objects greater than 50 lbs without help to avoid damaging their body.
- **Injury from Vehicles or Machinery -** Staff will ensure the area is clear, including having support staff maintain a safety margin around moving equipment. Staff will not operate equipment when tired.
- **Driving while tired** - Staff will not operate a vehicle while under the influence of any substance or while tired. Travel plans will be made to allow staff to obtain the appropriate rest prior to operating equipment or vehicles.

Manufacturing

- **Injury from Machinery -** Staff will follow all safety guidelines for facility, lab, and relevant equipment. Staff will be trained on the safe operation of the equipment, and be overseen when using new equipment, until they show proficiency in it's safe usage.
- **Injury to Hearing -** Staff will be required to wear proper Personal Protective Equipment (PPE) to protect them from loud manufacturing processes. All staff will wear earplugs when near loud processes or equipment, to protect their hearing.

Testing Labs & Research Facilities

- **Radiation Exposure -** Staff will practice radiation safety to ensure that all staff are protected from radiation exposure and must wear PPE at all times when handling radioactive materials. Staff will not place radioactive substances in any container that is not appropriately labeled and appropriately shielded for such use, nor use any such radioactive substances in a manner that is not approved for nor essential for the task at hand. Radioactive material handling safety training will be provided to all staff working with radioactive substances, and they will prove proficiency through the appropriate certifications by the appropriate governing body (OHP, 2021).
- **Fire or Explosion -** Staff will utilize appropriate PPE which is rated for fire protection appropriate for the materials being handled. PPE will include fire resistant gloves, safety goggles, fire suites, and head coverings, as appropriate. Staff will practice fire safety to ensure that flammable and explosive materials do not come into contact with flame or other sources of combustion. Staff will not place flammable liquids or explosives in any container that is not appropriately labeled and rated for such use, nor use any such liquids or explosives in a manner that is not approved for nor essential for the task at hand. Dangerous materials handling safety training will be provided to all staff working with flammable or explosive substances, and they will prove proficiency through the appropriate certifications by the appropriate governing body.
- **Chemical Burns -** Staff will utilize appropriate PPE which is rated for chemical protection appropriate for the materials being handled. PPE will include chemical resistant gloves, safety goggles, lab suits, and hair covering. Staff will not place chemicals in any container that is not appropriately labeled and rated for such use, nor use chemicals in a manner that is not approved or essential for the task at hand. Dangerous materials handling safety training will be provided to all staff working with chemicals, and they will prove proficiency through the appropriate certifications by the appropriate governing body.
- **Cryogenic Burns -** Staff will utilize appropriate PPE which is rated for cryogenic protection appropriate for the materials being handled. PPE will include cryogenic resistant gloves, safety

goggles, protective lab suits, and head coverings as appropriate. Staff will not place cryogenic liquids in any non-cryogenic rated containers, nor use cryogenic liquids in a manner that is not approved or essential for the task at hand. Dangerous materials handling safety training will be provided to all staff working with cryogenic substances, and they will prove proficiency through the appropriate certifications by the appropriate governing body.

Office Work

- **Mental health/stress, upper body pain, carpal tunnel syndrome, eye strain, migraines, (musculoskeletal discomfort, in general) -** Staff will follow Health and Human services guidelines for office staff, ensuring that their office environment and tasks do not adversely affect their health.

Launch

- **Injury from Rapid Unscheduled Destruction** - All non essential staff will maintain a 5 mile safety margin from any fueled launch vehicle, or any pressurized fuel or oxidizer containers of sizes capable of fueling launch vehicles.
- **Injury from harmful propellants -** All staff will be made aware of harmful chemicals, especially fuels and oxidizers which pose a threat to health. All storage facilities and containers will have appropriate MSDS information and warnings and signage posted in the appropriate locations. Dangerous materials handling safety training will be provided to all staff working with propellants, and they will prove proficiency through the appropriate certifications by the appropriate governing body.

Health

- **Pre-existing conditions, Mental Health** - The mission program will provide for health insurance coverage for all staff. This will be used by staff to maintain their health and address health issues before they worsen.

In-Lab safety protocols:

Hazard Control Measures

- Eliminate: Remove all sources of hazard.
- Substitute: If required, workers must opt for less hazardous chemicals or perform less hazardous operations.
- Controls: Use equipment to reduce potential hazards. Eg. ventilation system, fume hoods, built in needle with safety mechanisms, etc.

- Supervisor and work practices: Laboratory rules must be followed throughout time spent in the lab to reduce risk. Workers must be trained and verified before using the laboratory.
- Personal Protective Equipment (PPE): Workers are required to wear PPE throughout their time in the laboratory. The PPE will include chemical resistant gloves, safety goggles, lab suits, and hair covering.

Factors that determine which control and protective measures to apply:

- Degree of toxicity: Highly toxic chemicals/materials require effective ventilation.
- Potential exposure: Frequency, duration, and concentration of hazard exposure.
- Exposure route: Inhalation and/or skin absorption are common exposure routes. Injection could occur when needles or sharp objects are present.
- Effectiveness and viability of controls: Effectiveness of engineering controls, such as glove boxes and remote handling of hazardous/toxic materials.
- Effectiveness of PPE: Permeability of the glove materials to reduce exposures while handling hazardous materials, effectiveness of lab suite to ensure safety of the worker, etc.
- Procedure: Determines the lab equipment required and the level of safety required during the session.
- Effectiveness of other aspects: such as safety plan, general laboratory safety rules to mitigate exposures.

