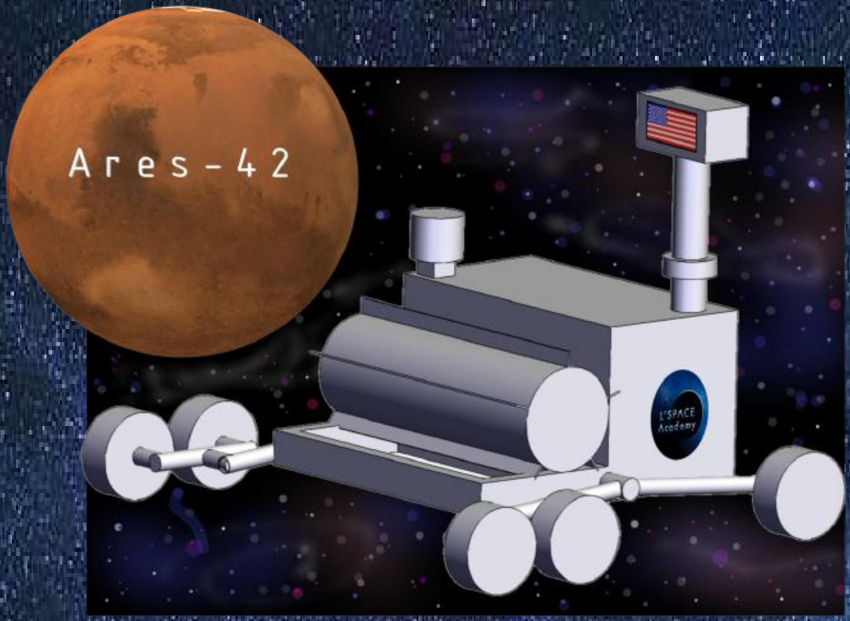
L’SPACE
Mission Concept Academy
ARES-42



Preliminary Design Review
Team #2

Table of Contents

1 Introduction and Summary

2 Evolution of Project

3 Deployment Scheme and Vehicle Design

4 Payload Design and Science Instrumentation

1. Introduction and Summary

1.1. Team Introduction

ARES-42 (Area Resource Exploration Site Surveyor) is composed of 10 team members whose specialties include: Astrophysics, Chemistry, Aerospace, Bio, Computer, Mechanical, Nano, and Electrical Engineering. The ARES-42 mission would like to give special recognition to Aidan Earley, the project mentor.

Nicole Alvarado
CSU Los Angeles
Los Angeles, California

Nicole is the ARES-42 Project Manager and Business Administration division Scheduler. She specializes in team organization with experience as a Project Manager for NCAS. Nicole is a Mechanical Engineering undergraduate and has an associates degree in Physics.

Andrew Avila
California Polytechnic University-Pomona
Pomona, California

Andrew is the ARES-42 Deputy Project Manager and lead Electrical Engineer. He is working towards his Electrical Engineering degree. He has previous exposure to university research and team proposals.

Jacob Pedersen
University of Washington
Seattle, Washington

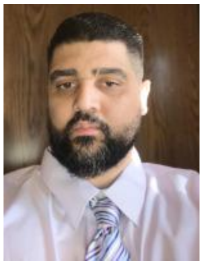
Jacob is the ARES-42 Engineering division lead and lead Software Engineer. He enjoys programming
In multiple languages and especially hardware development. He is a Computer Engineering undergraduate with an associates degree
in Science.

Ashley Perez
California Polytechnic University-Pomona
Pomona, California

Ashley is the ARES-42 Science division lead Astronomer. She is currently an aerospace engineering undergraduate, with an emphasis in astronautics. She has previous years of experience in university-level research and work, as well as exposure to proposal writing.

Daniel Campos
Santiago Canyon College
Orange, California

Daniel is the ARES-42 Business Administration division Budget manager. He is currently working towards an associates degree in Astronomy and Physics. Daniel has previous university-level research experience, as well as exposure to proposal writing and mission planning



Antonio (Tony) Ramirez
East Los Angeles College
Monterey Park, California

Antonio is the ARES-42 Business Administration lead and Engineering division CAD specialist. With a B.A in Media Arts & Visual Effects, Tony decided to take his 3D design background into engineering.

Naomi Hahn
De Anza College
Cupertino, California

Naomi is the ARES-42 Science division lead and lead Hydrologist. Naomi is currently a college sophomore as a Mathematics major with plans to transfer into Astrophysics, and has strengths in conducting high-level academic research and lab analysis.

Milton Saldana
UC Davis
Davis, California

Milton is the ARES-42 lead Mechanical Engineer. Milton is currently studying Aerospace Engineering and has experience in academic research

Nil Sanli
UC Riverside
Riverside, California

Nil is the ARES-42 Science division lead Geologist. Nil is a first year bioengineering major, Nil is dedicated to pursuing a career in synthetic biology.

Lauren Takiguchi
UC San Diego
San Diego, California

Lauren is the ARES-42 Science division lead Physicist. Lauren is currently pursuing a Nanoengineering undergraduate degree with a minor in Chemistry and specialization in Chemical Engineering. She has previous years of experience in university-level research and work experience in industry.

1.2. Mission Overview

1.2.1. Mission Statement

The primary goal of the ARES-42 mission is to characterize subsurface ice on Mars via laser spectroscopy, and the specific landing site Arcadia Planitia, near Erebus Montes. This landing site has been chosen because it displays certain geographical features that typically form as a byproduct of once having flowing water. The data gathered during the mission will offer valuable insights and knowledge into the composition and characteristics of the subsurface ice, specifically near the landing zone. This information is of extreme use when considering future human landing sites, where an abundant amount of suitable ice will be necessary for human survival.

1.2.2. Mission Requirements

There are many requirements that must be met, prior to launch and while on the Martian surface, in order to have a successful mission. Design-wise, the spacecraft shall not exceed 30 kg and shall not surpass a volume larger than 100 cubic centimeters. These specific mass and volume constraints must be met to ensure that the rover can fit in its allocated payload space. Additionally, the rover's design must include a rigid, 6" ring capable of supporting our payload. This ring will allow the rover to be lifted out of its payload position and onto the Martian surface to start gathering data. Additionally, the rover's RTG must be capable of providing energy to the rover throughout its entire duration on the Martian surface (3 Earth years). Finally, since the science instrumentation (a laser spectrometer) is not placed on a mechanical arm, the rover must have the mobility means necessary to position itself in locations that are optimal for data collection.

As mentioned in the previous section, the primary goal of the mission is to characterize subsurface ice on Mars via laser spectroscopy. In order to do this, every instrument on board must function properly to ensure that this data is able to be gathered. The rover's main cargo is a laser spectrometer, internally mounted in the belly section of the rover. Aside from successful operation of the rover, the primary mission requirement is that the laser spectrometer and its subcomponents function properly. One of these components is the laser pulse generator that will be used to drill, similar to SuperCam on the Mars Perseverance Rover. Additionally, the spectrometer on board must be able to accurately collect data following each drilling cycle, and send this data back to the lander via its communications systems. To complete this relay, the spacecraft must be able to communicate with the lander directly, which will then send the information back to the scientists on Earth to be gathered and fully analyzed.

Finally, the mission shall not exceed the budget of $300,000,000. This budget utilizes full cost accounting, so every cost must be budgeted and accounted for. At a minimum, this budget should take into account all of the following: science personnel time for the design of the experiment and analysis of the data, engineering personnel time for building and testing the mission concept and for mission operations, every aspect of the team's travel costs (i.e flights, rental cars, meals, etc.), all costs for any outreach events and materials necessary to run them, and all other direct costs, from the manufacturing of the rover and its instrumentation to the facilities at which the rover will be manufactured and tested.

1.2.3. Mission Success Criteria

To define a successful mission, there are several different criteria which have been selected to measure performance. The scientific objective is to adequately and successfully collect samples in mass of ice within our sample space. These criteria include:

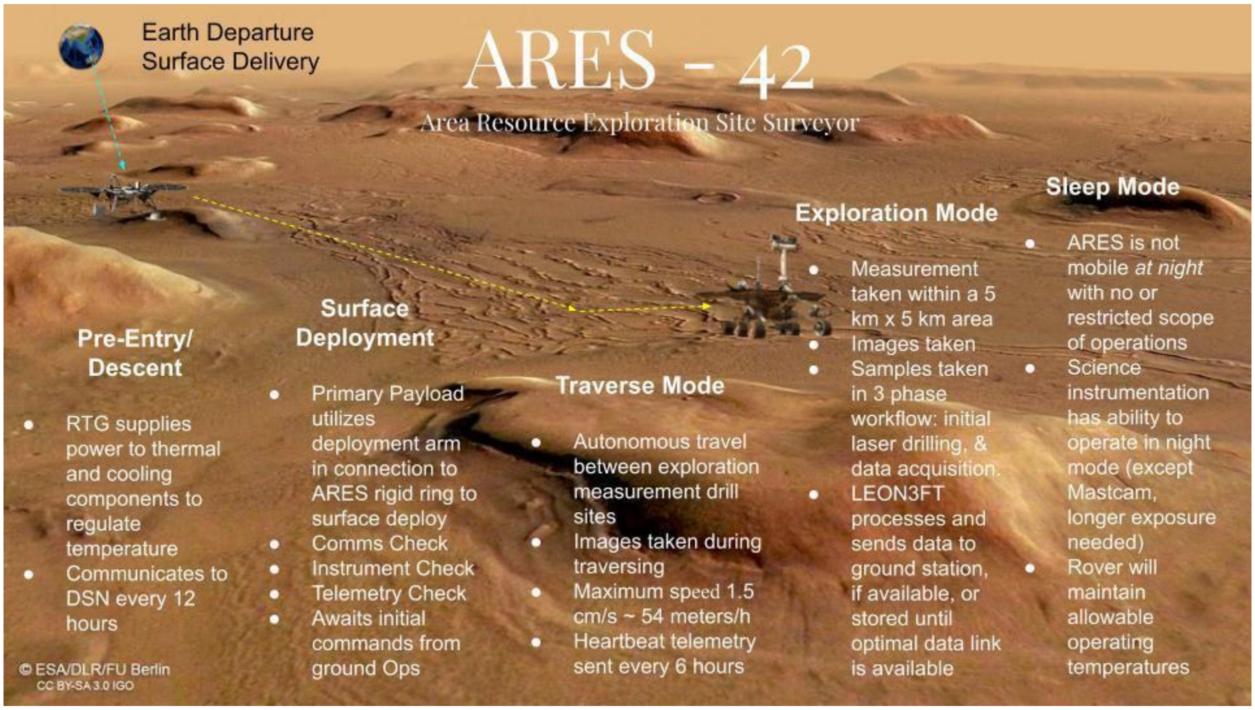
1. Surviving transport
2. Safely deploy from the lander
3. Autonomously navigating the martian surface to the sample site
4. Full function of all systems in a high radiation environment
5. Successfully collect all samples desired, AND excess samples as desired
6. Maintain communication with earth

These criteria must be met OR exceeded to be an example of a successful mission. Below is a table of explicit definitions for what a successful mission means based on the above criteria.

Criterion	Successful	Unsuccessful
1.	Rover has not sustained damage to structure (system), power and thermal (subsystems), instruments, and mobility that would render it unable to be removed from the payload bay.	Components melt from EDL, break from pressure or turbulence.
2.	During the hoist process out of the payload bay, wheels unfold and all six wheels meet the martian surface in unison.	Wheels fail to unfold, rover gets damaged from hoist process, does not get set down with all 6 wheels having points of contact with surface and is unable to resolve issue through remote troubleshooting.
3.	Rover is capable of traversing any portion	Rover power and mobility is unable to

	of the exploration area of 5 km x 5 km. Damage to none or one of two RVS cameras, while one camera is still fully operational with expected resolution and data relay.	navigate through obstacles in terrain to explore any portion of the 5km x 5km area. Damage to both RVS cameras, such that both cameras do not operate with expected resolution and data relay.
4.	All systems receive power from RTG, allowing at minimum, vital subsystems such as power and thermal to operate simultaneously with at least one task not vital to rover life such as use of science instrumentation.	All systems receive no power from RTG or enough power that only vital subsystems can operate without possibility of use of instrumentation or mobility. Unable to troubleshoot remotely in order to resolve power issues. Failure mitigation such as material radiation hardening or heat dissipation of RTG fails and is unable to be corrected through remote troubleshooting.
5.	Rover is able to drill at minimum one sample site where payload was positioned by deployment arm or any of the 25 proposed sites within the exploration area. Rover is able to conduct a single or multiple phase drilling process as expected and LEON3FT is able to process data for communications or at minimum system able store data of samples for possible manned mission retrieval and troubleshooting.	Rover is not able to drill any sample site. Rover is able to conduct a single or multiple phase drilling due to failure of science instrumentation without possibility of troubleshooting from Earth. LEON3FT is unable to process data or the system is unable to store data for future collection.
6.	At every point from launch our payload shall be in communication with Earth; sends sample data consistently and either or both high gain antenna and low gain antenna redundancy system is operable at minimum. Rover is able to send and receive data to and from the main payload via LGF or/and to and from orbiters such as MRO. Rover is able to relay data and health of the rover to the DSN through UHF.	The rover is unable to communicate with Earth or data is received in a manner that does not allow for meaningful analysis and resolution of communication issues is not possible via remote troubleshooting; both LGF and UHF fail and are unable to transmit or receive data.

1.2.4. Concept of Operations (COO)



Pre-Entry/ Descent

- RTG supplies power to thermal and cooling components to regulate temperature
- Communicates to DSN every 12 hours

Surface Deployment

- Primary Payload utilizes deployment arm in connection to ARES rigid ring to surface deploy
- Comms Check
- Instrument Check
- Telemetry Check
- Awaits initial commands from ground Ops

Traverse Mode

- Autonomous travel between exploration measurement drill sites
- Images taken during traversing
- Maximum speed 1.5 cm/s ~ 54 meters/h
- Heartbeat telemetry sent every 6 hours

Exploration Mode

- Measurement taken within a 5 km x 5 km area
- Images taken
- Samples taken in 3 phase workflow: initial laser drilling, & data acquisition.
- LEON3FT processes and sends data to ground station, if available, or stored until optimal data link is available

Sleep Mode

- ARES is not mobile *at night* with no or restricted scope of operations
- Science instrumentation has ability to operate in night mode (except Mastcam, longer exposure needed)
- Rover will maintain allowable operating temperatures

© ESA/DLR/FU Berlin
CC BY-SA 3.0 IGO

Figure 1. *Concept of Operations (COO) graphic depicting operational phases from beginning to mission end.*

The ARES-42 rover is a secondary payload unit which will rendezvous to Mars aboard the primary payload. During interplanetary travel, the ARES rover will have the main source of power, the radioisotope thermoelectric generator (RTG), on and functional. The RTG will supply power to thermal and cooling components in order to regulate the temperature of the rover and to send communications to Earth twice a day. All other components will be idled meaning overall minimum power usage for the rover. Excess heat will be exhausted through the payload bay vent to space (cold temperature body). After the primary payload has executed entry descent and landing, the ARES rover will be deployed on the surface of Mars by the primary payload robotic arm unit. The robotic Arm attaches to the ARES deployment O-ring and lifts the rover out of the payload bay. As the rover is lifted, the wheel deployment process occurs so that the rover is securely positioned with all 6 wheels in contact with the Martian surface. Details of the deployment process are discussed in section 3.1.2 of this document. Upon detachment, the ARES rover will immediately begin checking the health of vital operations. The rover's RTG will supply the required 17.9 Watts of power needed to power the ARES-42 science instrument, Theia. Once operational checks respond as nominal, the rover will begin communication to the primary payload, which will relay communications to the Mars Reconnaissance Orbiter (MRO) and eventually to the Earth communications base via the Deep Space Network (DSN) antennas on Earth. Details of the ARES rover data handling is addressed in section 4.1.2. Once a connection is established, commands are sent back to ARES. After the health of the rover is established, ARES will enter traverse mode. The rover could travel a maximum velocity of 1.296 Km/Sol and explore within a 5 km x 5 km area of the greater Arcadia Planitia site which encompasses the landing site near Erebus Montes. Ground control will check the health of the rover through heartbeat telemetry sent by ARES every 6 hours. ARES will send photos of potential water-ice testing sites within the established region as it treks in between drills sites. The rover will conduct 3 data collection phases at drill sites equally distanced away from one another via its suite of instruments and begin measuring samples. Sample data will be stored and relayed to the main payload and will be sent to the Earth communications base. ARES will idle all components of the rover which are not vital to regulating the temperature of the rover or communications during Martian nights and storms as to mitigate damage. The rover is capable, if need be, to travel slowly at night depending on the visibility of its on board RVS navigation safety systems. ARES ' operational mission timeline is set for three Earth years.

1.2.5. Major Milestones Schedule

Space Flight Pre-Phase A: Concept Studies

ARES-42 mission and science potential reviewed and identified through the scope of customer requirements. Roles and personnel responsibilities/requirements identified and mapped to mission objectives. Discuss preliminary Life cycle rough order of magnitude (ROM) cost, Schedule, and risk estimates. All departments collaborate on design and instrumentation feasibility and budget. Begin introducing expectations for the Concept of Operations (COO). Ensure operations concepts and goals meet needs and expectations of end users and human explorers. MCR and informal proposal Review. Complete Milestone: Team Organization. Deadline 9/13/2021

Phase A: Preliminary Analysis

Determine feasibility of system and prepare initial baseline of mission plans; Risk Management Plan, perform trade studies, Manufacturing and Integration Plan, and Validation and Verification Plan. Establish performance characteristics and predictions of technological autonomy and human command dependent systems. Begin Computer Aided Design iterations of rover design. Establish team divisions and facilities. Utilize Pre-Phase A estimates to formally optimize and establish mission architecture. Prepare for System Requirements (SRR), Non-advocate, and System Design (SDR) Reviews. Complete Milestone: Draft Section 1 & 2. Deadline 9/27/21

Phase B: Definition

Develop a baseline mission proof of concept based on program requirements and expectations. Complete preliminary design of technological systems for the rover. Demonstrate consistency of planning, cost, and schedule baselines from the previous phases. Establish personnel teams specializing in designated mission experiments. Mature Rover design and COO plans. Prepare system and materials overview. Create a minimum of one back-up plan for each system. Research material data sheets. System Requirements (SRR), Non-advocate, and System Design (SDR) Reviews. Complete Milestone: Draft section 3 & 4. Deadline 10/11/2021

Phase C: Design

Developed a space flight system within customer constraints as a secondary payload. Build and integrate subsystems and experimentation tools into rover design. Prepare payload for Assembly, Test, and Launch Operations (ATLO) testing with primary payload. Develop rover design communications commands and telemetry. Fully mature and define selected preliminary designs. Develop hardware and software designs. Preliminary Design (PDR), Complete Milestone: Revised Section 1 & 2 and Draft section 5, 6, & 7. Deadline:s 11/8/2021 and 10/8/2021

Phase D: Development

Integrate and assemble rover components and perform validation of assembly. Compare progress against budget and scheduling plans from previous phases. Validate communications and telemetry systems. Prepare operator's, maintenance, and operation manuals. Monitor Martian site weather conditions and launch requirements on Earth. Provide support to launch and checkout of the system. Critical Design (CDR), Test Readiness Review (TRR), and Flight Readiness Review (FRR). Complete Milestone: Revised Section 3, 4, 5, 6 & 7. Deadlines: 11/1/2021 and 11/15/2021

Phase E: Operations Phase (Mission Operations & Data Analysis)

Conduct the primary mission to meet initial requirements as outlined in previous phases. Ensure and maintain support to rover systems. Sustain systems which require human involvement. Process, store, and maintain mission data. Maintain system architecture. Mission operations are set to end June 2030. Apply for mission extension and end of outlined mission lifecycle.

1.3. Deployment Scheme and Vehicle Design Summary

Vehicle restrictions:

Mass Constraint: Up to 30 kilograms (kg)

Volume Constraint: Up to 100 cubic cm

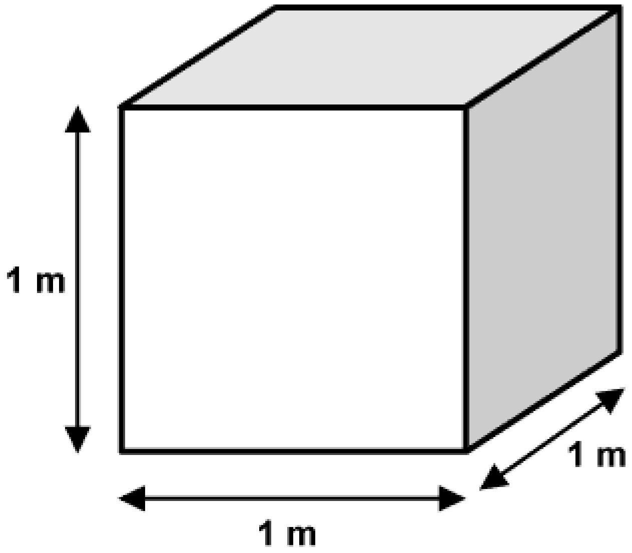


Figure 2. *Volumetric dimensions of flight payload bay*

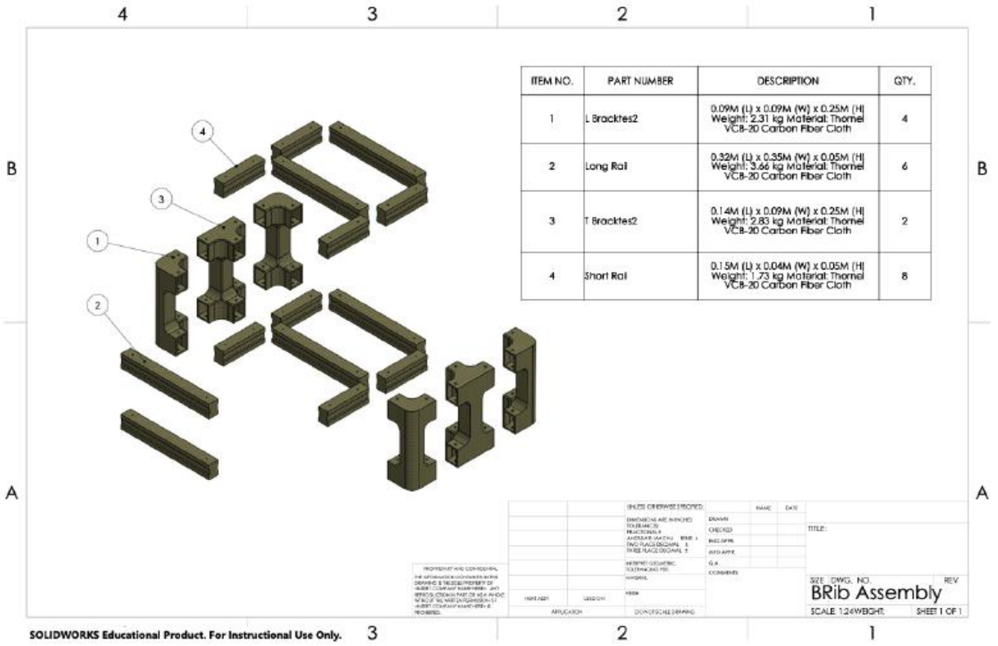
Proposed dimensions (upper bounds) and mass constraint:

Length: 0.62 m (.025m tolerance between forward and rear).

Width: 0.74 m (.10m tolerance on left and right for the main fuselage, room for the mobility system to protrude)

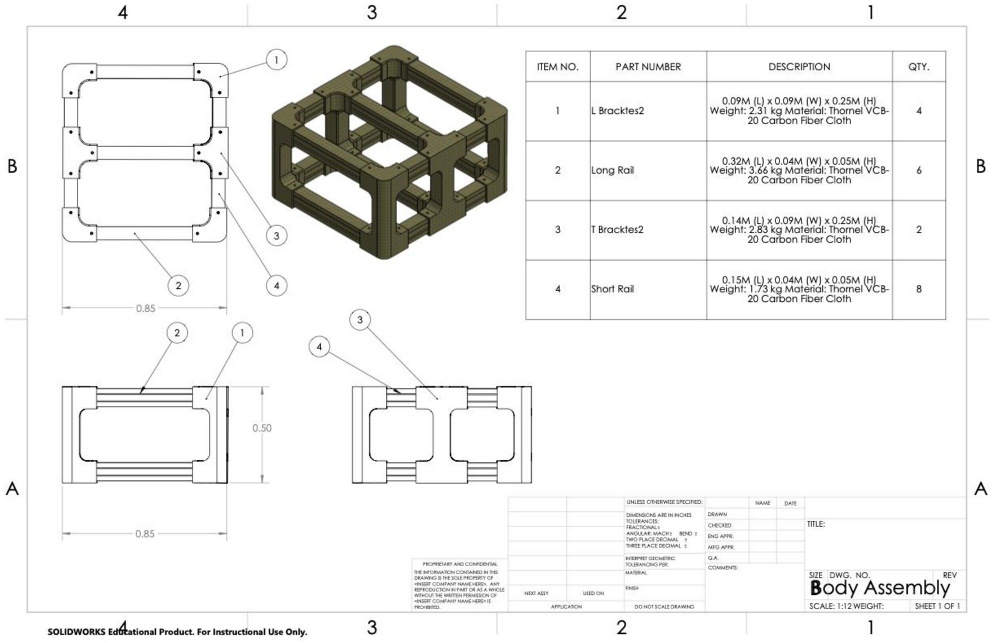
Height: 0.56 m

Mass: ARES-42 rover will utilize the entire allowance of 30 kg.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	L Bracktes2	0.09M (L) x 0.09M (W) x 0.25M (H) Weight: 2.31 kg Material: Thornel VCB-20 Carbon Fiber Cloth	4
2	Long Rail	0.32M (L) x 0.35M (W) x 0.05M (H) Weight: 3.66 kg Material: Thornel VCB-20 Carbon Fiber Cloth	6
3	T Bracktes2	0.14M (L) x 0.09M (W) x 0.25M (H) Weight: 2.83 kg Material: Thornel VCB-20 Carbon Fiber Cloth	2
4	Short Rail	0.15M (L) x 0.04M (W) x 0.05M (H) Weight: 1.73 kg Material: Thornel VCB-20 Carbon Fiber Cloth	8

Figure 3. *Solidworks CAD 3D Rover body assembly parts*



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	L Bracktes2	0.09M (L) x 0.09M (W) x 0.25M (H) Weight: 2.31 kg Material: Thornel VCB-20 Carbon Fiber Cloth	4
2	Long Rail	0.32M (L) x 0.04M (W) x 0.05M (H) Weight: 3.66 kg Material: Thornel VCB-20 Carbon Fiber Cloth	6
3	T Bracktes2	0.14M (L) x 0.09M (W) x 0.25M (H) Weight: 2.83 kg Material: Thornel VCB-20 Carbon Fiber Cloth	2
4	Short Rail	0.15M (L) x 0.04M (W) x 0.05M (H) Weight: 1.73 kg Material: Thornel VCB-20 Carbon Fiber Cloth	8

Figure 4. *Solidworks CAD 3D Rover body assembled parts & measurements*

Deployment of experiment:

The science team has selected an instrument which comes in the form of a camera. Given that all samples will be taken aiming directly downward at the Martian surface and from a fixed distance for consistency, the instrument has been designed to be fixed to the center midsection of the rover's belly. Because the instrument is fixed to the belly of the rover and there is no mechanical arm for positioning the instrument for the individual samples, the rover will use its main mobility system to position the camera directly over the sample area for the instrument to be able to take that sample. An internally mounted instrument in the belly section of the rover has many benefits, one of the biggest being the omission of a mechanical deployment system and therefore one less critical failure point to ensure the success of our mission. Furthermore, a totally internal instrument allows for protection from damage, dust contamination, and the need for more electronic components. Finally, opting to use an internally located, belly mounted instrument orientation means there is no need for any deployment of any type.

Summary of interfaces:

1. Power: SNAP-19 Radioisotope thermoelectric generator and all supporting hardware to balance heat, power delivery and power levels.
2. Mobility: Six wheel design selected for stability characteristics and a decreased probability of critical failure of a wheel. This includes four, forward driving wheels and two, rocker attached rear wheels for stability which will unfold.
3. Communications: Advanced system to record data and share it back to earth as quickly and effectively as possible.
4. Instrumentation: Scientific device, and all supporting hardware to allow it to perform its sampling and communication with the rover vision system and communication system.

1.4. Payload and Science Instrumentation Summary

In the development stage, there are several components that are being considered for use in the mission design. The instrument design has been separated into two core responsibilities, namely determining a method of collecting data on the sublevel ice, and the secondary instrument which processes the collected data, which would then be sent back to the project team on Earth for further examination. The following paragraphs will be split to further detail the concerns and considerations for the two core aforementioned responsibilities.

The method of data collection must be considerate of the Martian environment and terrain, as well as be capable of performing collection without the presence of a human being in the vicinity. Drilling utilizing physical processes carries a high risk without an onsite team to be there to carry out repairs and replacements for drill bits. Mechanical drills are also significantly more massive than other methods of data collection, and require coolant to lower the temperature caused by friction. As a result, it is not a method of data collection that is being considered. Drilling via laser pulses, similar to the SuperCam on the Mars Perseverance Rover, is the most likely direction of sample/data collection, as it produces minimal alteration to the Martian landscape with high precision, and can be operated remotely. The only current concern is the depth at which a laser will drill to, as sublevel ice varies from being covered by 1-10 meters of soil. SuperCam's maximum range is 7 meters, and while this falls within the range, extreme cases (i.e. ice at the maximum 10 meters) must be considered. With the experiment being mobile, the chance of only encountering these extreme cases will be minimized.

As for the method of data processing, the SuperCam (figure 23) also consists of a spectrometer (figure 12) with three spectrographs to analyze the plasma created through the laser drilling process to determine the chemical composition. The combination of both a laser drill and a spectrometer is a common practice for collecting/processing data on celestial bodies, which as a tested product will increase the likelihood of mission success. Utilizing a proven instrument is necessary, as the current consideration for the experiment has not been implemented yet on Mars.

In the current development, the instruments present on the experiment will greatly reflect the SuperCam, and will have a predicted combined mass of 10.4 kilograms, a power usage of 17.9 watts, and occupy a volume of 38cm x 24cm x 19cm (NASA Mars Perseverance Rover, 2020).

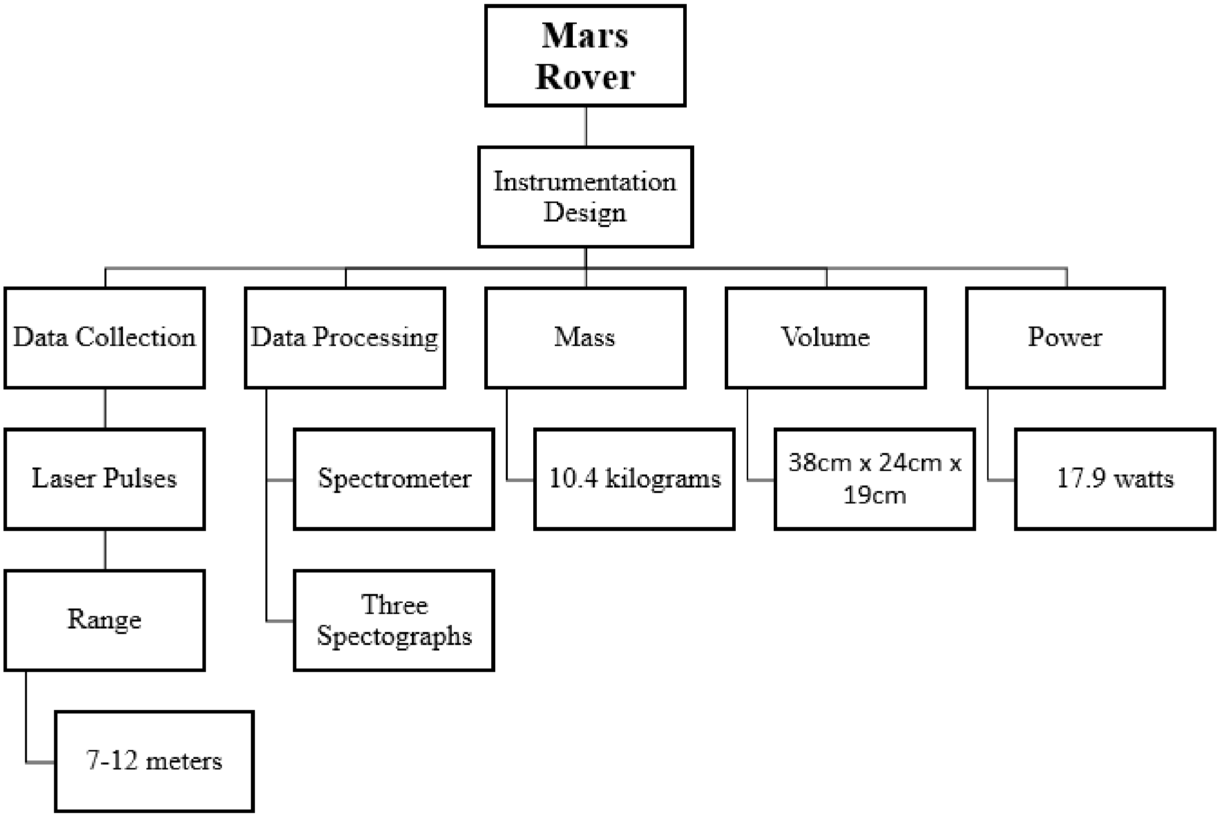


Figure 4: *Payload and Science Instrumentation Work Breakdown Structure*

2. Evolution of Project

2.1. Evolution of Mission Experiment Plan

Oriented towards human-exploration, the primary objective of this mission is to utilize laser-pulse drilling along with a laser spectrometer to collect data, which will then be sent back to the science team on Earth for further analysis. Given that the mission is not focused on finding ice itself, but rather testing the suitability of ice for human-exploration purposes, a landing spot has been pre-chosen. The landing spot is Arcadia Planitia, specifically the lower areas near Erebus Montes. During the creation of the final mission experiment plan, the team considered several landing sites, what type of science will be conducted on the Martian surface, as well as whether or not the science will be geared towards human-exploration or astrobiology.

The landing sites that were being considered included: Arcadia Planitia near Erebus Montes, Deutronilus Mensae near Hellas Planitia, and Nilosyrtis Mensae near Moreaux Crater. The team ultimately decided on Arcadia Planitia due to its high consistency of ice relative to other northern mid-latitudes, as well as its geographical flow-like features which suggest stagnated terrestrial ice streams below the surface. As far as the science that will be conducted, the team is still choosing between a couple of options, but leaning towards collecting and characterizing water ice below the martian subsurface. Other options that are currently being considered include: characterizing the water ice via temperature readings and measuring radiation levels beneath the ice. Finally, after a week of deliberation, it was finalized that the mission will be focused on human-exploration, rather than astrobiology. This final decision was made in order to aid and assist humankind’s safety as it treks into the cosmos. Putting humans on Mars exponentially increases the amount of science that can be conducted on the surface. Before this can happen, however, it must be ensured that future martians will have the in-situ resources that are necessary to live and thrive on the Red Planet.

2.2. Evolution of Deployment Scheme and Vehicle Design

Power

Iteration #1: Instruments could be transported in a solar array storage container. Upon landing the container unit would open to unfold an origami-like mechanism (size dependent on dimensions of instrumentation) and act as a landing platform.

Issues that come with solar arrays: weather conditions (dust storm), long/latitude, dust (can be solved with air blowing or mechanical wiping system), and possible high cost. Benefit: less volume.

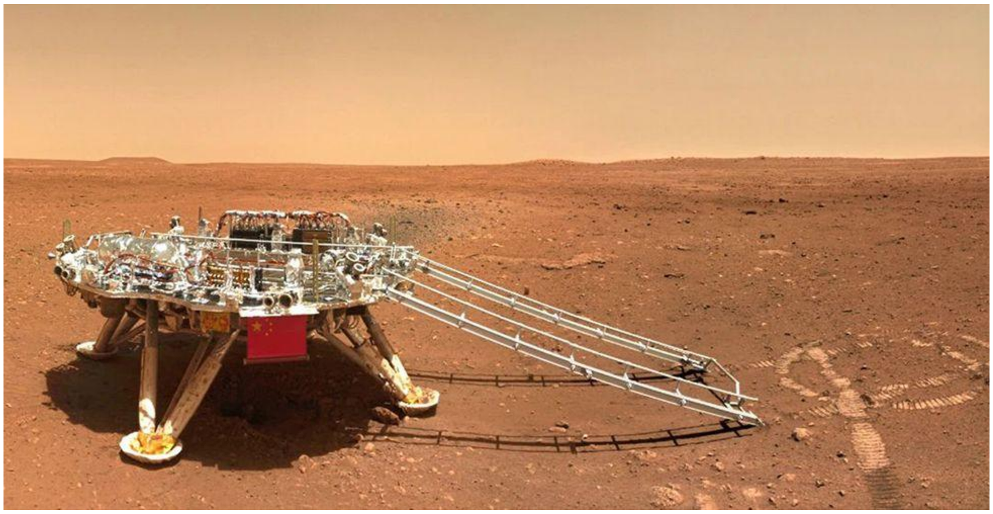


Figure 5. *China National Space agency's Zhurong Mars rover landing platform.*

Iteration #2: Back up/alternate power source in addition to electric (solar) busses: RTGs to provide electrical power from radioactive decay of plutonium-238 Radioisotope Thermoelectric Generators. Another consideration would be a lithium battery as another option for redundancy power as a backup to solar busses.

Iteration #3: Only radioisotopic thermoelectric power. This option annexes solar which allows the vehicle to be less susceptible to external factors on Mars such as storms and lack of sunlight. It brings with it three primary constraints: weight, power output and time.

MOST RTGS ARE 1 TO 2 METERS LONG, AND 0.5 TO 1 METER WIDE. OF COURSE, THESE MEASUREMENTS CHANGE IN EVERY DESIGN, BUT MOST RTGS BUILT TO DATE FOLLOW A RELATIVELY SIMILAR DESIGN PATTERN. WITH ALL ISOTOPES, THERMAL PROTECTION AND CASING ON BOARD, MOST RTGS RANGE FROM 35 TO 50 KILOGRAMS.

Figure 6. *University of Calgary RTG perspective of mass and volume.*

Power iteration closing notes:

According to the University of Calgary, an average RTG mass ranges from 35 kg to 50 kg. This range greatly exceeds our missions mass restraints, and in parallel, volume restrictions. We will need to implement a smaller, lighter RTG which by proxy means it will have a shorter power life AND lower output.

Vehicle

Iteration #1: Tracked rover. In theory, tracks provide extreme stability and ability for traversing rough terrain. A tracked style rover allows for weight to be spread over a wide area, reducing surface pressure which lessens the chances of getting stuck in soft terrain environments. ARES-42 is not a heavy rover, at 30 kg, this makes one of the largest benefits of tracks an unused benefit. The largest downfall of a tracked rover, by far, is the fact that if one track link fails, our rover is rendered useless. Introducing this severely critical failure point is why this design has been omitted.

