L’SPACE Mission Concept

Preliminary Design Review

Team 26

1. Introduction and Summary

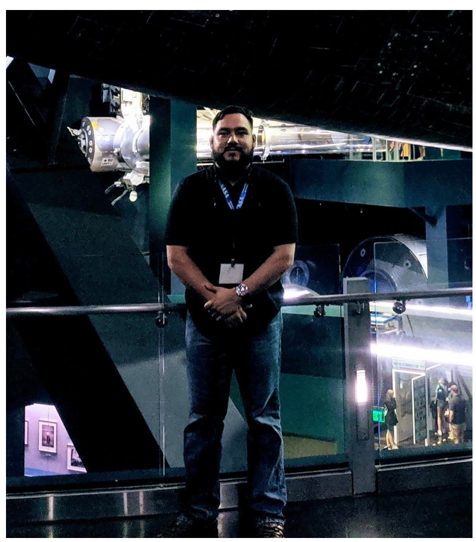
1.1. Team Introduction

Jorge Penaloza is the Project Manager and science team member. He studies at the University of Houston and is majoring in electrical engineering. Through past leadership experiences, Jorge brings support to his team while maintaining great motivation for leadership tasks. He also brings a strong mathematics background and prominent problem solving skills and analytical thinking.

Caitln Davitt is the Deputy Project Manager and science team member. She goes to The Illinois Institute of Technology and is majoring in computer science. She brings leadership skills for years of experience leading teams. She also brings great organizational skills to help keep the team on track.

Ricky Patel is the lead engineer of the engineering team. He goes to the Georgia Institute of Technology and is majoring in mechanical engineering. He brings a strong background of engineering from his academic curriculum, research experiences, and rocketry team.

Ruben Ontiveros is the aerospace engineer and part of the entry, descent, and landing subteam. He currently attends Austin Community College in Austin, TX and is majoring in aerospace engineering. He brings a strong design and engineering background from his previous NCAS internship, and 3D printing experience.



Talhah Waheed, is the electrical engineer on the engineering team and specializes in the power electronics and communications teams. He studies electrical engineering at the Illinois Institute of Technology. He has a strong background in circuit analysis and prototyping with a healthy supplement of CAD, programming, and vehicle propulsion experience

Anisha Kapoor is the software engineer on the engineering team. She studies software engineering and mathematics at Loyola University Chicago. She brings a background in information technology and environmental sustainability to the team.

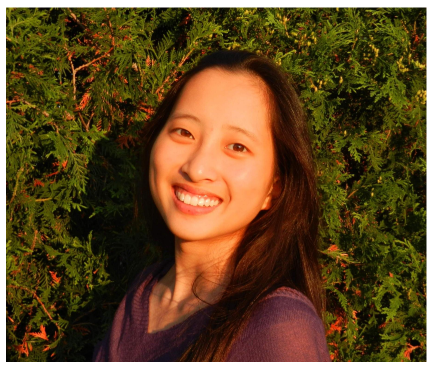
Isabelle Perron is the lead scientist and astrophysicist for the science team. She studies astrophysics and physics at the University of Minnesota Twin Cities. She brings a physics background to the team as well as good communication and leadership skills.

Kaitlyn Schrick is a manufacturing engineer on the engineering team. She is a part of the power systems and entry, descent, and landing subteams. She studies engineering technology and computer science at Southwestern Oklahoma State University. She brings a background in robotics and rocketry.

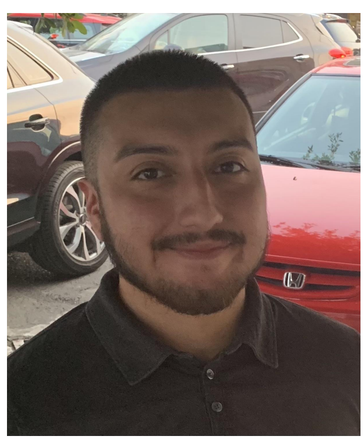
Rashed Khraisat is a mechanical engineer on the engineering team. He is a part of structures engineering. He studies mechanical engineering at Illinois Tech. He brings a solid background in CAD and structures.