Procedures to use laboratory:

- Finish training and get approved by a lab personnel
- Specify the amount of time required to use the laboratory
- Fill form concerning what procedures are expected to be conducted and specify the requirements needed to fulfil the experiment
- Include the members expected to work in the laboratory
- Include if any materials are brought to the laboratory
- Reserve the laboratory for use
- Review the laboratory handbook and pass the “General lab procedures test” (Glenn Research center chemical hygiene plan, 2020).
- Apply for a laboratory permit card for all the members using the laboratory
- *Optional: Reserve a lab technician to oversee the procedure and to give direction

*It is recommended to have a lab technician during the duration of time spent in the laboratory. This has been seen to reduce potential risks or/and injuries caused during lab sessions.

5.2. Vehicle/Payload Safety

5.2.1. Environmental Hazards

The Martian environment can cause hazards for Poli'ahu. Dust storms can completely knock out communications and even operations entirely (Witze, 2018). Poli'ahu will receive its power through an array of solar panels, which means the Martian climate poses an extreme hazard to its ability to function on the planet. Because the Martian atmosphere is only 1% the thickness of the atmosphere of Earth, dust particles can persist in the air for a much longer time. This heightens the probability of operations being hampered because the dust blocks sunlight and can reduce the amount of light available for recharging Poli'ahu.

Another concern is that the Sun is predicted to reach solar maximum in 2025. This is close to the launch of Poli'ahu, which is currently slated for 2024. The uptick in solar activity also correlates with the estimated landing of the rover in May of 2025 and the primary mission beginning. When at solar maximum as part of the eleven-year Solar Cycle, activity within the Sun is enhanced, leading to an increase in the intensity of solar wind and radiation (Tran, 2020). Since Solar Cycle 25 was confirmed to have begun in 2020, activity will ramp up until its peak as Poli'ahu is launched, begins its transit to Mars, lands, and conducts both calibration and first operations. Peak solar activity also increases the possibility of a coronal mass ejection, which means it is even more likely for the payload to be struck by solar radiation while en route to Mars or while on the surface, posing serious threats to systems operations.

Third possible hazard to Poli'ahu is the excessive cold temperatures on Mars. The subsystems in Poli'ahu could operate between -40 degrees to 104 degrees Fahrenheit ("Rover Temperature Control," n.d.). The temperature on Mars can range from 71 degrees Fahrenheit during the day, to -140 degrees Fahrenheit during the night ("Rover Temperature Control," n.d.). Thermal subsystem, involving heat pads, will be installed to heat the internal parts of the rover that require a higher temperature.

5.2.2. Hazard Mitigation

Failure Mode and Effects Analysis

Hazard	Potential Failure Mode	Potential Effects of Failure	S E V	Potential Causes / Mechanisms of Failure	Current Design Controls Prevention	O C C	Current Design Controls Detection	D E T	R P N	Recommended Actions
Radiation	Solar radiation	a. Radiation damages all electrical components b. Data has errors	9	-Coronal mass ejections -Very little protection from radiation due to Mars' induced magnetosphere	-Them most sensitive components will be placed inside the rover body -Rover will be put to sleep during expected coronal mass ejections	5	-Monitoring of solar activity	3	135	Mitigate -Integrate software that detects and compensate for errors
Dust	Dust accumulates on solar panels	a. Batteries cannot fully charge b. Mission fails due to insufficient power to subsystems	9	-Dust storms	-Solar panels will be larger to accomodate for accumulated dust	4	-Monitoring of Mars weather	3	108	Mitigate -Calculate area needed to accomodate for dust accumulation
Extreme Cold	Temperatures are low	a. Instruments and subsystems partially fail b. Instruments and subsystems fail	9	-Temperatures on Mars can range between -140 degrees to 71 degrees Fahrenheit	-Thermal control system will be implemented - Thermal sensitive components will be placed inside the rover body -RHU's will be placed around batteries -Thermal switches and mechanical thermostats will monitor and regulate temperature - Survival heaters will turn on when temperatures are too low.	3	-Thermal switches will detect when temperatures are too low and will activate heaters.	2	54	Mitigate -Design thermal system to keep components at opperating temeperatures

Radiation

Radiation-hardened electronics (RAD-hard electronics) will be designed to be less susceptible to damage from radiation and temperature (John P. Hageman, 2015). Protective materials will be used to reduce potential radiation. Wiring will have protective coating to reduce potential radiation and minimize any adverse effects. Instruments sensitive to radiation will be kept deep in the rover, where the exposures are minimal. During coronal mass ejections that are projected to hit the rover, the rover will be shut down to avoid damage to the electrical components.

Dust Storms

The rover, its instruments, and its wiring will be covered by material that can prevent the accumulation of dust particles. Execution will be similar to the hazard mitigation strategies for radiation. Dust storms also lead to inconsistent power supply, thus a lithium battery will be installed to store energy. In case a dust storm hits, the battery will provide instruments with sufficient power.

Along with batteries, it is also crucial to decide how power will be distributed and if any instruments could be shut down during this period to conserve energy. For this mission, the cameras will be powered on throughout the entire time spent on Mars. This helps to capture images and help monitor the surroundings of the rover at all times. RIMFAX will also be operating, but once data of the particular region has been collected, the rover will shut the instrument.

Excessive Cold

The rover and instruments will be protected by a thermal system involving passive insulation, RHUs, and active heaters near the battery in the WEB, and within key components. These heat mitigation components will help maintain a higher internal temperature to ensure all components work properly, and are maintained above their critical temperatures.

If active heating systems fail, the power management regime will be modified to maintain heat-generating components around the battery along with the passive RHU's to ensure the battery maintains usable temperatures. Finally, in critical temperature situations, where battery power may be lost for long periods of time, the computer's system will be put into an auto-start and battery trickle-charge mode to ensure that any power that eventually is generated will be prioritized to enable restart of the rover.