Figure 7: *NASA testing a tracked rover in Greenland.*

Iteration #2: Wheeled rover. Similar in design to previously deployed Mars rovers such as Curiosity and Perseverance, though redesigned to fit customer volumetric constraints. A six wheeled rover with a primary drive differential at the center, interconnecting the drive wheels. The benefit of this design is that it has long been tested by prior rovers, so the likelihood of success with this design is high. The reason this design was not selected is because with fixed wheels, we are unable to meet the volumetric restrictions for the mission.

Figure 8. *Digital model of Perseverance, a larger form rover which is powered via RTG and designed by the Jet Propulsion Laboratory.*

Iteration #3: Foldable rover. Benefits with this rover is that we can have a larger footprint on Mars while packaging it in a smaller form factor for transport. Downsides include more intricate electronics, and the addition of another failure point (being the wheelS unfolding upon deployment from the lander to the martian surface). This is the design we selected because the likelihood of the wheels unfolding is low, and this rover has all of the benefits of the aforementioned designs while meeting our volume requirement.

Figure 9. *Design iteration for the Sorato Lunar Rover, designed by ISpace.*

2.3. Evolution of Payload and Science Instrumentation

In order to select the necessary science instrumentation to characterize ice sites and assess suitability for future usage, the team proposes laser-pulse drilling and laser spectrometry as the most plausible method to collect relevant data. Remote data collection efforts like Mars SWIM informed the landing site decision of Arcadia Planitia toward Erebus Montes, a region expected to have plentiful ice deposits. Currently, the composition and finer details of the ice at these spots are unknown-this is where ARES-42 comes in to expand current knowledge on sites that may be suitable to launch future human exploration missions.

Just like the SuperCam instrument aboard the Perseverance Rover, the ARES-42 payload will include a similar SuperCam with a laser-induced breakdown spectrometer (abbreviated LIBS). LIBS utilizes a high energy laser pulse at 1064 nm to produce light emitting plasma, returning emission spectra lines of elements in samples of interest. Based on successes from LIBS on Perseverance, the main advantages include analysis of element composition without sample preparation, rapid analysis times, low power consumption, and low detection limits for trace elements at targets up to 7 meters away. For human exploration purposes, it is crucial to detect trace elements at ppb or ppm concentrations in order to assess the suitability of the ice at Arcadia Planitia.

For data acquisition and analysis, a remote micro-imager (RMI) is also part of the SuperCam instrument suite. The RMI produces emission line spectra and analyzes the data generated to determine chemical and molecular composition. Through multiple measurements at a single location, the sample's geochemistry and mineral content can be determined directly. Furthermore, since SuperCam can collect measurements without having to mechanically operate an arm to manipulate the target, it can analyze samples faster and with higher confidence than previous iterations. In total, the hardware of SuperCam has a mass of 10.6 kilograms and a volume of 38 cm x 24 cm x 19 cm.

Instruments Aboard MCA Payload

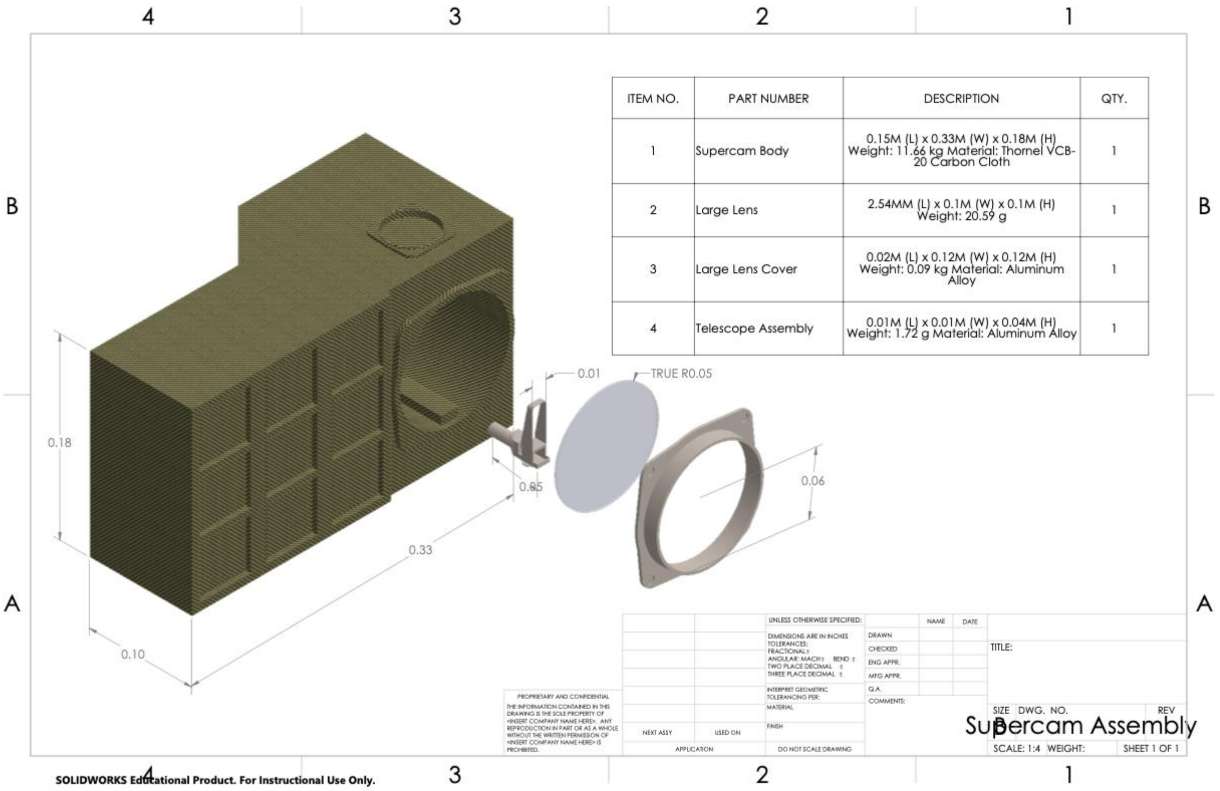
Iteration #1:
NASA's InSight Lander boasts a burrowing heat probe similar to the concept of an martian ice melting tool ARES-42 considers utilizing.

Figure 10. *In this image from Oct. 26, 2019, the InSight Mars lander's heat probe, or "mole," is seen after backing about halfway out of the hole it had burrowed. (Image credit: NASA/JPL-Caltech). Science.com*

Iteration #2:
Thermal drilling on Earth utilizes heat to core ice samples, ARES-42 is conceptualizing tools that will remove ice or melt it into its water phase for research.

Figure 11. *The drill head of the thermal drill. Credit: Tony Wendricks. Icedrill.org*

Iteration #3:
Laser spectroscopy to collect spectroscopy data on heated samples to determine composition. Laser pulses are used to emit photons towards a sample of soil for example, where the photons are then collected and transmitted through optical fibers for analysis. A single of multiple spectrometers can then be used to analyze the light as it is dispersed into their mirrors.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Supercam Body	0.15M (L) x 0.33M (W) x 0.18M (H) Weight: 11.66 kg Material: Thornel VCB-20 Carbon Cloth	1
2	Large Lens	2.54MM (L) x 0.1M (W) x 0.1M (H) Weight: 20.59 g	1
3	Large Lens Cover	0.02M (L) x 0.12M (W) x 0.12M (H) Weight: 0.09 kg Material: Aluminum Alloy	1
4	Telescope Assembly	0.01M (L) x 0.01M (W) x 0.04M (H) Weight: 1.72 g Material: Aluminum Alloy	1

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

Figure 12. *Solidworks CAD 3D model of SuperCam instrument.*

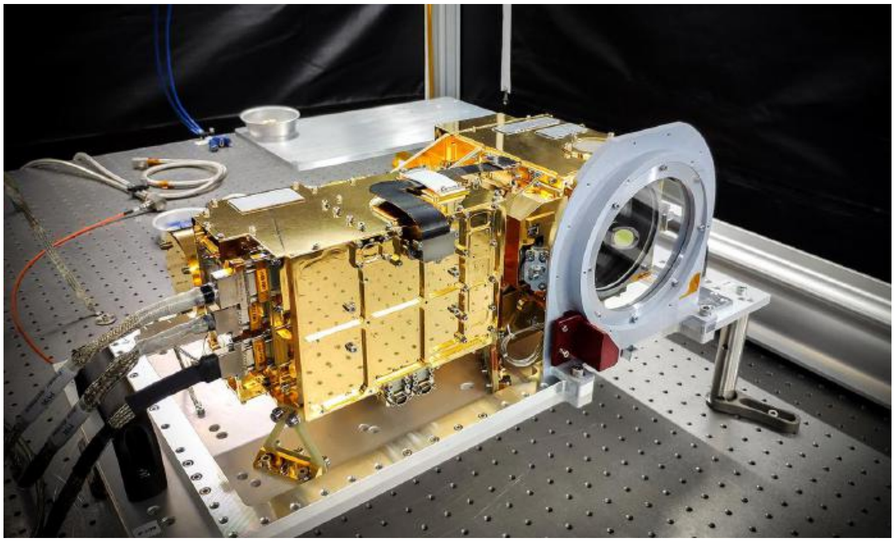


Figure 13. *SuperCam instrument aboard NASA's Perseverance Rover. Credit: NASA/JPL-Caltech. nasa.gov.*

3. Deployment Scheme and Vehicle Design

3.1. Selection, Design, and Verification

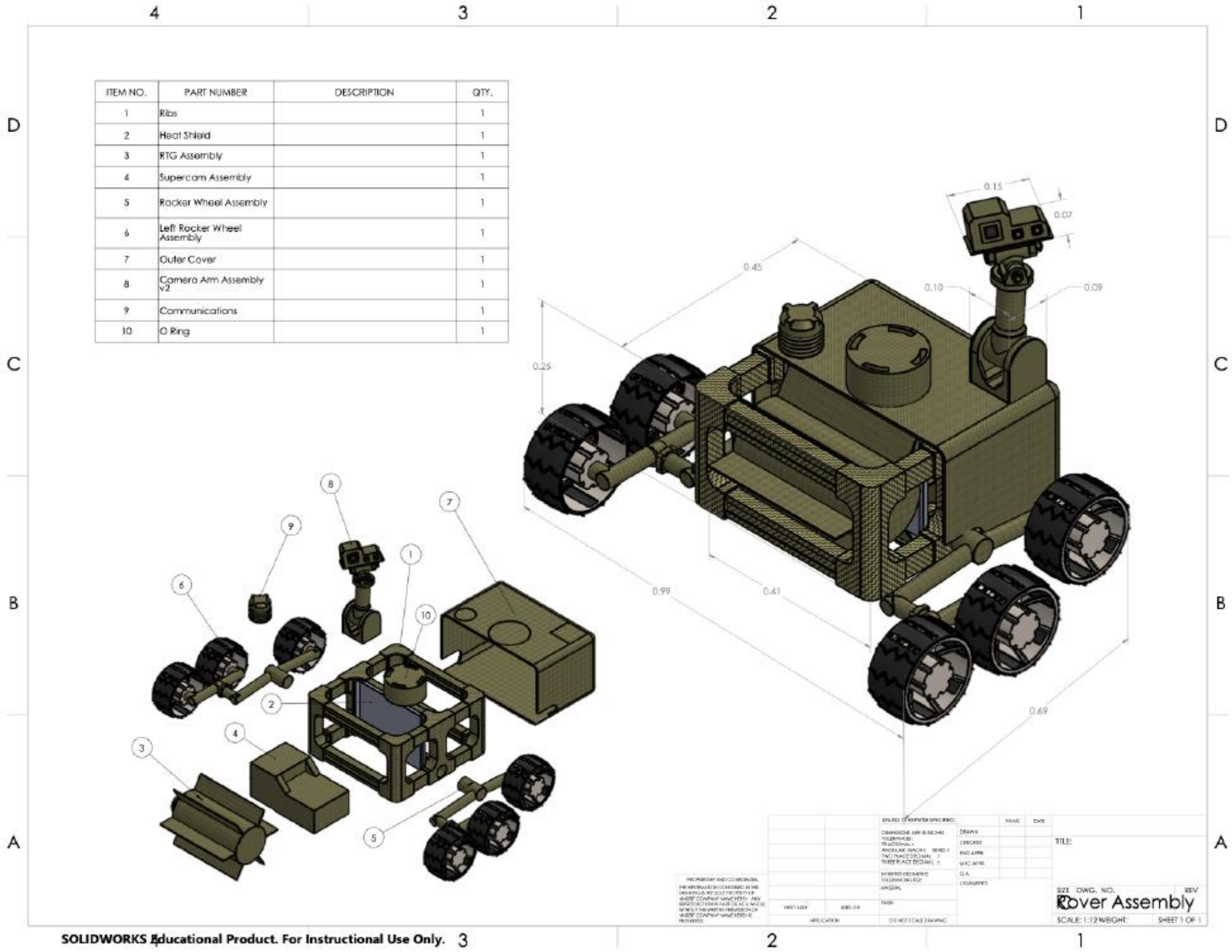
3.1.1. System Overview

The rover will consist of 6 wheels, suspension, body/frame, the Theia instrument, and cameras to give visuals to the control room on earth. The rover itself is 0.62 m (L) x 0.74 m (W) x 0.56 m (H) and will be made out of T800 Carbon Fiber (Thornel VCB-20 Carbon Cloth used for reference in solidworks). The rover deployment will have the frame connected to the lander by the ring that will be implemented onto the rover and will carry a maximum of 30kgs. The lander will use a crane to deploy the rover using the ring connection that is built into the body of the rover and this will allow the rover to conduct the experiment.

The important communication aspect of the rover will be to have Ultra-High Frequency Antennas to communicate with the landing craft after deployment. This specific component will allow us to have a reliable connection to make sure that the rover is getting commands to execute the experiment and reduce communication failure. Communication failure would be either the lander not being able to talk to ARES-42 and thus not receiving commands or failing to communicate directly with Earth and having total communication failure. As a backup failsafe, the rover will also contain a Low Gain Antenna to communicate through deep space and for redundancy.

The power supply will be a Radio Isotopic Thermoelectric Generator to guarantee that the rover has enough power to operate as well as reducing the failure due to the environment. Reducing failure was the main reason that RTG was chosen over solar panels and this allows us to have the power supply to heat the rover as well. This power supply will also allow the mission to have an extended life for the mission and allow the team to continue to collect data.

The main instrument, Theia, is connected to the frame of the rover by having the instrument mounted to the bottom of the body (belly mounted). The equivalent instrument on Perseverance is arm mounted and that takes a lot of resources and materials, to reduce weight and cost the decision was made to remove the arm. The camera will also be mounted on top of the rover body with a pivoting arm to help navigate and allow those in the control room to see what the rover is facing. The camera was chosen to have an arm to make sure that the rover would have a 360° view and give the best possible chance of choosing the best route to maneuver the rover.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Ribs		1
2	Heat Shield		1
3	RTG Assembly		1
4	Supercam Assembly		1
5	Rocker Wheel Assembly		1
6	Left Rocker Wheel Assembly		1
7	Outer Cover		1
8	Camera Arm Assembly v2		1
9	Communications		1
10	O Ring		1

Figure 14. *Solidworks CAD 3D model of ARES-42 entire Rover body assembly.*

3.1.2. Subsystem Overview

Rover Deployment System (RDS)

Upon touchdown on the Martian surface, the rover will be safely stowed inside of the main lander. **For the rover to be successfully deployed, it will be hoisted by a crane integrated on the lander itself out of the meter cube in which it has been stowed for the trip**. The rover will have a half ring with a diameter of 6 inches (15.24 cm) in diameter, constructed out of carbon fiber and manufactured in parallel with the rover body. Thus, the ring is integrated into the rovers body during the manufacturing process of the carbon fiber body, and is therefore totally integrated into the structure of the body. Its construction of T800 carbon fiber brings our chance of breaking under our 30kg load highly unlikely. The characteristics of the T800 carbon fiber allow for a 1,107 °C of margin in terms of breaking down the carbon fiber, as compared to the EDL’s expected maximum temperature of roughly 2,550 °C (Perseverence’s max temp on EDL).

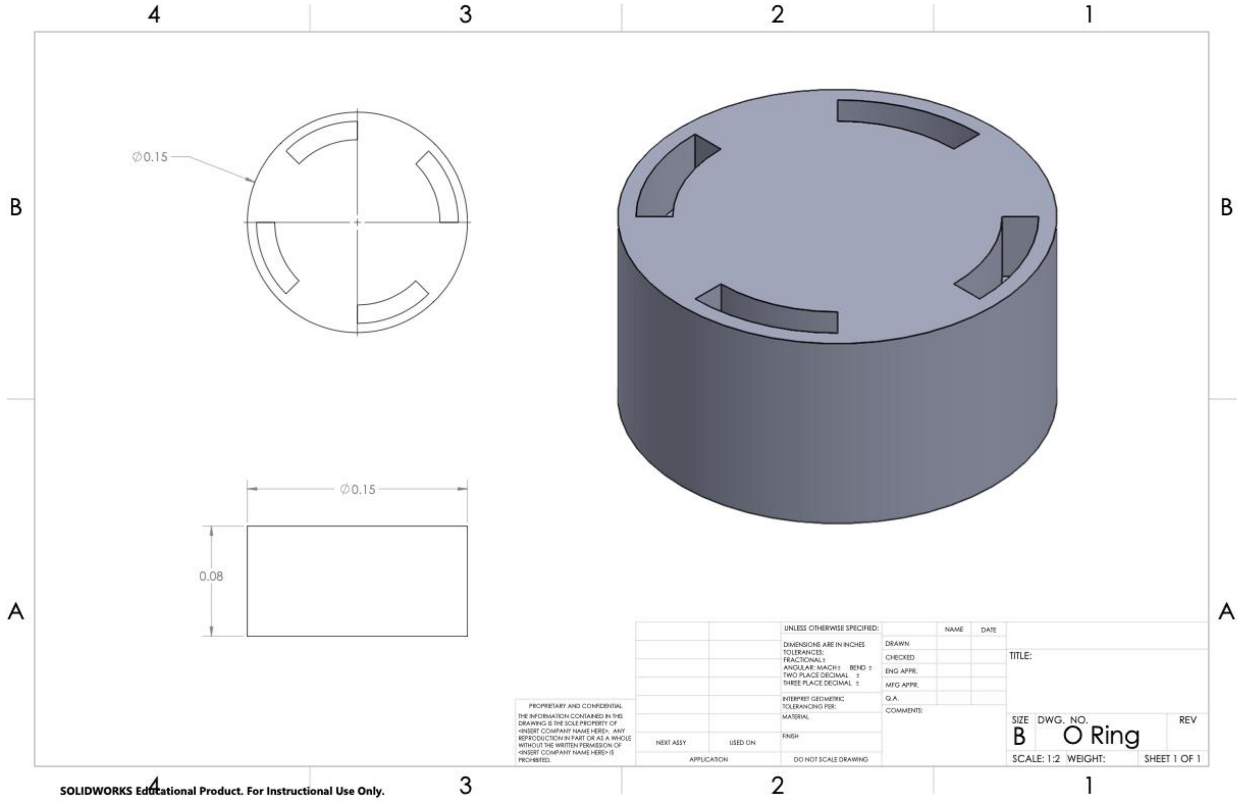


Figure 16. *CAD drawing of ARES-42 deployment Ring*

Communications

The perspective of the engineering team is to provide the communications system (as designed by the science team to meet their requirements for data transmittal) with adequate power and function at all times. This means ensuring software is optimized for system power selection at correct time intervals upon the instrument's request. The UHF system and supporting antennae will utilize 14W at maximum when transmitting data, which is possible both when the rover is moving and also when the rover is collecting samples. There is no time when the rover will utilize a maximum required wattage for movements and taking a sample, and this will be safeguarded in the ARES-42 systems software. Communications are further detailed in section 4.1.2. subsystem overview of this document.

Power

The rover will utilize a miniature radio isotopic thermoelectric generator (RTG) as a central source. The driving element will be plutonium-238 (Pu-238). Pu-238 offers a half life of 87.7 years and a very reasonable power density of .57 watts per gram, not to mention lower shielding requirements than other elements. Based on this half life, we can use the following equation to calculate effective power production loss over time:

$$1 - (½)^{(1/half\ life)}$$

Therefore, from launch, we will burn 0.787% per earth calendar year from the date of manufacture. Our RTG will utilize 1.0kg of Pu-238 which gives us an effective available supplied wattage of exactly 40.3 W. From the previous calculation, we can also derive the fact that we will lose .317161 W per year from the date of RTG creation. For example, after 15.7 earth years, the RTG will have lost a total of 5 W of power output, in other words a remaining effective output wattage of 35.3 W. At 40.3 W, there is ample overhead to move the rover, idle the instrument instrument, and power the RVS along with all other electronics onboard at once. Our maximum, required wattage for what is deemed as standard operations under our mission objective is 36 W, therefore under current operations, our rover would autonomously need to change the way which it operates in 13.55 earth years which gives ARES-42 more than enough time to successfully collect all desired samples.

The RTG outputs 525 W of heat as a byproduct. The RTG is oriented in the aft section of the rover, and is completely vented to the atmosphere, with the hot sides facing outward from the starboard and port sides. The heat source module has multiple radiation fins on it, for direct venting to the atmosphere and dissipation of the 525 W of heat through convection. With the rover being positioned directly against the forward compartment, it allows for natural heating of our rovers' enclosed area, which is another benefit of this design.

Lastly, overpowering is a concern that must be dealt with. As a minor correction parameter, a large 30 W dimmable LED will be placed on the top of the rover and it will emit extra wattage on an as needed purge basis up to 30 W. This eliminates the need for more convection cooling, which is necessary.

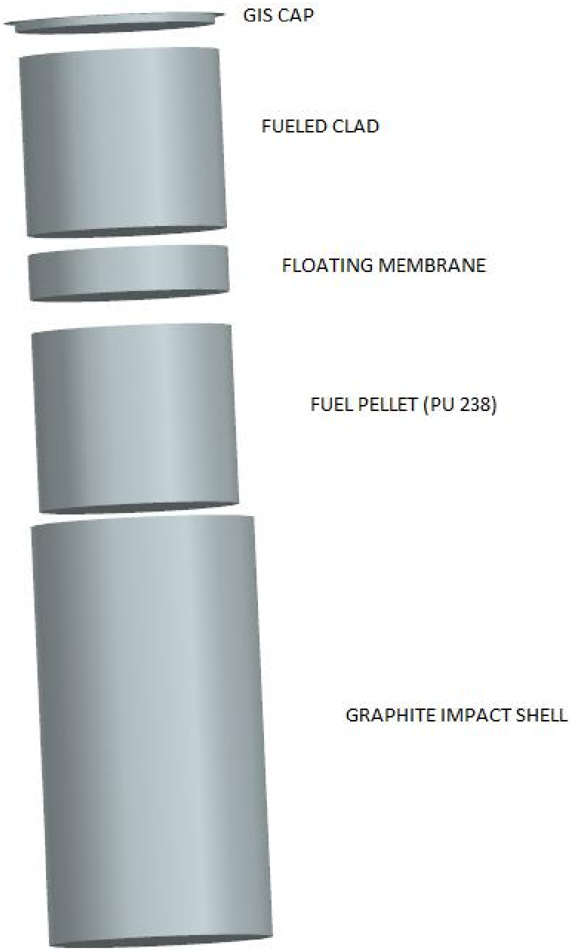
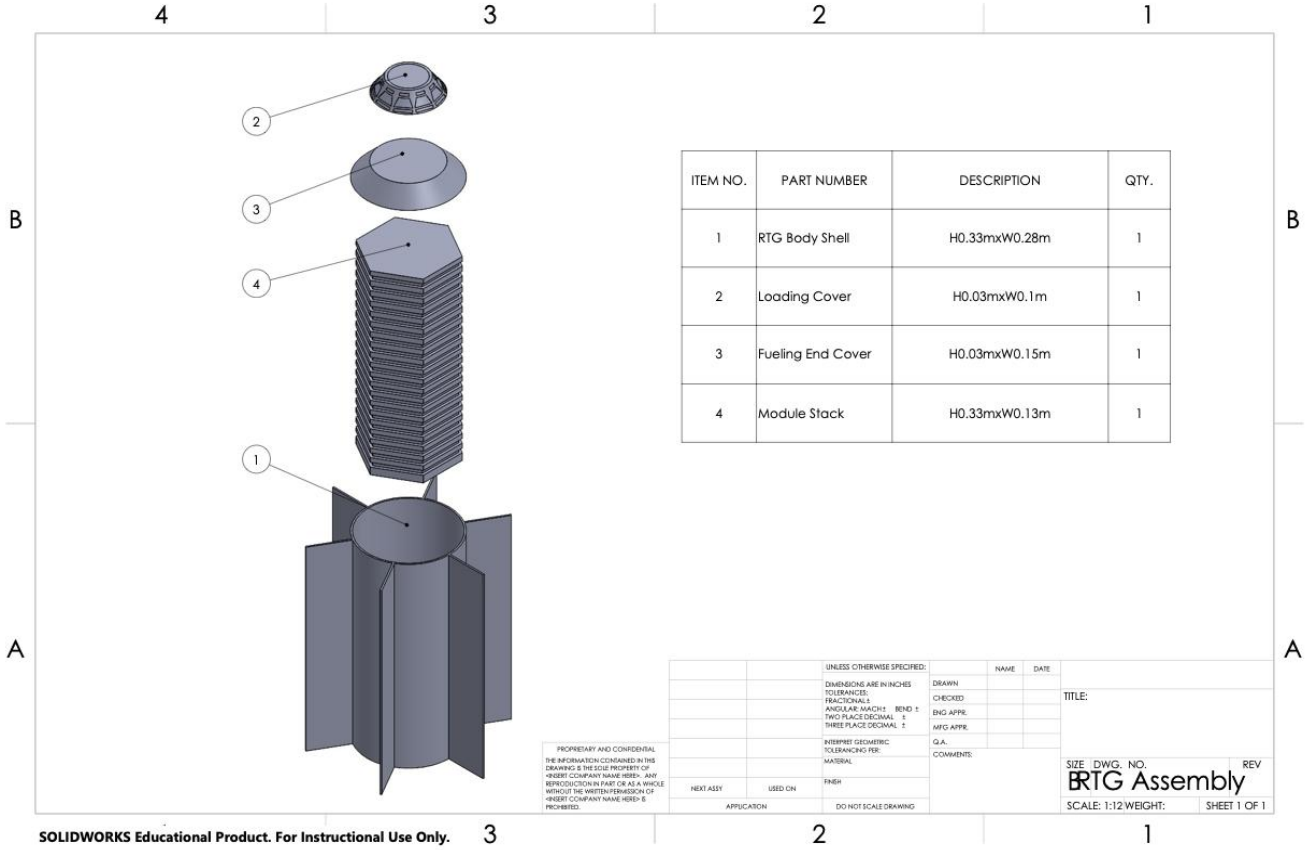


Figure 17. *NX Model of heat source module breakdown*

Figure 18. *Example of a Radioisotope Thermal Generator from the Department of Nuclear Energy*

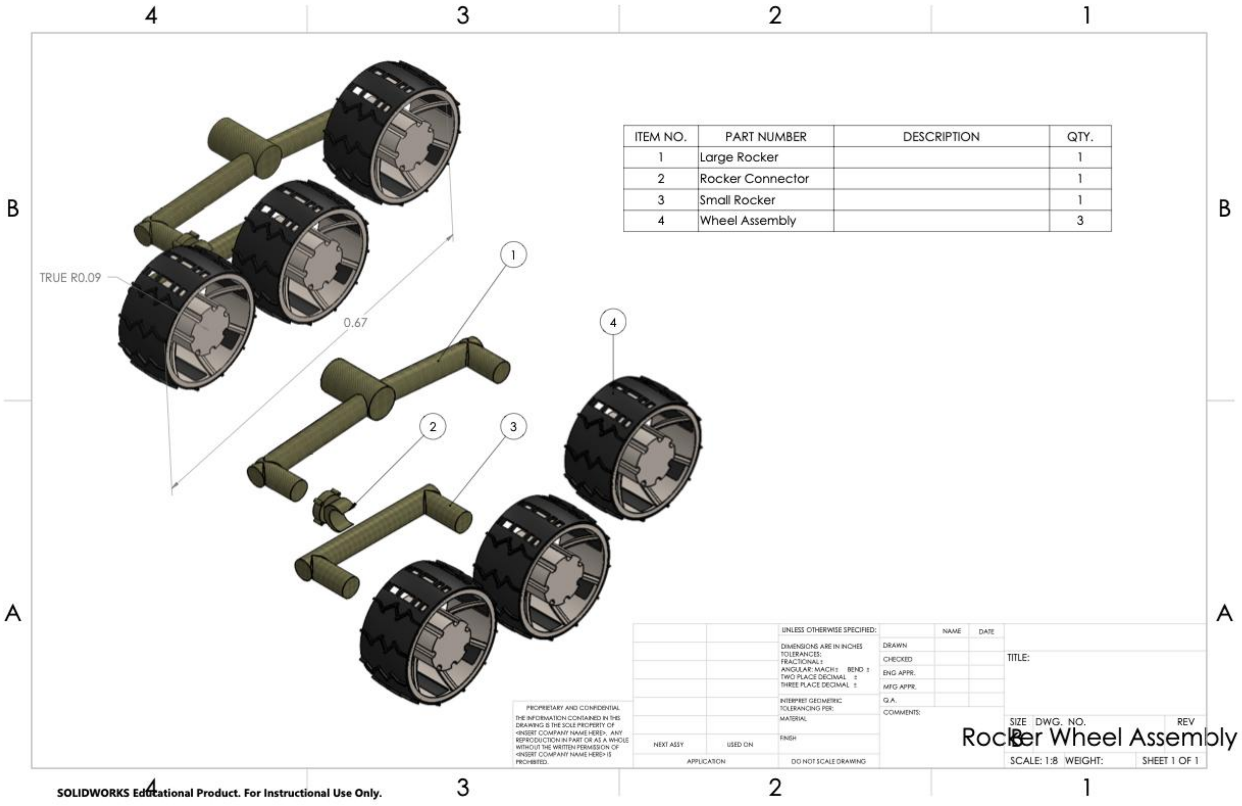


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RTG Body Shell	H0.33mxW0.28m	1
2	Loading Cover	H0.03mxW0.1m	1
3	Fueling End Cover	H0.03mxW0.15m	1
4	Module Stack	H0.33mxW0.13m	1

Figure 19. *Solidworks CAD 3D model of ARES-42 Radioisotope Thermal Generator assembly*

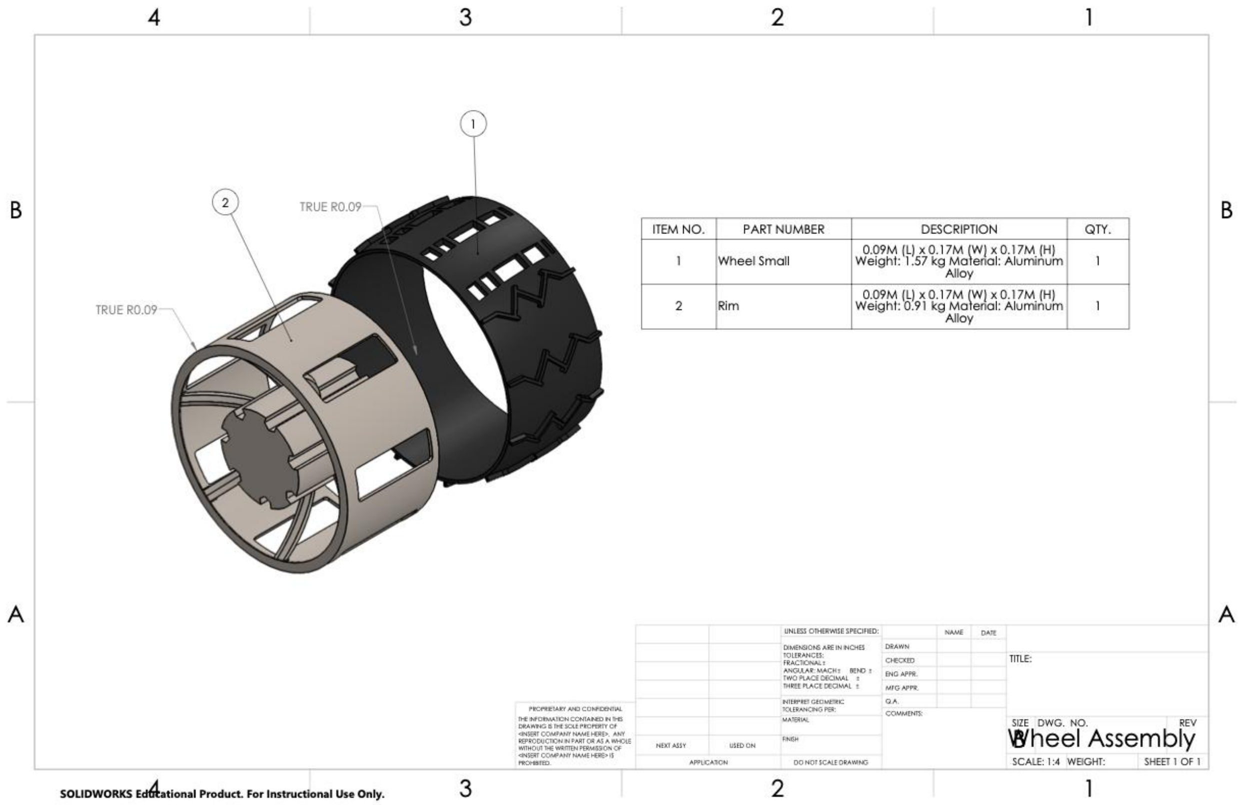
Mobility

The rover will rely on six constant points of contact on the Martian surface. A six point system gives margin for wheel failure, which is not a totally unlikely occurrence. Furthermore, six points gives the rover more stability and ability to use a rocker style suspension system which has been proven many times over on rovers from Sojourner to Perseverance. The vessel will be carbon fiber, titanium ribbed wheels. The forward four will be fixed and have primary drive shafts to our center vehicle torque vectoring differential, and the rear two will be for stability only (no drive gearing, same dimensions as the forward four). The rear pair will unfold in the process of the RDS phase. All wheels are capable of a 360-degree pivot for improved maneuvering characteristics. The wheel design and power configuration will allow for the rover to travel a maximum speed of 1.5 cm per second.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Large Rocker		1
2	Rocker Connector		1
3	Small Rocker		1
4	Wheel Assembly		3

Figure 20. *Solidworks CAD 3D model of ARES-42 rocker & wheel assembly*

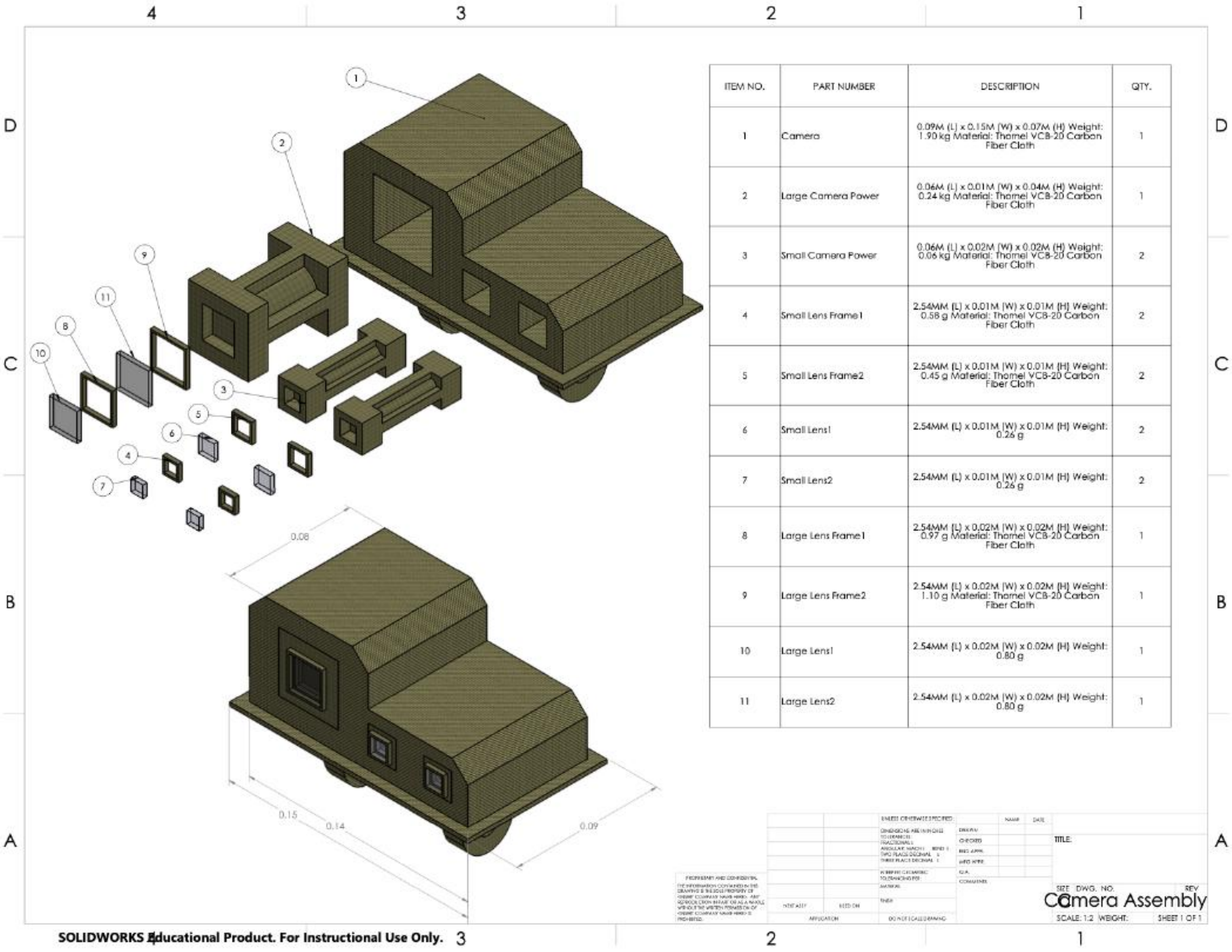


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Wheel Small	0.09M (L) x 0.17M (W) x 0.17M (H) Weight: 1.57 kg Material: Aluminum Alloy	1
2	Rim	0.09M (L) x 0.17M (W) x 0.17M (H) Weight: 0.91 kg Material: Aluminum Alloy	1