Joshua Wood is the Physicist on the science team. He is an Information Technology major at the University of Central Florida in Orlando, Florida. He is familiar with many scientific and physics concepts and has experience combining technological tools with scientific data.

Lucy is the Logistics member on the business team. She is a computer science major at the University of Wisconsin-Madison and is from Minneapolis, Minnesota. She brings a background of software and administrative skills to the team.



Joel Is an electrical engineer and a financial planner on this team. He is an electrical engineering major with a concentration in computer engineering at Texas State University. He has a background in circuit and electronic design. He also has a background in software.



1.2. Mission Overview

1.2.1. Mission Statement

The goal of this mission is to be able to map water ice in the permanently shadowed regions of the lunar south pole. Team 26 is aiming to determine the abundance of water ice in the top meter of the regolith to ~+-1% accuracy and have a spatial sampling of around 100 meters. This will help future humans by mapping the areas with the most water for in-situ resource utilization of a future lunar base.

1.2.2. Mission Requirements

To establish a good foundation, the mission's lander constraints are to keep within a mass of 180 kg, a volume configuration of 60.1 cm x 71.1 cm x 96.5 cm or less, and a budget cap of $200 million or less. Our design will also need to be able to land successfully, resist dust build up for the duration of the mission, successfully navigate the lunar surface, establish communications, and collect and analyze samples of the lunar regolith.

- Scientific instruments will not exceed 50 kg of lander weight
- Mission lander is to detect and map ice-water within a 10 M beneath the lunar surface
- Precise landing of lander on to chosen lunar site

1.2.3. Mission Success Criteria

- Map lunar ice abundance with ~+-1% accuracy and a spatial sampling of around 100 meters
- Sustain surface temperature varying from $500 \circ F$between sunlight and shade
- Collect and analyze the distribution, physical state and composition of ice deposits with a +-1% accuracy
- Drive in near real time
- Be able to navigate difficult terrain by driving diagonally, spinning in circles, moving in any direction without changing the way it is facing and be able to “walk” on soft soil.

1.2.4. Concepts of Operations (COO)

- At 10,000 meters above the lunar surface the rover will start descending
- At around 1980 meters above the lunar surface the thrusters will fire
- The rover’s velocity will be reduced to almost 0 m/s just above the lunar surface
- The rover will land.
- The rover will turn on and establish communication with Earth.
- The rover will map out the desired area, collect 100 different samples of soil, test these samples for water abundance, communicate the results back to headquarters, and recharge itself when needed.

1.2.5. Major Milestones Schedule

Pre-Phase A/Conceptual Study: Design a small space lunar lander exploration mission to determine water ice on the top 1 meter of regolith in the lunar south pole with ±1% accuracy and a spatial sampling of around 100 meters. The collected data will allow for further analysing of mineral volatility and composition, as well as determine origin of hydrogen traces.

Phase A/Preliminary Analysis: The lunar lander will be delivered by a lunar orbiting craft. Launch dates and time will be dictated by the primary mission as the lander is a secondary payload. A lander must be designed and built to traverse the lunar surface. The lunar lander must have the ability to communicate with the lunar orbiting craft (primary mission), and the lunar lander must include an infrared spectrometer. This project's budget is 200 million USD.