6. Activity Plan

6.1. Budget

The mission budget has been broken down into a multi-year, categorized budget. This facilitates the planning and organization of expenses for each fiscal year of the mission, as well as tracking key categories of spending by division and activity. The itemized budget has been organized into the following primary categories: Personnel, Travel, Outreach, and Other Direct Costs. The latter category has been broken up into subcategories for Science Instrumentation, Commercial-Off-The-Shelf (COTS) Components, Materials & Supplies, Manufacturing Facility Costs, Test Facility Costs, and Integration & Shipping Costs. These itemized costs are detailed in Table 6.1-1.

Salaries are based upon a simplified salary rate dictated for this mission solicitation, which is $80k plus 28% for Employee Related Expenses (ERE). The workforce has been categorized into the following categories: Scientists, Engineers, Administrators, Human Resources, Public Relations, Intern Program Managers, stipends for interns, and contractors.

Travel expenses were calculated using research to identify per person costs for economy class airfare from the west coast to Orlando, Fl, hotel accommodations, transportation, and the U.S. General Services Administration's Fiscal Year 2020 Per Diem Rates for Cocoa Beach, Florida (GSA, 2021). These rates were used to determine costs for launch team travels, as well as for travel expenses for team members for other operational requirements, such as vehicle integration, testing, launch integration support, outreach coordination, and any other travel that is needed throughout the mission.

Mission vehicle manufacturing and development costs entail a mix of 3rd party manufacture, commercial off the shelf (COTS), custom built, custom integrated components. The mission design estimates a cost of $33M for a rover, using a combination of pricing methods depending on the component, see Table 6.1-1. Some components use the COTS prices with some overhead for faulty or non-spec manufacturing deficiencies. The larger science instruments use a $1M per kg calculation, as well as for certain complex rover subsystems.

The Poli'ahu mission program allocates a budget for development of a pathfinding vehicle in year 1-2 to work out component and manufacturing tolerances and procedures. Additionally, the mission plan will subsequently begin building two working rovers in years 3-4.

One of these vehicles will be designated as the flight article, and the other will be built to the same spec, as a backup and engineering analog on Earth. This backup will be used by engineers and mission operators during the primary vehicle's mission on Mars' surface. The costs for these additional test and backup vehicles are $25M for the pathfinder and its iterations, and $29M for the backup rover. The price for the backup rover is predicated upon current plans for it to be built concurrently with the primary flight vehicle.

The RHU cost was determined by the mass of the plutonium in the RHU and the Pu-238 price since the cost of 1lb Pu-238 approximately 4M dollars the RHU the tea is using approximately 0.08lb (40grams); therefore, (0.08lb * 4M$) / 1lb (453.592 grams) = $3.2M dollars.

The team determined the cost of Aerogel by calculating the dimensions and since one cubic centimeter can be purchased for $1 dollar, the team was able to get approximately $20,000 for the aerogel cost, which is approximately 1lb (453.592 grams).

Testing costs contain costs for Temperature/Vacuum chamber testing of 336 (14 days for 24 hours a day) hours, at a rate of $2,500 an hour. The testing and systems integration team will utilize the advanced laboratory services offered by Arizona State University (ASU). This will require the general lab for individual instrument and component testing, as well as specialty equipment, as outlined in Table 6.1-1.

Finally, the team has allocated $2,500 an hour, estimating 200 hours, for planetary protection activities such as baking and otherwise sterilizing the instruments and spacecraft, to ensure that no microbial life from Earth can contaminate Mars. Some of these resources will also be used to ensure compliance with US Nuclear Safety declarations and protocols due to the radioactive Pu-238 used in the rover's Light Weight Radioisotope Heaters (LWRHUs).

Table 6.1-1: Poli'ahu Mission Budget

				YEAR 1		YEAR 2		YEAR 3		YEAR 4		YEAR 5		
										Launch Year				
Cost Center Breakdowns	Description	Unit Type (hr/unit)	**Unit Cost $**	**QTY**	**Cost $**	**QTY**	**Cost $**	**QTY**	**Cost $**	**QTY**	**Cost $**	**QTY**	**Cost $**	**Full Mission Category Sub-Total**
PERSONNEL				16	$1,448,400	17	$1,550,800	27	$2,651,500	28	$2,087,150	17	$1,350,775	$9,088,625
Scientist Salaries	$80K Salary + $22,400 (ERE @28%)	/person salary	$102,400	**2**	$204,800	**2**	$204,800	**3**	$307,200	**3**	$307,200	**3**	$307,200	**$1,331,200**
Engineer Salaries	$80K Salary + $22,400 (ERE @28%)	/person salary	$102,400	**5**	$512,000	**5**	$512,000	**5**	$512,000	**5**	$512,000	**2**	$204,800	**$2,252,800**
Administrator Salaries	$80K Salary + $22,400 (ERE @28%)	/person salary	$102,400	**2**	$204,800	**2**	$204,800	**3**	$307,200	**3**	$307,200	**3**	$307,200	**$1,331,200**
Human Resources Salaries	$80K Salary + $22,400 (ERE @28%)	/person salary	$102,400	**1**	$102,400	**1**	$102,400	**2**	$204,800	**2**	$204,800	**1**	$102,400	**$716,800**
Public Relations Salaries	$80K Salary + $22,400 (ERE @28%)	/person salary	$102,400	**0**	$0	**1**	$102,400	**2**	$204,800	**3**	$307,200	**2**	$204,800	**$819,200**
Intern Program Management.	$80K Salary + $22,400 (ERE @28%)	/person salary	$102,400	**1**	$102,400	**1**	$102,400	**2**	$204,800	**2**	$204,800	**1**	$102,400	**$716,800**