Figure 21. *Solidworks CAD 3D model of ARES-42 wheel assembly*

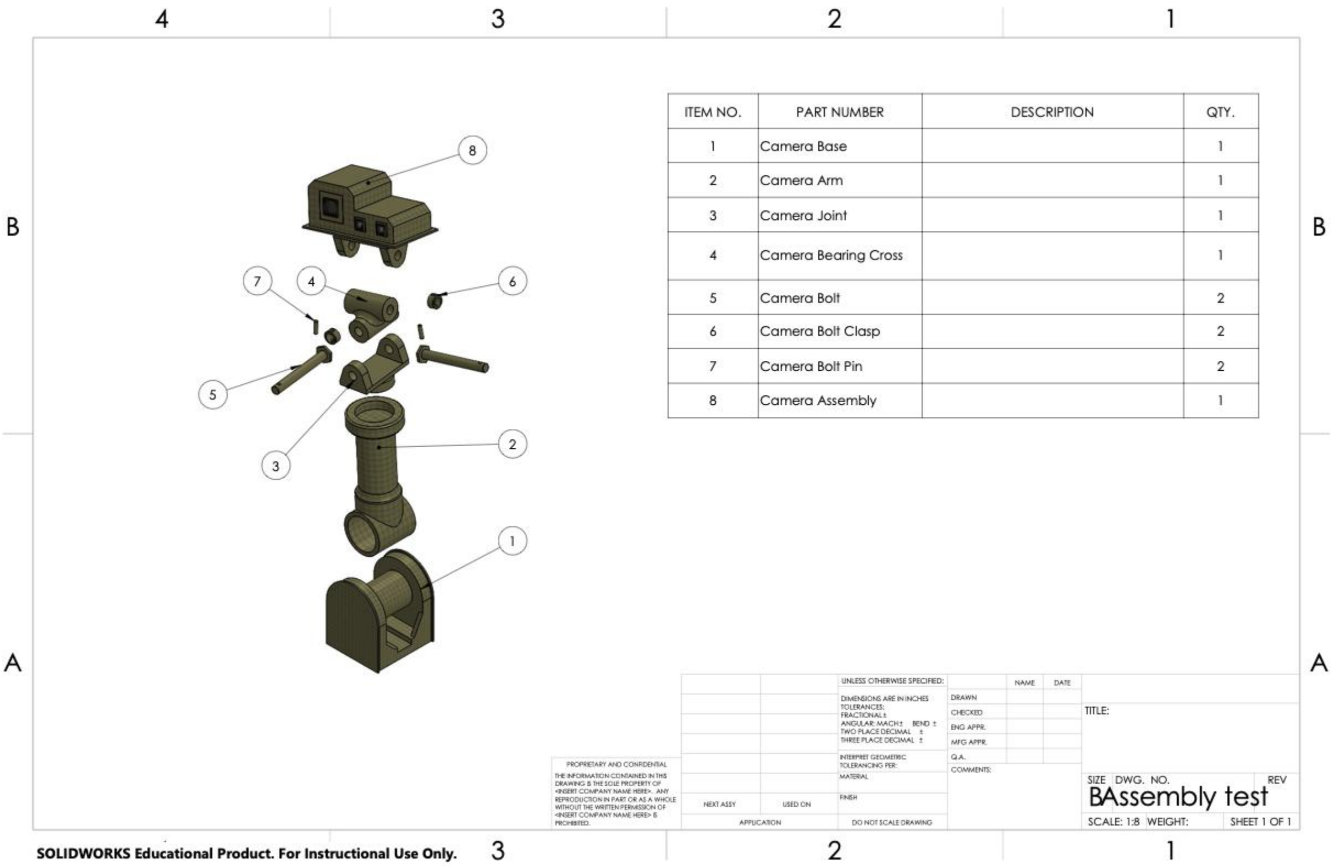
Rover Vision System (RVS)

The rover will have two, adjacently mounted navigation cameras for autonomous navigation. One top mounted on the forward edge of the rover for analysis up to 15 meters ahead of current location, and one mounted on the front face of the rover looking downward for closer skimming of obstacles directly in front of the rover. This adjacent mounting arrangement gives the rover a complete forward-facing visual and the ability to understand how the wheels will react to what is ahead. Having two cameras not only gives the decision making software a more complete picture for more competent decisions on path selection, but also removes a critical failure point in the form of a RVS camera failure, as navigation can continue with a single camera, despite the forward camera being mounted facing forward). The RVS cameras provide inputs to our autonomous decision making software in order to maneuver the rover entirely on its own. The RVS has an effective identification range of 25 meters and an image resolution of 5120x3840 pixels, and an image output resolution of 20 megapixel. Power allowance for the RVS is included in the 4W for required system power at all times.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Camera	0.09M (L) x 0.15M (W) x 0.07M (H) Weight: 1.90 kg Material: Thornel VCB-20 Carbon Fiber Cloth	1
2	Large Camera Power	0.06M (L) x 0.01M (W) x 0.04M (H) Weight: 0.24 kg Material: Thornel VCB-20 Carbon Fiber Cloth	1
3	Small Camera Power	0.06M (L) x 0.02M (W) x 0.02M (H) Weight: 0.06 kg Material: Thornel VCB-20 Carbon Fiber Cloth	2
4	Small Lens Frame1	2.54MM (L) x 0.01M (W) x 0.01M (H) Weight: 0.58 g Material: Thornel VCB-20 Carbon Fiber Cloth	2
5	Small Lens Frame2	2.54MM (L) x 0.01M (W) x 0.01M (H) Weight: 0.45 g Material: Thornel VCB-20 Carbon Fiber Cloth	2
6	Small Lens1	2.54MM (L) x 0.01M (W) x 0.01M (H) Weight: 0.26 g	2
7	Small Lens2	2.54MM (L) x 0.01M (W) x 0.01M (H) Weight: 0.26 g	2
8	Large Lens Frame1	2.54MM (L) x 0.02M (W) x 0.02M (H) Weight: 0.97 g Material: Thornel VCB-20 Carbon Fiber Cloth	1
9	Large Lens Frame2	2.54MM (L) x 0.02M (W) x 0.02M (H) Weight: 1.10 g Material: Thornel VCB-20 Carbon Fiber Cloth	1
10	Large Lens1	2.54MM (L) x 0.02M (W) x 0.02M (H) Weight: 0.80 g	1
11	Large Lens2	2.54MM (L) x 0.02M (W) x 0.02M (H) Weight: 0.80 g	1

Figure 22. *Solidworks CAD 3D model of ARES-42 camera assembly*



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Camera Base		1
2	Camera Arm		1
3	Camera Joint		1
4	Camera Bearing Cross		1
5	Camera Bolt		2
6	Camera Bolt Clasp		2
7	Camera Bolt Pin		2
8	Camera Assembly		1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
SIZE B
DWG. NO. Assembly test
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

SOLIDWORKS Educational Product. For Instructional Use Only.

Figure 23. *Solidworks CAD 3D model of ARES-42 camera assembly*

3.1.3. Dimensioned CAD Drawing of Entire Assembly

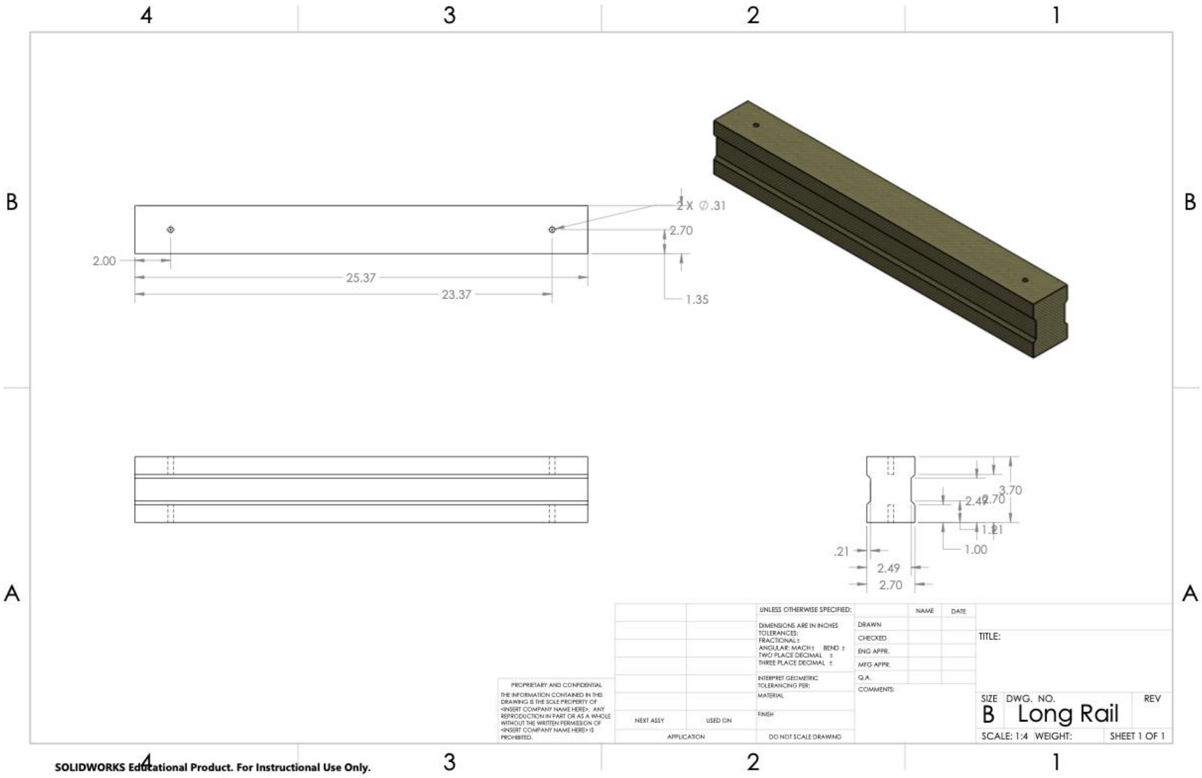


Figure 24. *CAD drawing of Long rail that supports the body structure of the rover. 0.64 m (L) x 0.07 m (W) x 0.09 m (H) Material: Thornel VCB-20 Carbon Cloth*

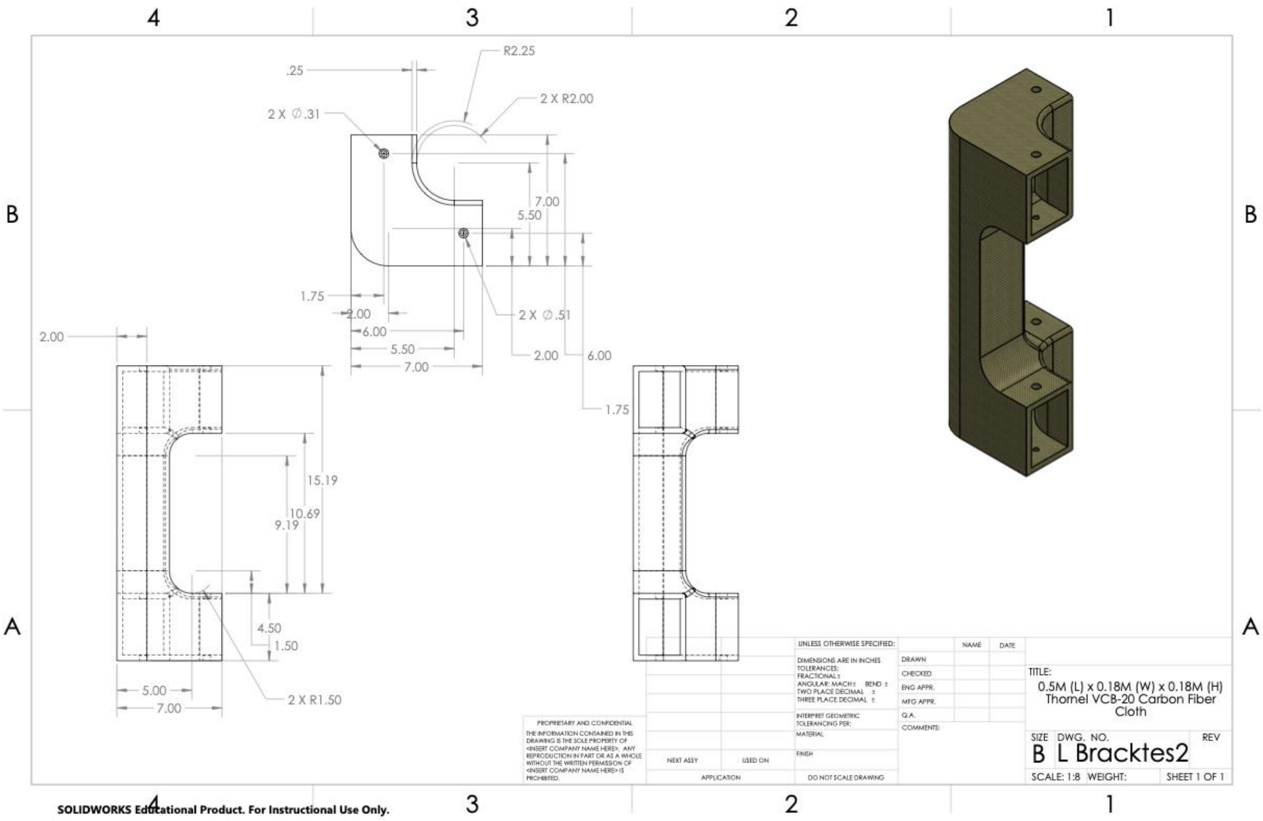


Figure 25. *CAD drawing of L brackets connecting the bones of the rover body. 0.5 m (L) x 0.18 m (W) x 0.18 m (H) Material: Thornel VCB-20 Carbon Cloth*

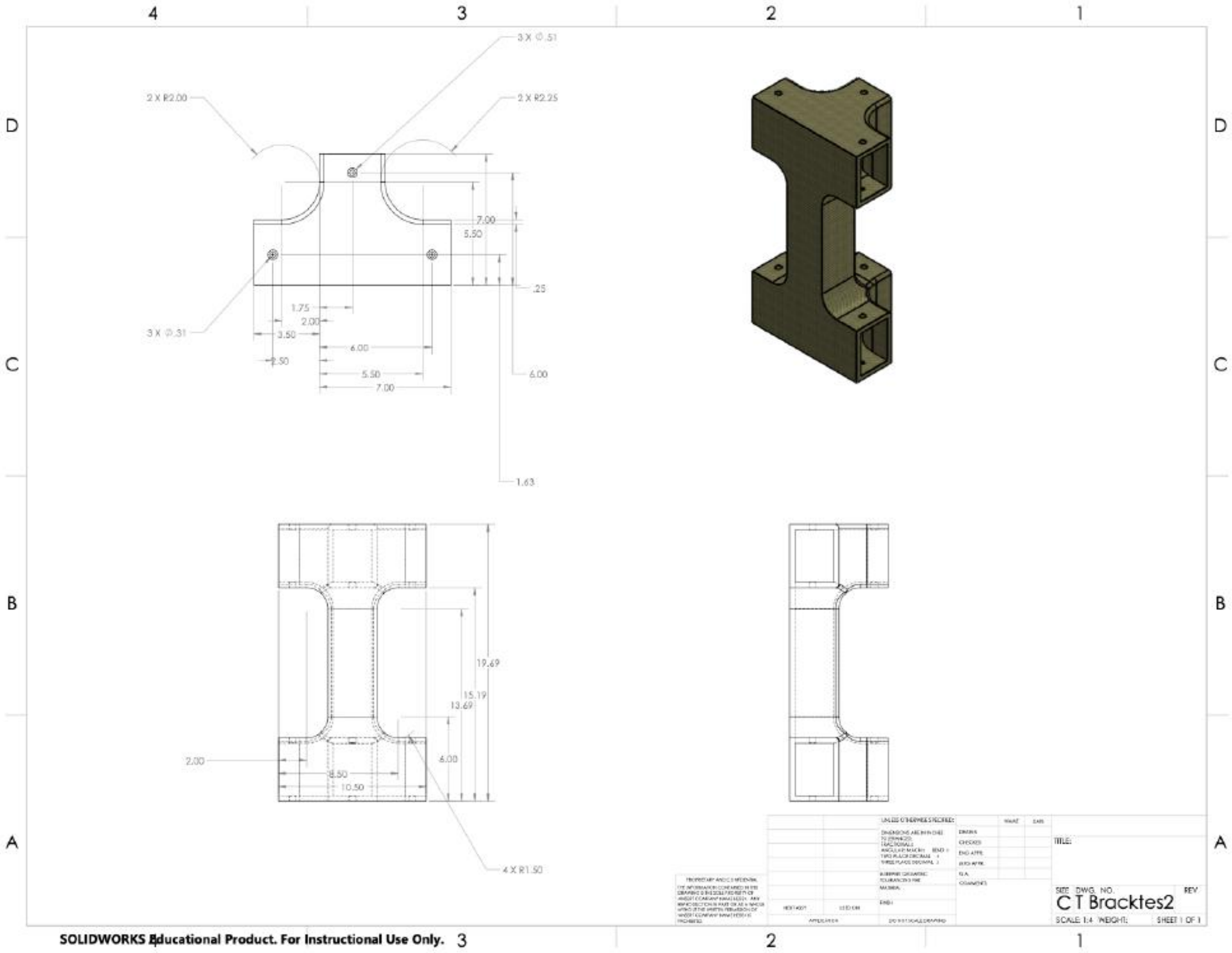
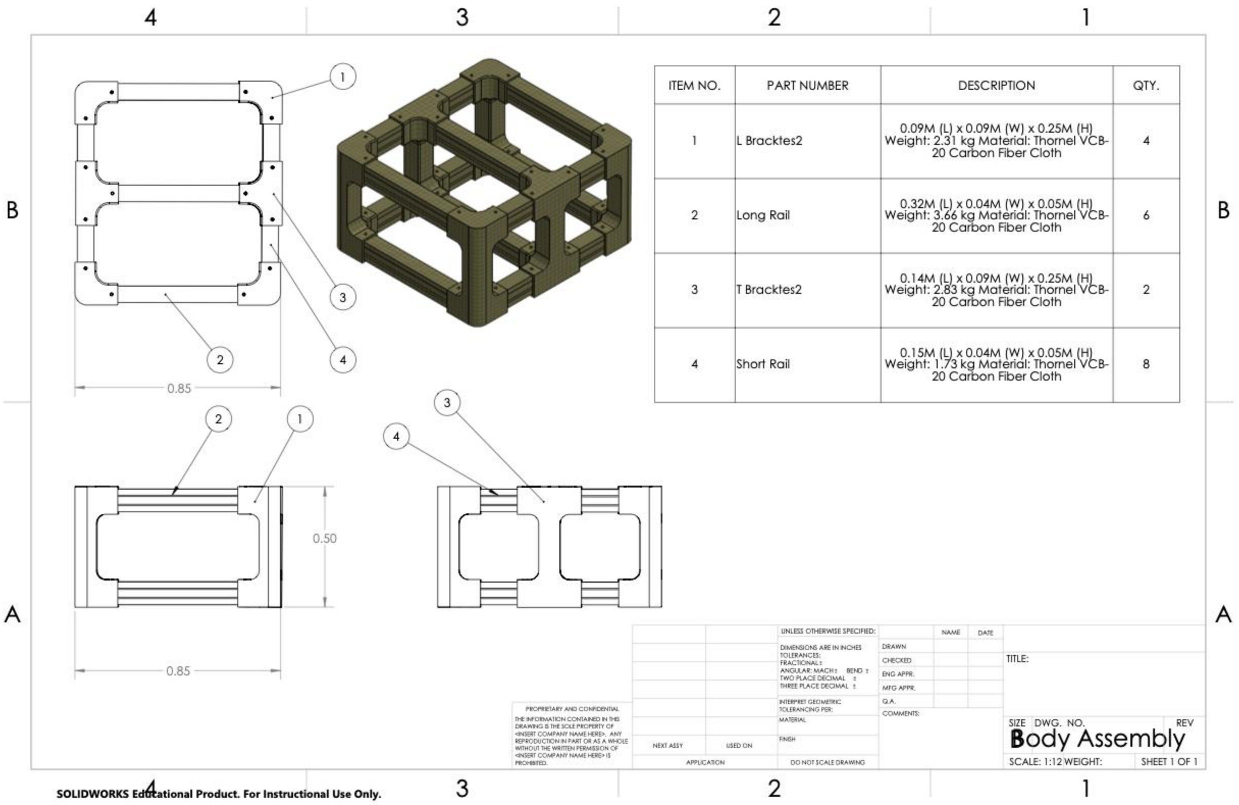


Figure 26. *CAD drawing of T bracket connecting the bones of the rover body. 0.5 m (L) x 0.36 m (W) x 0.18 m (H) Material: Thornel VCB-20 Carbon Cloth*



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	L Bracktes2	0.09M (L) x 0.09M (W) x 0.25M (H) Weight: 2.31 kg Material: Thornel VCB-20 Carbon Fiber Cloth	4
2	Long Rail	0.32M (L) x 0.04M (W) x 0.05M (H) Weight: 3.66 kg Material: Thornel VCB-20 Carbon Fiber Cloth	6
3	T Bracktes2	0.14M (L) x 0.09M (W) x 0.25M (H) Weight: 2.83 kg Material: Thornel VCB-20 Carbon Fiber Cloth	2
4	Short Rail	0.15M (L) x 0.04M (W) x 0.05M (H) Weight: 1.73 kg Material: Thornel VCB-20 Carbon Fiber Cloth	8

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

Figure 27. *CAD drawing of ARES-42 rover body assembly connecting the bones of the rover body. 0.62 m (L) x 0.74 m (W) x 0.56 m (H) Weight: 16.30 kg Material: Thornel VCB-20 Carbon Cloth*

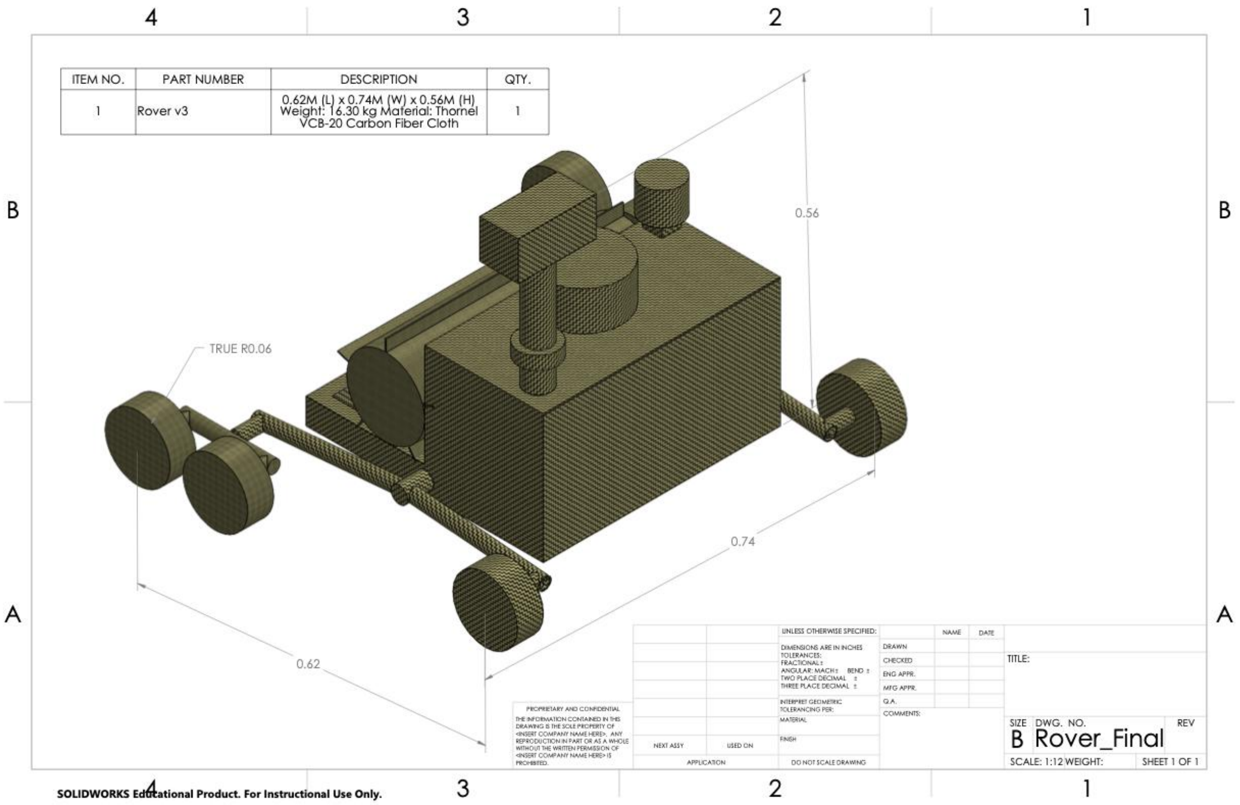


Figure 28. *CAD drawing of entire ARES-42 rover assembly 0.62 m (L) x 0.74 m (W) x 0.56 m (H) Weight: 30 kg Material: Thornel VCB-20 Carbon Cloth*

(Left Blank Intentionally)

3.1.4. Manufacturing and Integration Plans

The manufacturing of the components making up the Ares-42 payload will differ based on their purpose to the mission. It is important to note that all semiconducting electronic components must be radiation hardened in order to reduce the susceptibility of radiation damage.

The engineering components will be manufactured and tested alongside NASA at the Jet Propulsion Laboratory (JPL) in Pasadena, CA. This will include the rovers chassis, legs, wheels, battery, camera system, and communications. The manufacturing process will begin January 2022 and will roughly take 1-2 years . Due to its low weight and high strength, T800 Carbon fiber will be used as the primary materials for the rovers chassis and legs, the wheels of the rover will also use T800 Carbon fiber as well as titanium. In order to power the rover and the scientific equipment mounted on it, the rover will be equipped with a miniature radioisotope thermoelectric generator (RTG) and a single lithium -ion rechargeable battery in case the rovers power demand temporarily exceeds the RTG"s steady electrical output levels. The radioisotope fuel (Pu-238) will be manufactured in a ceramic form in order to resist shattering under the rough conditions of space travel. Perseverance utilized a similar power source that was provided to them by the U.S Department of Energy.

The Scientific components will be outsourced to the Los Alamos National Laboratory (LANL) in New Mexico since they developed the SuperCam science instrument aboard the Perseverance rover that the laser-induced breakdown spectrometer is inspired by. This instrument will be responsible for drilling the surface utilising laser pulses and will include a spectrometer that will be responsible for measuring the chemical composition of the plasma created by the laser. In order to satisfy the secondary payload size constraints of the Ares-42 mission the SuperCam instrument must be scaled down to fit a volume of 38cm x 24cm x 19cm, as such it should be estimated that the cost and development time for this instrument will increase.

3.1.5. Verification and Validation Plans

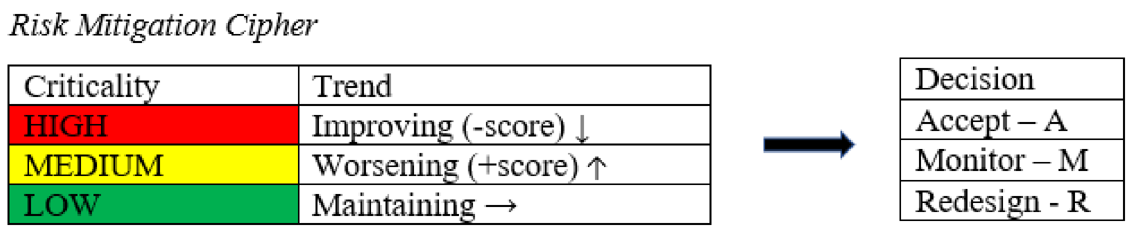
Verification and Validation of the rovers subsystems will mostly take place in simulated chamber environments in order to test different temperatures, as well as the conditions of space travel. NASA already has facilities capable of conducting these types of tests at the Johnson Space Center in Texas. It is important that the scientific instruments of the rover along with the antenna, battery, and computer systems be able to function in a vacuum chamber and after being exposed to radiation in order to test their durability on Mars.

In order to verify the communication system can function adequately in an environment similar to Mars the UHF must be able to transmit and receive data as well as communicate the status of the assembled rover in a vacuum chamber; this will simultaneously ensure that the computer and battery systems are functional. The laser-induced breakdown spectrometer will also be tested under similar conditions in order to verify that it can collect accurate readings; it must be able to drill a distance of 7m on a sample of terrain of known composition and the spectrometer must be able to correctly measure the contents of the sample. The rover consumes its maximum power when cooling: 36 W, in addition to the consistent 4.03 W for the RVS/electronics the total maximum power the RTG must be able to produce is 40.03W, In order to verify that the RTG can output the maximum power required the power system will be measured using a bench power supply.

In order to validate if the rover will be able to withstand entry and landing on the martian surface the payload will be placed inside its landing spacecraft and then placed on a vibration table. The structure will then be gradually exposed to 2,370 degrees Fahrenheit (about 1,300 degrees Celsius) in order to simulate the friction generated as it will descend through the Martian atmosphere After simulating these conditions for six minutes (same time as InSight) the rover will be examined for any damage and the scientific components will be examined to determine if they can still fulfill their respective purpose. Validation of the Rover Vision System as well as the mobility of the rovers legs and wheels will be done in the Mojave desert due to its similar terrain to the surface of Mars. The rover must be able to autonomously navigate itself to a predetermined location without damaging any of the scientific instruments.

3.1.6. FMEA and Risk Mitigation

Risk mitigation is of the utmost importance when planning any mission, but even more so when planning a deep space mission. The charts below highlight the risks associated with our rover from lander exit onward. The main systems (as highlighted in 3.1.1 AND 3.1.2) have been assembled with the aim for an extremely low overall budget for risk, and inevitably failure. The acceptable range for risk, as decided upon by the engineering team, is as follows: all systems development is carried out with the primary goal of an end risk ranking NOT exceeding the (3, 3).



Risk Mitigation Cipher

Criticality	Trend
HIGH	Improving (-score) ↓
MEDIUM	Worsening (+score) ↑
LOW	Maintaining →

Decision
Accept – A
Monitor – M
Redesign - R

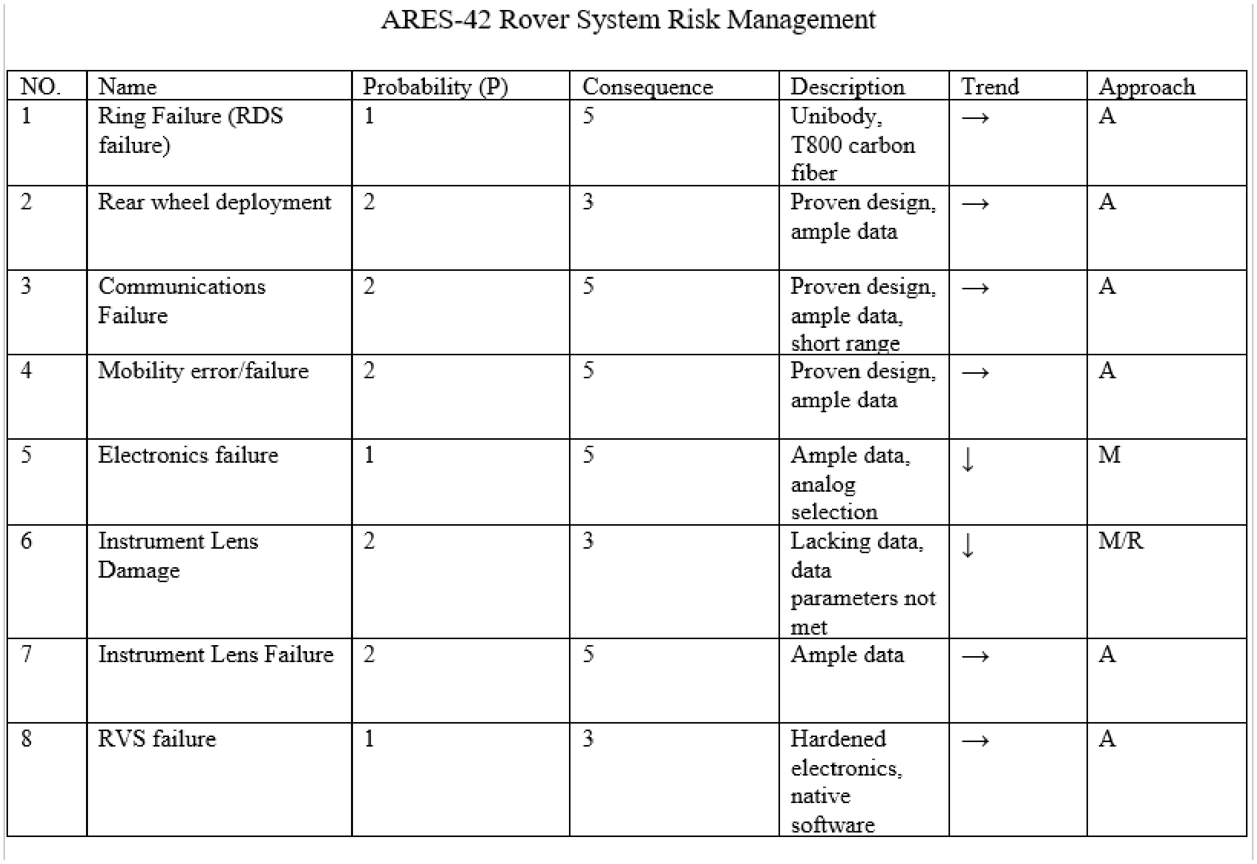
Table 1. *Risk Mitigation Cipher*

Decision is our path forward for future development and risk reduction:

Accept (A): The failure is not probable and therefore acceptable.

Monitor (M): The risk of this failure is currently not probable, but could lead to critical failure, therefore will be monitored for future improvements.

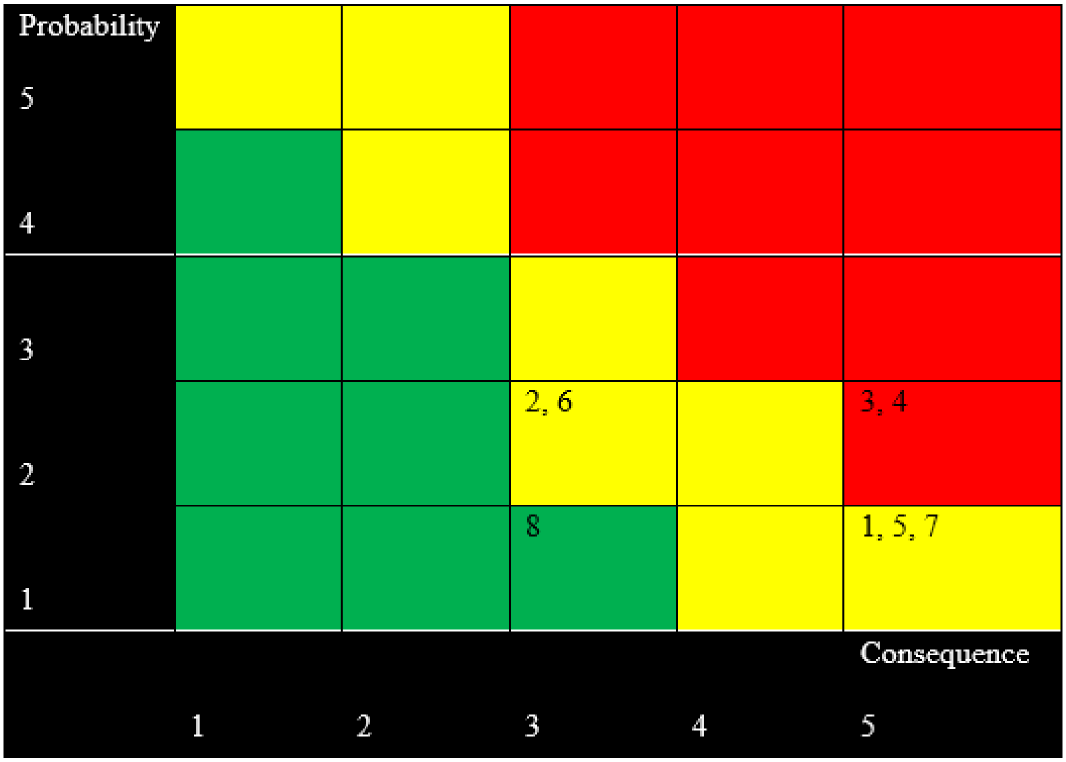
Redesign (R): The failure is probable to the point that it is unacceptable and requires redesign.



ARES-42 Rover System Risk Management

NO.	Name	Probability (P)	Consequence	Description	Trend	Approach
1	Ring Failure (RDS failure)	1	5	Unibody, T800 carbon fiber	→	A
2	Rear wheel deployment	2	3	Proven design, ample data	→	A
3	Communications Failure	2	5	Proven design, ample data, short range	→	A
4	Mobility error/failure	2	5	Proven design, ample data	→	A
5	Electronics failure	1	5	Ample data, analog selection	↓	M
6	Instrument Lens Damage	2	3	Lacking data, data parameters not met	↓	M/R
7	Instrument Lens Failure	2	5	Ample data	→	A
8	RVS failure	1	3	Hardened electronics, native software	→	A

Table 2. *ARES-42 Rover System Risk Management table*

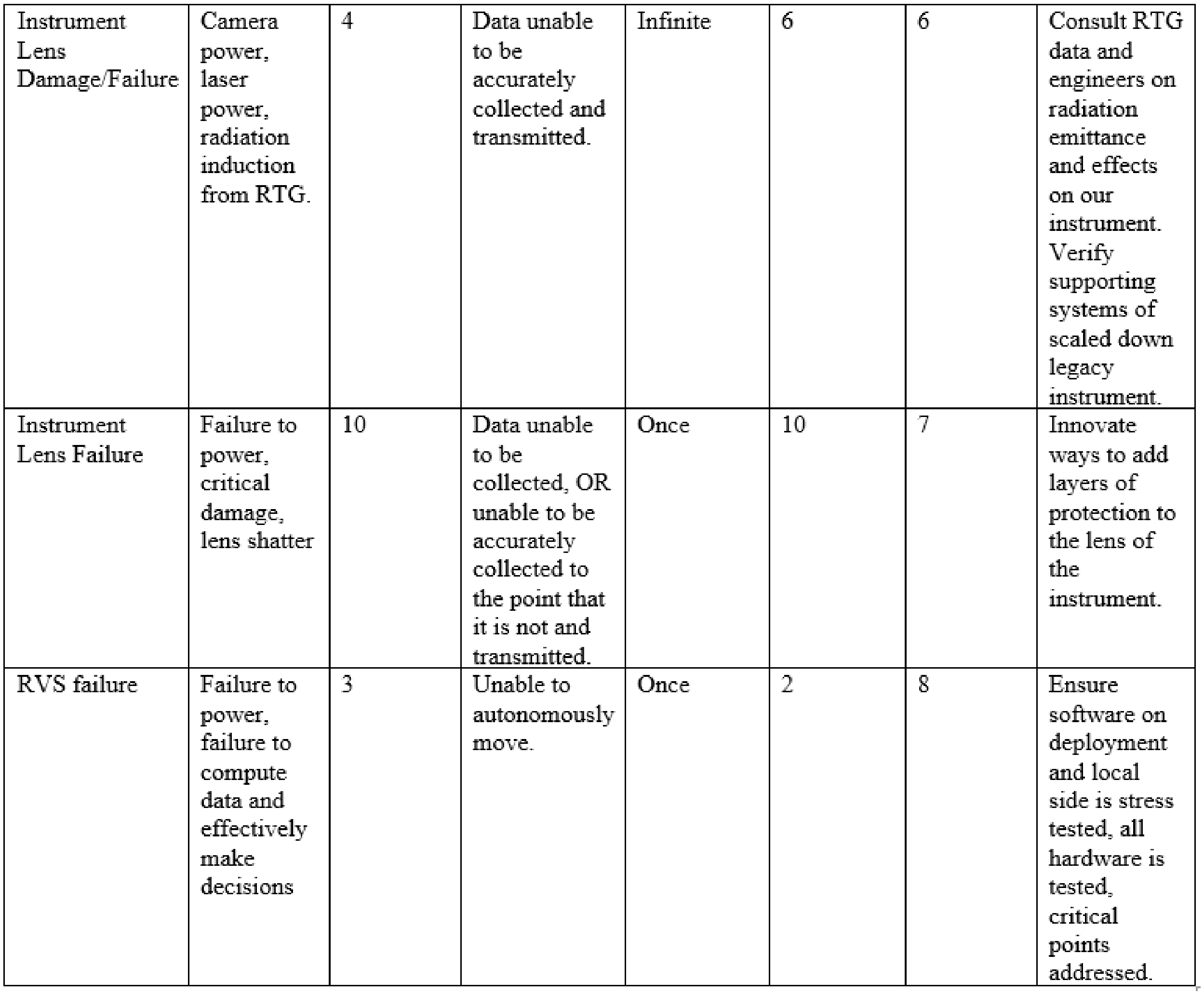


Probability					
5	🟨	🟨	🟥	🟥	🟥
4	🟩	🟨	🟥	🟥	🟥
3	🟩	🟩	🟨	🟥	🟥
2	🟩	🟩	🟨 2, 6	🟨	🟥 3, 4
1	🟩	🟩	🟩 8	🟨	🟨 1, 5, 7
					Consequence
	1	2	3	4	5

Table 3. *Top down risk management matrix at an individual systems level*

The FMEA chart for the ARES-42 rover shown in Table 4 provides risks in further depth than the top-down view shown in Table 3. A minor system failure can easily evolve into a critical mission failure, so all elements of the system are taken into consideration.