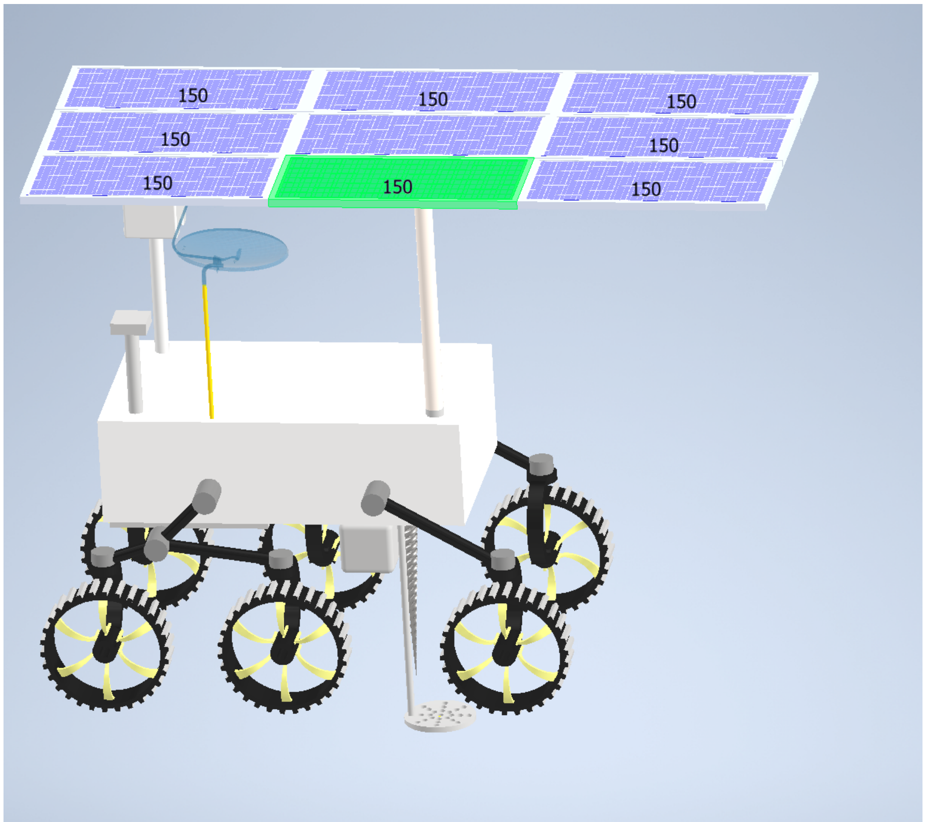
Phase B/Definition: Entry, descent, and landing phase will begin 10 km from lunar surface in free fall. The spacecraft will be equipped with SPLICE landing technology to determine a safe and even landing zone. The spacecraft might also be equipped with secondary emergency landing technology, depending on budget, volume, and mass constraints. This will be determined by cost and weight. Engineering, science, and business subteams have been created. Please see Gantt for specific personnel information.

Phase C&D/Design and Development: During this phase, the design of the rover will be completed. As the final sketches and designs for the rover are worked on, a Critical Design Review (CDR) will be drafted. In addition to this,, the spacecraft and its components will be built, tested, and reviewed many times. This will ensure quality products and allow any changes that need to be made.

Phase E: Now, the system will be tested to make sure it is ready for operations. The data will then be collected and stored in a database.

1.3. Descent Maneuver and Vehicle Design Summary

Our entry, descent and landing will be fully autonomous. Detailed preloaded maps of the lunar surface will be used in conjunction with a series of real time images captured by laser scanners as our spacecraft makes its descent. Onboard computers will then be able to determine position and location based on this information, which will determine a safe landing zone. Using this system will allow for a more precise landing closer to craters, or areas that cast shadows. Based on what the sensors onboard the rover capture, course corrections will be made in order to ensure a safe landing. Deceleration and course correction are a part of an advanced precision landing technology developed by Nasa called SPLICE. This technology is explained further down in the document.



1.4. Payload and Science Instrumentation Summary

Panoramic Camera: Used for taking detailed images of the lunar surface and for real time navigation when being operated on earth.

InfraRed Spectrometer: This instrument will analyze mineral samples collected and determine whether the hydrogen samples encountered belong to water molecules (H2O) or to hydroxyl (OH)

Solar Panels: Used to charge the rover. It unfolds on the top of the rover when analysis ladrillneeded for charging.

Sample Analysis Lab: Used to analyze samples collected by the scoop and drill. It is attached to the back of the rover.