Intern Stipend	$18/hr 12 weeks full time (480hrs) = $8,640 + $ (ERE @28%) = $2,419	/per 12 week internship	$11,060	**5**	$55,300	**5**	$55,300	**10**	$110,600	**10**	$110,600	**5**	$55,300	**$387,100**
Contractors	Misc. Contractors such as SME's, Manufacturing, Specialists, Etc. $100K Salary + $28,000 (ERE @28%) / 48 weeks	/person weeks	$2,667	**100**	$266,700	**100**	$266,700	**300**	$800,100	**50**	$133,350	**25**	$66,675	**$1,533,525**
TRAVEL					$2,332		$2,332		$4,664		$22,154		$1,166	$32,648
PROJECT OPS TRAVEL	**Travel for Operations Requirements Like testing etc...**				**$2,332**		**$2,332**		**$4,664**		**$5,830**		**$1,166**	**$16,324**
Flights Costs	~$250 round-trip with American Airlines from LAX to MLB (and back)	/person	$250	**4**	$1,000	**4**	$1,000	**8**	$2,000	**10**	$2,500	**2**	$500	**$7,000**
Hotel Costs	$137.7 per night (avg. of first 6	/person	$138	**4**	$552	**4**	$552	**8**	$1,104	**10**	$1,380	**2**	$276	**$3,864**

	results with filters)													
Transportation Costs	$124 for the cheapest rental car (a very rough price)	/person	$124	**4**	$496	**4**	$496	**8**	$992	**10**	$1,240	**2**	$248	**$3,472**
Per Diem Costs	$71 for meals and incidentals	/person	$71	**4**	$284	**4**	$284	**8**	$568	**10**	$710	**2**	$142	**$1,988**
LAUNCH TEAM TRAVEL	**(4 day/3 night)**				**$0**		**$0**		**$0**		**$16,324**		**$0**	**$16,324**
Flights Costs	~$250 round-trip with American Airlines from LAX to MLB (and back)	/person	$250	**0**	$0	**0**	$0	**0**	$0	**28**	$7,000	**0**	$0	**$7,000**
Hotel Costs	$137.7 per night (avg. of first 6 results with filters)	/person	$138	**0**	$0	**0**	$0	**0**	$0	**28**	$3,864	**0**	$0	**$3,864**
Transportation Costs	$124 for the cheapest rental car (a very rough price)	/person	$124	**0**	$0	**0**	$0	**0**	$0	**28**	$3,472	**0**	$0	**$3,472**
Per Diem Costs	$71 for meals and incidentals	/person	$71	**0**	$0	**0**	$0	**0**	$0	**28**	$1,988	**0**	$0	**$1,988**
OUTREACH					$13,120		$14,120		$21,120		$22,120		$14,120	**$84,600**

Outreach Materials					**$1,120**		**$2,120**		**$3,120**		**$4,120**		**$2,120**	**$12,600**
Printed Pamphlets/Flyers	Approx. $100 for 100 flyers (color)	/campaign of 1000 fliers	$1,000	**1**	$1,000	**2**	$2,000	**3**	$3,000	**4**	$4,000	**2**	$2,000	**$12,000**
Website Annual Hosting	Creating/maintaining website $0 “free platform”	/year	$120	**1**	$120	**1**	$120	**1**	$120	**1**	$120	**1**	$120	**$600**
														$0
Outreach Venue Costs					**$12,000**		**$12,000**		**$18,000**		**$18,000**		**$12,000**	**$72,000**
Conference Fees (booth/vendor/sponsor)		/event	$5,000.00	**2**	$10,000	**2**	$10,000	**3**	$15,000	**3**	$15,000	**2**	$10,000	**$60,000**
Conference Fees (participants/attendees)		/attendee /event	$1,000.00	**2**	$2,000	**2**	$2,000	**3**	$3,000	**3**	$3,000	**2**	$2,000	**$12,000**
OTHER DIRECT COSTS					$26,693,500		$91,509,592		$62,939,260		$9,190,750		$0	**$190,333,102**
|> Science Instrumentation														**$0**
Dynamic Albedo of Neutrons Spectrometer (DAN)	Neutron Spectrometer	/kg	$3,900,000	**0**	$0	**0**	$0	**2**	$7,800,000		$0		$0	**$7,800,000**
Radar Imager for Mars’ Subsurface Experiment (RIMFAX)	Ground Penetrating Radar	/kg	$4,500,000	**0**	$0	**0**	$0	**2**	$9,000,000		$0		$0	**$9,000,000**
Subsystem Dev & Manufacture														
Structure			$7,796,000	0.5	$3,898,000	0.5	$3,898,000		$0		$0		$0	**$7,796,000**
Mobility Subsystem	Wheels, Suspension, motors		$4,891,000	0.5	$2,445,500	0.3	$1,467,300	0.2	$978,200		$0		$0	**$4,891,000**

Guidance & Navigation			$1,500,000		$0	0.5	$750,000	0.5	$750,000		$0		$0	**$1,500,000**
Command & Telemetry Subsystem			$1,920,600		$0	0.5	$960,300	0.5	$960,300		$0		$0	**$1,920,600**
Communications Subsystem			$186,000		$0	0.5	$93,000	0.5	$93,000		$0		$0	**$186,000**
Power Subsystem			$6,950,000		$0	0.5	$3,475,000	0.5	$3,475,000		$0		$0	**$6,950,000**
Thermal Subsystem			$1,050,000		$0	0.5	$525,000	0.5	$525,000		$0		$0	**$1,050,000**
Commercial Off-The-Shelf (COTS) Components					$0		$0		$0		$0		$0	
Thermal Components	Radioisotope Heating Units (RHU)	$/unit	$320,000		$0	**10**	$3,200,000		$0		$0		$0	**$3,200,000**
Aerogel	1 cm3=$1 WEB internal Insulation Web Surface Area = 9120 cm		$10,000		$0	**2**	$20,000		$0		$0		$0	
Camera Systems	2 NavCam and 4 HazCam		$26,200,000		$0	**1.5**	$39,300,000		$0		$0		$0	**$39,300,000**
SSD	Mercury SSD		$750,000		$0	**2**	$1,500,000		$0		$0		$0	**$1,500,000**
IMU	Northrop Grumman		$100,000		$0	**2**	$200,000		$0		$0		$0	**$200,000**
Materials and Supplies														
Chassis Materials	*Aluminum 7075	/sheet	$574		$0	8	$4,592		$0		$0		$0	**$4,592**
Manufacturing Facility Costs														