Component	Failure Mode(s)	Severity (Low to high, 1-10)	Failure Effects	Occurrence	Detection (Low to high, 1-10)	Risk Number	Action Required
Ring	Failure to support 30kg mass	10	Rover fails to deploy	Once	10	1	Review body construction.
Rear Wheel Deployment	Failure to deploy	4	Rover stability decreased by 28%	Once	5	2	Consult engineers who constructed heritage hardware. Simulate deployment in all possible conditions
Comm System	Failure to reach either lander, Odyssey OR DSN.	10	No data transmittal	Up to number of samples + a constant of 10	10	3	Verify antennae and rotation assembly are functioning properly. Re-test, reverify results.
Mobility Error	Wheel, bearing or drive failure	7	Unable to reach all* sample sites	Infinite	4	4	Simulate landing AND sample sight meticulously.
Electronics Failure	General failure	10	Unable to power systems, no data transmittal or mobility.	Infinite	2	5	Simulate all circuits multiple times and tier list risk areas for redesign.



Instrument Lens Damage/Failure	Camera power, laser power, radiation induction from RTG.	4	Data unable to be accurately collected and transmitted.	Infinite	6	6	Consult RTG data and engineers on radiation emittance and effects on our instrument. Verify supporting systems of scaled down legacy instrument.
Instrument Lens Failure	Failure to power, critical damage, lens shatter	10	Data unable to be collected, OR unable to be accurately collected to the point that it is not and transmitted.	Once	10	7	Innovate ways to add layers of protection to the lens of the instrument.
RVS failure	Failure to power, failure to compute data and effectively make decisions	3	Unable to autonomously move.	Once	2	8	Ensure software on deployment and local side is stress tested, all hardware is tested, critical points addressed.

Table 4. *ARES-42 FMEA chart*

3.1.7. Performance Characteristics and Predictions

A successful mission for ARES means that all stages of the mission occur as planned and each system performs as expected. From the moment ARES touches the regolith at the landing sight, until the moment the rover is retrieved by humans in the future, ARES must be fully functional.

The following four events are considered critical for the success of our mission:

- Rear pair of wheels unfold during RDS phase, and the surface is met as expected
- Mobility system functions as desired for travel to Arcadia Planitia from the landing zone.
- Instrument is undamaged and fully functional throughout the duration of the mission
- Communications, hardware, and software function fully and consume as much OR less power than expected

Before developing system features to ensure success, we must go into external factors that must be considered at the outset. Harsh weather conditions on Mars could impede progress. As a secondary payload onboard our lander, we do not have the luxury of planning a date for our earth departure, and therefore a specific arrival date. Thus, we will plan a rover deployment date where on that date the rover will be exposed to the Martian atmosphere and hoisted out of the lander compartment and onto the surface. We will plan on contacting the surface in the beginning of the Martian summer for the advent of less harsh weather as well as a softer ground for the laser imaging to impede. The following explanations are parameters required for effective functionality.

External and Internal Radiation Interference with Electronics

Due to weight constraints and ARES-42 becoming extremely compact, taking into account the proximity which our radioisotope thermoelectric generator will be in relation to our electronics and also the effects of the ambient radiation levels on Mars- all of our hardware will be radiation hardened. The average, natural radiation level on Mars ranges from 24-30 rads (240-300mSv/yr) This process has a single downside: cost. Every piece of hardware onboard ARES is necessary and critical for success, therefore it is extremely important we have no failures. To ensure this, all hardware will undergo the CMOS7 process developed by Sandia National Laboratories to harden all electronics onboard. The process is based around a central silicon insulation structure formed by an internal oxide layer and five levels of metal interconnect- this gives us extreme reliability and protection from both high bursts of radiation as well as slight exposure over a period of time. CMOS7 radiation hardened components are reliable over time in environments reaching up to 107 rads (1070mSv/yr) giving our hardware an operating margin of 77 rads (770mSv/yr), high bound.

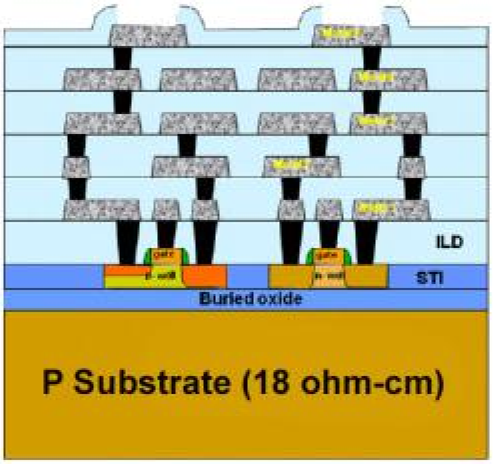


Figure 29. *Example of a rad-hardened board from Sandia National Laboratories.*

Mobility

In our planned mission, the most difficult terrain we will be forced to traverse with the rover is what lies directly in the middle of the landing site and the sample site. The terrain is an absolute unknown, as the lander vision system will autonomously decide where exactly to land (near the site selected, of course) for an optimal touch down. This means we are forced to plan for worst case terrain. With that said, a four-wheel drive system is required. As touched on in 3.1.1 AND 3.1.2, we will be utilizing a pair or rear stabilization wheels out of necessity, to eliminate the possibility of the rover tipping where our relative angle to the surface becomes unsafe (<28 DEGREES). The drive system, powered by an electric motor, will be like that of the system Perseverance. We do not have the luxury of any sort of suspension system due to weight, so the rear two stability wheels are necessary for keeping the rover upright during traversal. With a primary, center mounted diff and drive shafts to the fixed four wheels, we will have no problem making it to the sample site. We can assume we will not be climbing anything extreme based on the imaging we have examined in JMARS, and furthermore, once at the sample plane the terrain is flat which calls for low impact maneuvering.

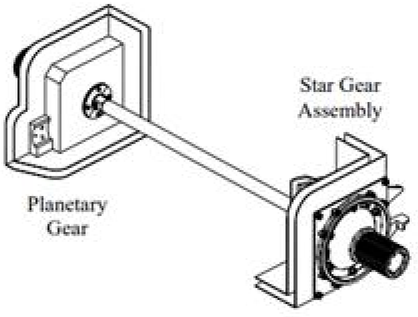


Figure 30. *Center Mounted Differential System*

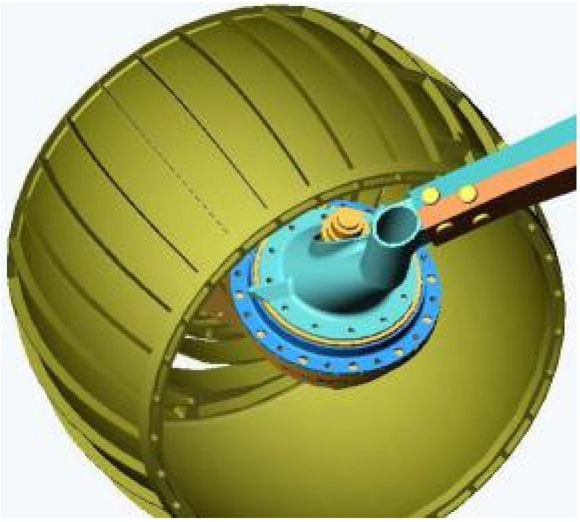


Figure 31. *Proposed wheel drive system*

3.1.8. Confidence and Maturity of Design

ARES-42's instruments being used on the rover have been proven in the Martian atmosphere as well as handling the rough surface terrain. The SuperCam was launched with the Perseverance rover which will allow our team to communicate with. In addition to receiving feedback and first hand experience with the instrument's performance on Mars, we will be able to have ARES-42 venture out to the Mojave desert to simulate realistic terrain and conditions. Using the data from the SuperCam on the Perseverance rover and in person trials will allow for us to gain a full picture and understanding of the instrument's capabilities and restrictions with our mission goal.

The project used the main Perseverance rover as inspiration for design features that were proven beneficial, however we made changes that would reduce material usage, complexity, and higher chance for failure. The main change was the elimination of the SuperCam's arm from Perseverance and instead attaching it to the main body of ARES-42. The change was made to obey the weight and dimension restrictions set by the mission rules.

Another major evolution of the project was the Power Supply choice and the final choice of a Radioisotope Thermoelectric Generator rather than solar panels. After intense discussion about the durability, dependence on compliant weather, and possible power shortfalls caused us to rule them out effectively. The RTG also allowed us to heat the rover body and electronics while electronically powering it as well, something that was not as easily achieved with the solar panels.

The team also chose the Perseverance rover wheels as reference to create our own, this similarity included the material and design. The only change that was needed to be made was scaling down the size of the wheel to fit our rover frame. The scaling down of size was also made to reduce mass, material usage, and thus cost while still providing the same strong structure.

3.2. Recovery/Redundancy System

A well thought out recovery and redundancy system is crucial for any mission of this magnitude, but especially when the importance of each subsystem is increased greatly due to size and weight constraints. Since we do not have the luxury of incorporating backup parts for each sub system, we have designed each system with their own set of redundant safety parameters to ensure successful operation throughout the entirety of the mission. In addition to these parameters for redundancy, extensive testing and refining processes to ensure each and every design and integration plan aligns exceedingly well.

An important note is that while Team 2 has not been tasked with the EDL portion of this mission, all selected materials and structures have been designed with extreme pressure conditions and heat cycling in mind. T800 carbon fiber gives us over 1,000 °C of margin from maximum expected heat index, and therefore inspires confidence in all materials. The integrity of the rovers structure and systems being in perfect order upon arrival on Mars is crucial.

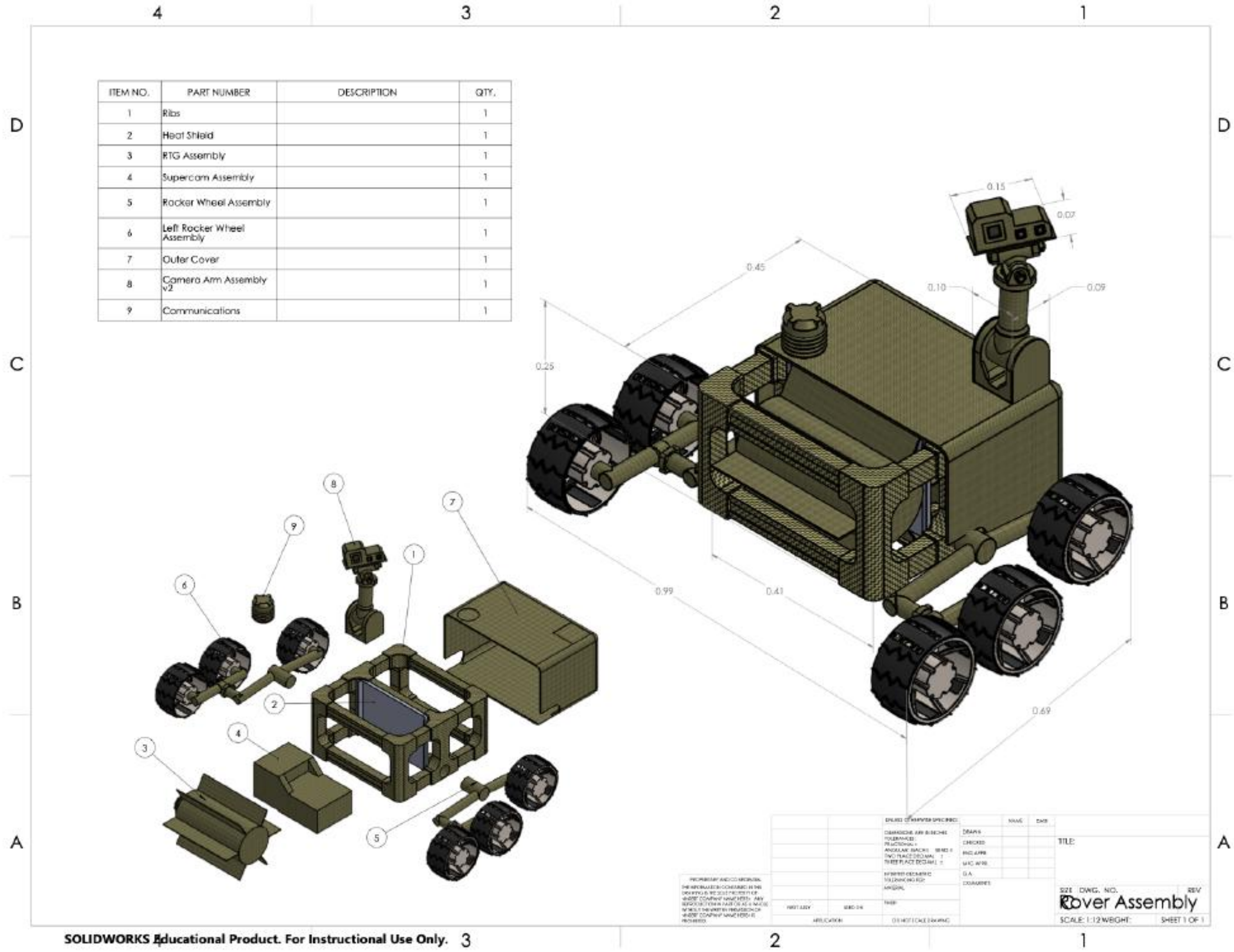
Our selected hardening process for our electronic hardware gives us almost double the temperature range of effective operation as compared to the temperature range on Mars, AND alleviates the concern of radiation affecting our computing capabilities with 76 rads of margin after taking maximum ambient rads into account.

Elaborating on redundancy systems more broadly:

- RVS has two cameras instead of one, alleviating a critical failure point that a single camera would provide.
- Six wheels rather than four, alleviating mobility hindrance in the case of a wheel failure.
- Multiple communications mediums.
- RTG output wattage can power our mobility system five times over, power margins are optimized (taking decay into account).

3.3. Payload Integration

Overall, the ARES-42 Rover will be divided into two compartments separated into two equal halves. All components will be directly mounted onto the Rover chassis; the mounts will be attached in either a top or lower section relative to the cross-section of the Rover body. The Science instrumentation: telescope unit and 3 spectrometers will be mounted on the top section of the ARES Rover chassis. One navigational lens, the electrical, and thermal components will be mounted towards the bottom and attached directly to the rover body base plate.The majority of the components will be housed and enclosed within the ARES body. Navigational and scientific instrumentation will be exposed to the Martian atmosphere outside of the Rover body for functional purposes.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Ribs		1
2	Heat Shield		1
3	RTG Assembly		1
4	Supercam Assembly		1
5	Rocker Wheel Assembly		1
6	Left Rocker Wheel Assembly		1
7	Outer Cover		1
8	Camera Arm Assembly v2		1
9	Communications		1

Figure 32. 3D *CAD drawing of entire ARES-42 rover assembly Exploded view*

Top section

The science instrumentation will be exposed to the Martian atmosphere in order to collect crucial mission data. Heaters for the individual spectrometers will be mounted to the top of the rover chassis. Thermoelectric coolers will be mounted to the base plate and extend upwards towards each individual component. The Heating and cooling systems interact with the science instrumentation directly in order to keep them running at optimal temperatures. These components are referred to in detail in section 4.1.2 of the document. As described in section 3.1.2 the UHF antenna will be mounted on a swivel and attached to the top of the rover frame and will also be exposed to the martian atmosphere. The UHF is the primary communications resource which will relay the information collected by the telescope and spectrometers through the communications cycle. The Top mounted navigation camera will be mounted externally and will be adjacent to the UHF and spectrometer and will have a 360 degree view of the Rovers surroundings.

Lower Section

Support and passive mission systems are located and mounted to the bottom of the Rover chassi in order to ensure active mission systems such as the telescope and spectrometer instrumentation clearance from As described in section 3.1.7 of this document, all hardware will be radiation hardened through the CMOS7 process in order to protect hardware from failure due to proximity to the Rover’s RTG. The RTG will be external to the chassis, mounted directly onto the base plate and attached to the side of segmented partition plate of the chassis for weight reduction and heat exhaustion purposes. Initially a Lithium Ion battery was to also be mounted alongside the RTG, though redesign of the rover meant the Ion battery was a redundancy the rover design could remove. LGA1 will be mounted externally to the rear bottom side of the ARES-42 frame. The bottom mounted skimming camera will be mounted externally to the Rovers base plate.

[Left blank intentionally]

4. Payload Design and Science Instrumentation

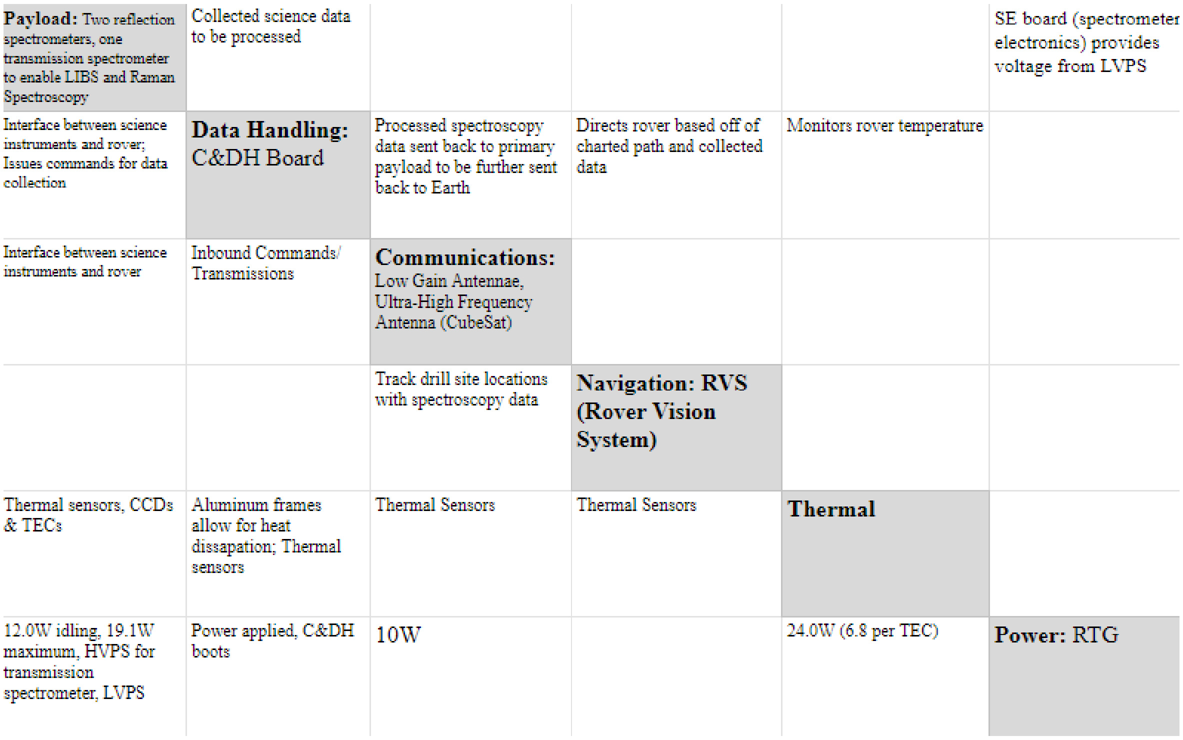
4.1. Selection, Design, and Verification

4.1.1. System Overview

As previously discussed, the primary scientific instrumentation will greatly resemble components present in the SuperCam on the Mars 2020 Perseverance Rover, as it has been tested both in simulated and the actual Martian environment. The main power source on the vehicle will be a radioisotope thermoelectric generator (RTG), as it is internal and therefore will not be subjected to the Martian environment, as opposed to solar panels. As dust storms are present on the planet, solar panels are susceptible to loss of power due to dust and debris covering the panels and hindering their ability to absorb sunlight. Solutions to addressing this specific issue are also costly and would add weight to the payload. The RTG interfaces with C&DH board to supply unregulated power to the science instrumentation, where it then regulated and distributed amongst the instrumentation through a high-voltage power supply (HVPS; for the transmission spectrometer), and the low-voltage power supply (LVPS; for the two reflection spectrometers). Thermal components will be distributed throughout the vehicle, to maintain optimal performance temperature for each instrument, along with thermometers to track current temperature as to adjust to temperature changes accordingly. Spectroscopy data collected from the spectrometers will be processed through the C&DH Board, and transmitted back to the primary payload.

The overall scientific instrumentation needs to remain between -15 ℃ to 0 ℃, the laser specifically requiring -15 ℃. As for power requirements, the instrument consumes 12.0 W idle, 19.1 W at maximum, along with an additional 6.8W for each individual thermoelectric cooler (3 total). The UHF consumes 10 W.

The instrumentation aboard the rover was selected based on flight record and reliability, as well as relevance to the scientific goals and concerns. Opting for an instrument which utilized a laser for drilling and spectroscopy to collect data on the composition of the Martian surface as a means to determine relative concentrations of hydrates present in the sample was the most ideal option. Any form of mechanical drilling comes with risk without human presence, as well as concern for being as noninvasive as possible to the martian surface. Despite its relatively non-invasive drilling techniques, Theia will be able to collect data on ice sheet depth to be compared with previous SHARAD data, offering a surface level investigation and data set to be utilized to inform future human landing sites. In the first round of drilling operations, the rover will take 18.5 hours to travel from drill site to drill site, for each distance of 1km.



Payload: Two reflection spectrometers, one transmission spectrometer to enable LIBS and Raman Spectroscopy	Collected science data to be processed				SE board (spectrometer electronics) provides voltage from LVPS
Interface between science instruments and rover; Issues commands for data collection	**Data Handling:** C&DH Board	Processed spectroscopy data sent back to primary payload to be further sent back to Earth	Directs rover based off of charted path and collected data	Monitors rover temperature	
Interface between science instruments and rover	Inbound Commands/ Transmissions	**Communications:** Low Gain Antennae, Ultra-High Frequency Antenna (CubeSat)			
		Track drill site locations with spectroscopy data	**Navigation: RVS (Rover Vision System)**		
Thermal sensors, CCDs & TECs	Aluminum frames allow for heat dissapation; Thermal sensors	Thermal Sensors	Thermal Sensors	**Thermal**	
12.0W idling, 19.1W maximum, HVPS for transmission spectrometer, LVPS	Power applied, C&DH boots	10W		24.0W (6.8 per TEC)	**Power:** RTG

Table 5. *N^2 Chart depicting how each of the ARES-42 Rover's systems interact with one another.*

(Left Blank Intentionally)

4.1.2. Subsystem Overview

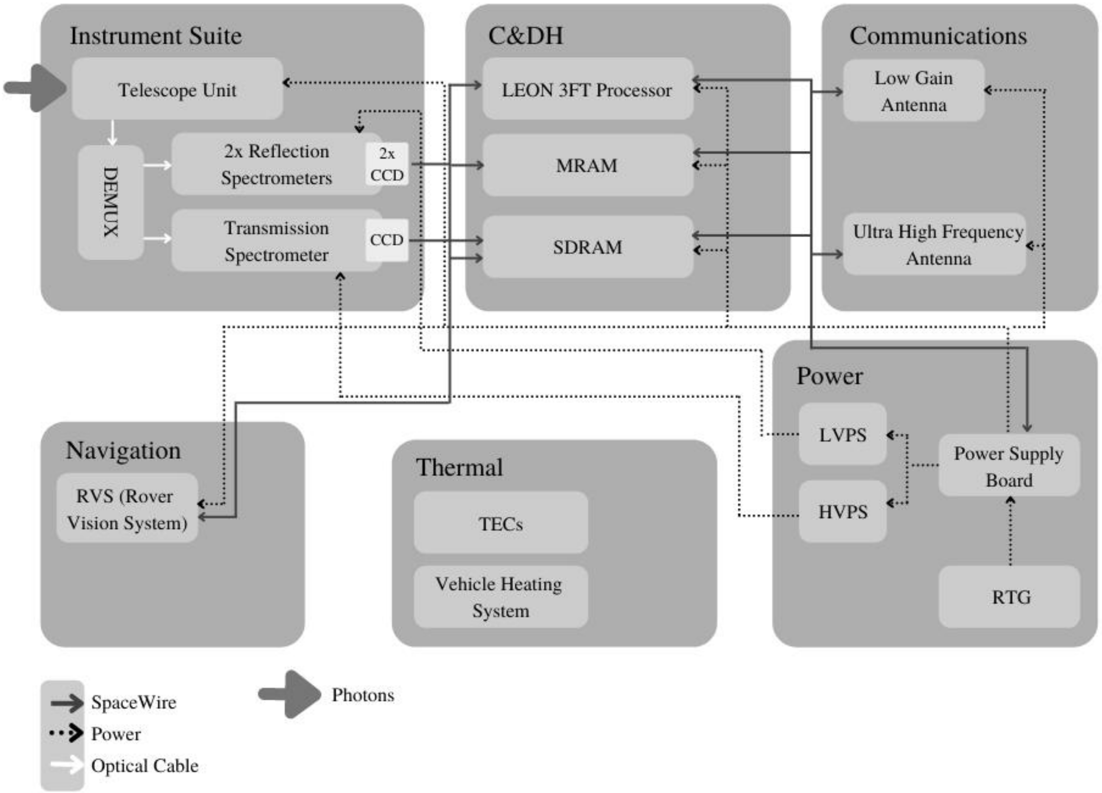


Figure 33. *ARES-42 Rover Subsystem blueprint*

Science Instrumentation

The scientific instrumentation will be split into two sections: The description of the telescope component, which produces and focuses the laser to break down the material at the target point, and the three spectrometers, which are fed light from the telescope through optical fibers.

Telescope Unit

The belly-mounted telescope unit consists of a laser which produces a green and red wavelength through the use of two Galilean beam expanders, before they are focused with a supplemental continuous-wave laser and directed towards the target.

The benefits of utilizing Galilean beam expanders allows for the telescope unit to have a more compact design, as it does not require the use of a correction lens.

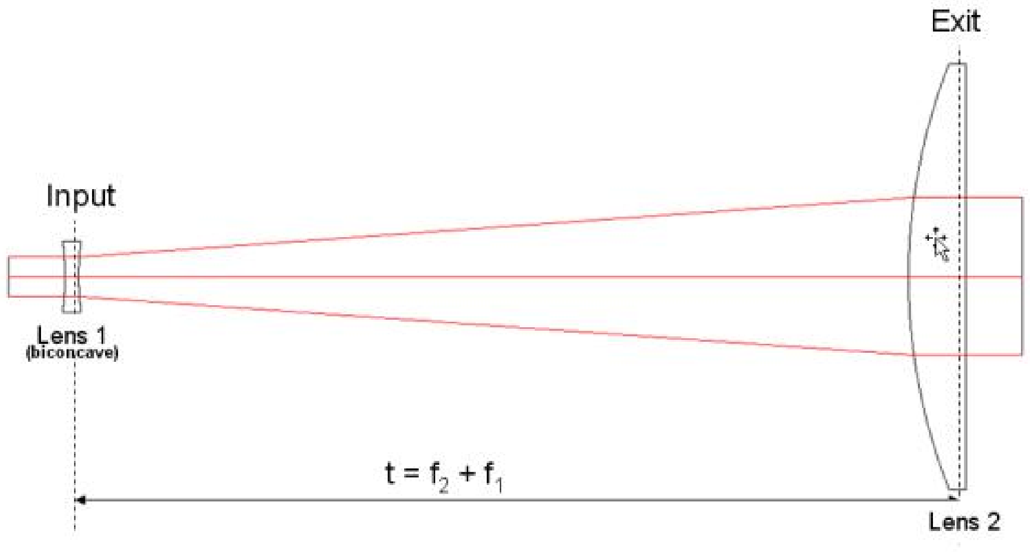


Figure 34. *A Galilean beam expander does not have a focal point in between the two lenses, as opposed to a Keplerian beam expander. Retrieved from Newport Optics Technical Note.*

Both the Raman and LIBS spectroscopy techniques require a pulsed laser, however, it is specifically the collimated green laser that enables Raman spectroscopy. Raman spectroscopy suffers at remote collection distances, and thus the best minerals and organics identified through Raman spectroscopy are phosphates, carbonates, and sulfates. This, however, works well with the target compounds that Theia hopes to observe, as Mars is known to have an abundance of hydrated sulfates, which can be used to determine the relative depth and concentration of sublevel ice sheets on Mars.

Photons that are emitted through the pulsed laser are then collected and transported through optical fibers to an optical demultiplexer (demux), where the light is split amongst the three spectrometers. The demux receives light from the telescope unit in the 245-853 range and is able to split the light through two dichroic mirrors, before distributing them.

The theory behind an optical demultiplexer is analogous to a prism separating sunlight into a rainbow spectrum, however, within the scope of the scientific instrumentation, the optical demultiplexer takes the collimated beam and uses a lens to focus each separate beam to a specific point on the surface of a prism, where each beam is refracted differently, and further separated into their components. These components are passed through another lens which when angled properly, sort the separated components at focal points, which within the instrument, are the input optical fiber bundles of the spectrometers.

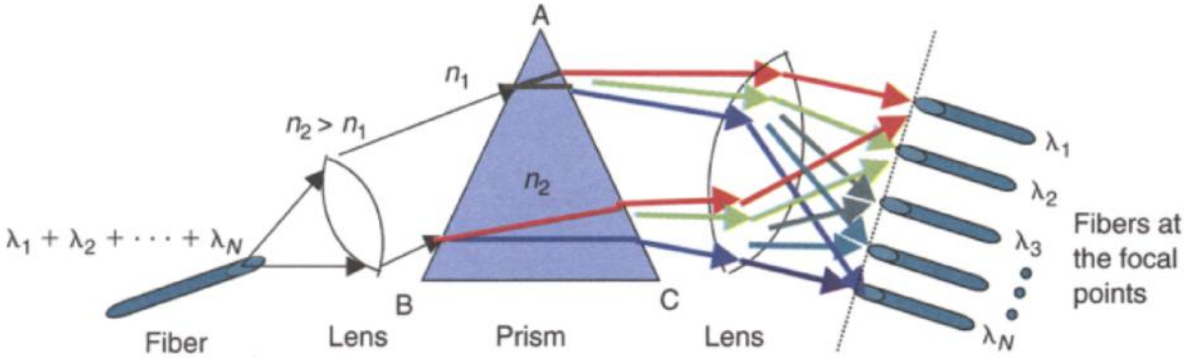


Figure 35. *Graphic of a collimated beam of polychromatic light impinges on a prism surface. Graphic depicts each wavelength component refracted differently. Retrieved from Optical Components by Ajmal Muhammad and Robert Forchheimer.*

The optical demux in Theia splits the light in three ways, a UV band for the UV reflective spectrometer, a violet band for the violet reflective spectrometer, and the remaining light is directed towards the transmission spectrometer, which passes through a filter to remove the green band of the remaining laser light (532 nm). This exclusion of green laser light is necessary for the transmission spectrometer, which is primarily responsible for enabling Raman spectroscopy, as to decrease Raman excitation of the silica present in prior components (Wiens, et al. 2020).

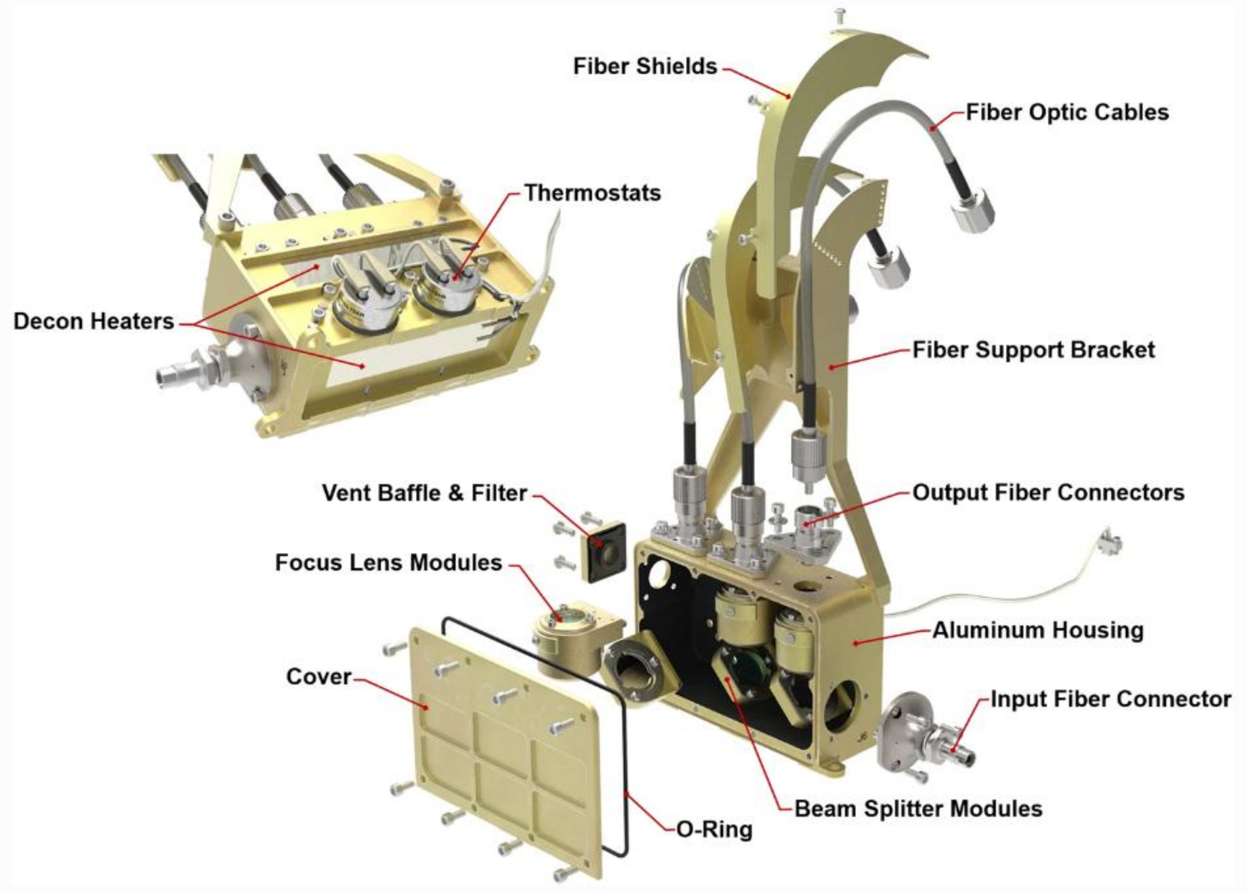


Figure 36. *SuperCam's Demux Unit. Retrieved from The SuperCam Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests by Roger C. Wiens, et. al.*

Spectrometers

The two reflection spectrometers are Czerny-Turner monochromators, which operate by accepting light passed through a slit which is aimed at a collimation mirror, as techniques for diffraction require the accepted light being collimated (light components are parallel with one another). The collimated light is then reflected to a diffraction grating to disperse the light prior to being reflected to a focus mirror, where the focused and separated light images are displayed onto the CCD Module of the spectrometer. The reflection spectrometers are almost identical, only differing in the diffraction gratings present, as well as the coating for CCD module due to the specializations in UV and violet spectra. The grating for the UV spectrometer is 240 nm, and the violet spectrometer's grating is 300 nm.