Regolith and Ice Drill: Used to collect samples deeper in the lunar surface. It is attached to the side of the rover in a horizontal position and can rotate 90 degrees to be in a vertical position. Once it is rotated into the vertical position, it can move up and down to collect the samples.

Scoop: Used for scoping up surface samples. It is attached to a movable arm that can swivel around the rover.

Antennas: Used for sending information collected back to headquarters. It is attached to the top and can be retracted back into the rover.

Battery: Used to power the vehicle. It is inside of the rover and will be powered by solar panels.

2. Evolution of Project

2.1. Team 26 started the mission experiment plan with the decision to land on the lunar surface rather than fly by it for study. It was decided that a lander would be put on the surface to search for lunar ice. After research and the use of advanced imaging, the Shackleton crater was chosen for the mission. It best fits the criteria for our purpose. With the Shackleton crater in mind, a more detailed plan developed. After landing, the rover would explore the depths of the crater, collecting samples when needed and driving to the higher portions of the crater where light hits to recharge before descending back into the crater for further study.

2.2. Team 26's evolution of descent maneuver and vehicle design started with simple concepts and ideas. Once our mission purpose was decided, a lander was chosen to best accomplish this purpose. The team used Mars rover designs to progress with our own design elements and plans. The perseverance rover design was a big inspiration for the design of this rover. It was then decided on solar power early on as the rover can recharge at the top of the crater when needed. Entry, descent, and landing was originally planned around the parachute and air bag method used with the current Mars rovers. The landing strategy soon changed to the SPLICE method, a process that uses boosters, lasers, and cameras to safely land on the lunar surface. This change happened because this method is more tailored specifically to the lunar environment. The team felt that it would be a better option to not only keep our rover and on board instruments safe, but also to test this method in the environment it was created for.

2.3. Evolution of Payload and Science Instrumentation

The instrumentation plan consisted of very barebones features. This included basic movement and coordination instrumentation and maneuverability features. The reason it proceeded this way at first was to map out, most efficiently, what our payload could support while keeping additions to a minimum. Moving forward, Team 26 proceeded to implement more essential movement and communication protocols along with safety features. For movement and comms, a power supply. This presented us with a lot of safety challenges and constraints leading us to implement power shutoff safeties and system redundancy procedures. For example, a lander that undergoes power failure shall report all features available vitals and telemetry data back to mission control, proceeding to enter into power conservation mode. This was a very crucial phase in development as the team started thinking past basic movement essentials. Finally, the lander was outfitted with more customized accessories and probes that have an impacting, but not necessarily critical role in the lander’s success. For example, the lander was fitted with a solar panel array mounted on the top of the chassis and positioned to optimize energy potential. Though a lander does need a means of charging to survive for a considerable period of time, the array was not immediately necessary in the lander’s success, which is why this, and additional features were added in this third and final iteration.

3. Descent Maneuver and Vehicle Design

3.1. Selection, Design, and Verification

3.1.1. System Overview

The descent maneuver that will be used is called the SPLICE strategy. This stands for the Safe and Precise Landing - Integrated Capabilities Evolution. It will use this multistep method to safely decelerate and land in the target area.

The main body of the spacecraft will be a rover. This will house all of the scientific payload instruments and be able to navigate the terrain of the lunar surface. This main body will interact with the descent maneuvering system. The separate parts of the descent maneuvering system will be attached to the rover and assist in a safe landing.