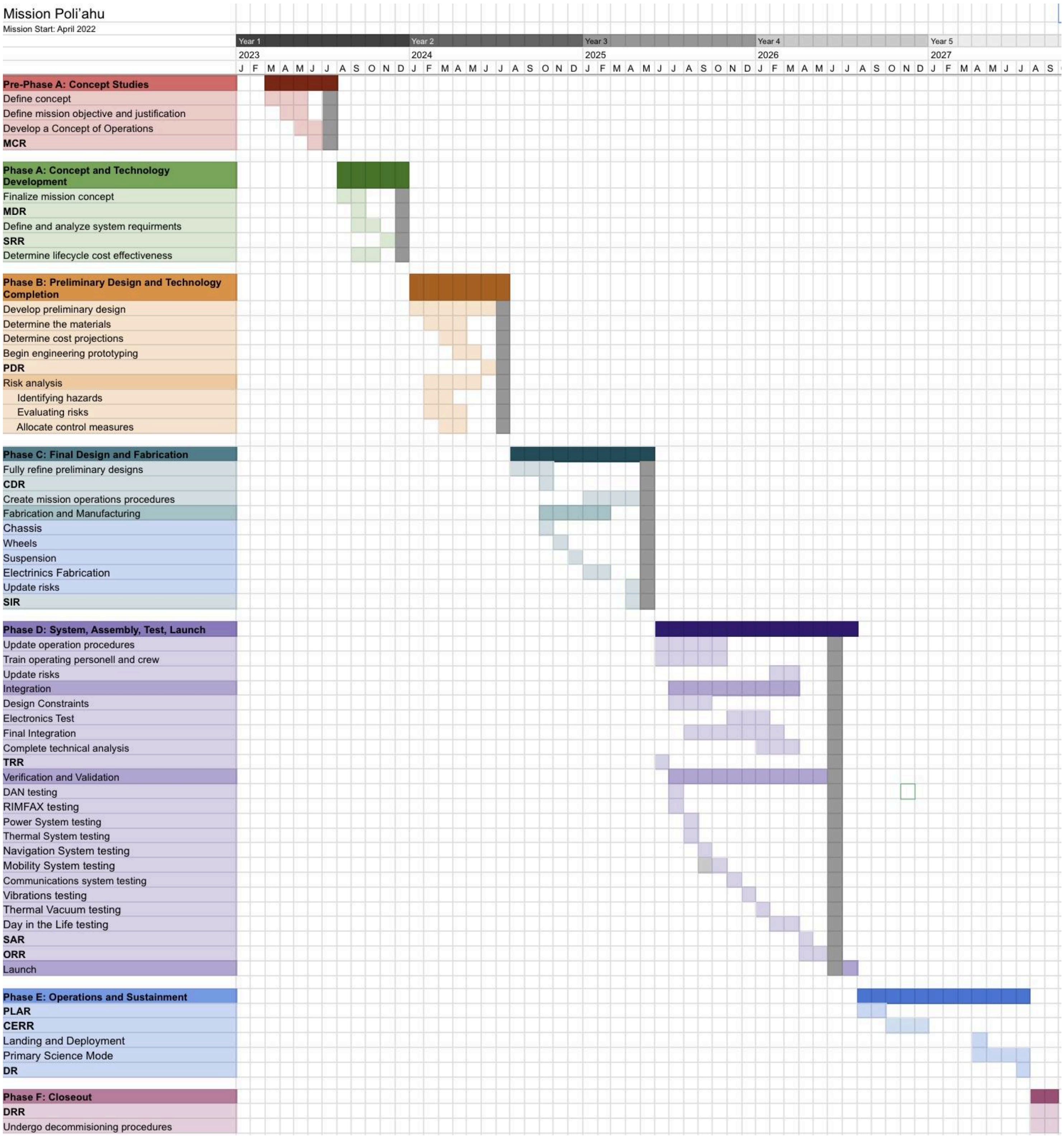
Manufacture of Pathfinder Vehicle (for size and proof of concept)	Calculated from Primary Vehicle manufacture Cost		$25,000,000	**0.5**	$12,500,000	**0.5**	$12,500,000		$0		$0		$0	**$25,000,000**
Manufacture of Primary Vehicle (Flight Article)	Calculated from Subsystems Costs x1.5 of $33,000,000		$49,500,000	**0.1**	$4,950,000	**0.3**	$14,850,000	**0.5**	$24,750,000	**0.1**	$4,950,000		$0	**$49,500,000**
Manufacture of Secondary Vehicle (Earth Ops Article)			$29,000,000	**0.1**	$2,900,000	**0.3**	$8,700,000	**0.5**	$14,500,000	**0.1**	$2,900,000		$0	**$29,000,000**
Testing Costs														
Thermal Vacuum Testing	TVac Chamber $2,500/hr		$2,500		$0		$0		$0	**336**	$840,000		$0	**$840,000**
ASU Thermal Analysis	Preliminary instrument thermal analysis prior to Tvac		$120		$0	**200**	$0	**400**	$48,000		$0		$0	**$48,000**
ASU General Lab	Laboratory testing and integration		$83		$0	**800**	$66,400	**600**	$49,800		$0		$0	**$116,200**
ASU Piston Cylinder	Testing structure with piston cylinder up to 2GPa		$83		$0		$0	**120**	$9,960		$0		$0	**$9,960**
Integration & Shipping Costs														
Vehicle Cleaning & Planetary Protection Costs	Heating and Sterilization		$2,500		$0		$0		$0	**200**	$500,000		$0	**$500,000**