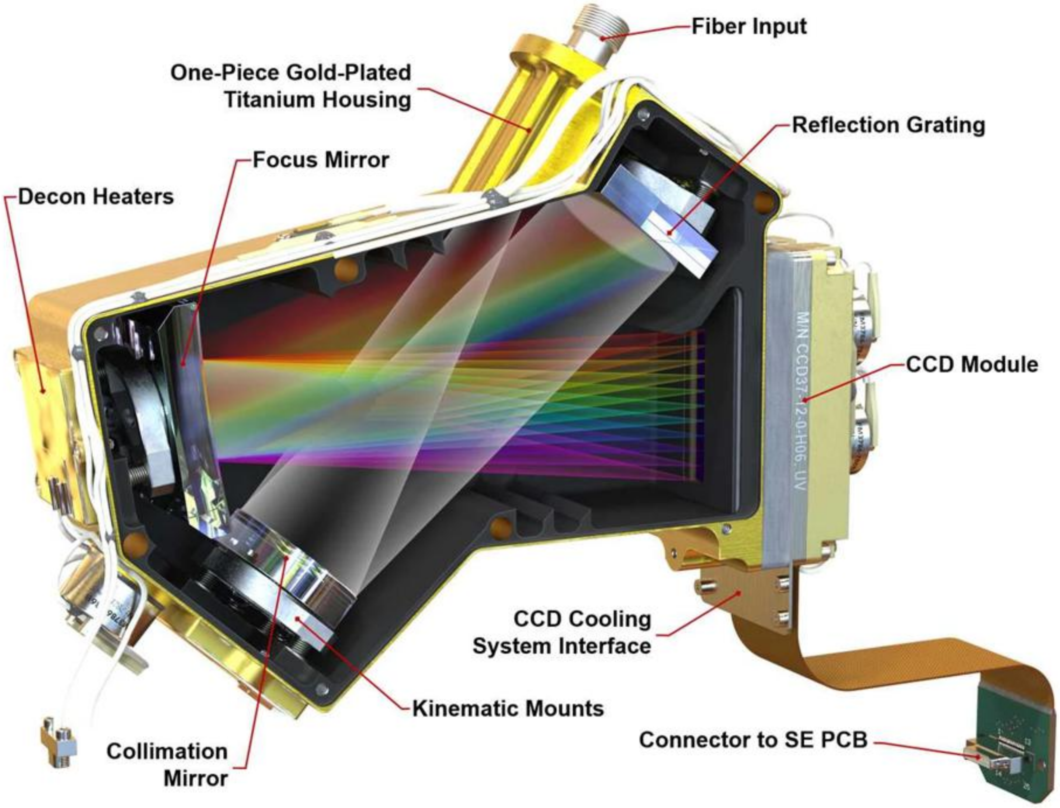


Figure 37. *SuperCam's Reflection Spectrometer. Retrieved from The SuperCam Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests by Roger C. Wiens, et. al.*

Theia's transmission spectrometer, which is meant to enable Raman spectroscopy, has a slightly more complex design compared to the Czerny-Turner reflection spectrometers. Namely, due to Raman's spectroscopy limitations with remote collection, an image intensifier is necessary. However, the transmission spectrometer begins similarly to a reflection spectrometer, imputed light through a slight is collimated through a lens prior to reaching diffraction gratings. From here, the design of the transmission spectrometer introduces several consecutive lenses which continue to diffract the orange, green, and red bands of light. The components pass through the intensifier and are refocused using another series of relay lenses before projecting onto the CCD Module.

While the transmission spectrometer was designed with Raman spectroscopy in mind, it also enables TRL, or time-resolved luminescence. Both Raman and TRL techniques pair well on Mars, as Raman spectroscopy struggles with the presence of emitted fluorescence due to organic substances, despite this fluorescence lasting very briefly (nanoseconds). Despite this being an issue for Raman spectroscopy on Earth, it benefits in the search for organic materials, rare earth elements and metals on a celestial body where that information becomes pertinent (Wiens, et al. 2020).

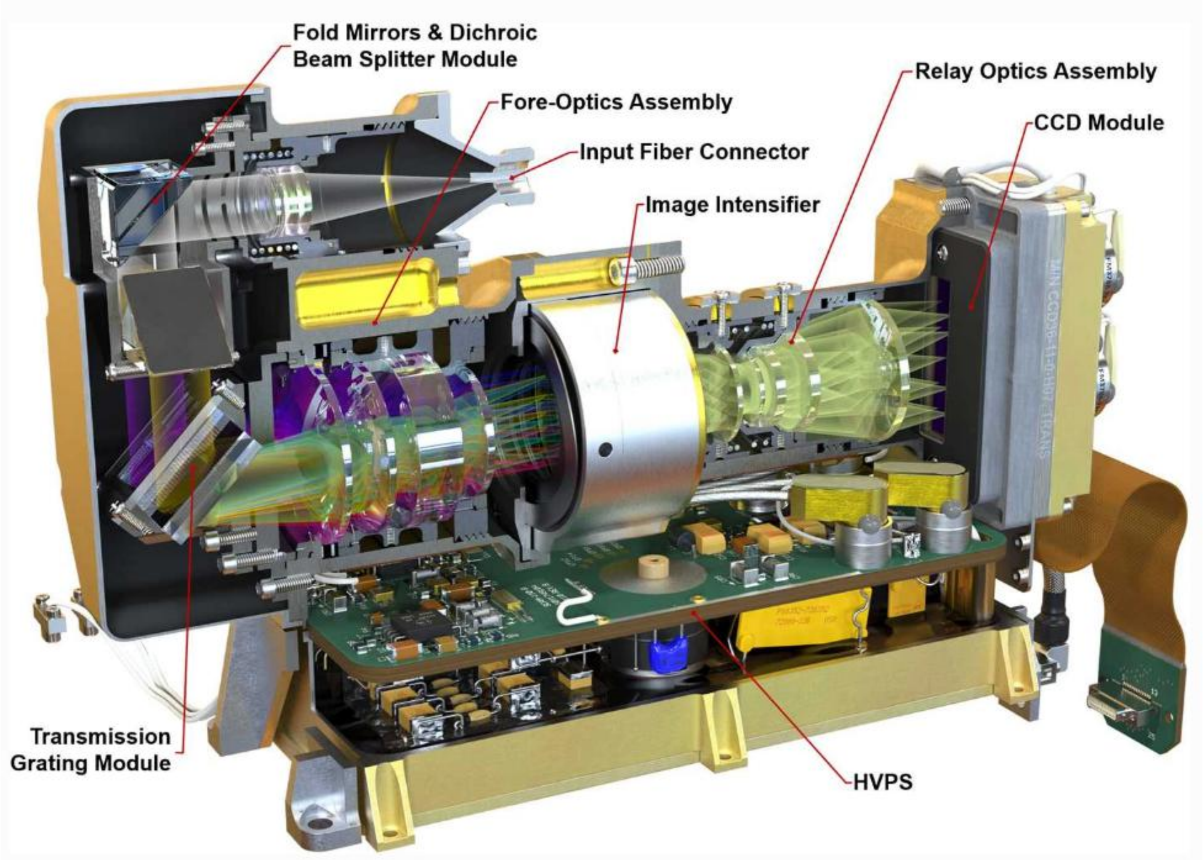


Figure 38. *SuperCam's Transmission Spectrometer. Retrieved from The SuperCam Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests by Roger C. Wiens, et. al.*

Due to the inclusion of the image intensifier in the transmission spectrometer, the transmission spectrometer has a high-voltage power supply (HVPS), as opposed to the low-voltage power supply (LVPS) for the two reflection spectrometers. These individual power supply components will be discussed in a later section.

The spectrometers are constructed with a titanium casing, which has a low coefficient of thermal expansion. In the ChemCam, the casing for the spectrometers were made of beryllium, however this was opted for titanium in the design of the spectrometers in the SuperCam due to health risks associated with inhaling beryllium dust.

Data Handling

Data handling and commands will be done through the C & DH module, which consists of LEON3FT processor. This processor has been specifically designed for space and non-Earth missions, and has been used on Mars missions in conjunction with science instrumentation. It is also designed to be fault-tolerant, which means that the processor can correct up to 4 errors per tag/32 bit word (CAES, 2021) in both the register file and cache memory. The ability for a processor to make error correction is necessary for remote non-manned missions, especially when considering the communication delay between Earth and Mars to be in the range of 5-20 minutes. The correction algorithm of the LEON3FT processor runs parallel to any instruction set given, so as to not decrease the duration that commands are issued while the processor looks and corrects errors.

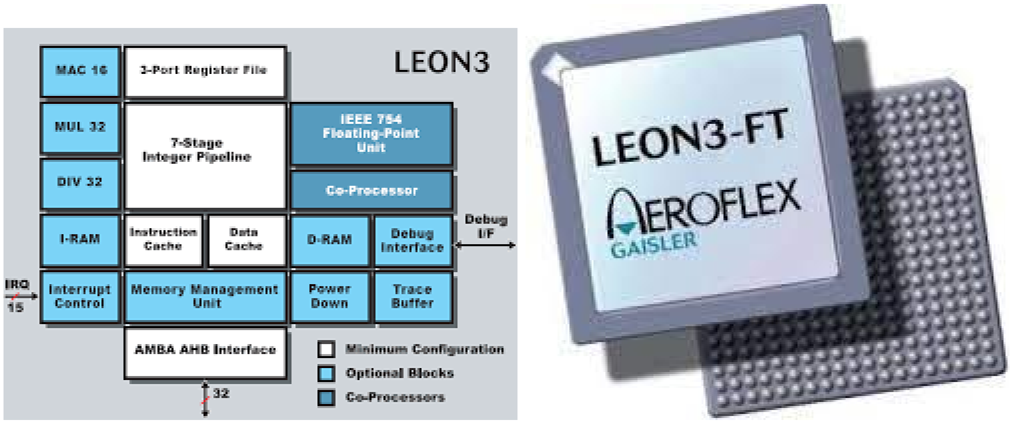


Figure 39. *Overview of the components in the LEON3FT SPARC v8 32-bit Processor. Retrieved from CAES.*

The LEON3FT processor core has 1.4 DMIPS/MHz with multi-processor support. The C & DH module interfaces with the spectrometers through the CCD interfaces allowing the data collected by the CCD module to have direct memory access to the SDRAM component of the board. Overall, the C & DH board allows Theia to interface with the rest of the vehicle, which is necessary for the experiment design, as the continued motion of the vehicle relies upon data collected through the spectrometers.

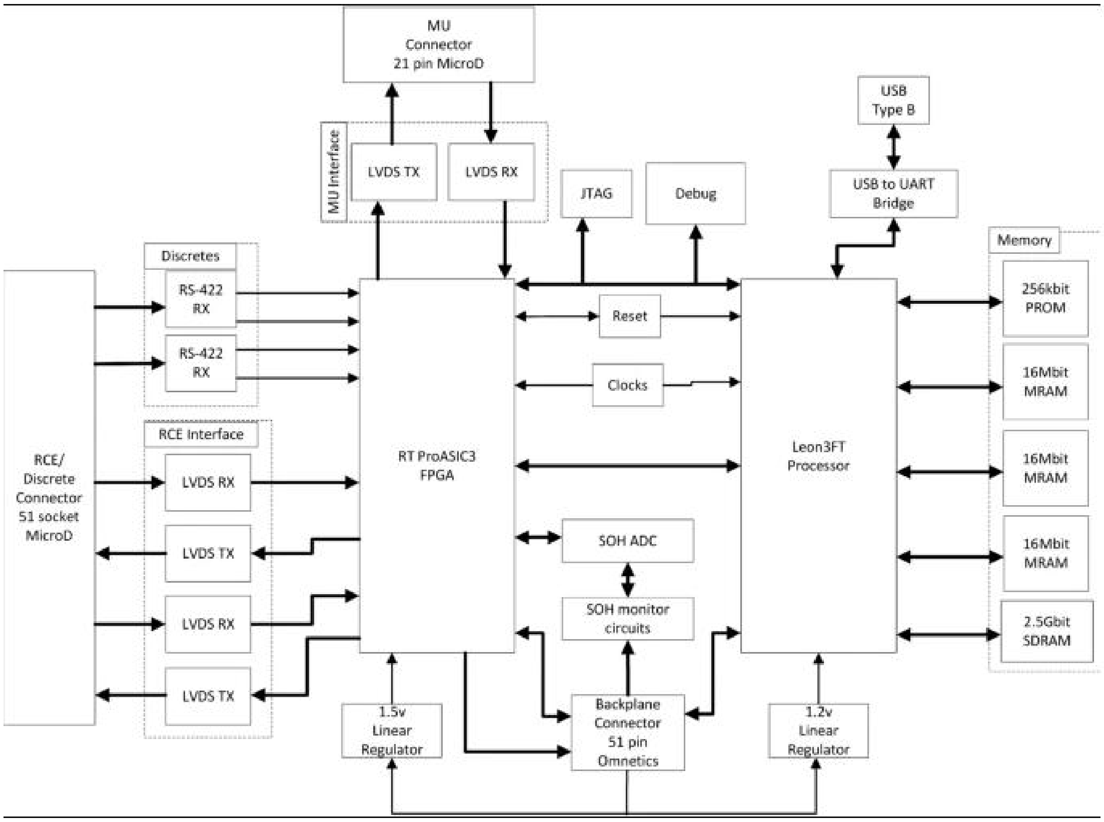


Figure 40. *Overview of SuperCam's C&DH Board. Retrieved from The SuperCam Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests by Roger C. Wiens, et. al.*

Thermal

The thermal instrumentation for the science instrument relies heavily on the use of thermostats/thermal sensors to monitor the temperature of the instrumentation to make sure that the instruments are at their optimal operational temperature - for the spectrometers their thermal sensors are located on the external casings. Each component, along with their thermal sensors, has individual heaters (including the CCD).

There is also a larger thermal system in place which provides heating to other instrumentation aboard the vehicle through running fluid through the RTG power generator and running it in cables throughout the vehicle.

The thermoelectric coolers (TECs) that interface with the CCDs modules on the spectrometers are used for cooling, which occurs before any spectroscopy is begun. CCDs must be cooled while in use, as they generate thermal noise, which is decreased through the cooling process (Wiens et al. 2020). Along with these cooling processes, other science instrumentation, such as the laser in the telescope unit, will be heated to an operational temperature of -15 ℃. However, due to the environmental temperature of Mars, the instrument is unable to maintain a constant temperature of 0 ℃, and therefore the science instrumentation is best done in the morning hours.

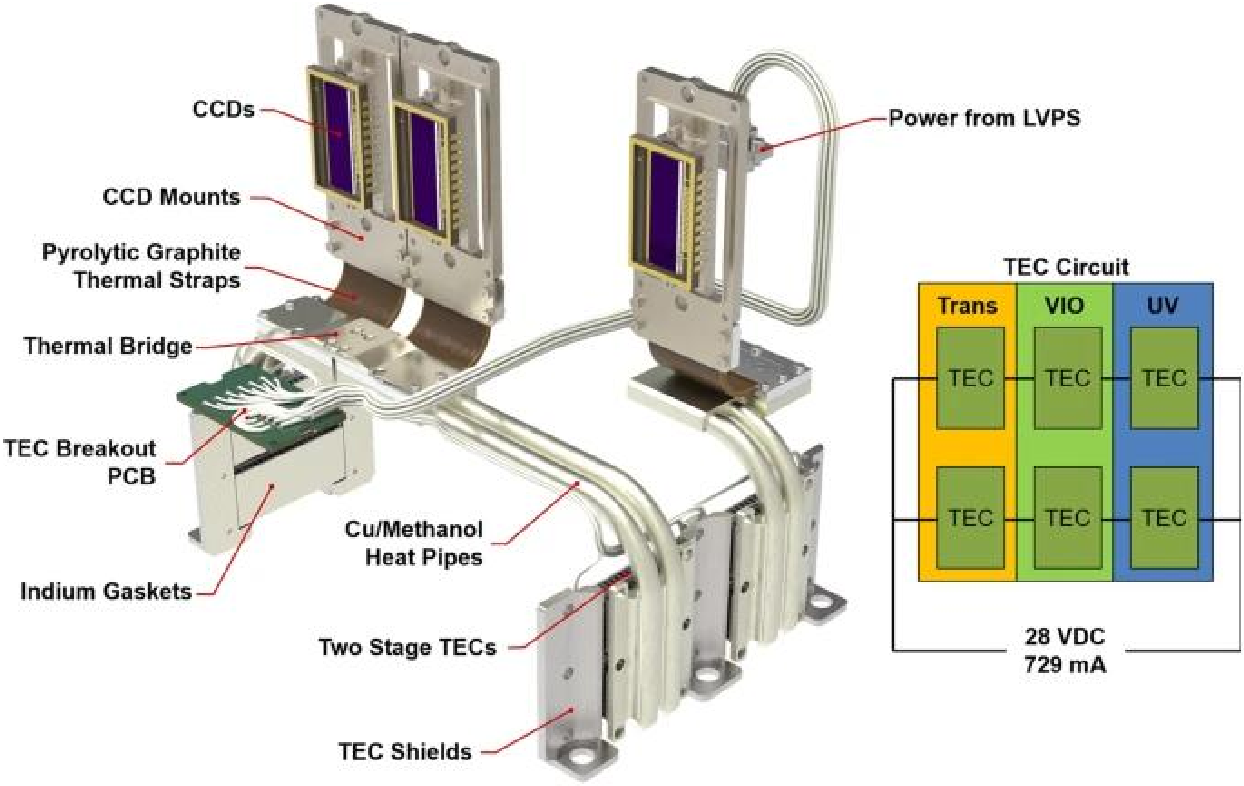


Figure 41. *Cooling instrumentation for CCDs on SuperCam. Retrieved from The SuperCam Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests by Roger C. Wiens, et. al.*

Power

The primary power source for the vehicle, the RTG, has already been discussed in previous sections, however specific power supplies are present for the science instrumentation. A high-voltage power supply (HVPS) was necessary to include for the transmission spectrometer's intensifier, due to the subtlety of remote Raman spectral images, and a low-voltage power supply (LVPS) is used to distribute power to the two reflection spectrometers.

The instrument overall consumes 12.0 W when idle and a maximum of 19.1 W when other components are operational, such as the CCDs, the HVPS, and the intensifier in the transmission spectrometer. TEC's for the CCDs consume an additional 24.0W.

Communications

The primary component for communication for the rover is an ultra-high frequency antenna (UHF), along with a low gain antenna to serve as a backup, and allow for the rover to communicate with the deep space network should emergencies arise. However, the rover will mostly rely on direct communication with the primary payload through the UHF to transfer data collected by the science instrumentation. The interfacing component between the antennae and the instrumentation will be the C & DH board, as prior to being transmitted to the primary payload for further transmission, data will be processed through the board.

The low gain antenna (LGF) has a broader focus, and as a result has a lower data rate, which is why it will only serve as a backup communications, while the ultra-high frequency antenna has a restricted broadcast range and is not capable of communicating directly with the deep space network. Instead, it communicates directly to the primary payload and orbiting relays. The benefit of utilizing a UHF as a primary point of communication, is that they are relatively small, and thus will allow the rover to stay within mass and volume constraints. The UHF has a frequency range of 350-500 MHz.

The specific UHF that will be utilized for the ARES-42 proposed mission will be the CubeSat UHF Antenna System, with a maximum power usage of 10 watts and operating temperatures between -40℃ to 85℃. The UHF peak gain is 1.37 dB, which falls within the range of low gain, and has a return loss of 14 dB between 400-500MHz.

4.1.3. Manufacturing Plan

Manufacturing for the instrument will be done both in-house as well as through the use of external suppliers and manufacturers.

In-House Manufacturing

Smaller components and hardware will be prototyped at JPL’s Additive Manufacturing Center (AMC), which has already aided in the production of the MOXIE and PIXL instruments aboard Perseverance. These prototypes will provide insight into potential problems which may arise while constructing the vehicle, and will allow for cheaper testing and re-modeling processes. These smaller prototyped components can also serve as placeholders when conducting tests which do not require the functionality of the original instrument, as to avoid any damage to the original instrument, especially if the test was concerned with the vehicle’s ability to traverse more harsh/inclined terrain. Specifically, prototypes for the titanium casing around the three spectrometers can be constructed at this facility, as well as the case for the telescope/laser portion of the instrument.

Materials and metal alloys will be developed at JPL's Metallurgy Facility, which working in conjunction with the AMC, will be responsible for constructing instrument casings. Each casing will be specific to the ideal operating temperature of the instrument component, and thus a center which specialises in creating various material combinations while allowing for reduced in-house costs is a necessity.

External Suppliers/Manufacturers

A majority of the science instrumentation will be constructed through partnerships with other facilities, with smaller components and interfaces being purchased from external suppliers. The SuperCam was designed and manufactured at the Los Alamos National Laboratory, and Theia, as it bears similarities to the ChemCam/SuperCam, will be manufactured there as well. It is important to the success of the instrument that it is manufactured in a location with experience in similar instrumentation, specifically the manufacturing of the internal spectrometer components.

While the majority of the spectrometers will be constructed at the Los Alamos National Laboratory, minor components will be produced elsewhere. For example, the mirrors present in the spectrometers will be manufactured by OPCO Laboratory, Inc., as the company specializes in producing parts for optical applications, namely spectroscopy and telescoping. Along with the mirrors present in the spectrometers, the mirrors in the telescope & laser portion of the instrument will also be produced by OPCO. Mirrors constructed by this company are used aboard the SuperCam, and therefore have flight heritage and are proven to be reliable. OPCO also produces diffraction gratings for various wavelengths, which will also be considered.

However, the most likely candidate for producing the diffraction gratings used in the spectrometers will be Wasatch Photonics. Wasatch Photonics produces volume-phase transmission gratings, as well as Raman spectrometers. While the spectrometers have already been discussed as being produced elsewhere, the fact that Wasatch Photonics has knowledge in one of the methods of spectroscopy which the vehicle will be employing only strengthens its choice as a manufacturer for components of Theia.

Components of the C&DH board will also have various suppliers. The LEON3FT processor is produced by CAES, which was designed with consideration to the environment of space. CAES will also produce the MRAM, SDRAM, and the programmable read-only memory module. The FPGAs will be produced by the Microsemi Corporation.

In regards to communications systems, the CubeSat UHF Antenna System is manufactured by NanoAvionics

4.1.4. Verification and Validation Plan

The verification and Validation plan of the SuperCam instrument will be supported by an environmental qualification model (EQM) and flight model (FM). In order to test if there is a performance change after exposure to the vibration environment, the SuperCam flight model will undergo a series of environmental qualification tests. These will include random vibration and thermal vacuum which will take place in the Los Alamos facilities. A random Vibration test is performed in each of the three axes for one minute per axis. After vibrating each axis a visual inspection will be performed and accelerometer data will be reviewed to assess any mechanical change to the unit. It is important that the instrument and its smaller parts are able to function in a vibrating environment to ensure the longevity of the mission on Mars.

Mars-pressure testing of the SuperCam will take place at thermal chambers to prevent issues like electric field leakage through the unit. These issues could endanger the mission. For the pressure testing, nitrogen will be the test gas of choice because it is easier and safer to use in a thermal chamber and is very similar to the Martian atmosphere.

The thermal management system on SuperCam, which maintains the electronics at an acceptable temperature to avoid thermal-induced failure, verified with finite element modeling and thermal/vacuum testing. In addition, electromagnetic compatibility and electromagnetic interference tests will be performed using the environmental qualification model at the JPL facility.

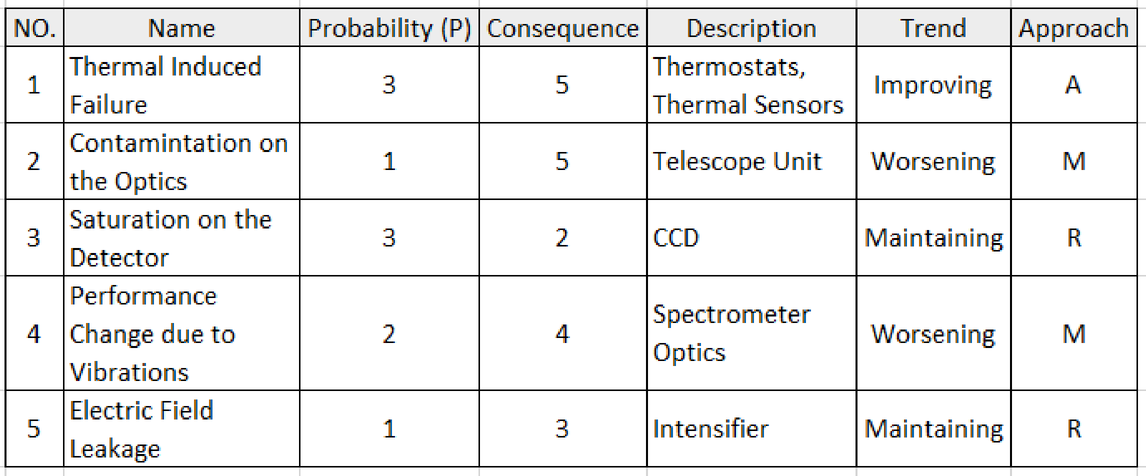
4.1.5. FMEA and Risk Mitigation

Charts are presented which analyze the risks associated with our science instrument. The science instrument has been assembled considering the project mission, budget, and weight restrictions.

Decision is our path forward for future development and risk reduction:

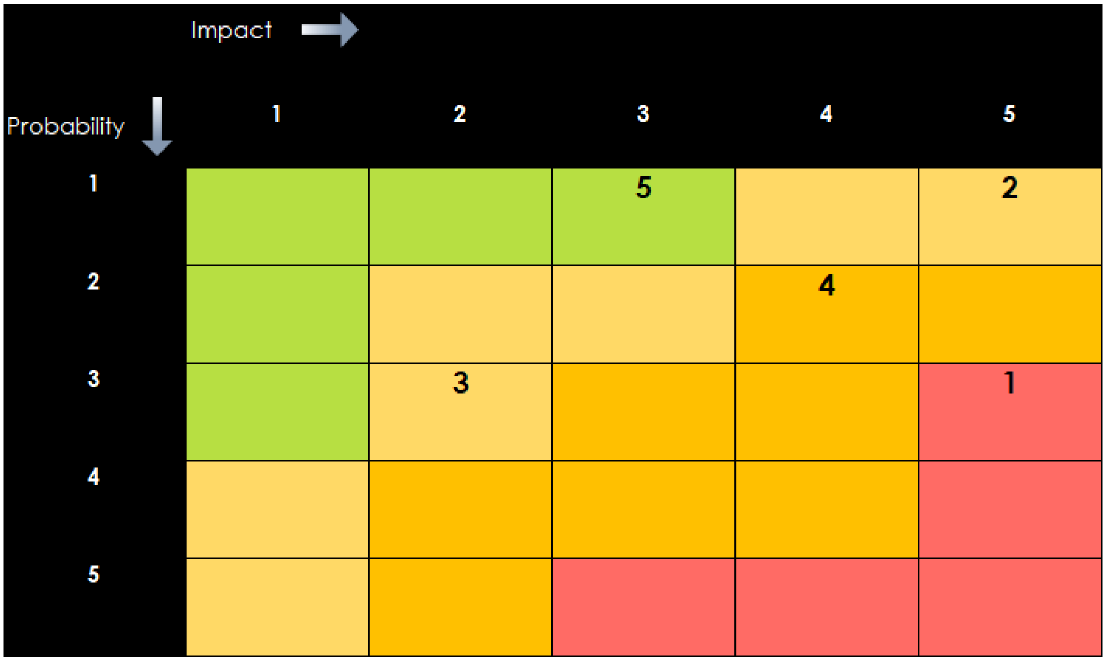
- Accept (A): The failure is not probable and therefore acceptable.
- Monitor (M): The risk of this failure is currently not probable, but could lead to critical failure, therefore will be monitored for future improvements.

- Redesign (R): The failure is probable to the point that it is unacceptable and requires redesign.



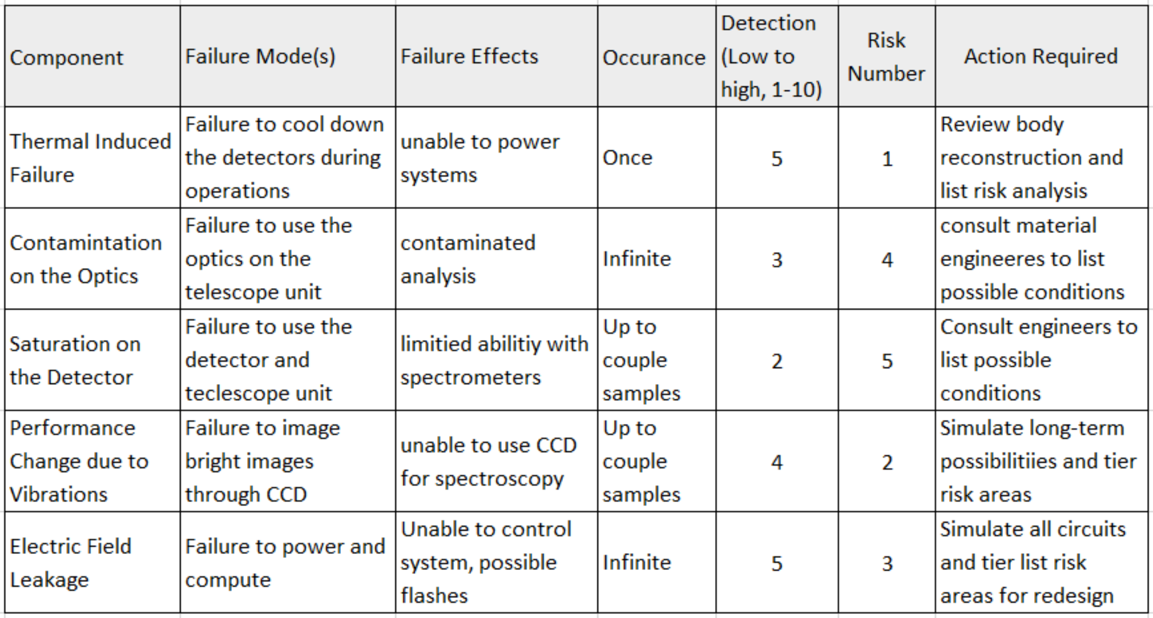
NO.	Name	Probability (P)	Consequence	Description	Trend	Approach
1	Thermal Induced Failure	3	5	Thermostats, Thermal Sensors	Improving	A
2	Contamintation on the Optics	1	5	Telescope Unit	Worsening	M
3	Saturation on the Detector	3	2	CCD	Maintaining	R
4	Performance Change due to Vibrations	2	4	Spectrometer Optics	Worsening	M
5	Electric Field Leakage	1	3	Intensifier	Maintaining	R

Table 6. *ARES-42 Rover System Risk Management*



Probability ↓ / Impact →	1	2	3	4	5
1	🟩	🟩	🟩 5	🟨	🟨 2
2	🟩	🟨	🟨	🟧 4	🟧
3	🟩	🟨 3	🟧	🟧	🟥 1
4	🟨	🟧	🟧	🟧	🟥
5	🟨	🟧	🟥	🟥	🟥

Table 7. *Top down risk management matrix at an individual systems level*



Component	Failure Mode(s)	Failure Effects	Occurance	Detection (Low to high, 1-10)	Risk Number	Action Required
Thermal Induced Failure	Failure to cool down the detectors during operations	unable to power systems	Once	5	1	Review body reconstruction and list risk analysis
Contamintation on the Optics	Failure to use the optics on the telescope unit	contaminated analysis	Infinite	3	4	consult material engineeres to list possible conditions
Saturation on the Detector	Failure to use the detector and teclescope unit	limitied abilitiy with spectrometers	Up to couple samples	2	5	Consult engineers to list possible conditions
Performance Change due to Vibrations	Failure to image bright images through CCD	unable to use CCD for spectroscopy	Up to couple samples	4	2	Simulate long-term possibilitiies and tier risk areas
Electric Field Leakage	Failure to power and compute	Unable to control system, possible flashes	Infinite	5	3	Simulate all circuits and tier list risk areas for redesign

Table 8. *Simplified FMEA chart which shows the risk analysis of the science instrument as described by the probability and impact of the critical mission failure scenarios.*

4.1.6. Performance Characteristics

Power and Durability

One of the main purposes of the mission ARES-42 is to successfully retain information from Mars. Without having a continuous flow of data, the mission is not fulfilled and the results can't be verified. Due to the weather conditions on Mars, solar panels are not feasible. To ensure the durability of the rover and keeping clear communication with ARES, the main power source on the vehicle is decided to be a radioisotope thermoelectric generator (RTG) that is a type of nuclear battery and doesn't require sunlight. Even though the landing time is planned based on the beginning of the Martian summer to reduce the impacts of harsh weather, the weather conditions are still not good enough to rely on solar energy. This will allow uninterrupted power and communication during dust storms and other weather conditions.

Thermal and Temperature

Due to the weather conditions on Mars, the instrument relies on the use of thermostats and thermal sensors. The thermal system maintains a warm temperature during cruise to Mars to avoid contamination on the optics and cools the detectors during operations on Mars. In order to meet the thermal requirements that drive the design of the thermal management systems on SuperCam, some adjustments in terms of time were made.

One of the requirements being the need to cool CCDs during operation, it’s been decided to use the thermoelectric coolers (TECs) in the design. Another requirement is maintaining the electronics at an acceptable temperature to maintain reliability and avoid thermal-induced failures. Due to the environmental temperature of Mars, the instrument can't maintain a temperature of 0 ℃. Therefore, along with the thermal system that provides heating through running fluid, the science instrument will be used in the morning hours.

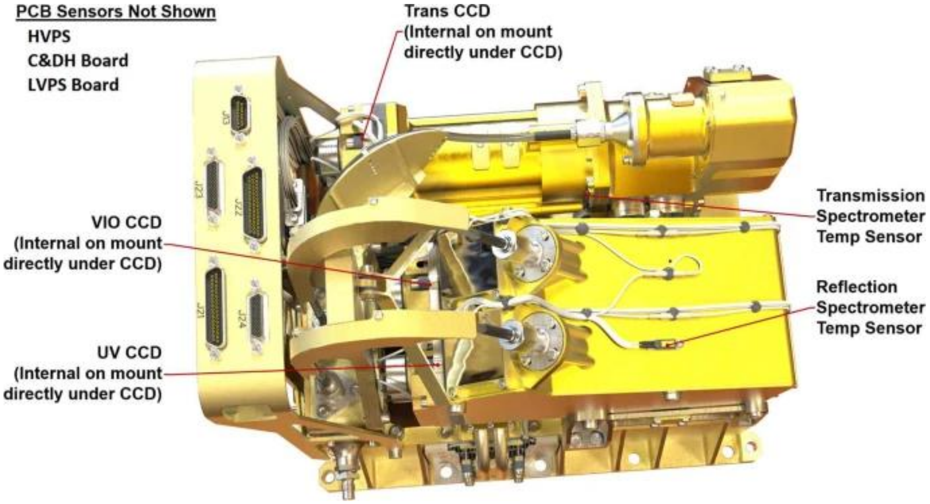


Figure 42. *The SuperCam Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests*

4.2. Science Value

4.2.1. Science Payload Objectives

ARES-42 mission science goal is to characterize subsurface ice on Mars for habitable environment characteristics by using a laser spectrometer to gather data that will be used to inform future human exploration teams of the presence and suitability of the water feedstock to support human exploration. ARES-42 chose to use a laser spectrometer because it will offer us significant data about the Martian environment. For example, it will allow the rover to characterize rocks that are far away (about 7 meters). This will let the rover discover rocks that may have been in water or formed in water without having to travel to reaching distance. This will help to save on power consumption. It prevents the rover from traveling to reaching distance from a rock only to find that it has no properties relating to water, thus putting the power it took to reach it to waste. The laser spectrometer also runs on very little power, operating at only 17.9

watts. This lets ARES-42 allocate power to other power-intensive sections of the rover, such as thermal control and attitude control. The laser spectrometer can also characterize Martian dust to detect if it may be harmful to humans, which will be of great help to the future human exploration team. The mission success criteria is to achieve at least a 90% success of the initial mission to characterize subsurface ice on Mars for habitable environment characteristics. ARES-42 rover will be able to begin an exploration of the area surrounding the landing site immediately in order to achieve its task of collecting data on sublevel ice. The secondary instrument processes collected data, which will then be sent back to the project team on Earth for further examination.

4.2.2. Creativity/Originality and Significance

ARES-42 science objective is unique because it will be characterizing an area of Mars that has never been explored before. The ARES rover will have the opportunity to further discover the glacial history involving lobate debris aprons. More specifically, Arcadia Planitia. This landing site has debris-covered glaciers that have since been discovered but never explored (Figure 43).

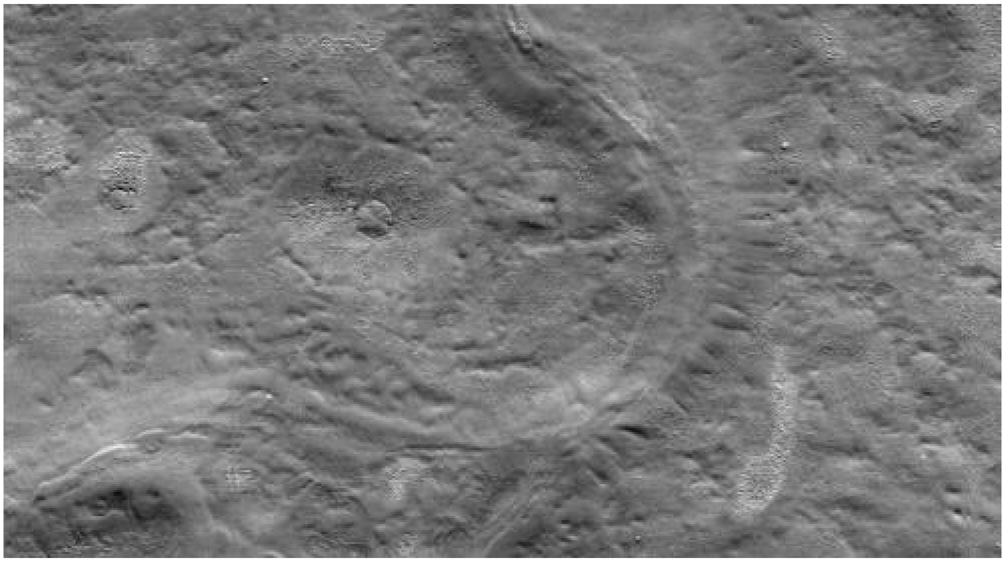


Figure 43. *Example of Arcadia Planitia Terrain (Image credit: NASA/JPL/Arizona State University)*

As you can see from Figure 44, the winding terrain mimics ice streams in ice sheets located in Antarctica (Figure 44).

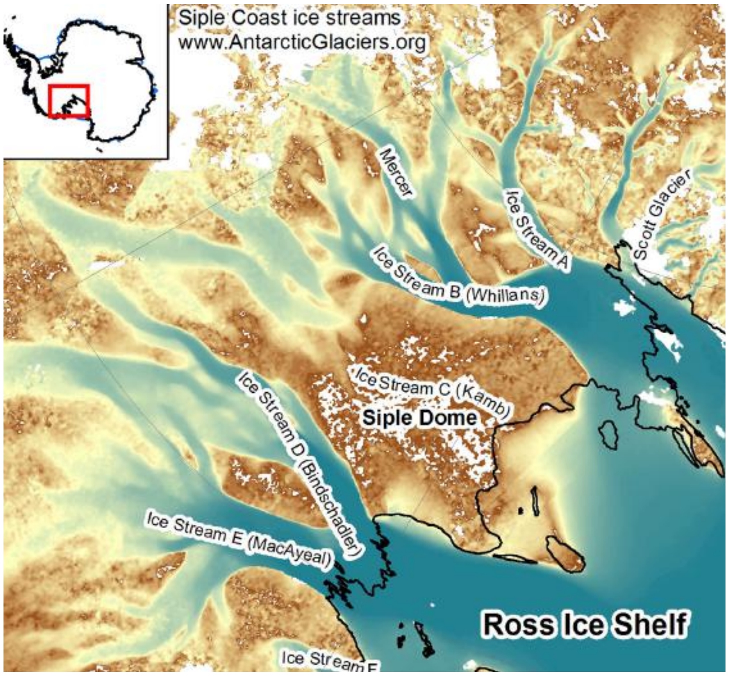


Figure 44. *Antarctica's Ice Streams (Image credit: antarcticglaciers.org)*

This similarity gives ARES-42 hope that there may be water underneath these possible debris-covered glaciers. Because Arcadia Planitia has never been explored by anything or anyone, it could be a big step in understanding Mars' past environment. If Arcadia Planitia ends up having water underneath the debris-covered glaciers, it may be a critical site for having our human exploration team land, as they'll need 100 metric tons of water. The specific site ARES-42 is going to explore is shown in Figure 45. This landing site was deemed optimal using the program Java Mission-planning and Analysis for Remote Sensing, otherwise known as JMARS. This program "...is a geospatial information system (GIS) developed by ASU's Mars Space Flight Facility to provide mission planning and data-analysis tools…" (jmars.asu.edu). ARES-42 is able to see various types of information, such as temperature, elevation, and landscape. A small section, shown in Figure 45, was marked and analyzed.