3.1.2. Subsystem Overview

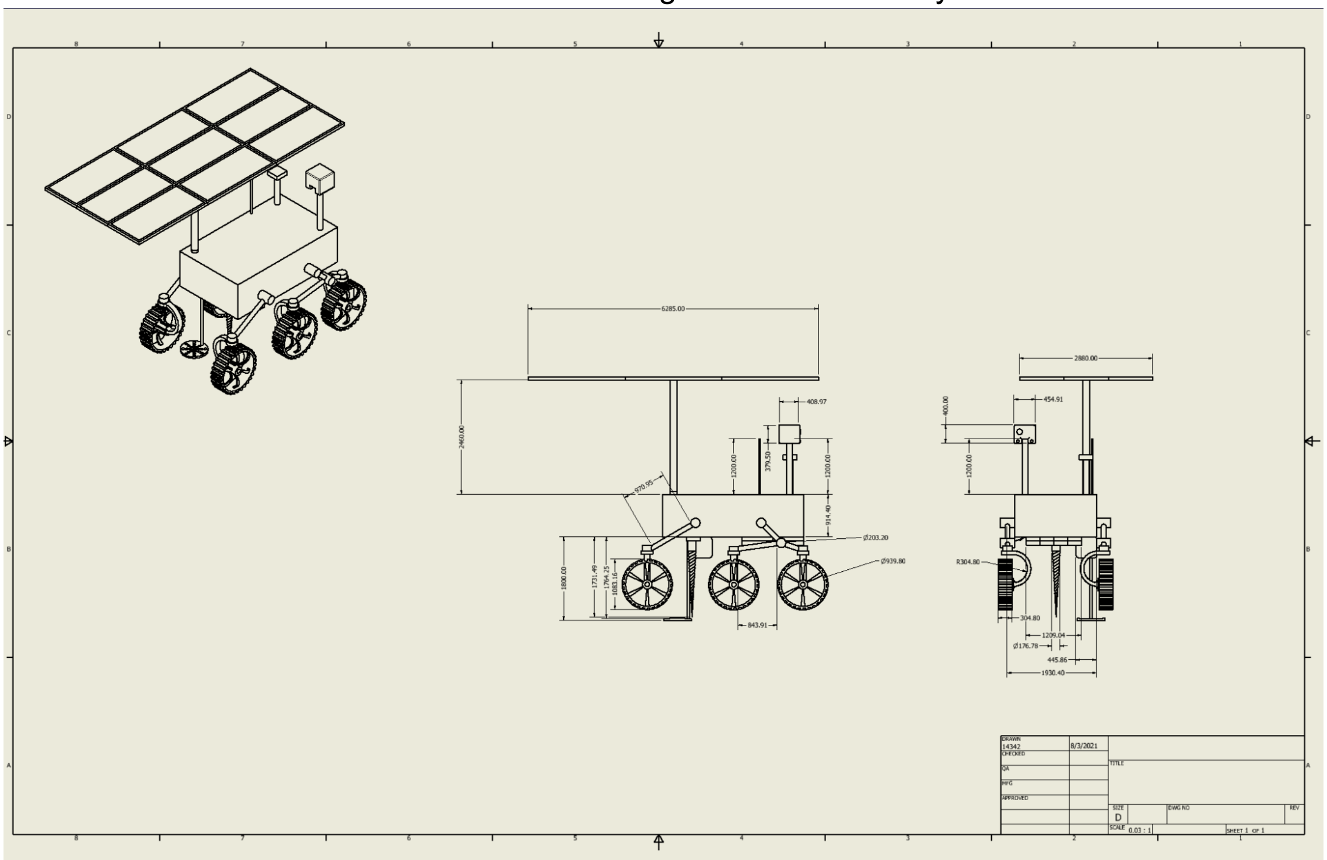
For our descent method, the recently created SPLICE strategy, or the Safe and Precise Landing – Integrated Capabilities Evolution is being used. The following systems are what are being used for this method. First, the Navigation Doppler Lidar (NDL). This system unit has three telescopes connected at specified fixed angles that are angled for best performance. These are connected to an electronics box and laser using fiber optic cables. While the vehicle is descending, the NDL will send laser beams towards the lunar surface and use the reflected returns to determine an estimate of the lander’s altitude and velocity.

Next is the Terrain Relative Navigation (TRN). This unit uses a camera to take live pictures as the lander descends and compares them to existing orbital pictures uploaded into its software to determine its location.