Vehicle Transport From Integration Site	Includes crated for crate from ASU to Cape Canaveral		$750		$0		$0		$0	1	$750		$0	**$750**
					$0		$0		$0		$0		$0	**$0**
Annual Mission Cost					**$28,157,352**		**$93,076,844**		**$65,616,544**		**$11,322,174**		**$1,366,061**	**$199,538,975**
Total Annual Cost Margin	30% Margin				**$8,447,206**		**$27,923,053**		**$19,684,963**		**$3,396,652**		**$409,818**	**$59,861,693**
Total Annual Mission Cost					**$36,604,558**		**$120,999,898**		**$85,301,507**		**$14,718,826**		**$1,775,879**	**$259,400,668**

6.2. Schedule

The preliminary mission schedule is shown on the next page. Initially, an August 2024 launch date was decided on, however it became apparent that the mission timeline would better fit a slightly longer duration. An alternative launch date was decided on to allow for a five year mission length. This date will allow the rover to land on Phlegra Dorsa in the northern hemisphere of Mars close to the start of summer with launch in July 2026 and arrival in April 2027. Table 6.2-1 shows the current mission schedule. Margins are shown in grey.

Table 6.2-1: Mission Schedule Gantt Chart



6.3. Outreach Summary

Team Aegir plans to increase public awareness and appreciation for the STEM field by reaching out to students and promoting through Poli'ahu's website. Team Aegir will reach out to students by:

Student Tours and Lectures

Tours to the lab of Poli'ahu's assembly will be provided for students. Lectures will vary based on age group but will be available for students K-12. Schools across the country will be able to register for a specific three-hour time slot where they can meet the team, listen to a lecture, and view the rover prototype. The Poli'ahu tours will keep the same format regardless of age but will have different levels of depth in the explanation of the material. A line of merchandise can also be produced for Poli'ahu, such as a shirt depicting the mission insignia and a small model kit of the rover itself that can be assembled. The public can also register to view the launch in-person and virtually for free. There will also be lectures at selected regions across the country, all of which lead up to the launch time. Team Aegir also plans on providing lectures to schools all over the country. The lectures will either be in-person or virtual at the discretion of the institution(s). The purpose of student tours and lectures is to inspire the next generation of STEM students and provide a possible career path for them to be a part of the mission. The team aims to host said lectures to discuss the progress updates of the mission, share any significant discoveries, and invite the public to contribute by participating in fun activities. Audiences of all ages are welcome.

Internships

In order to prepare the next generation of STEM students, Team Aegir will be providing internships. Internships will be provided through all stages of the mission. The goals when providing internships to students are:

- Build a pipeline for future NASA missions
- Exposing students to day-to-day engineering tasks
- Providing students with hands-on experience
- Pairing students with mentors to provide guidance in order to succeed
- Reinforcing students abilities to work in teams
- Create excitement for space exploration and interest in the mission

Team Aegir will be looking to hire the following types of undergraduate and graduate interns:

- Engineering Students: Aerospace, mechanical, electrical, systems, and other engineering students will be working alongside engineers to design, manufacture and test the rover. This will provide the mission with fresh ideas to approach problems that may come up during the mission.

- Computer Science Students: Computer science students will be working with Software Engineers and Data Scientists towards Automation tools Data Acquisition.
- Science Students: Science students will be working with scientists to ensure that the instruments on the rover align with the science goals of the mission. They will also help interpret data provided by the rover.

Internships will assist public outreach of the mission because it seeks to promote science and the use of technology for discovery and the advancement of humanity. These opportunities can also motivate people to take the skills they learn from the internships to improve the quality of life on Earth.

Presenting at Conferences

Team Aegir will reach out to other STEM members and the general public by presenting at conferences and using social media. The team will apply to present at STEM conferences like Space Tech Expo, SciTech Forum, and SpaceCom. Team Aegir will also be applying to present in conferences supporting minorities in engineering such as the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS), the Society of Hispanic Professional Engineers (SHPE), the National Society of Black Engineers (NSBE) and the Society of Women Engineers (SWE). The team will be presenting the goals, plans, and current advancements in the mission through a poster session. The purpose of presenting at conferences is to inform STEM students and professionals about Poli'ahu and increase interest in and support for NASA missions.