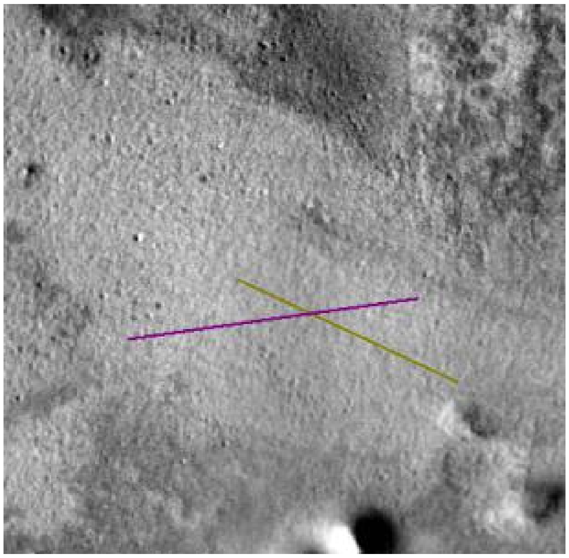


Figure 45. *ARES-42 Landing Site Using JMARS*

The purple and yellow lines crossing this site are used to see the difference between elevations. From the information we get using JMARS, we can see that the yellow line is relatively level, making it an optimum landing site for our rover. It varies 8 meters in height. The purple line goes up the hill, or glacier, and can be seen in the graph showing the elevation change. It varies 18 meters in height. All of this data can be found in Figure 46.

Figure 46: *ARES-42 Landing Site Elevation*

4.2.3. Payload Success Criteria

As stated previously, ARES-42's mission success criteria is to achieve at least a 90% success of the initial mission to characterize subsurface ice on Mars for habitable environment characteristics. To ensure the mission is successful, various failure modes are present in the scientific payload instrument. The first one is in our LEON3FT processor, and it has a built-in algorithm meant to search and correct errors in the ARES rover's cache and register file. This ensures that our rover can process information smoothly and be able to fix any errors it may have internally. The second one is the thermometers located in the instrument. If the operational temperatures specific to the instruments are passed and the rover begins to overheat, the thermal system will momentarily shut down until the temperature decreases. This is only accomplished by the thermometers being present. As for the success threshold, the mission can still be successful even if no ice was found. This would be if the mission finds concentrations of hydrates, which can further inform future missions of sites with an increased probability in near-surface sublevel ice. Hence with more information gained on in-situ hydrates, data can be gained as to the location of ice and the mission will still be successful. This mission's payload is extremely significant because without it, characterizing Martian rocks and possibly finding rocks around Arcadia Planitia that may have been in water or formed in water would be extremely difficult. ARES-42's laser spectrometer will allow the rover to efficiently find possible water sites and further inform future missions of sites, such as the human exploration team.

4.2.4 Experimental Logic, Approach, and Method of Investigation

The overarching scientific goal for ARES-42's mission is to characterize subsurface ice deposits in key areas of interest surrounding the landing site in Arcadia Planitia-gathering spectrometry data that will analyze the chemical composition of potential water feedstocks to inform future human exploration missions to Mars. After deployment of the Area Resource Exploration Site Surveyor (ARES) rover onto the surface of Mars, the main payload components including the LIBS, Raman, and VISIR spectrometers will begin collecting data. The remote micro imager (RMI) will collect images at each collection point to validate the geochemistry determined by the spectrometer suite. The LIBS instrument looks for evidence of hydrates, VISIR spectrometer characterizes mineralogy and chemical composition, and the Raman spectrometer looks for organic compounds. In summary, the three different types of spectrometers will utilize lasers or optical reflection to collect data on surface chemical composition at specific coordinates, and the information will be logged accordingly at each point. The spectrometers will collect the data on the sublevel ice and the LEON3FT processor core will process the collected data and send it back to Earth for further analysis.

To further explain the data collection procedure, the desired workflow is broken down into 3 main phases, as follows: 1) initial laser drilling, 2) secondary drilling operations, and 3) data acquisition. As far as physical rover movement is concerned, the rover will first take 25 equidistantly spaced measurements in a 5 km x 5 km area. In the initial drilling process, the presence of hydrates will be determined in the sample in the first 5 cm below the surface at each of the 25 points. After hydrate presence at the 25 points are calculated, the points will be ordered from highest hydrate percentage to lowest and the rover will return to the point of highest hydrate percentage. In the secondary drilling operations, the rover will move to the point of highest hydrate percentage and drill 5 cm, where the RMI will take an image to send back to Earth. The spectrometers will then evaluate if the percentage of hydrate increases, there are harmful toxins, content of the actual ice, and mineral concentrations. In the next step of drilling operations, the lasers will cool down below critical temperatures and will be repeated until ice is found no longer safe to drill or max usefulness. If there is ice, the instrument will note how many drilling sequences are necessary to reach it, logging depth beneath the surface. The drill hole will be sealed to decrease the amount of exposed ice sublimating. Then, the specific location will be flagged to include concentration of minerals, presence or absence of ice, or relevant toxins of interest for future human exploration experiments. The data will then be sent back to Earth using the Ultra-High Frequency Antennas.

As shown in the JMARS figures below, the landing site chosen by the team is located in lower mid-latitudes of Arcadia Planitia, specifically near Erebus Montes. According to a previous SWIM study, there is high confidence that a massive layer of subsurface ice exists in Arcadia Planitia. This evidence provides the conclusion that Arcadia Planitia is a favorable site because of ice accessibility and abundance which has the potential to yield significant scientific value. As shown in figure 40 below, ARES-42 will be landing along the yellow surface line because there is limited elevation gain meaning the area will be relatively flat.

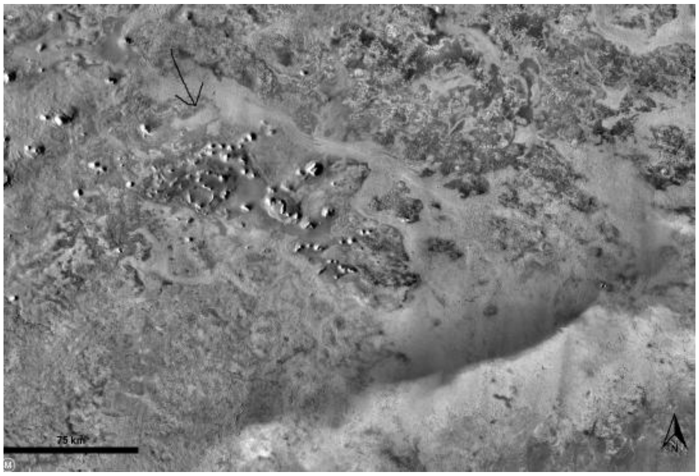
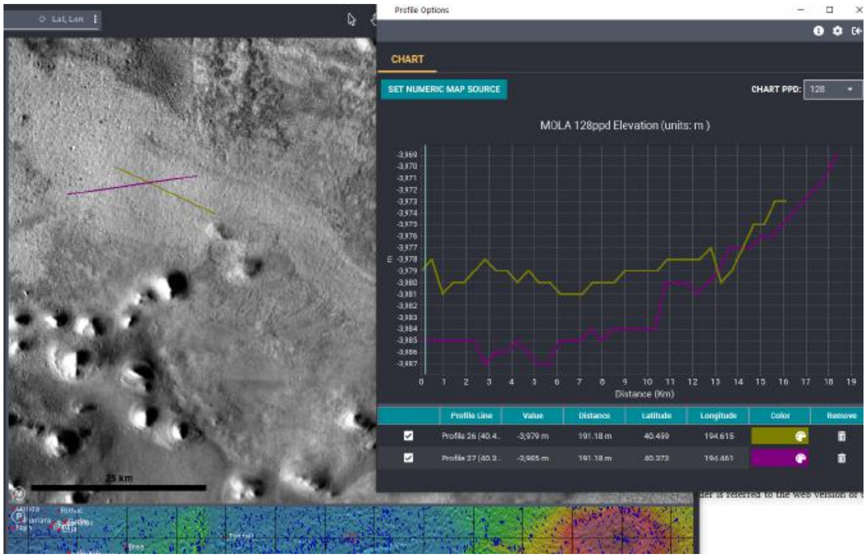


Figure 47. *JMARS image of the proposed landing site in Arcadia Planitia, at coordinates:40.824°N, 194.422°E*



	Profile Line	Value	Distance	Latitude	Longitude	Color	Remove
☑	Profile 26 (40.4…	-3,979 m	191.18 m	40.459	194.615	🟨	🗑
☑	Profile 27 (40.2…	-3,985 m	191.18 m	40.272	194.461	🟪	🗑

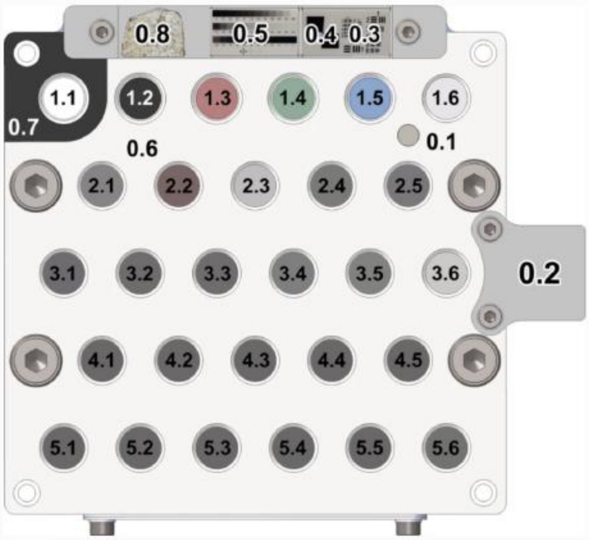
Figure 49. *Zoomed in image on JMARS of the proposed landing spot. The chart on the right details the elevation gain along the yellow surface line, where the elevation gain is minimal.*

4.2.5. Testing and Calibration Measurements

In order to calibrate the 3 spectrometers and RMI onboard the rover, a suite of calibration targets will need to be equipped onto the rover to ensure proper reference to known materials. Calibration ensures that the information collected by each instrument is robust to environmental factors, motion, and aging. It is essential that the ARES-42 contains numerous reference points to known materials in order to compare observations from the RMI and spectrometers. However, the calibration of targets for the suite of spectrometers on ARES-42 requires multiple unique calibration standards in order to yield maximum informational output from each individual instrument. Because of this, each unique spectrometer requires its own calibration target which makes calibrating this instrument suite a complex challenge. To further complicate this challenge, cross calibrations between spectrometry techniques are required for synergistic combinations of spectrometer data.

The following methods will be used to calibrate the RMI, LIBS, Raman, and VISIR spectrometers, in compliance with the thermal and mechanical requirements of this mission. On the rover, there is a geometric target for RMI calibration featuring 2 plates with targets for dynamic performance and point spread function diagnostics to correct the images. Additionally, a Martian meteorite slab is then attached in the middle of the RMI geometric target. The samples 1.1 to 1.5 pictured in the figure below serve as calibration standards for the RMI and VISIR spectrometers, for imaging calibration. For the Raman spectrometer, there is an organic calibration standard made of polyethylene terephthalate (PET) that makes sure that organic molecules can be detected by optimizing the laser pulse parameters. There is also a diamond calibration target for the Raman spectrometer because diamond has the strongest Raman signal for solid material references. Lastly, the LIBS will be calibrated with a titanium plate to optimize the emission spectra for accurate calibration under different environmental conditions.

Fig. 2



Arrangement of targets with identifiers for each of them

Figure 50. *Photo of the SuperCam Calibration Target, courtesy of Manrique et al.*

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

At up to 5 meters, the LIBS instrument has an upper detection limit, precision, and accuracy at this range. If the potassium emission line at 767 nm is detected with a signal to noise ratio greater than 64 at this range, then the laser is sufficiently able to detect the target. The LIBS instrument can be validated by clearing 0.5 mm into material with a hardness of 5 on the Mohs scale at a distance of 5 m.

Next, the Raman spectrometer can be validated by testing a sample of carbonate and getting a signal to noise ratio greater than 20 at 7 meters distance. For VIS spectroscopy, it is sufficient to get a signal to noise ratio greater than 50 at 800 nm and IR spectroscopy requires a signal to noise ratio greater than 56 at 2.6 microns (using carbonates with reflectance = 0.5). The relative response of the spectrometer will be known with a precision better than 1% and the absolute response will be known with a precision better than 20%.

The RMI requires a spatial resolution that is better than 80 microradians when viewing a target of interest greater than 2 meters away. Calibration of the RGB pixels on the RMI requires an accuracy of +/- 20% and the pixel to pixel accuracy will be +/- 5%. These values ensure repeatability of measurement and the calibration targets ensure that measurements can be compared to baseline standards in case of contamination or other sources of error. Comparison to standards on Earth enable data from Mars to be easily translated to measurements on Earth regardless of the conditions present.

All instruments will be required to pass the qualifications of the Engineering Qualification Model (EQM) and the Flight Model (FM). Features that must be inspected in these tests include resolution, wavelength pass, straylight, signal to noise ratio, instrument transfer functions, flux and integration time, and relative and absolute spectra response. All of these components must be tested extensively through vibration and thermal cycles.

4.2.7. Expected Data and Analysis

Examples of spectrometer calibration data, actual data collected by the instruments, and data analysis and error correction are shown in the figures below. With LIBS spectroscopy, one can expect elemental analyses of composition of the rocks and soil collected. With Raman spectroscopy, one can identify biological molecules and organic materials. As mentioned earlier, the individual spectrometers must be calibrated with the proper calibration targets necessary to perform accurate measurements.

Examples of spectrometer calibration data

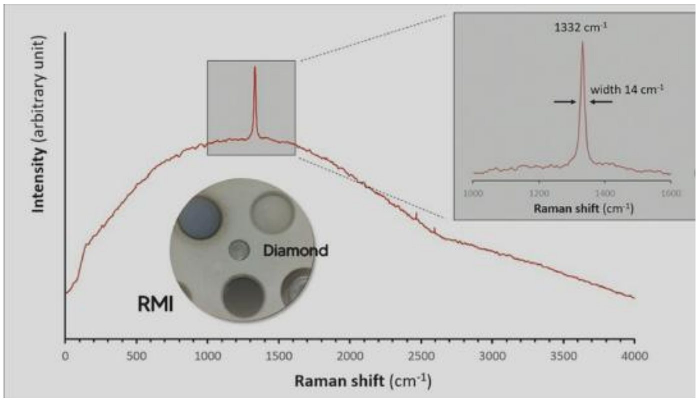


Figure 51. *Raman spectra of diamond, courtesy of Manrique et al.*

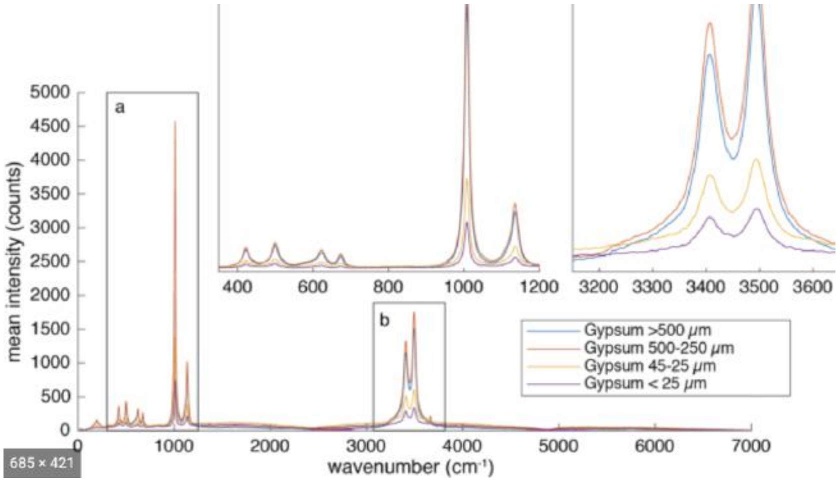


Figure 52. *LIBS spectra of gypsum targets onboard rover, courtesy of Senesi et al.*

Examples of actual data collected by instruments

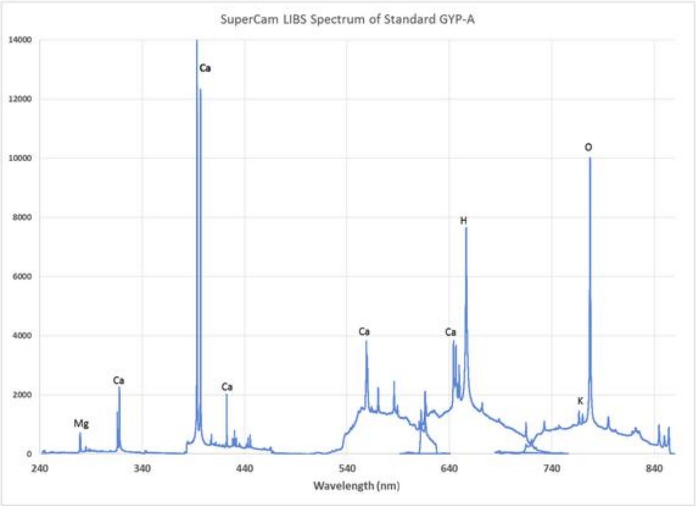


Figure 53. *Emission lines seen in a sample using the SuperCam LIBS spectra, from wavelengths 240-840 nm. Courtesy of Reess et al.*

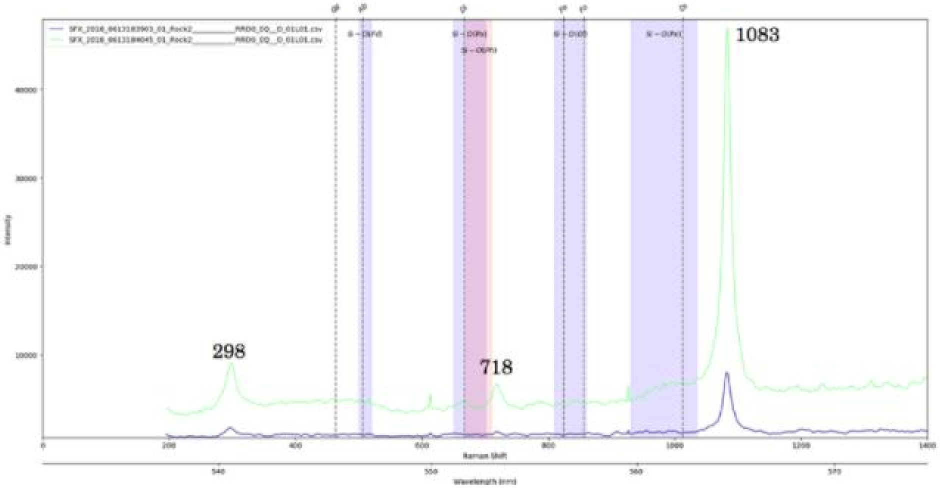


Figure 54. *Raman spectra of a collected rhodonite rock, courtesy of Reess et al.*

Examples of data analysis and error correction

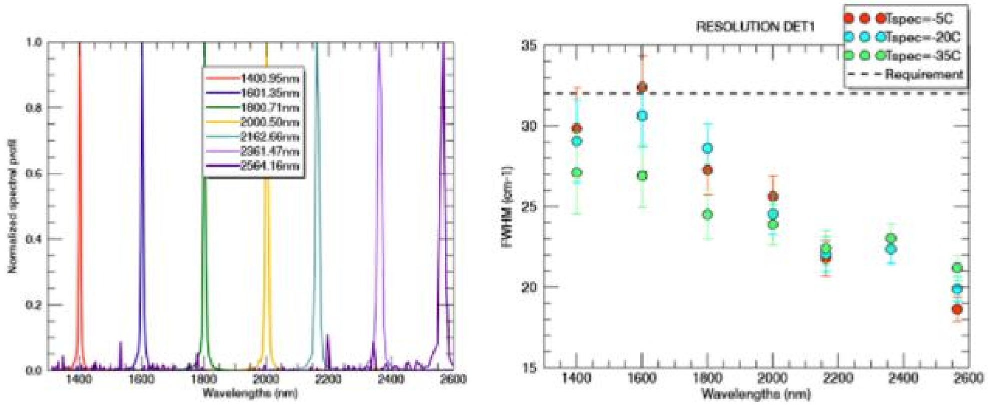


Figure 55. *Pictured is data analysis from the infrared spectrometer. A Gaussian fit is applied to the data to calculate a FWHM response with error bars at each wavelength tested, courtesy of Reess et al.*

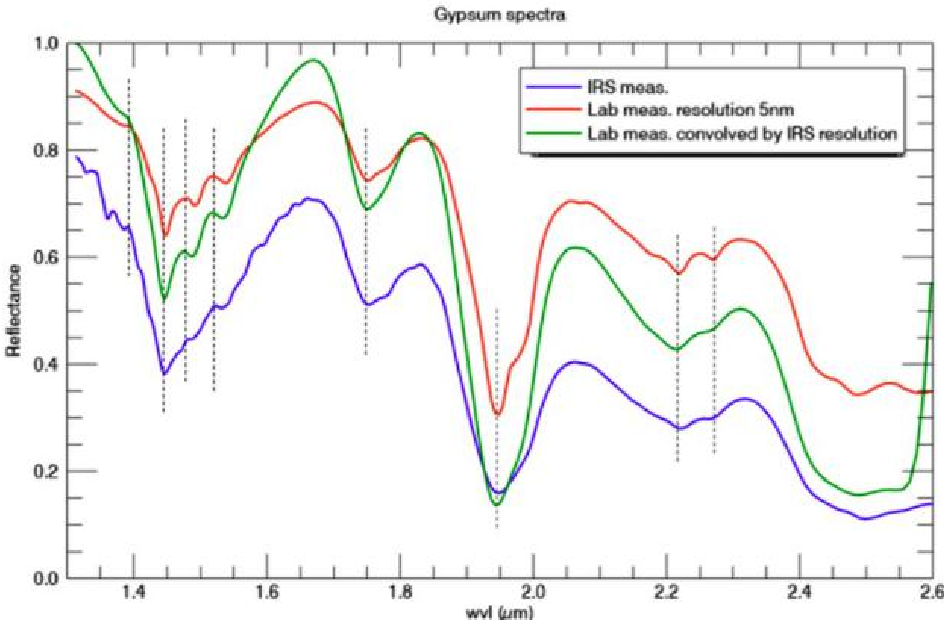


Figure 56. *High correlation between the IRS measurement, lab measurement with 5 nm resolution, and lab measurement convolved by IRS resolution confirm validity of IRS calibration, courtesy of Reess et al.*

(Left Blank Intentionally)

5. Safety

5.1. Personnel Safety

5.1.1. Safety Officer

The ARES-42 Safety Department is organized to identify and mitigate present and possible hazards to the ARES-42 mission personnel and payload. The ARES-42 mission lead safety officer, Antonio Ramirez, operates as the managing safety member and works in collaboration with two deputy safety officers; Nicole Alvarado, who specializes in personnel safety, and Daniel Campos, who specializes in payload safety. The overlapping team organization approach described in section 6.4 of this document is extended onto mission safety in order to operate under a check and balancing system which promotes collaboration and ensures mission success.

The lead safety officer shall:

- Ensure compliance with the Occupational Safety and Health Administration (OSHA) and NASA hazard communication requirements
- Mitigate stressful work conditions and hold meetings with subteam leads to review personnel stress levels
- Manage and track the efficacy of safety protocols.
- Organize and implement clear methods of communication of hazards identified by deputy safety officers for mission personnel.
- Provide and communicate the direction of the mission safety system to customers throughout the mission life-cycle.
- Determine the risk factor of resulting risks that stem from identified hazards.
- Ensure the safety system extends throughout the mission life cycle: testing, manufacturing (including contracted), assembly, pre-launch, and operations through the end of primary mission operations.
- Lead and manage secondary safety of mission operations until operations cease.
- Provide contact numbers and protocol for personnel to file when injured
- Provide access to labels and information for hazardous materials such as Material Safety Data Sheets (MSDS)

Deputy safety officer shall:

- Identify and implement mitigation of hazardous conditions starting from the Pre-Phase A portion of the mission project life cycle.
- Perform employee training and safety audits of workplace
- Communicate the specific safety system outlined by the lead safety officer to ARES-42 mission personnel.
- Inform the decision-making process for mitigation of identified and resultant risks through expertise.

  Serve as an active point of contact between mission personnel and the safety department.

5.1.2. List of Personnel Hazards

Personnel safety is aligned with safety protocols outlined by State, Federal, NASA, and customer guidelines. Mitigation of the risks to personnel is overseen and monitored weekly by the deputy safety officers and monthly by the lead safety officer. There are several hazards identified by the ARES-42 safety department which could cause serious harm, impairment, and/or death to personnel. Identifying personnel hazards is critical to the success and efficiency of the ARES-42 mission. A list of workplace hazards includes but are not limited to:

Health/ Physical

Threats of personnel exposure of the COVID-19 virus and other illnesses through viral infection and bloodborne pathogens, sudden personnel health emergencies. External risks include bombing and active shooter hazards. Additional health hazards include extreme mental stress.

Fire/ Electrical

Use and contact with flammable materials pose fire risks to personnel through contact or inhalation. Hazards include worn or frayed electrical cords, electrical cords running through doorways, long lengths of electrical cords in use continuously, exposed electrical wiring around outlets, switches, and lights (page 17 NASA Safety Guide).

Equipment/ Occupational

Hazards due to the operation of heavy equipment and vehicles may occur if improperly used or accidental contact is made, repetitive motion and strain, falling from heights, extreme conditions such as wind tunnel and laboratory exposure to machinery, poor sensory environment such as visibility and hearing, exposure to debris, exposure to harsh vibrations, and restrictive range of motion due to ill-fitting Personal Protective Equipment (PPE).

Chemical/ Radiation

Laboratory risk of handling and being exposed to harsh chemicals. Exposure to hazardous materials and substances such as chemicals and radiation associated with the rover build and assembly of radioactive components such as the RTG.

5.1.3. Hazard Mitigation

The ARES-42 safety department has implemented steps to mitigate the aforementioned personnel hazards and resulting hazards of the identified risks in order to protect employees from exposure. The following ARES-42 personnel workplace prevention plans have been implemented throughout the analysis, design, and development of Phases A through D. The mission has imposed risk mitigation modeled after the NASA AMES research flight center Wind tunnel operations division Safety Manual ("Wind Tunnel Operations").

Health/ Physical

Mitigation for the prevention of the spread of airborne illnesses such as COVID-19 includes remote working when applicable to the employee's mission function. If teleworking is not an available option, then ARES-42 protocol shall follow State and Federal guidelines set forth by the Center for Disease Control (CDC). Steps for prevention include keeping the workplace disinfected, requiring employees to stay 6 feet apart, requiring face masks, requiring face masks to be worn by employees when indoors, and requiring weekly proof of a negative COVID test or proof of vaccination.

Prevention for blood-borne illness and transmission of pathogens is provided by mandatory employee first aid training, certification through the Red Cross, and implementation of proper care and handling. Per OSHA guidelines it is mandatory for all employees to wear PPE and Respiratory Protective Equipment (RPE) when handling bodily fluids to prevent the risk of exposure.

Fire/ Electrical

ARES-42 employees have mandatory fire safety training for small workplace fires and possible chemical/fluid-fed fires which burn at higher intensities. Fuel and flammable materials are stored with proper caution and warning labels and are handled away from ignition sources. Fluid and Pressure system isolation is in place to protect employees from fluid or gas lines whose sudden release can cause fire or physical harm. Such isolation methods include alarm systems and emergency shut-off systems with redundancy. An example of a fluid isolation system is shown in figure 47. Energy control systems are put into place in order to act as a warning system and isolate energy devices and mechanical devices which should not be operated due to malfunction and possible risk to employees. Additional safety systems are put into place in order to train employees on how to prevent interaction with hazardous electrical devices. Lockout Tagout protocol as outlined by OSHA is another preventative tool that restricts access of hazardous devices to trained and authorized personnel only as shown in figure 48 ("Wind Tunnel Operations" 91).

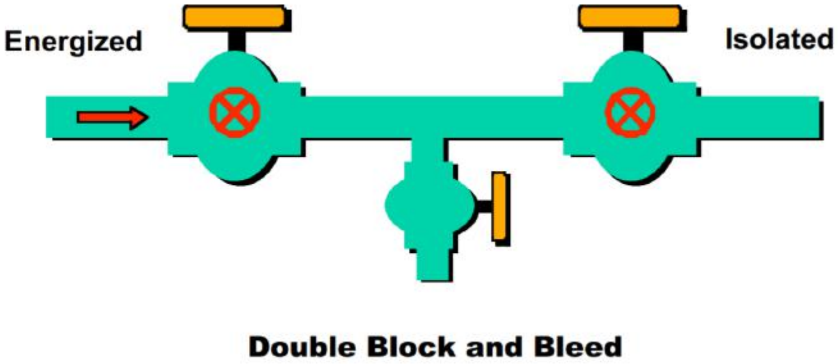


Figure 57. *Double block and bleed method of emergency isolation system for the unexpected release of fluids as shown in the AMES Safety Manual*

Figure 58. *Employee and visitor lockout tagout measures, Personal Danger Tags (Do Not Operate) as shown in the AMES Safety Manual.*

Equipment/ Occupational

Heavy equipment is regulated to only be operated by employees who hold certification and training on the specific equipment. Employees must be approved to operate and given access to heavy equipment upon approval. Emergency shut-off systems are in place on equipment to shut off and minimize damage to surroundings and personnel. ARES-42 mission requires that all personnel regardless of worksite adhere to the Lift and Cranes flowchart protocol shown in figure 49 which was developed at NASA's AMES research center. Hearing damage is mitigated through the use of signs, limited exposure, and the mandatory use of hearing protective devices (HPD). Examples of workplace cautions are shown in figure 50. ARES-42 Safety division complies with OSHA regulations and implements a hearing program that identifies, tracks, and controls noise through hearing protection and limiting exposure. Implementation of the Fall-Protection Work Plan, a tool to assist supervisors and work crew in planning work that poses fall hazards (“Wind Tunnel Operations” 59). PPE is regulated and used to protect employees from general, chemical, dust, particle, pyrotechnic, and thermal hazards. PPE is required to fit the employee and be available in a size that allows the employee to be both protected from the outlined hazard as well as safely perform duties while wearing PPE.

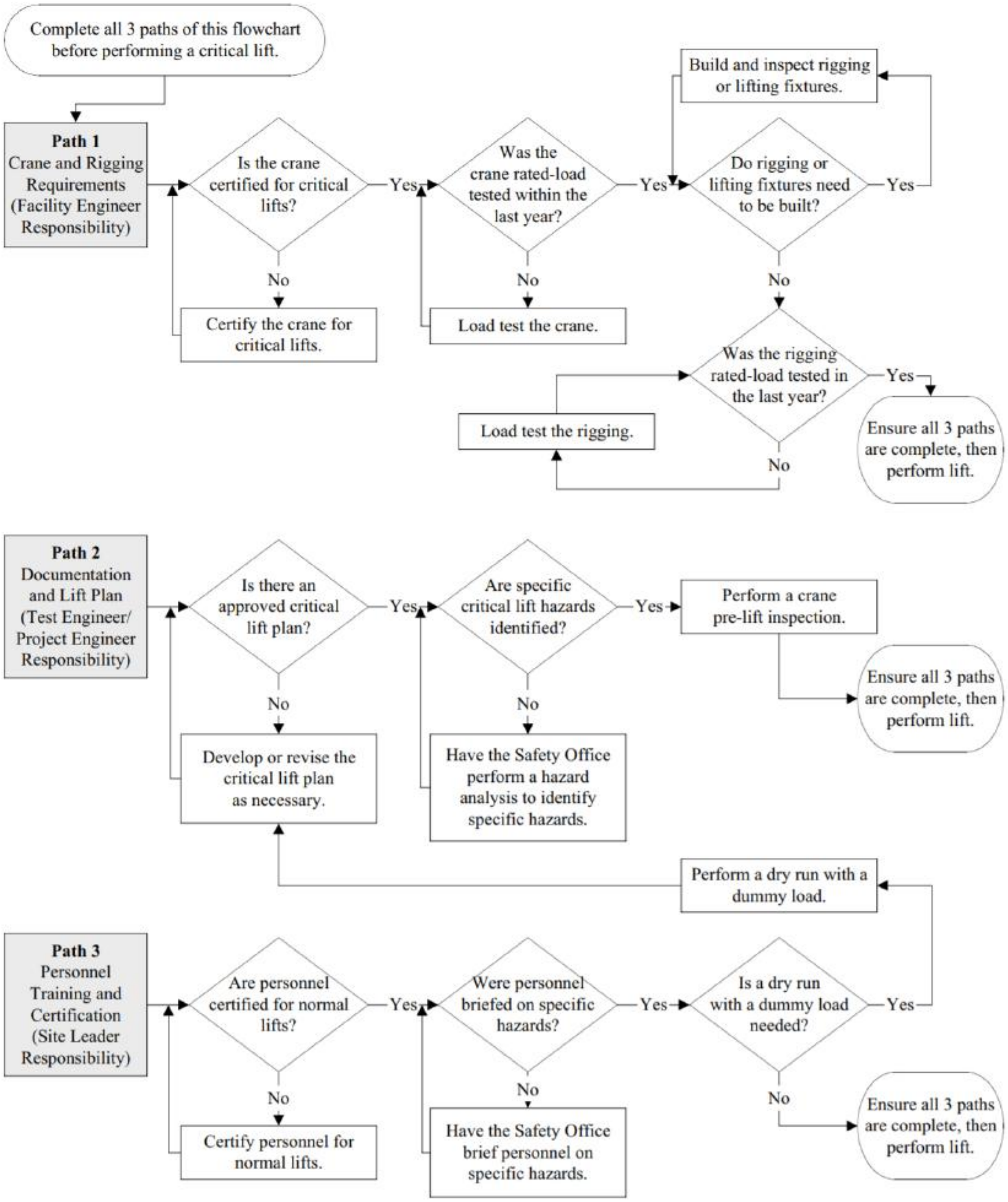


Figure 59. *AMES research facility Lifts and Cranes flow chart used to determine paths of operation, AMES Safety Manual.*

Figure 60. *Black and yellow Noise caution signs are mandatory in work areas with the potential for causing hearing damage as shown in the AMES Safety Manual.*

Chemical/ Radiation

PPE and RPE are required for outlined job functions in order to prevent inherent exposure to harmful materials and substances such as specified roles within a laboratory. It is mandatory to have access to MSDS documents for all employees who may come into contact with hazardous materials. Employees have access to binders with information on all manufacturer material data sheets which describe safety, health, and information about the hazardous materials. Labeling, employee training, and posted descriptions of labeling for hazardous material are mandatory for any workplace where exposure to hazardous materials is inherent to the employee's role. Hazardous and waste containers shall be labeled with hazardous waste labels and dated in accordance with the Environmental Procedures and Guidelines ("Wind Tunnel Operations" 35). Both general and workplace task-specific emergency response protocols are included in employee safety training ("Workplace Safety & Health" 5).

5.2. Vehicle/Payload Safety

5.2.1. Environmental Hazards

As alluded to in the previous section, there are a number of potential hazards leading up to the launch date of the ARES-42 mission. Identifying these hazards prior to launch in order to minimize any potential surprises along the way is crucial to ensure mission success. The list of hazards that are introduced post-launch are significant, but manageable. These hazards include the following: extreme vibrational loads during launch and descent into the Martian atmosphere, increased radiation exposure mid-flight and on the Martian surface, varying characteristics of the regolith and terrain between different regions, and large changes in temperature and weather. These hazards and the precautionary measures taken to mitigate them will be further discussed in the next section.

5.2.2. Hazard Mitigation

The first post-launch hazard that must be dealt with is the extreme vibrational loads that the spacecraft will encounter while launching from Earth and while also descending into the Martian atmosphere. According to a NASA research paper, titled “Rocket Launch Induced Vibration and Ignition Overpressure Response”, it was concluded that “the vibration/acoustic launch environment was estimated to account for 30 to 60 percentof the first-day space failures.”
One source of these large vibrational loads comes from the acoustic noise generated by the rocket engines. As the rocket engines ignite, the noise produced bounces off of the launch pad, and back up to the rocket. These sound waves, ranging from 5 Hz - 200 Hz, can cause major structural damages to the rocket body and in turn, all cargo on board. In addition to the acoustic noise created, other sources of vibrational loads come from aerodynamic pressure and vibrations from the rocket’s engines. The first step that will be taken to minimize the effect of the sound waves is the industry-standard procedure of flooding large amounts of water under the rocket while it takes off from the launch pad. In doing so, the water is able to absorb much of the sound waves created, preventing them from reflecting off of the asphalt and back up to the rocket. To ensure that the spacecraft itself is capable of handling these vibrational loads, extensive testing will be done during and after the production of the rover. These tests will place the rover and its components under vibrational loads similar to those that may be experienced during launch. During these tests, sensors will be placed on numerous parts of the rover and science instrumentation. The data collected by the sensors will be analyzed by the scientists and engineers creating the rover, and any necessary adjustments will be made to ensure the spacecraft will be able to safely ascend away from Earth and descend into Mars.

Another post launch hazard that must be addressed is increased radiation exposure during the journey to Mars and while on the Martian surface. The two main sources of space radiation are galactic cosmic radiation (GCR), which originates from outside of the solar system and consists of ionized atoms, and solar particle events (SPE). While the flux of this type of radiation is relatively low, it can still cause considerable damage due to its near-light speed travel and atomically heavy composition. When passing through an object, a strong ionization occurs that could damage electrical equipment. SPE’s, on the other hand, originate from within the solar system and are the result of solar flares (SF) and coronal mass ejections (CME). SPE’s consist of highly energized electrons, protons, and alpha particles that get dispersed throughout space following the aforementioned SF’s and CME’s. The Earth’s magnetic sphere and atmosphere provide great protection from these events on and near the surface of the planet. The ARES-42 mission, however, will not have the protection of Earth’s magnetic field or dense atmosphere. To combat this, comprehensive testing will be conducted at NASA’s Radiation Effects Facility. This facility will allow the team to essentially bombard the spacecraft with radiation, similar to what it will face on its interplanetary trip, within a controlled environment. This will offer great insight to ensure that the selected materials and technological systems are able to handle the harsh environment of interplanetary travel. To protect the spacecraft, hardened materials that are less susceptible to particle penetration and charging will be utilized. Furthermore, layered aluminum will be used to slow down more energetic particles to protect the electronics onboard. Redundancy of more sensitive electronic components will also be used to ensure that the overall system can continue to run properly if one component fails.