It also uses a Hazard Detection Lidar (HDL). This unit is a sensor that uses the laser in a 3D imaging system to scan the lunar surface below and create a 3D map of the landing field. This allows the lander to determine the safest place to land and avoid hazards such as steep slopes.

Finally, it uses a Descent and Landing Computer (DLC) which allows it to accomplish all of this. It is a high-performance multicore computer processor unit. It analyzes all of the SPLICE sensor data and determines the landers altitude, velocity, and surface/terrain hazards. It also determines the safest landing location by computing the hazards it is given. This system was made for the lunar surface and has done well in testing so far. It also has a lower weight in total when compared to other methods that were researched.

3.1.3. Dimensioned CAD Drawing of Entire Assembly



3.1.4. Manufacturing and Integration Plans

Our rover design will be manufactured by Lockheed Martin. Lockheed Martin was chosen for their ongoing research and development of their own lunar lander with partner General Motors. The rover will take 6 months to complete and will cost close to 35 million dollars to be built and moved to Kennedy Space Center’s Vehicle Assembly Building (VAB), where it will be test fitted with other critical components to ensure fitment in the lander. Scaled down 3D printed models of all components will be made and test fitted before initial order of the lander is approved to confirm integration. This stage will determine whether design changes need to be made. Assembly will begin as soon as the components are completed. The rover will be autonomous so no additional personnel is required to pilot it, preprogrammed missions will be executed from mission control.

3.1.5. Verification and validation Plans

To Validate the design as well as verify its ability to perform in the harsh conditions of space there will be a series of quality engineering, stress analysis, and controls verifications. To accomplish these different components of the land rover, it would require extra materials like those on the exterior of the chassis. This would allow us to run stress and thermal tests. All joints must be quality tested in the sense that no screw be too loose and no part be too large or small. If the parts are not within reasonable tolerances then the structure will be weakened and the costs of materials will needlessly increase without increasing structure stability. All controls can be validated individually as they do not require trial and error with respect to materials. Although controls to thrusters should be tested by holding the rover in place while the thrusters activate to allow measurement of the force of the individual thrusters. Verification and validation will be crucial to the mission so to prevent the major consequences given the scenario if any of the components fail. These are all things that are crucial to the mission and so experts with an abundance of experience from Lockheed Martin in this department will undoubtedly be able to accomplish this.

3.1.6. FMEA and Risk Mitigation

- Majority of risks will fall under class III and Class IV risks. The risks will have an occurence rank of 1 or 2.
    - Power failure
    - Chassis integrity failure
    - Comms failure.

3.1.7. Performance Characteristics and Predictions

Team 26 has carefully chosen which methods, designs, and strategies were desired to use for this lander. Our descent system, for example, was a system created by NASA specifically to be used on the lunar surface. This system will allow the lander to create a 3D map of the lunar surface, determine its location, determine the safest spot to land in the landing field, and slow itself down as it uses lasers to determine its altitude and velocity, all while it is descending towards the surface. Because of the careful design of this SPLICE method, it is believed that it will do well on the lunar surface. The powered landing that will be happening while all of the sensors are working to make it go smoothly should work well in the lunar atmosphere. There are no harsh winds or weather in the lunar atmosphere that would give the lander any turbulence as it descends. The use of the 3D mapping and imaging systems will be able to guide our lander to a safe landing on the lunar surface.