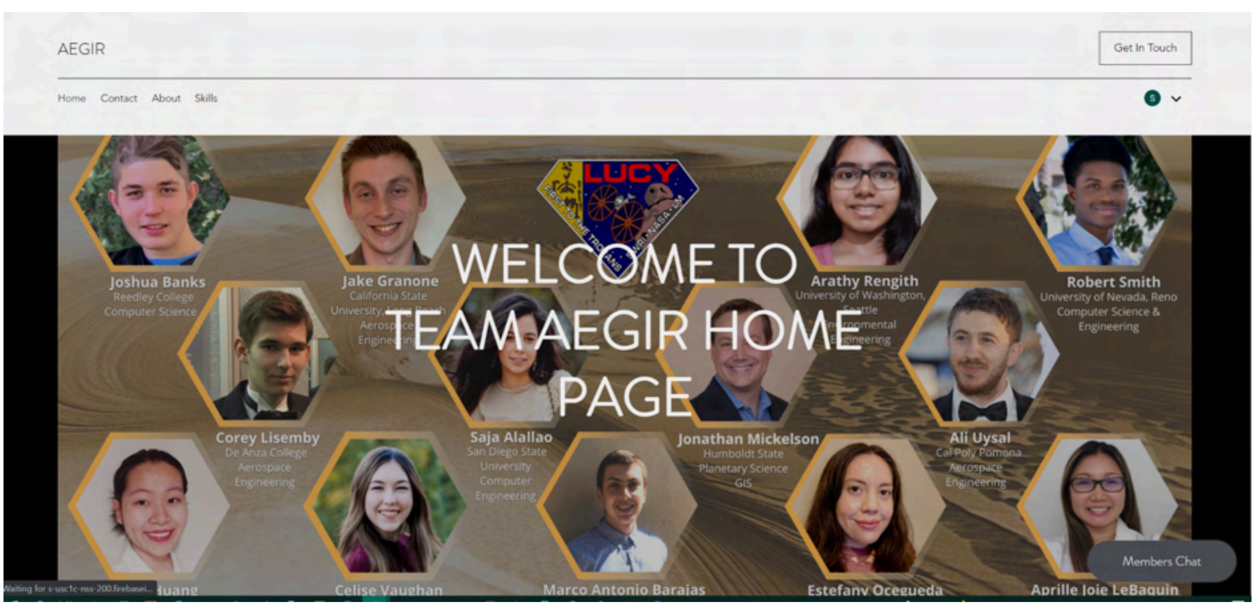


Figure 6.3-1 Team AEGIR Website Link

Another way Team Aegir will increase awareness in STEM is by providing information and updates about the mission and allowing people to be part of the mission through a website. Similar to other flagship NASA missions, namely other Mars rovers and JunoCam aboard the Juno spacecraft in orbit around Jupiter, Poli'ahu will have a website dedicated to public research. Here, raw images from the rover are received from the primary lander and uploaded to the website. On the website, anyone aged thirteen and higher will be able to create an account to assist mission control with processing data and images. Members can then upload their results for future analysis by the team. Anyone who processes an image with scientifically significant results will be credited with discoveries. Figure 6.3-1 shows an example of the website.

6.4. Program Management Approach

The structure of Team Aegir was organized according to the course of study for each team member. This includes their academic majors, skill sets, and interests within the project. Team meetings are held every Tuesday and Thursday at 8:00 PM Pacific Time Zone (PT), and work sessions are held on Fridays and Saturdays at 8:00 PM (PT). The purpose of a work session is to provide an opportunity for team members to ask questions regarding their delegated tasks and to help each other with literature research and documentation of the Preliminary Design Review project. Team members are advised to attend work sessions; however, they have the option to work independently. Team members are also encouraged to review L'SPACE Mission Concept Academy (MCA) recorded sessions in addition to completing MCA skill modules to build and refine their skill sets.

If a team member is unable to attend a team meeting or work session, they have the individual responsibility to communicate directly with anyone from the Leadership subteam (see Figure 6.4-1 for the Organizational Chart) of a future absence. Special arrangements can be made to accommodate the absentee's schedule. A few examples of possible reasons regarding their absence include conflicting schedules with college classes, upcoming exams, major projects, employment schedule, illness, or emergencies. The subteam leaders will provide updates to the absentee regarding the meeting content, weekly goals, plan of action, assigned tasks, and a safe space for the team member to privately share any questions or concerns. These procedures keep team members informed of the project's progress and needs as well as provide a safe space for the team member to express their thoughts and concerns. The Leadership subteam shall provide guidance and support to each team member to help them succeed in their tasks.

Team members are also encouraged to communicate and collaborate with each other in assigned tasks using Discord text or voice channels. Team members can reach out to the Team Mentor and the Mission Concept Academy faculty through the MCA Discord server or Team Discord server if they need clarification of specific guidelines in the MCA solicitation, the preliminary design review explanation, or research documents. The Team Mentor arranges weekly office hours for team members to attend for additional guidance in developing the PDR.

The Deputy Project Manager has created a shared Google Drive folder for team members to work on the PDR simultaneously. They have the ability to create new documents and save their progress in the shared folder. They can view each other's work and collaborate with each other on assigned tasks.

Team Aegir mostly consists of undergraduate engineering majors. To alleviate conflicts within the team roles, the Project Manager requires team members to select at least two roles in the Organizational Chart: a primary role and a secondary role from the Engineering, Science, or Business Administration subteams. The secondary role must be selected from a different subteam. This structure was developed to encourage an additional support system to all subteams in the Organizational Chart. Team members are provided with the opportunity to select their roles in areas where their strongest skills can be refined and flourished as well as roles they are interested in cultivating new skills.