Another hazard that could pose an immediate threat to the mission is the varying characteristics of the regolith and terrain between different regions on the Martian surface. Similar to Earth, the Martian surface is full of differing geological features, such as sand dunes or very rocky terrain. Either one of these situations could pose a threat to the mission. In order to combat these circumstances, the rover consists of a six-wheel drive system, with wheels that are similar to those used on the Mars Exploration rover. They will be made out of high strength aluminum, with wedges throughout in order to allow for increased grip and traction on the more loose surfaces. Due to weight constraints the ARES-42 mission is not able to provide suspension, however, the composition of the wheels gives a sturdy springiness to the rover. This will be particularly helpful when traversing over more rocky terrain. The rover will also have a camera attached to its body to allow for continuous oversight of its path. While prepared for rough terrain, this camera will give the team visual feedback of the rover's surroundings, which will allow the team to choose the most optimal path. If caught in a less-than-favorable terrain position, the wheels will have a wide range of motion that will allow the team to maneuver the rover out of the position. If this is not possible, a pair of rear stabilization wheels will be used on the rover to eliminate the possibility of tipping where our relative angle to the surface becomes unsafe, meaning an angle greater than 28 DEGREES from the horizontal axis. Prior to launch, the rover's drive system will be tested in the Mojave Desert, where conditions similar to those on the Martian surface can be found. This will ensure that the rover is absolutely capable of navigating through the terrain, allowing the team to reach its intended destination with a minimal amount of difficulties faced along the way.

Finally, the large changes in temperature and sometimes unpredictable weather patterns could pose a threat to the ARES-42 mission. Due to the thin Martian atmosphere and its large distance from the Sun, it is much colder than Earth. The average temperature on Mars is around minus 80 degrees fahrenheit, but can range from minus 195 degrees Fahrenheit to 70 degrees fahrenheit from the poles to equator, respectively. The chosen landing site for the mission (Arcadia Planitia) is located in between these two regions. As such, measures must be taken to ensure that the low temperatures on Mars do not affect any of the science instrumentation on board the rover. In order to combat these low temperatures, the rover will be powered using a Radioisotope Thermoelectric Generator (RTG). This power source not only provides the necessary power requirements for the rover to operate, but also produces heat as a byproduct of its power generation. While designed and tested to operate in harsh conditions, this source of heat ensures that the rover's body and science instrumentation remain at ideal operating temperatures. Weather changes on Mars could also be an issue that the ARES-42 team will have to face. While the Martian atmosphere is almost 100 times thinner than Earth's, it is still thick enough to support winds and large dust storms that can engulf the entire planet. Given Mars' thin atmosphere, winds do not seem to pose a threat to the mission. The dust that the wind kicks up, however, could be a problem if it coats the rover and/or gets into small mechanical crevices. While the rover getting covered in dust is not ideal, it would not be the end of the mission in terms of power generation. Another positive consequence of using RTGs as opposed to solar panels is the fact that power is generated internally, rather than collected externally via solar panels that could get covered in thick layers of dust. The RTGs allow the rover to continually produce energy even if it does get layered with some dust. The more concerning issue with the dust is trying to mitigate how much of it gets into the small mechanical components of the rover, which could block and resist the movement of the rover parts. This is a large concern, as mechanical failure of anything on the rover would likely lead to mission failure. One precaution that will be taken is the automatic pause on any rover movements during any of these dust storms. The team will be monitoring the weather patterns near the rover to identify any dust storms in a timely manner and pause all operations. Additionally, during construction of the rover, small gaps between any parts will be kept to an absolute minimum. For parts of the rover where this is unavoidable, such as the wheel and gear components, extensive testing will be done prior to operation in order to ensure that the rover is capable of operating in extremely dusty environments.

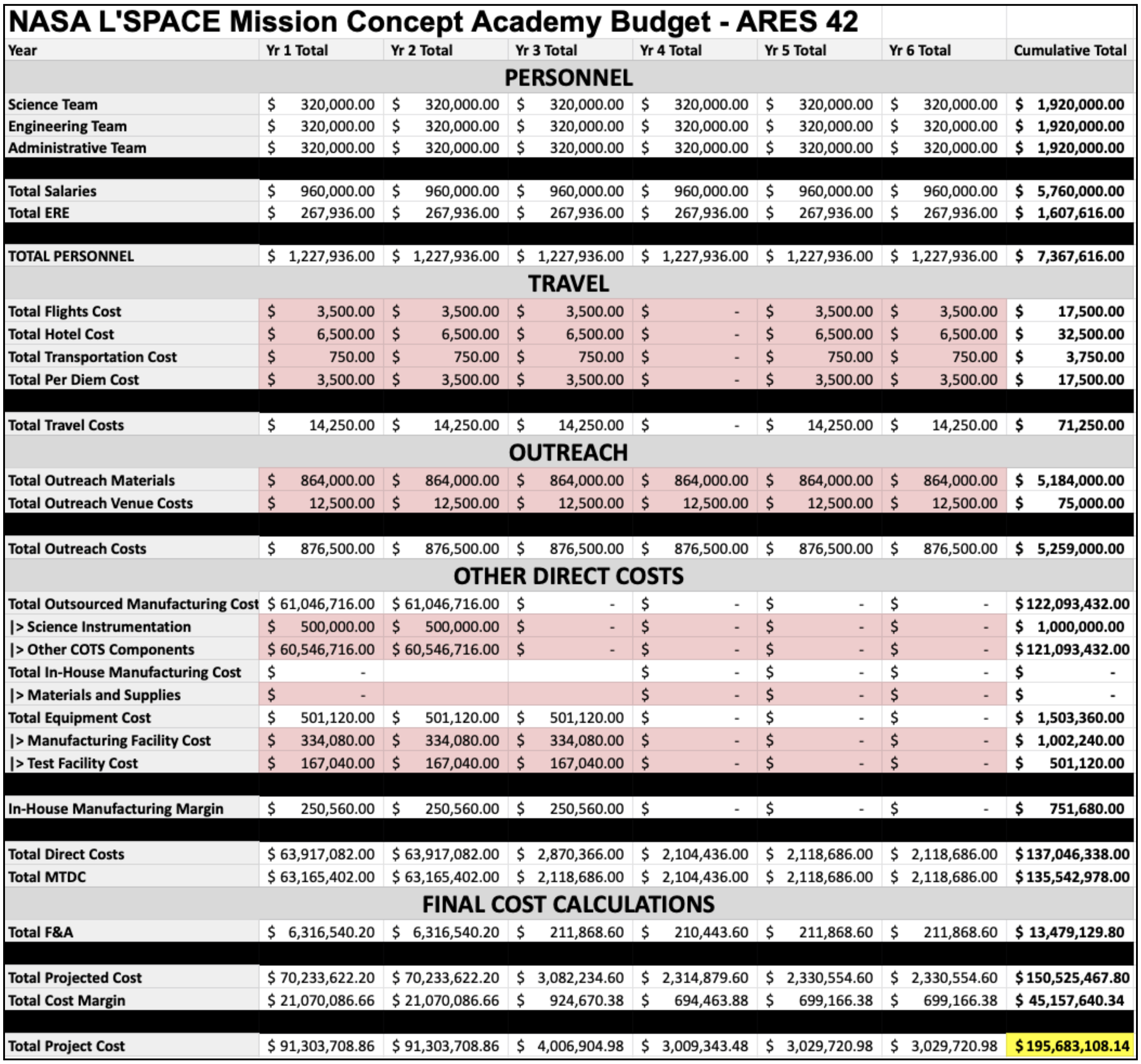
(Left Blank Intentionally)

6. Activity Plan

6.1. Budget

The following section includes all budgeting plans for the ARES-42 mission. This budget plans for a 6-year mission beginning Monday, August 23rd, 2021, and going through Monday, August 23rd, 2027. This mission length takes into account the creation and testing of the science equipment, the travel time from Earth to Mars following the launch, and the necessary time period for data collection and analysis following touchdown on the Martian surface. The total project cost is $ 195,683,108.14. This total cost takes into account all of the following: salary of all personnel, employee related expense (ERE) benefits, all travel costs (flight, hotel, transportation, and per diem), outreach events (including venue costs), and other direct costs related to the science and engineering aspects of the project (facility costs for manufacturing/testing, materials/supplies, and science instrumentation costs). A total cost margin of 30% is also included to ensure that fluctuations in cost along the way are not detrimental to mission success. The full budget can be seen at table 9 below.

(Left Blank Intentionally)

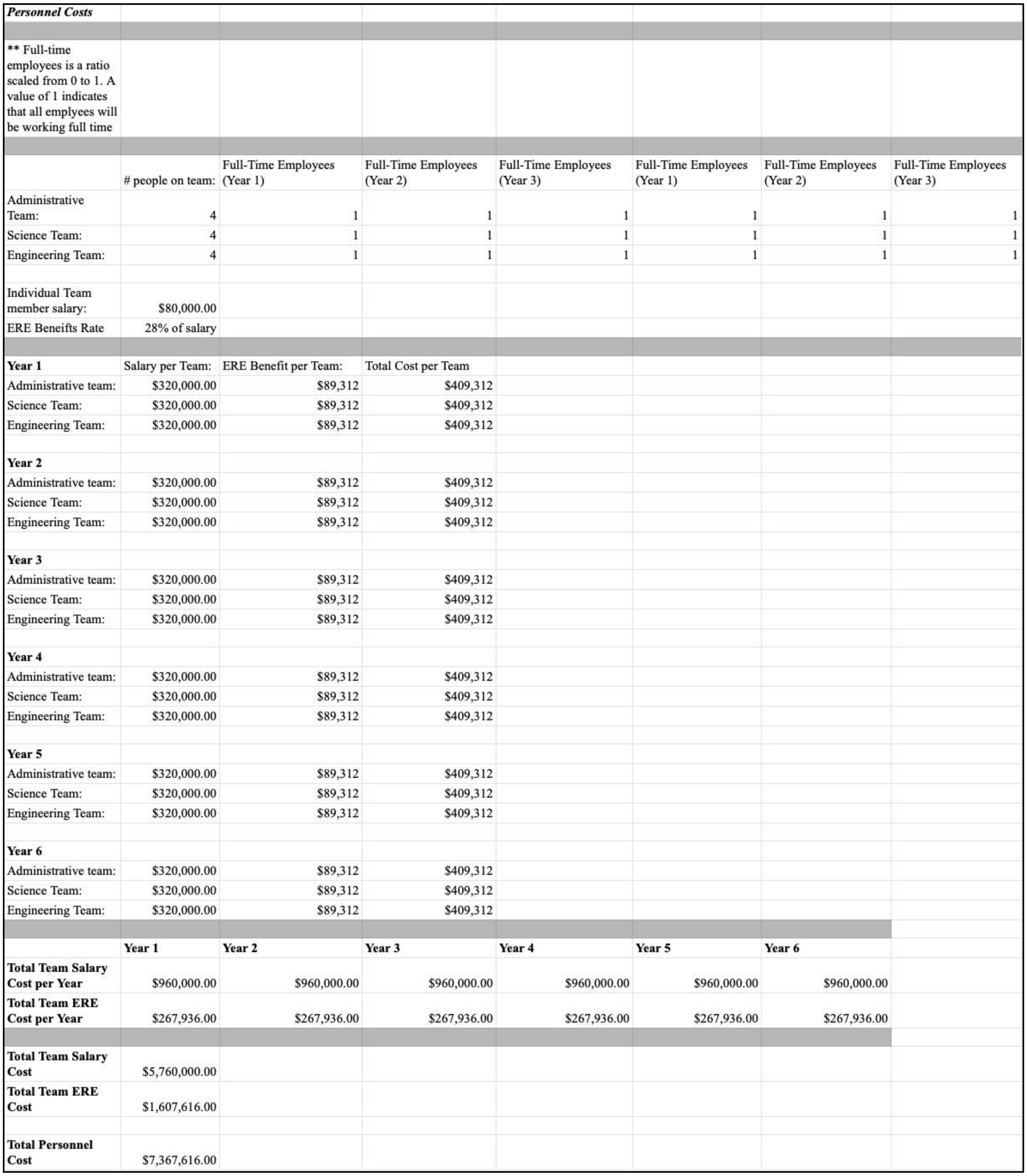


NASA L'SPACE Mission Concept Academy Budget - ARES 42							
Year	**Yr 1 Total**	**Yr 2 Total**	**Yr 3 Total**	**Yr 4 Total**	**Yr 5 Total**	**Yr 6 Total**	**Cumulative Total**
PERSONNEL							
Science Team	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	**$ 1,920,000.00**
Engineering Team	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	**$ 1,920,000.00**
Administrative Team	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	$ 320,000.00	**$ 1,920,000.00**
Total Salaries	$ 960,000.00	$ 960,000.00	$ 960,000.00	$ 960,000.00	$ 960,000.00	$ 960,000.00	**$ 5,760,000.00**
Total ERE	$ 267,936.00	$ 267,936.00	$ 267,936.00	$ 267,936.00	$ 267,936.00	$ 267,936.00	**$ 1,607,616.00**
TOTAL PERSONNEL	$ 1,227,936.00	$ 1,227,936.00	$ 1,227,936.00	$ 1,227,936.00	$ 1,227,936.00	$ 1,227,936.00	**$ 7,367,616.00**
TRAVEL							
Total Flights Cost	$ 3,500.00	$ 3,500.00	$ 3,500.00	$ -	$ 3,500.00	$ 3,500.00	**$ 17,500.00**
Total Hotel Cost	$ 6,500.00	$ 6,500.00	$ 6,500.00	$ -	$ 6,500.00	$ 6,500.00	**$ 32,500.00**
Total Transportation Cost	$ 750.00	$ 750.00	$ 750.00	$ -	$ 750.00	$ 750.00	**$ 3,750.00**
Total Per Diem Cost	$ 3,500.00	$ 3,500.00	$ 3,500.00	$ -	$ 3,500.00	$ 3,500.00	**$ 17,500.00**
Total Travel Costs	$ 14,250.00	$ 14,250.00	$ 14,250.00	$ -	$ 14,250.00	$ 14,250.00	**$ 71,250.00**
OUTREACH							
Total Outreach Materials	$ 864,000.00	$ 864,000.00	$ 864,000.00	$ 864,000.00	$ 864,000.00	$ 864,000.00	**$ 5,184,000.00**
Total Outreach Venue Costs	$ 12,500.00	$ 12,500.00	$ 12,500.00	$ 12,500.00	$ 12,500.00	$ 12,500.00	**$ 75,000.00**
Total Outreach Costs	$ 876,500.00	$ 876,500.00	$ 876,500.00	$ 876,500.00	$ 876,500.00	$ 876,500.00	**$ 5,259,000.00**
OTHER DIRECT COSTS							
Total Outsourced Manufacturing Cost	$ 61,046,716.00	$ 61,046,716.00	$ -	$ -	$ -	$ -	**$ 122,093,432.00**
|> Science Instrumentation	$ 500,000.00	$ 500,000.00	$ -	$ -	$ -	$ -	**$ 1,000,000.00**
|> Other COTS Components	$ 60,546,716.00	$ 60,546,716.00	$ -	$ -	$ -	$ -	**$ 121,093,432.00**
Total In-House Manufacturing Cost	$ -			$ -	$ -	$ -	**$ -**
|> Materials and Supplies	$ -			$ -	$ -	$ -	**$ -**
Total Equipment Cost	$ 501,120.00	$ 501,120.00	$ 501,120.00	$ -	$ -	$ -	**$ 1,503,360.00**
|> Manufacturing Facility Cost	$ 334,080.00	$ 334,080.00	$ 334,080.00	$ -	$ -	$ -	**$ 1,002,240.00**
|> Test Facility Cost	$ 167,040.00	$ 167,040.00	$ 167,040.00	$ -	$ -	$ -	**$ 501,120.00**
In-House Manufacturing Margin	$ 250,560.00	$ 250,560.00	$ 250,560.00	$ -	$ -	$ -	**$ 751,680.00**
Total Direct Costs	$ 63,917,082.00	$ 63,917,082.00	$ 2,870,366.00	$ 2,104,436.00	$ 2,118,686.00	$ 2,118,686.00	**$ 137,046,338.00**
Total MTDC	$ 63,165,402.00	$ 63,165,402.00	$ 2,118,686.00	$ 2,104,436.00	$ 2,118,686.00	$ 2,118,686.00	**$ 135,542,978.00**
FINAL COST CALCULATIONS							
Total F&A	$ 6,316,540.20	$ 6,316,540.20	$ 211,868.60	$ 210,443.60	$ 211,868.60	$ 211,868.60	**$ 13,479,129.80**
Total Projected Cost	$ 70,233,622.20	$ 70,233,622.20	$ 3,082,234.60	$ 2,314,879.60	$ 2,330,554.60	$ 2,330,554.60	**$ 150,525,467.80**
Total Cost Margin	$ 21,070,086.66	$ 21,070,086.66	$ 924,670.38	$ 694,463.88	$ 699,166.38	$ 699,166.38	**$ 45,157,640.34**
Total Project Cost	$ 91,303,708.86	$ 91,303,708.86	$ 4,006,904.98	$ 3,009,343.48	$ 3,029,720.98	$ 3,029,720.98	**$ 195,683,108.14**

Table 9 *ARES-42 Team Budget*

ARES-42 consists of 10 members broken into 3 sub-teams: administration, science, and engineering, each containing four members. Each team member will work full time (40 hrs/wk) throughout the entirety of the four-year mission, and receive a salary of $80,000 in addition to a 28% ERE benefit rate. Although the team currently consists of 10 members, the budget allocates costs for a total of 12 team members, since this is the amount that the team initially started with. Two more team members must be identified to assist with the mission. For the 12 team members over a six-year mission the total salary cost is $5,760,000.00 and the total ERE cost is $1,607,616.00. This brings the total cost of all personnel to $7,367,616.00. Table 10 provides a more detailed view of the personnel aspect of the total budget below.

(Left Blank Intentionally)



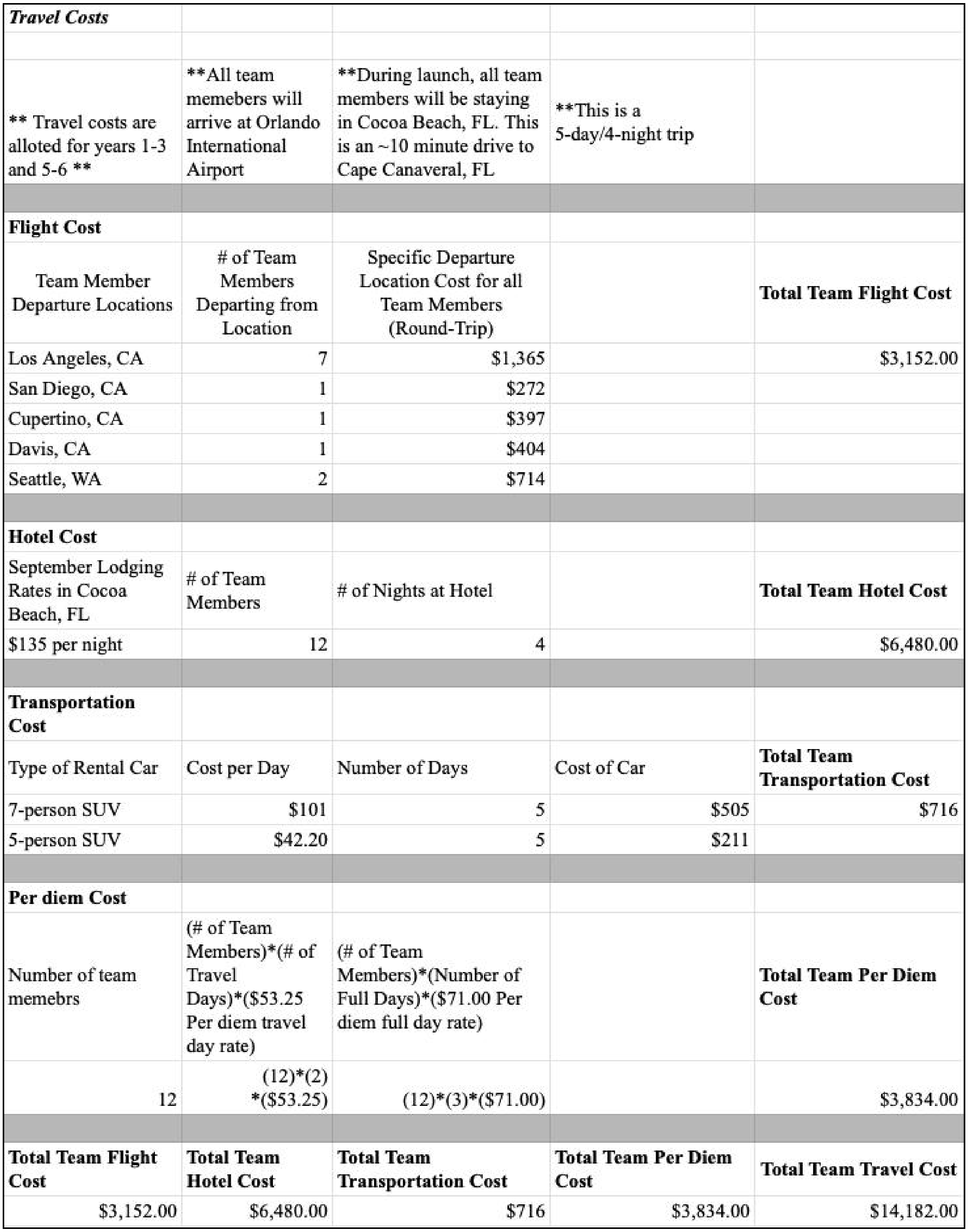
Personnel Costs							
** Full-time employees is a ratio scaled from 0 to 1. A value of 1 indicates that all emplyees will be working full time							
	# people on team:	Full-Time Employees (Year 1)	Full-Time Employees (Year 2)	Full-Time Employees (Year 3)	Full-Time Employees (Year 1)	Full-Time Employees (Year 2)	Full-Time Employees (Year 3)
Administrative Team:	4	1	1	1	1	1	1
Science Team:	4	1	1	1	1	1	1
Engineering Team:	4	1	1	1	1	1	1
Individual Team member salary:	$80,000.00						
ERE Beneifts Rate	28% of salary						
Year 1	Salary per Team:	ERE Benefit per Team:	Total Cost per Team				
Administrative team:	$320,000.00	$89,312	$409,312				
Science Team:	$320,000.00	$89,312	$409,312				
Engineering Team:	$320,000.00	$89,312	$409,312				
Year 2							
Administrative team:	$320,000.00	$89,312	$409,312				
Science Team:	$320,000.00	$89,312	$409,312				
Engineering Team:	$320,000.00	$89,312	$409,312				
Year 3							
Administrative team:	$320,000.00	$89,312	$409,312				
Science Team:	$320,000.00	$89,312	$409,312				
Engineering Team:	$320,000.00	$89,312	$409,312				
Year 4							
Administrative team:	$320,000.00	$89,312	$409,312				
Science Team:	$320,000.00	$89,312	$409,312				
Engineering Team:	$320,000.00	$89,312	$409,312				
Year 5							
Administrative team:	$320,000.00	$89,312	$409,312				
Science Team:	$320,000.00	$89,312	$409,312				
Engineering Team:	$320,000.00	$89,312	$409,312				
Year 6							
Administrative team:	$320,000.00	$89,312	$409,312				
Science Team:	$320,000.00	$89,312	$409,312				
Engineering Team:	$320,000.00	$89,312	$409,312				
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	
Total Team Salary Cost per Year	$960,000.00	$960,000.00	$960,000.00	$960,000.00	$960,000.00	$960,000.00	
Total Team ERE Cost per Year	$267,936.00	$267,936.00	$267,936.00	$267,936.00	$267,936.00	$267,936.00	
Total Team Salary Cost	$5,760,000.00						
Total Team ERE Cost	$1,607,616.00						
Total Personnel Cost	$7,367,616.00						

Table 10 *ARES-42 Team Personnel Budget*

The planned launch date for the mission is Tuesday, September 24, 2024. Each team member will travel to Cape Canaveral, FL, arriving Sunday, September 22, 2024, and will depart Thursday, September 26, 2024, a 5-day/4-night stay. Ten team members will be flying out of California (Los Angeles, San Diego, Davis, and Cupertino), and two team members will be flying out of Seattle, WA. The total round trip flight costs for all team members amounts to $3,152.00. One 7-seater SUV and one 5-seater SUV will be utilized for all transportation needs from the time of arrival to the time of departure. The total cost for the two rental cars amount to $716.00. Lodging rates in Cocoa Beach, FL, during September, are $135 per night. This brings the total for 12 team members (each with their own room) over a 4-night stay to $6480.

The per diem rates (to cover all meals and incidentals) for each individual team member are $71 for full days, and $53.25 for the first and last days of travel. Including the launch date, travel costs are also allocated for years 1-3 and 5-6. These costs account for all necessary travel plans in the years prior and post launch. These travel plans include all pre-launch meetings, outreach events, and post-mission closeout meetings. Taking this into account, the total per diem cost for the team is $17,500.00. Upon adding up all of the travel costs, the total travel fees come out to be $71,250.00 for the entire team, over the six year mission. Table 11 provides more insight into the team travel costs.

(Left Blank Intentionally)



Travel Costs				
** Travel costs are alloted for years 1-3 and 5-6 **	**All team memebers will arrive at Orlando International Airport	**During launch, all team members will be staying in Cocoa Beach, FL. This is an ~10 minute drive to Cape Canaveral, FL	**This is a 5-day/4-night trip	
Flight Cost				
Team Member Departure Locations	# of Team Members Departing from Location	Specific Departure Location Cost for all Team Members (Round-Trip)		**Total Team Flight Cost**
Los Angeles, CA	7	$1,365		$3,152.00
San Diego, CA	1	$272		
Cupertino, CA	1	$397		
Davis, CA	1	$404		
Seattle, WA	2	$714		
Hotel Cost				
September Lodging Rates in Cocoa Beach, FL	# of Team Members	# of Nights at Hotel		**Total Team Hotel Cost**
$135 per night	12	4		$6,480.00
Transportation Cost				
Type of Rental Car	Cost per Day	Number of Days	Cost of Car	**Total Team Transportation Cost**
7-person SUV	$101	5	$505	$716
5-person SUV	$42.20	5	$211	
Per diem Cost				
Number of team memebrs	(# of Team Members)*(# of Travel Days)*($53.25 Per diem travel day rate)	(# of Team Members)*(Number of Full Days)*($71.00 Per diem full day rate)		**Total Team Per Diem Cost**
12	(12)*(2) *($53.25)	(12)*(3)*($71.00)		$3,834.00
Total Team Flight Cost	**Total Team Hotel Cost**	**Total Team Transportation Cost**	**Total Team Per Diem Cost**	**Total Team Travel Cost**
$3,152.00	$6,480.00	$716	$3,834.00	$14,182.00

Table 11 *ARES-42 Team Travel Budget*

Another portion of the total budget has been allocated for public outreach and venue costs for all outreach events. ARES-42 has planned the following mission outreach events:

- Creative sharespace initiatives such as naming rover instrumentation, mission patch design, and logistics for the NASA TV broadcast of the virtual *Future of Space* segment which includes budget for access to technology and high speed internet access for participants in need.
- Multi-phase workforce initiative such as rover design challenges Phase 1: K-12 design challenges and Phase 2: Intern Computer Aided Design workforce training and development of rover designs.
- Yearly On-site Intern sessions and *ARES Creation Conference* at the Kennedy Space Center in the Dr. Kurt H. Debus Conference Facility

The total cost for all outreach events and venues is $ 5,259,000.00 USD.

The largest portion of the budget is allocated for other direct costs related to the mission. This includes the costs for the following: all outsourced manufacturing for science instrumentation and commercial-off-the-shelf (COTS) components, materials and supplies, manufacturing facilities, and testing facilities. The proposed science instrumentation is very similar to Mars' Perseverance Rover's Supercam Spectrometer. All necessary components for the science instrumentation will be manufactured and tested at Los Alamos National Laboratory, as this was the same location where Supercam was manufactured. The engineering components related to the rover's main body will be manufactured and tested at Jet Propulsion Laboratory (JPL) in Pasadena, CA. This will include the Rover's chassis, legs, wheels, battery, camera system and communications. The manufacturing process will begin in January 2022 and take ~2 1/2 years. As for the power system, ARES-42 will utilize a scaled-down version of the same Radioisotope thermoelectric generator that was used for the Mars 2020 Rover. This RTG will be manufactured by the U.S. Department of Energy. Currently, the proposed science instrumentation costs $1,000,000.00 and the "Commercial off-the-Shelf" components come in at $121,093,432.00. This brings the total outsourced manufacturing cost to $122,093,432.00. The total cost for the manufacturing and test facilities is $1,503,360.00. This cost includes a standard in-house manufacturing margin of 50% to account for changes in design specifications during the early stages of the project's development. This brings the total for all other direct costs related to the mission to $ 137,046,338.00. All costs have been updated for inflation. Additionally, all calculated costs using the NICM tool have been included. Table 12 offers a more in depth view of all other direct costs related to the mission.

**** represents the new cost when adjusted for inflation*

Science Instrumentation:

Telescope Cost

- *Cost = {49 for Visible/UV or 95.4 for Infrared}*(Diameter[cm])*$_{1.47}$

  *Cost = 49*20 = $980 = *** $1,135.54*

Spectrometer Data Processing

- *Total Instrument B/C/D Cost = 1,646 * TotalMass^0.31 * TotalMaxPwr^0.35*

  *Total Science instrumentation cost = 1,646*10.4^0.31*17.9W = $60,892.40 =*

  **** $70,556.59*

Wrap Factors for Science Instrumentation

*a) Management Cost = 0.071 * (SensorCost)1.032*

*Management cost = 0.071*60892.4 = $4,342.40 = *** $5,031.61*

*b) Systems Engineering Cost = 0.493 * (SensorCost)0.865*

*Systems Engineering Cost = 0.493 * 60892.4 = $30,019.90 = *** $34,783.52*

*c) Product Assurance Cost = 0.143 * (SensorCost)0.942*

*Product Assurance Cost = 0.143 * 60892.4= $8,707.6 = *** $10,088.95*

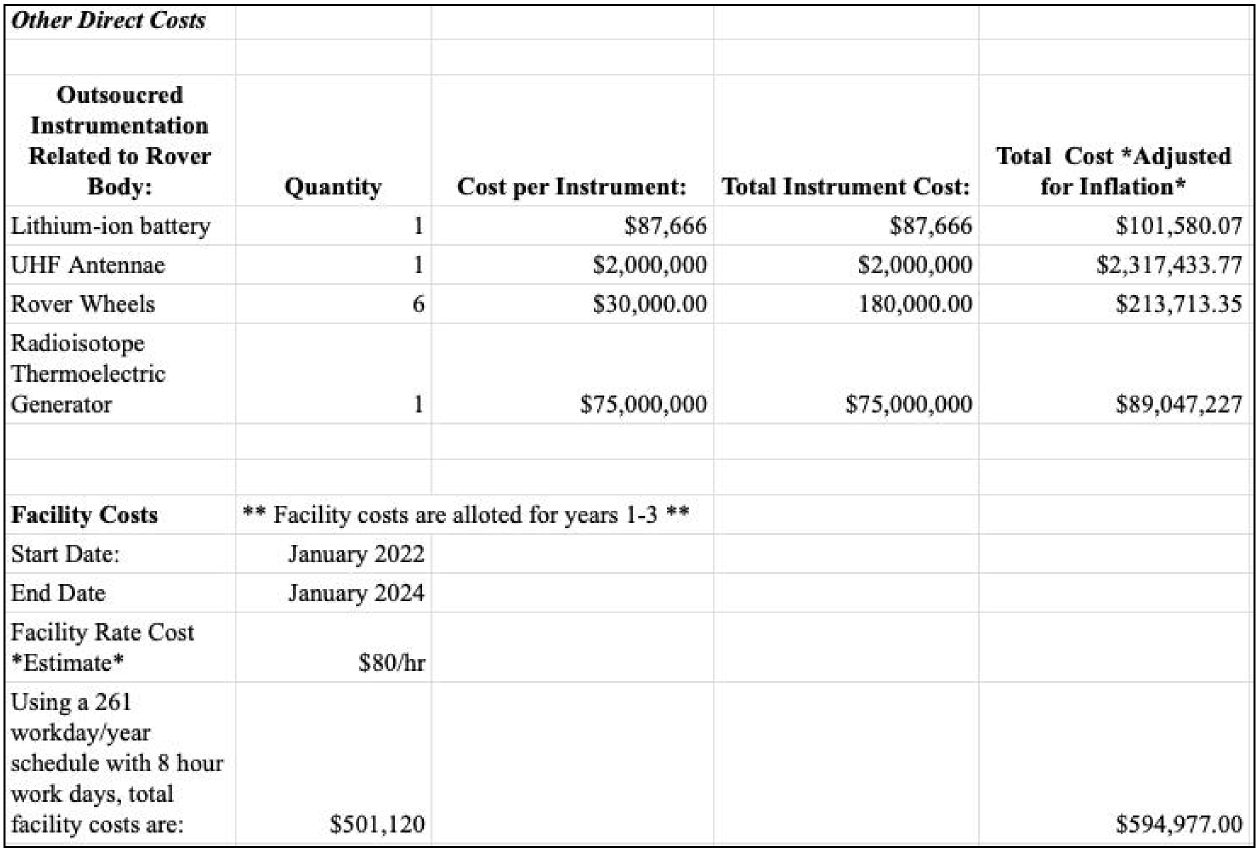
*d) Integration and Test Cost = 0.146 * (SensorCost)*

*Integration and test cost = 0.146 * 60892.4 = $8,890.30 = *** $10,300.99*

Chassis and Legs Cost:

- *Cost = 232 * TotalMass^0.73*

  *Cost = 232 * (~10 kg^0.73) = $1,245.9 = *** $1,443.65*



Other Direct Costs				
Outsoucred Instrumentation Related to Rover Body:	**Quantity**	**Cost per Instrument:**	**Total Instrument Cost:**	**Total Cost *Adjusted for Inflation***
Lithium-ion battery	1	$87,666	$87,666	$101,580.07
UHF Antennae	1	$2,000,000	$2,000,000	$2,317,433.77
Rover Wheels	6	$30,000.00	180,000.00	$213,713.35
Radioisotope Thermoelectric Generator	1	$75,000,000	$75,000,000	$89,047,227
Facility Costs	** Facility costs are alloted for years 1-3 **			
Start Date:	January 2022			
End Date	January 2024			
Facility Rate Cost *Estimate*	$80/hr			
Using a 261 workday/year schedule with 8 hour work days, total facility costs are:	$501,120			$594,977.00

Table 12 *ARES-42 Other Direct Costs*

The last component of the budget includes the cost safety margins and benefit percentage rates. As mentioned before in the personnel cost section, all team members will receive an ERE benefit rate that is 28% of their $80,000 salary. A 10% margin has also been included for all facility and administrative costs such as office space, supplies, equipment, etc. A 50% manufacturing margin has also been included to account for any changes in design specifications during development. All margins aforementioned result in a 30% total cost margin. These costs have been automatically calculated and are included in all budget costs shown.

6.2. Schedule

The mission’s major milestones, tasks, and subtasks are outlined in the Gantt Chart provided below. The Phases Pre-Phase A through E described in Section 1.2.5 of this document encompass the overall work timetable for the tasks and deliverables shown in the Gantt Chart. The following schedules refer to the Phases and Review deliverables outlined in the above mentioned section of this document.

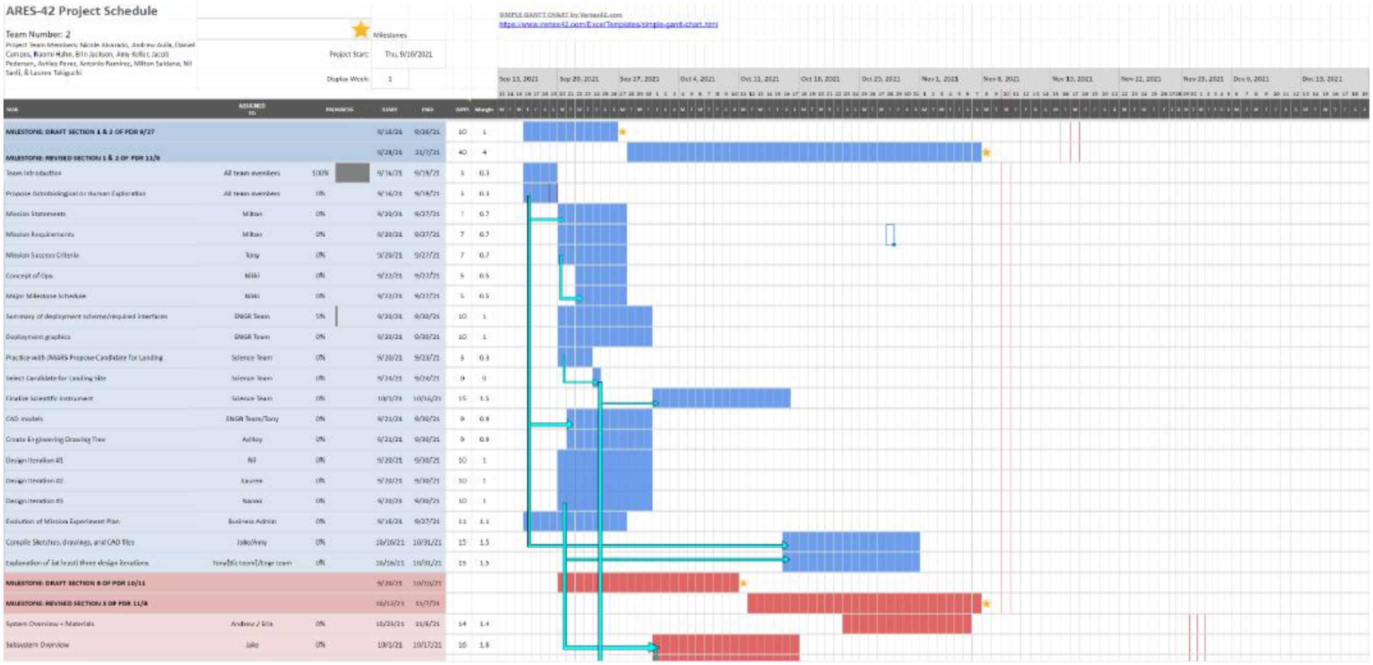
Development Schedule

In Phase D, the end of the development schedule of the ARES-42 mission is indicated at the September 2024 launch date. The launch window is still to be determined. The launch will be organized, supported, and run by the ARES-42 team personnel. Budgets for the launch are outlined in section 6.1 of this document. The budget accounts for a 5-day 4-night stay for personnel at the launch site, Cape Canaveral, Florida. In order for the launch to be approved, the PDR, CDR, TRR, and FRR are due for review on November 11, 2021. Hazard mitigation and research into environmental hazards on Mars is due for review October 17, 2021. The lead safety officer is set to have an overview of the launch site, weather and conditions by August 1, 2024, a month in advance of the launch. Research on Martian weather conditions in the context of landing site seasonal changes is due October 9, 2021.