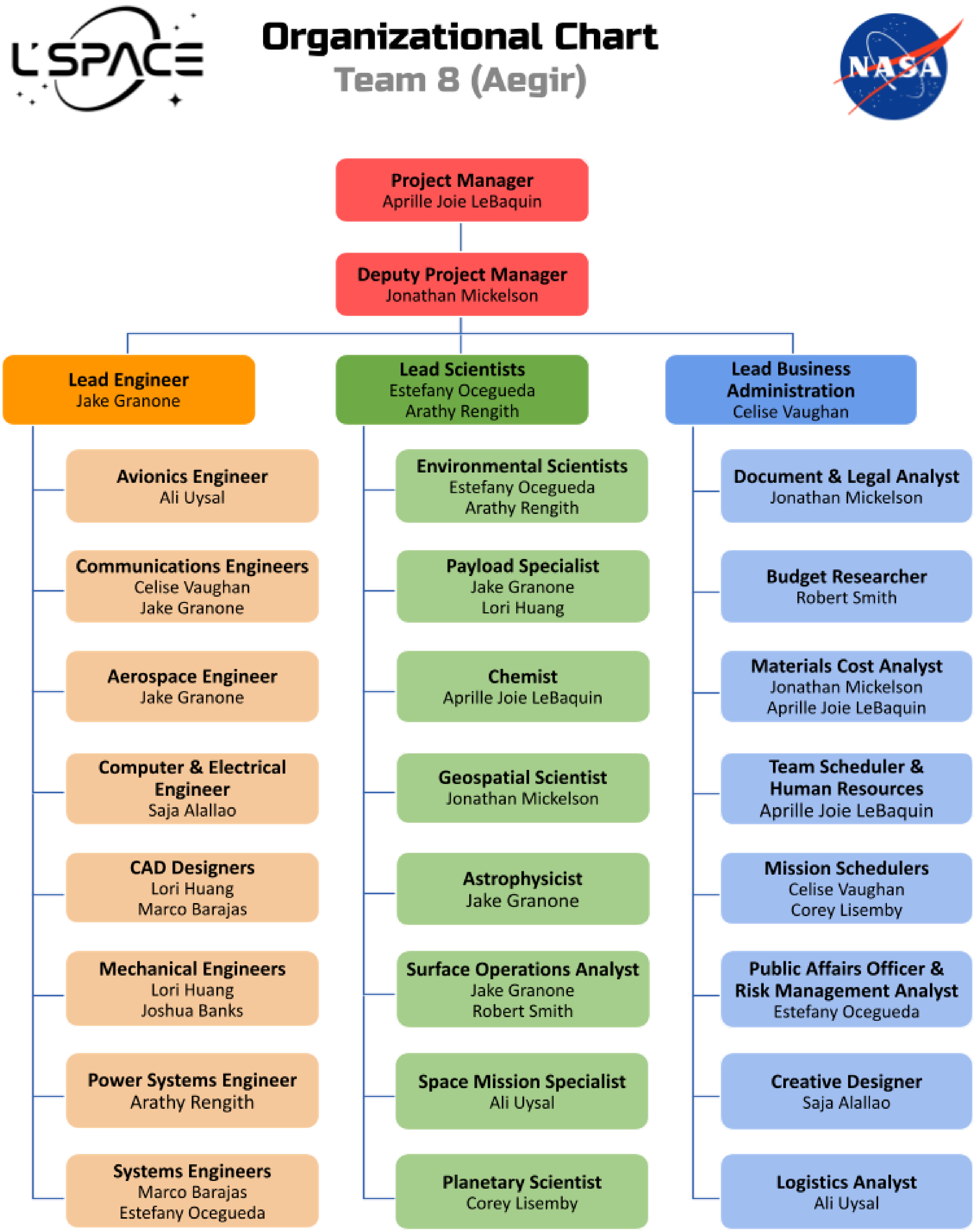


Figure 6.4-1: Organizational Chart displaying roles of each team member.

7.Conclusion

7.1 Mission Summary

The Poli'ahu Mission is an integral pathfinding step in NASA's plans for long-term human exploration on Mars. It is imperative that such exploration efforts utilize as many in situ resources as possible to improve the feasibility and reduce the cost of missions that originate from Earth. NASA estimates that even with recycling and reusability in place, 100-metric tons of water will be required to establish any long-term base of operations on Mars. Utilizing water from subsurface ice deposits will greatly expand NASA's ability to fund and accomplish these next steps on another planet for all humankind.

This robotic mission's primary science goal is to find the volume of water ice that NASA requires for future manned- missions. The mission plan will locate, map, and quantify the water ice reserves that are so critical for human exploration, while also setting new records and pushing the NASA robotic exploration mission's capabilities to new heights. This mission will land a rover at the furthest north on Mars of any rover to date to an exploration zone called Phlegra Dorsa in Arcadia Planitia.

The unique rover design will be one of the first to include an articulating solar panel to help gather sunlight at this high latitude where the sun does not rise as high in the sky and reduces available solar energy. The vehicle will also perform a mobile science campaign that will traverse the Martian landscape gathering atmospheric, visual, and underground measurements that will locate buried ice layers. The primary science instruments on the rover are RIMFAX and DAN. RIMFAX is a ground-penetrating radar instrument that can see layers up to 10 meters underground. DAN is a neutron spectrometer that can detect hydrogen, indicating the presence of water. This will be especially useful in detecting permafrost-type layers under a surface layer of dirt or sand.

The data gathered as the rover carries out its mission will be used by scientists to build detailed 3D maps of the surface and below ground topology of the region. These maps will provide quantifiable estimates of how much ice can be gathered/mined and by what methods. Throughout the mission, mission planners will also communicate with the rover, defining new regions of interest as they are located and adjusting its mission targets. These semi-autonomous mapping activities will continue throughout the primary mission period of 100 days. Post-mission activities will include continuing to publish data, releasing scientific and visual models of the region, and preparing reports and data for use by NASA's human exploration mission team.

7.2 Future Mission Plans

After successfully completing the PDR, the next mission milestone is the CDR. The CDR includes an overview which is considered to be the final mission design. To ensure that this design is ready to be manufactured, a more detailed and developed rover design will be required for the CDR. To accomplish this, aspects of the rover described in this PDR will be addressed more thoroughly. With more time, Team Aegir will continue to refine the mass budget and reduce the weight of components in the rover. The Mass constraint for this mission was a challenging obstacle to overcome, so future evaluation and justification of component priorities in relation to meeting the science objectives will prove to be beneficial.

Design changes made from the PDR will be documented while manufacturing and testing plans will be refined. When the final design has passed the CDR, electronics fabrication can begin along with manufacturing of the chassis, suspension, and wheels.

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