Phase D and C meet at the point that ATLO testing is ready at the completion of full maturity of design and integration of the hardware and software as a full payload on November 8, 2021. The preparation for integration of the payload is marked by the approval of the manufacturing and verification plans by October 21, 2021.

Operations Schedule

Operations schedule begins on the onset of the launch of the ARES-42 payload aboard the main payload. The launch date is to be determined within September 2024. The payload will rendezvous with Mars on a nine-month flight. The projected entry, descent, and landing phase is scheduled for June 2025. Upon landing of the primary payload and after health checks are completed for the primary payload through confirmation of communications with the Earth’s mission control, the surface deployment of ARES-42 will begin no later than the end of June 2025. Upon the complete separation of the ARES-42 rover, the rover will begin health checks and send communications to mission control via the primary payload. Traverse mode and autonomous exploration of the landing site Arcadia Planitia will occur within the 5 km x 5 km area within the site of Erebus Montes. The ARES-42 operational exploration phase: measurement and data collection are set to last 3 years until August 2027. The total mission timeline from Pre-phase A to end of operations and Phase E is 6 years.



ARES-42 Project Schedule

Team Number: 2

Project Team Members: Nicole Alvarado, Andrew Avila, Daniel Campos, Naomi Hahn, Erin Jackson, Amy Keller, Jacob Pedersen, Ashley Perez, Antonio Ramirez, Milton Saldana, Nil Sanli, & Lauren Takiguchi

Milestones

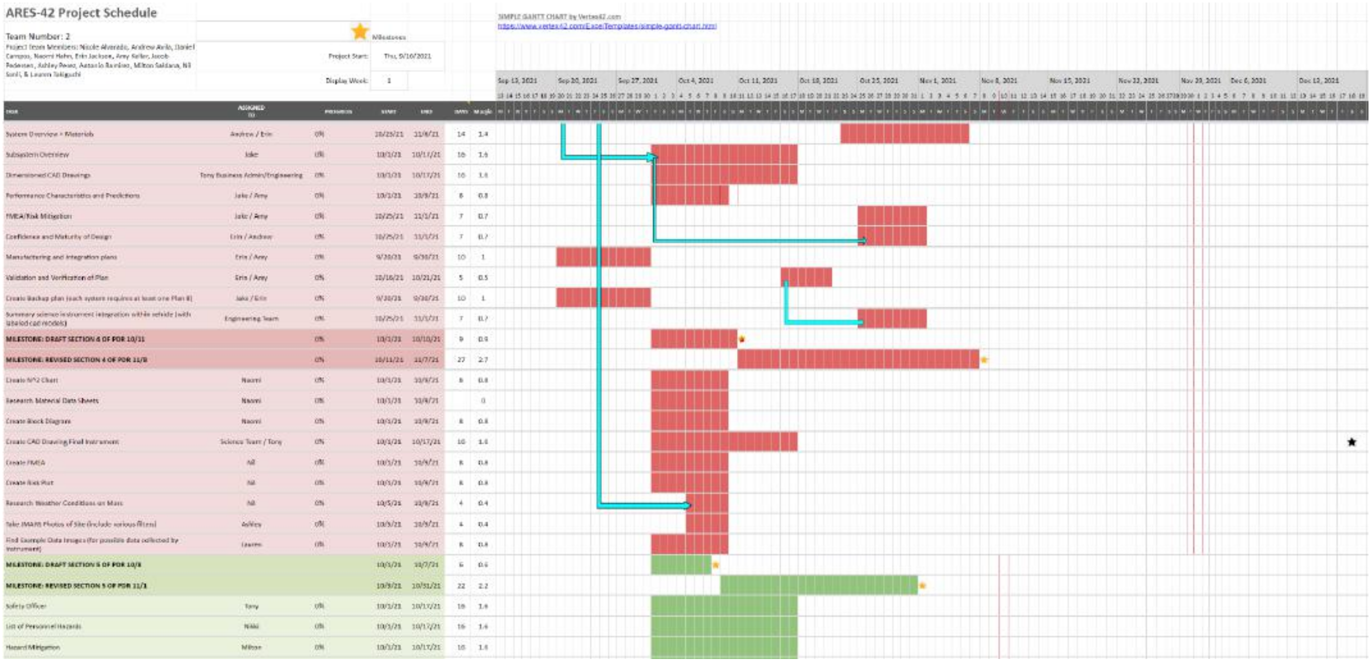
Project Start: Thu, 9/16/2021

Display Week: 1

SIMPLE GANTT CHART by Vertex42.com

https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
MILESTONE: DRAFT SECTION 1 & 2 OF PDR 9/27			9/16/21	9/26/21	10	1
MILESTONE: REVISED SECTION 1 & 2 OF PDR 11/8			9/28/21	11/7/21	40	4
Team Introduction	All team members	100%	9/16/21	9/19/21	3	0.3
Propose Astrobiological or Human Exploration	All team members	0%	9/16/21	9/19/21	3	0.3
Mission Statements	Milton	0%	9/20/21	9/27/21	7	0.7
Mission Requirements	Milton	0%	9/20/21	9/27/21	7	0.7
Mission Success Criteria	Tony	0%	9/20/21	9/27/21	7	0.7
Concept of Ops	Nikki	0%	9/22/21	9/27/21	5	0.5
Major Milestone Schedule	Nikki	0%	9/22/21	9/27/21	5	0.5
Summary of deployment scheme/required interfaces	ENGR Team	5%	9/20/21	9/30/21	10	1
Deployment graphics	ENGR Team	0%	9/20/21	9/30/21	10	1
Practice with JMARS Propose Candidate for Landing	Science Team	0%	9/20/21	9/23/21	3	0.3
Select Candidate for Landing Site	Science Team	0%	9/24/21	9/24/21	0	0
Finalize Scientific Instrument	Science Team	0%	10/1/21	10/16/21	15	1.5
CAD models	ENGR Team/Tony	0%	9/21/21	9/30/21	9	0.9
Create Engineering Drawing Tree	Ashley	0%	9/21/21	9/30/21	9	0.9
Design Iteration #1	Nil	0%	9/20/21	9/30/21	10	1
Design Iteration #2	Lauren	0%	9/20/21	9/30/21	10	1
Design Iteration #3	Naomi	0%	9/20/21	9/30/21	10	1
Evolution of Mission Experiment Plan	Business Admin	0%	9/16/21	9/27/21	11	1.1
Compile Sketches, drawings, and CAD files	Jake/Amy	0%	10/16/21	10/31/21	15	1.5
Explanation of (at least) three design iterations	Tony(Sci team)/Engr team	0%	10/16/21	10/31/21	15	1.5
MILESTONE: DRAFT SECTION 3 OF PDR 10/11			9/20/21	10/10/21		
MILESTONE: REVISED SECTION 3 OF PDR 11/8			10/12/21	11/7/21		
System Overview + Materials	Andrew / Erin	0%	10/23/21	11/6/21	14	1.4
Subsystem Overview	Jake	0%	10/1/21	10/17/21	16	1.6



ARES-42 Project Schedule

Team Number: 2

Project Team Members: Nicole Alvarado, Andrew Avila, Daniel Campos, Naomi Hahn, Erin Jackson, Amy Keller, Jacob Pedersen, Ashley Perez, Antonio Ramirez, Milton Saldana, Nil Sanli, & Lauren Takiguchi

Milestones

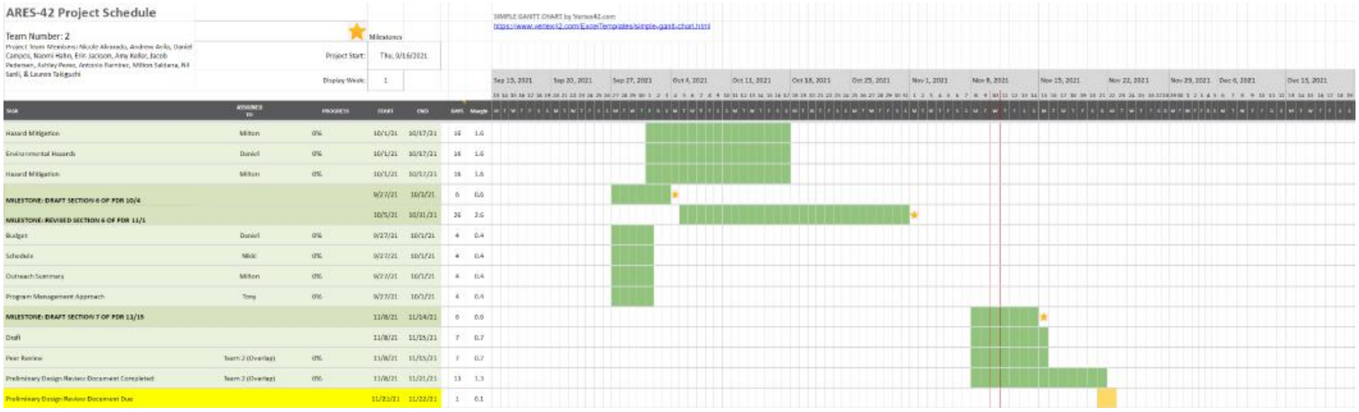
Project Start: Thu, 9/16/2021

Display Week: 1

SIMPLE GANTT CHART by Vertex42.com

https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
System Overview + Materials	Andrew / Erin	0%	10/23/21	11/6/21	14	1.4
Subsystem Overview	Jake	0%	10/1/21	10/17/21	16	1.6
Dimensioned CAD Drawings	Tony Business Admin/Engineering	0%	10/1/21	10/17/21	16	1.6
Performance Characteristics and Predictions	Jake / Amy	0%	10/1/21	10/9/21	8	0.8
FMEA/Risk Mitigation	Jake / Amy	0%	10/25/21	11/1/21	7	0.7
Confidence and Maturity of Design	Erin / Andrew	0%	10/25/21	11/1/21	7	0.7
Manufacturing and Integration plans	Erin / Amy	0%	9/20/21	9/30/21	10	1
Validation and Verification of Plan	Erin / Amy	0%	10/16/21	10/21/21	5	0.5
Create Backup plan (each system requires at least one Plan B)	Jake / Erin	0%	9/20/21	9/30/21	10	1
Summary science instrument integration within vehicle (with labeled cad models)	Engineering Team	0%	10/25/21	11/1/21	7	0.7
MILESTONE: DRAFT SECTION 4 OF PDR 10/11		0%	10/1/21	10/10/21	9	0.9
MILESTONE: REVISED SECTION 4 OF PDR 11/8		0%	10/11/21	11/7/21	27	2.7
Create N^2 Chart	Naomi	0%	10/1/21	10/9/21	8	0.8
Research Material Data Sheets	Naomi	0%	10/1/21	10/9/21		0
Create Block Diagram	Naomi	0%	10/1/21	10/9/21	8	0.8
Create CAD Drawing Final Instrument	Science Team / Tony	0%	10/1/21	10/17/21	16	1.6
Create FMEA	All	0%	10/1/21	10/9/21	8	0.8
Create Risk Plot	All	0%	10/1/21	10/9/21	8	0.8
Research Weather Conditions on Mars	All	0%	10/5/21	10/9/21	4	0.4
Take JMARS Photos of Site (include various filters)	Ashley	0%	10/5/21	10/9/21	4	0.4
Find Example Data Images (for possible data collected by instrument)	Lauren	0%	10/1/21	10/9/21	8	0.8
MILESTONE: DRAFT SECTION 5 OF PDR 10/8			10/1/21	10/7/21	6	0.6
MILESTONE: REVISED SECTION 5 OF PDR 11/1			10/9/21	10/31/21	22	2.2
Safety Officer	Tony	0%	10/1/21	10/17/21	16	1.6
List of Personnel Hazards	Nikki	0%	10/1/21	10/17/21	16	1.6
Hazard Mitigation	Milton	0%	10/1/21	10/17/21	16	1.6



ARES-42 Project Schedule

Team Number: 2

Project Team Members: Nicole Alvarado, Andrew Avila, Daniel Campos, Naomi Hahn, Erin Jackson, Amy Kellor, Jacob Pedersen, Ashley Perez, Antonio Ramirez, Milton Saldana, Nil Santi, & Lauren Takiguchi

★ Milestones

Project Start: Thu, 9/16/2021

Display Week: 1

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
Hazard Mitigation	Milton	0%	10/1/21	10/17/21	16	1.6
Environmental Hazards	Daniel	0%	10/1/21	10/17/21	16	1.6
Hazard Mitigation	Milton	0%	10/1/21	10/17/21	16	1.6
MILESTONE: DRAFT SECTION 6 OF PDR 10/4			9/27/21	10/1/21	6	0.6
MILESTONE: REVISED SECTION 6 OF PDR 11/1			10/5/21	10/31/21	26	2.6
Budget	Daniel	0%	9/27/21	10/1/21	4	0.4
Schedule	Nikki	0%	9/27/21	10/1/21	4	0.4
Outreach Summary	Milton	0%	9/27/21	10/1/21	4	0.4
Program Management Approach	Tony	0%	9/27/21	10/1/21	4	0.4
MILESTONE: DRAFT SECTION 7 OF PDR 11/15			11/8/21	11/14/21	6	0.6
Draft			11/8/21	11/15/21	7	0.7
Peer Review	Team 2 (Overlap)	0%	11/8/21	11/15/21	7	0.7
Preliminary Design Review Document Completed	Team 2 (Overlap)	0%	11/8/21	11/21/21	13	1.3
Preliminary Design Review Document Due			11/21/21	11/22/21	1	0.1

Figure 61. *ARES 42 GANTT chart, organizational tool used to describe important deadlines and milestones*

(Left Blank Intentionally)

6.3. Outreach Summary

ARES-42 recognizes that increasing public awareness and a greater appreciation for STEM is critical for meeting NASA human space exploration goals. Three Integral foundations of mission outreach include: social media, platforms for creative sharing, and career development opportunities. The ARES-42 outreach mission objective is to communicate the project mission objective to the general public, allow access of resources to a variety of socio-economic backgrounds, and to inspire greater diversity at NASA by promoting creativity amongst underrepresented groups in the aerospace industry.

Social Media

A central tool for increasing public awareness is the ARES-42 social media platforms which include a presence on Instagram, LinkedIn, Twitter, Facebook, YouTube, and Tiktok. These platforms serve as spaces to keep the greater community up to date on mission progress while meeting milestones and objectives from Phase A forward through to Phase E.

Interactive platforms which promote creative discord between subscribers and the ARES-42 Social Media team such as Instagram, YouTube, and Tiktok are useful for both informative purposes as well as setting creative challenges and remote community collaborations. Due to the CoronaVirus Pandemic and the onset of remote learning and collaboration, access to instruction to a broad and remote audience is both necessary for public safety and also acknowledges the current trend of communal interaction.

The social media team has daily, weekly, and monthly, goals set for follower interaction as well as objectives for extending opportunity to the community for questions and answers. These objectives are adaptive and sensitive to the response the community has to challenges. An example of a challenge would be a creative rover design collaboration on Instagram and Tiktok platforms for K-12 aged students:

> *Calling all creative minds! Just like how you learn at school, the ARES-42 Rover engineers and scientists had to work as a team to teach our little Rover Astronaut how to overcome challenges so it could explore Mars to get ready for Human Astronauts. We're showing you a video of the JPL Mars Yard with rocks and obstacles. We challenge you to use any creative way of getting the rover from one stage and passing the rover safely over for the next person to Duet this and move ARES safely to the next stage. Draw it, act it out, sing a song, or build with legos. At the end we'll repost the best duets that get ARES through the mission!*

Creative Sharespace

Similar to previous NASA rovers, aspects of the mission will be open to community involvement such as naming rover instrumentation, rover design challenges, and mission patch design. Initially, the mission outreach team will hold on-site presentations and challenges at a group of socio-economic and ethnically diverse Kindergarten through grade 12 schools. The broad challenge and creative competitions will be open to the general public and can be submitted both by mail and online. Submissions are open to students in the United States (U.S.) and U.S. territories. Submission requirements vary depending on the competition or challenge. For instrumentation naming, students should submit a short essay (max 200 words) and should include their name proposal, why they chose it, and what inspires them about the ARES-42 mission. The rover design competition will hold dual purposes. The competition will begin Phase 1 as a K-12 challenge for students to conceptualize a rover design that will meet certain criteria outlined for the competition. For all competitions the outreach team will select the top three entries per age brackets K-2, 3-5, 6-8, 9-12 and allow the public to vote on what submission is the overall winner. However, the rover design challenge will have winning submissions for each age group category. Phase 2 of the design challenge includes the task of ARES intern workforce training as interns modify and realize the design in Computer Automated Design (CAD) software. All other challenges will have one winner per competition. The winning contestants for all challenges will be invited to virtually participate in the *Future of Space* segment during the NASA TV launch broadcast of the ARES-42 mission. The segment will pose questions to the students and allow them to share their experiences as representatives to the broader K-12 audience.

Career Development

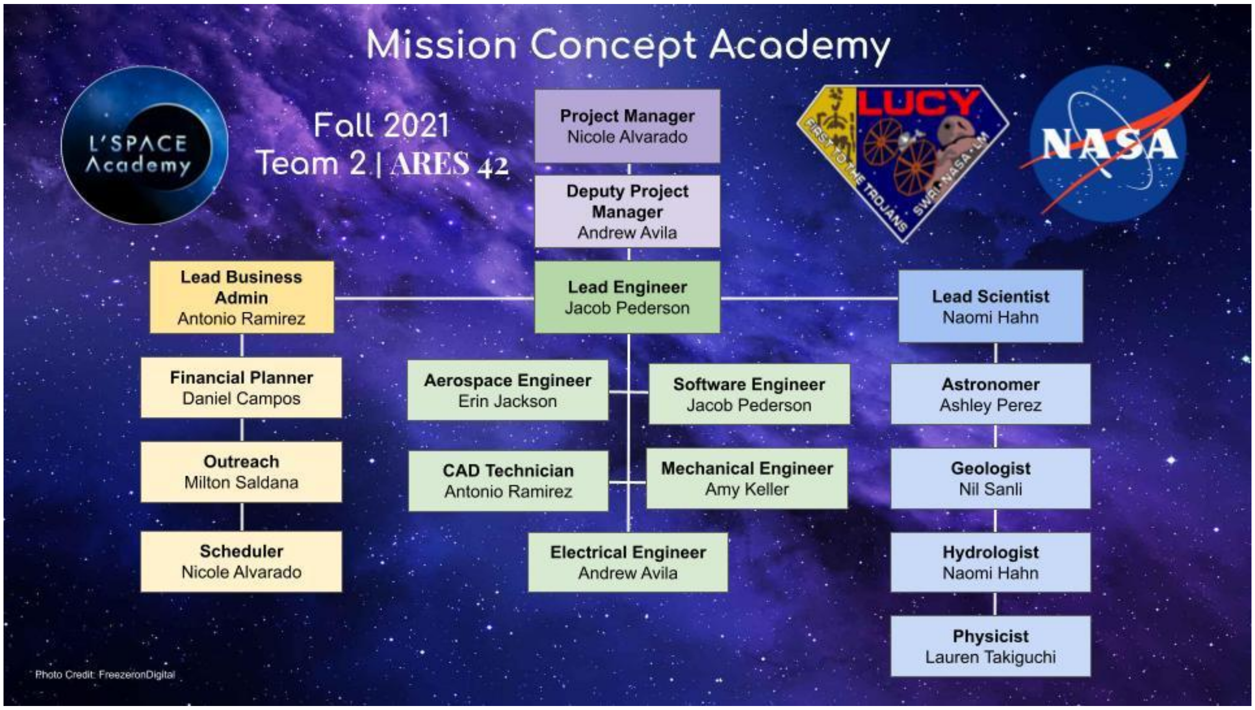
Additionally, ARES-42 outreach division will promote hands-on learning experiences by holding summer internship opportunities and job shadowing opportunities for college students. Internship sessions will last 12 weeks and will run July 5th of 2022, 2023, 2024, and 2025. Students will be able to actively develop career skill sets through the use of CAD software, access and training for tools that NASA scientists utilize for actual missions such as JMARS, and assist with completing objectives outlined by the outreach division. Examples of CAD skills development include phase 2 of the design challenge of realizing the concept of the K-12 Rover design winners. The broader College and University student demographic will be invited to participate in free webinars where they will learn about successful work habits outlined by current NASA employees such as the ARES-42 administrative, engineering, and science teams. Students will be responsible for their own housing and transportation and interns will earn $18.00 USD an hour with a typical intern workweek of 40 hours. Similar to the NASA Lucy mission, ARES will employ 50 interns per internship session, which accumulates to spending $432,000.00 USD each year on internship opportunities. Finally, the outreach division will organize and hold a yearly *ARES Creation Conference* at the Kennedy Space Center in the Dr. Kurt H. Debus Conference Facility. The conference will facilitate access to the broader community of expert speakers and Q & A sessions which will highlight the current status of the ARES-42 mission. The Creation Conference will be available online in order to meet the ARES-42 mission objective of providing access to a diverse socio-economic group. Participants will have to pay a fee of $20.00 USD per adult admission and no fee for children ages 12 and under. The conference budget will allot for Free Entrance vouchers upon request for participants experiencing financial hardship. The estimated cost of the venue is quoted at $1,250 per hour. The event will be held from 8am-1pm.

6.4. Program Management Approach

The ARES-42 mission is focused on providing an engineering and scientific foundation for preparing natural Martian resources for human utilization (specifically ice water resources). As a whole, the ARES-42 team is organized around addressing the complex concept of safety in human interplanetary exploration. With this core concept at the heart of the team's objectives, each team member is an integral member of a diverse system that requires overlap of duties in order to ensure the mission's efficacy.

ARES-42 is composed of 3 subteams: Business Administration, Engineering, and Science. Members of each subteam complete project tasks specific to their department titles but are also encouraged to collaborate on a daily basis with other sub-team members to supplement their work. With this collaborative system in place, all team members are able to make informed decisions as a whole, as members are required to collaborate on crucial mission decision voting. Examples of crucial mission decisions include: the ARES-42 project mission objective of human exploration, the project's landing site, and others. There are 5 leadership positions that act as points of organizational overlap: Project manager, Deputy Project manager, and the three subteam leads. These positions were selected by requiring submissions of interest and expertise, which were then voted on by the entire team. In order to facilitate the needs of subteam members, each department has a single point of leadership who organizes weekly subteam meetings, oversees subteam deliverable progress, and communicates at a minimum every 2 days with the project manager. The Project managers and Subteam leads hold roles apart from leadership and are expected to collaborate within their teams and other teams in order to meet their tasks. The Deputy Project manager's role extends over individuals' workflow by tracking work hours via a google excel sheet filled out by members whenever they work on mission tasks and by reaching out to individual members to support their needs in terms of scheduling. With the documentation of hours, the budget position is informed of hours and factors them into the overall project budget. The Project Manager's responsibilities include: team organization, communicating team schedules, outlining deliverable timelines and expectations with feasible margins considered, creating meeting outlines supportive of remote teamwork, and working with individuals on solving questions and issues which are not easily addressed by team collaborative sessions. The project manager and team leads organize weekly team meetings and complete tasks through remote team software such as Discord, When2Meet, Zoom, and a shared Google drive. Through the usage of remote collaboration tools mentioned, ARES-42 is able to define and meet expectations in a system that allows individuals to work flexible hours.

An issue that arose during Pre-Phase A was an accidental focus of subteam meeting time towards tasks that were unrelated to the ARES-42 mission tasks laid out in the Gantt Chart. This was immediately recognized by both the team lead and the project manager. The subteam lead addressed the mistake, clearly communicated the error to the subteam, and spoke with the project manager within hours of the meeting. The Project manager then created and implemented a new segment of the overall team weekly meeting to help ensure communication would always be discussed 2 weeks in advance of deliverable deadlines. This segment was named the Creators space, a block of time in each meeting where 3 points of communication are addressed in front of the entire team: A subteams completed and projected tasks for the week, questions the subteam has with real-time answers discussed by the entire team, and information on the following week’s tasks. This method of communication aligned directly with the overlap system of the organization and improved the understanding of tasks from the individual members up to the leadership. The ARES-42 team organization structure is strengthened by individual members' overlapping knowledge and is resilient to issues that arise due to this feature. During Phase B, the team utilized the ability to overlap and share responsibilities as a method of balancing the team as 2 members of the engineering team were no longer able to continue the mission due to scheduling conflicts with educational responsibilities. Outreach Lead, Milton Saldana, took over responsibilities for the aerospace and mechanical engineering roles. Engineering Team Lead Jacob Pederson assisted with the transition of responsibilities by communicating with the project manager and assisting with introducing responsibilities to Milton. Business Administration Lead, Antonio Ramirez, coordinated with the Project Manager, Nicole Alvarado, who assumed the outreach role responsibilities. All deliverables were managed and met on time in accordance to the customer's timeline, despite the change in roles and responsibilities. The project manager acknowledged the sudden loss of team members in an open discussion with the entire ARES-42 team to ensure that members had the ability to voice questions, concerns, or difficulties experienced. Weekly check-ins with team leads and team bonding segments such as discussions and peer reviews were introduced to overall team meetings in order to facilitate an open dialogue between members.



Mission Concept Academy

L'SPACE Academy

Fall 2021
Team 2 | ARES 42

Project Manager
Nicole Alvarado

Deputy Project Manager
Andrew Avila

Lead Engineer
Jacob Pederson

Aerospace Engineer
Erin Jackson

Software Engineer
Jacob Pederson

CAD Technician
Antonio Ramirez

Mechanical Engineer
Amy Keller

Electrical Engineer
Andrew Avila

Lead Business Admin
Antonio Ramirez

Financial Planner
Daniel Campos

Outreach
Milton Saldana

Scheduler
Nicole Alvarado

Lead Scientist
Naomi Hahn

Astronomer
Ashley Perez

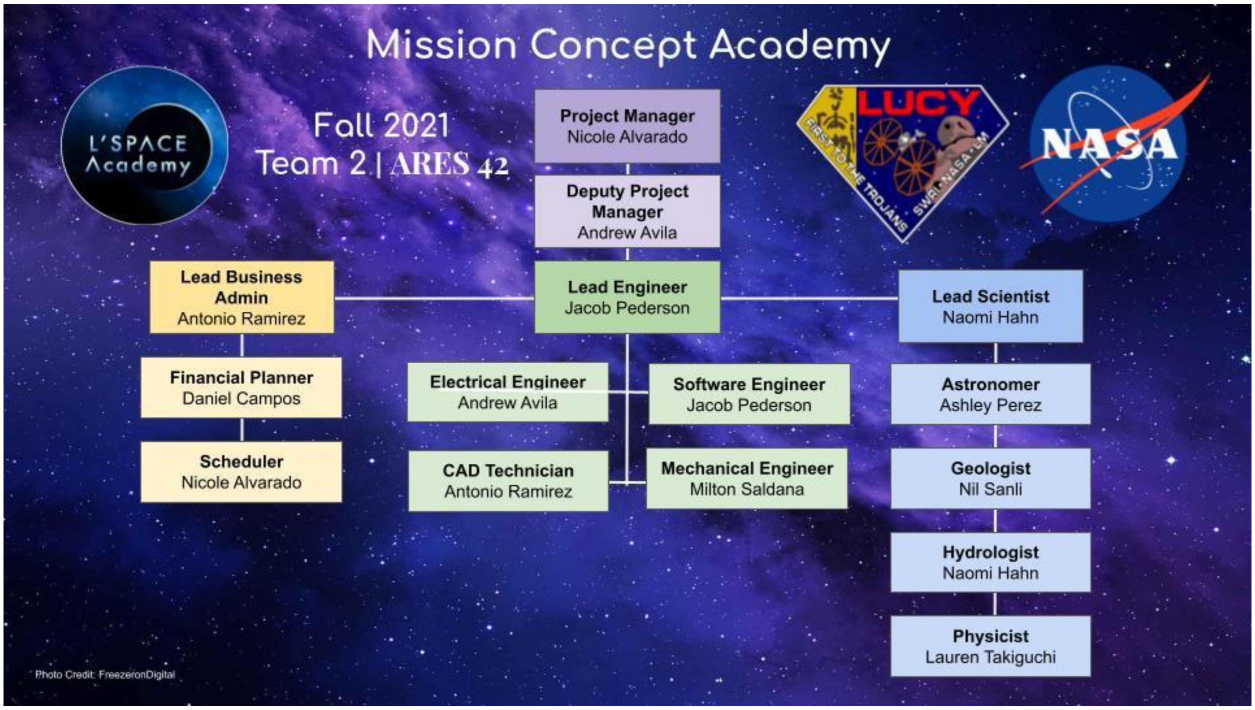
Geologist
Nil Sanli

Hydrologist
Naomi Hahn

Physicist
Lauren Takiguchi

Photo Credit: FreezeronDigital

Figure 62. *ARES-42 Initial Team Organization Chart*



Mission Concept Academy

L'SPACE Academy

Fall 2021
Team 2 | ARES 42

Project Manager
Nicole Alvarado

Deputy Project Manager
Andrew Avila

Lead Engineer
Jacob Pederson

Electrical Engineer
Andrew Avila

Software Engineer
Jacob Pederson

CAD Technician
Antonio Ramirez

Mechanical Engineer
Milton Saldana

Lead Business Admin
Antonio Ramirez

Financial Planner
Daniel Campos

Scheduler
Nicole Alvarado

Lead Scientist
Naomi Hahn

Astronomer
Ashley Perez

Geologist
Nil Sanli

Hydrologist
Naomi Hahn

Physicist
Lauren Takiguchi

Photo Credit: FreezeronDigital

Figure 63. *ARES-42 Final Team Organization Chart*

7. Conclusion

As the ARES-42 mission completes phase C and undergoes preliminary design review, the personnel support, hardware, and software design architectures are set to meet the client's requirements with the outlined budget of $196,000,000.00 and a scheduled launch date of September 2024. The mission is set to have 2 Earth years of operations until its end of mission in August 2027. The successful completion of the mission will provide crucial data that will support NASA's goals for manned exploration of Mars by the 2030’s. The primary goal of the ARES-42 mission is to characterize subsurface ice on Mars via laser spectroscopy. The chosen landing site is Arcadia Planitia, near Erebus Montes, because it displays certain geographical features that typically form as a byproduct of once having flowing water. The data gathered during this mission will offer valuable insights and knowledge into the composition and characteristics of the subsurface ice, which must be understood further before any human exploration missions can occur.

ARES-42 is 0.62M in length, 0.74M in width, 0.56M in height and will weigh approximately 30 kg. The material chosen to build the frame of the rover is Thornel VCB-20 carbon fiber cloth to increase strength and reduce weight in comparison to aluminum alloys. ARES-42 will include an instrument named Theia to observe the subsurface ice ARES-42 will be using the camera from Perseverance to see and relay information back to the control room on Earth. ARES-42 will be powered by a Radioisotope Thermoelectric Generator (RTG) based on the MMRTG that is currently on the Perseverance, however it will be reduced in size to accommodate ARES-42. The wheels for ARES-42 are also based on Perseverance’s wheels and will be made out of Aluminum.

The proposed science instrument Theia, which shares similarities to the SuperCam on Perseverance, plans to collect spectroscopy data on planned drill sites within a 5 km x 5 km square plot. This ensures that all data can be sent to the main payload through the ultra-high frequency antenna to be further sent back to the operations team on Earth, as the rover will remain in optimal communications range. The experiment design follows a three step process: initial laser drilling, secondary drilling operations, and data acquisition. In the initial laser drilling stage, the rover will drill at 25 sites to a depth of 5 cm, and rank the concentrations of hydrates found by highest to lowest based on site location. Following that ranking, the experiment will move to secondary drilling operations, where the rover will first go to the site with the highest ranked relative concentration, and drill another 5 cm (total depth 10 cm). In addition to taking note of the hydrate concentration, Theia will also collect measurements on mineral concentrations, to inform future manned missions on Mars of possible mining locations. Data acquisition occurs immediately after each secondary drilling operation, where the light given off by the material at the drill site is collected, sorted, and passed through three spectrometers to determine composition of the martian terrain

The specifications of the rover's design and its mission tasks are assessed at the conclusion of the engineering, manufacturing and development phase C. Once the PDR for the ARES-42 rover is reviewed and approved, steps to take the rover into the fabrication phase will begin. Final drawings are presented through completed analyses, simulations, schematics, software code, and test results.Tests on its durability, demonstration, and ability to perform its tasks, all while staying within the cost, risk, and schedule is key.

Assuming a successful defense of the PDR, the project would continue onward to phase D and the critical design review. If the ARES-42 project had additional time and resources to continue the development on the rover and mission, the team would aim to refine the rover’s design in regards to testing possible failure points via CAD modeling and efficiency in regards to data collection and life span. The project would further develop goals and the project timeline after phase D, based on achievable improvements to the rover. creating a second Gantt chart with new goals and timelines for the mission. If the mission were able to continue performing past the operational period on Mars outlined in this document, ARES-42 would enter a post mission phase. The post mission phase would consist of reprogramming the ARES-42 rover to be controlled in-situ by astronauts on the Martian surface. The mission would apply its ability to analyse subsurface ice and characterization of hydrates in real time at locations specified by human exploration crews on Mars.

Bibliography

"Antennas." *NASA*, NASA, https://mars.nasa.gov/mro/mission/spacecraft/parts/antennas/.

Caimi, R., Margasahayam, R., & Nayfeh, J. (n.d.). Rocket Launch Induced Vibration and Ignition Overpressure Response.

Caldwell, Sonja. "9.0 Communications." *NASA*, NASA, 16 Oct. 2021, https://www.nasa.gov/smallsat-institute/sst-soa/communications#9.5.7.

Damadeo, Kristyn. "Sensors Collect Crucial Mars Landing Data with Arrival of Perseverance." *NASA*, NASA, 31 Mar. 2021, https://www.nasa.gov/feature/sensors-collect-crucial-data-on-mars-landings-with-arrival-of-perseverance.

Dondero, Richard. "Radiation Hardened Enabling Technologies and Trusted Asics." *Radiation Hardened Enabling Technologies and Trusted ASICs. (Conference) | OSTI.GOV*, 1 Aug. 2011, https://www.osti.gov/servlets/purl/1106774.

"IGLOO2 Fpgas." *Microsemi*, https://www.microsemi.com/product-directory/fpgas/1688-igloo2.

Lawton, Natalie. "Planetary Rover Wheel and Lower Leg Structural Design to Reduce Rock Entanglements." *DEGREE PROJECT* , Space Engineering, master's level , 2020.

"LEON3FT Fault-Tolerant Processor." *CAES Pioneering Advanced Electronics*, https://www.gaisler.com/index.php/products/processors/leon3ft.

Lindemann, Randel A. "Jpl.nasa.gov." *Mars Exploration Rover Mobility Assembly Design, Test and Performance*, JPL / California Institute of Technology, http://jpl.nasa.gov/videos/vidcat.pdf.

"Mars 2020 Perseverance Launch Press Kit." *NASA*, NASA, https://www.jpl.nasa.gov/news/press_kits/mars_2020/launch/mission/spacecraft/power/.

Muhammad, Ajmal, and Robert Forchheimer. "Optical Components." *SlideToDoc.com*, Information Coding Group ISY Department, https://slidetodoc.com/optical-components-ajmal-muhammad-robert-forchheimer-information-coding/.

NASA. (n.d.). *SuperCam*. NASA. Retrieved November 21, 2021, from https://mars.nasa.gov/mars2020/spacecraft/instruments/supercam/.

NASA. (2020, April 22). *Mastcam*. NASA. Retrieved November 21, 2021, from https://mars.nasa.gov/msl/spacecraft/instruments/mastcam/.

NASA. (n.d.). *SuperCam*. NASA. Retrieved November 21, 2021, from https://mars.nasa.gov/mars2020/spacecraft/instruments/supercam/.

"Optics: How to Build a Beam Expander ." *Newport*, https://www.newport.com/medias/sys_master/images/images/he7/h44/8797226237982/Optics-How-to-Build-a-Beam-Expander.pdf.

"Radioisotope Thermoelectric Generator." *Wikipedia*, Wikimedia Foundation, 14 Nov. 2021, https://en.wikipedia.org/wiki/Radioisotope_thermoelectric_generator.

Space launch system begins vibration testing. SpaceFlight Insider. (2021, October 13). Retrieved November 19, 2021, https://www.spaceflightinsider.com/organizations/nasa/space-launch-system-begins-vibration-testing/.

Spiegel, Dr. Colleen. "How to Estimate Electricity Requirements." *Fuel Cell Store*, https://www.fuelcellstore.com/blog-section/how-to-estimate-electricity-requirements.

"Systems for Nuclear Auxiliary Power." *Wikipedia*, Wikimedia Foundation, 29 Oct. 2021, https://en.wikipedia.org/wiki/Systems_for_Nuclear_Auxiliary_Power#SNAP-9.

"Transit (Satellite)." *Wikipedia*, Wikimedia Foundation, 9 July 2021, https://en.wikipedia.org/wiki/Transit_(satellite).

"UHF Antenna System 1X1U Datasheet." *NanoAvionics*, 4 Dec. 2018.

"UHF (Ultra High Frequency) - Antennas for UHF Transmission Applications." *Electricalfundablog.com*, 18 Dec. 2020, https://electricalfundablog.com/uhf-ultra-high-frequency-antennas/.

"What Is a Radioisotope Power System?" *Energy.gov*, Office of Nuclear Energy, https://www.energy.gov/ne/articles/what-radioisotope-power-system.

Wiens, Roger C., et al. "The SUPERCAM Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests." *Space Science Reviews*, Springer Netherlands, 21 Dec. 2020, https://link.springer.com/article/10.1007/s11214-020-00777-5.

"Wind Tunnel Operations Division Safety Manual." *Global Warming: Early Signs*. 2006. https://www.nasa.gov/centers/ames/pdf/643640main_SafetyManual.pdf. Accessed 15 Oct. 2021.

"Workplace Safety & Health for Supervisors and Employees at NASA Headquarters." 2010. https://nodis3.gsfc.nasa.gov/npg_img/hq_pr_8715_0001_/hq_pr_8715_0001.pdf . Accessed 15 Oct. 2021.