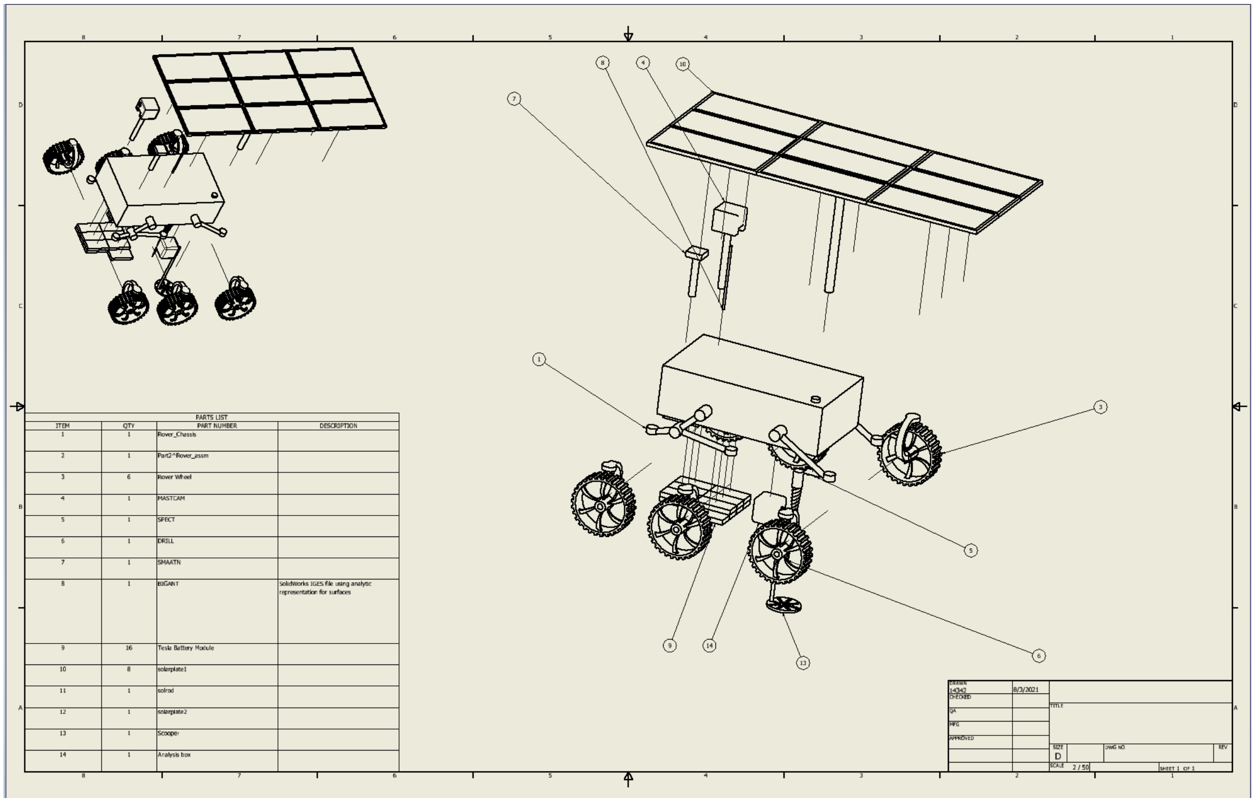
3.1.8. Confidence and Maturity

The spacecraft that Team 26 developed evolved quite a bit over the span of this project. Originally, the rover had the drill attached to the bottom. After analysing the CAD, it was realized that the drill would be too long to attach to the bottom of the spacecraft and would not fit inside of it either. The design was then changed to have the drill attached to the side of the rover in a horizontal position. It will then be able to rotate into a vertical position and drill to the desired depth. Various tests will be performed on the rover to prove that it will be able to withstand the lunar environment and complete its designated tasks. These tests include a temperature test to make sure the rover can withstand the cold temperatures that it will face in the shadowed Shackleton crater in the southern region. In addition to this, all parts will be tested to ensure durability, especially with all of the extra dust that could be stirred up while the rover is maneuvering the rocky lunar terrain. All joints and screws will be tested to ensure that they will not be worn down to failure and that they can withstand the conditions presented on the lunar surface.

3.2. Recovery/Redundancy System

Power and thermal runaway management are the primary concerns for safety systems. For a total or partial loss of power, the rover will boot into a safe mode in which the rover first sends critical telemetry data back to mission control (MC). The system will then operate on critical battery mode, using minimal power and taking advantage of duty cycle optimization where applicable. For a communication failure, internal or external, telemetry and systems data is sent to MC on instance of the error. The rover will attempt to establish and maintain a successful connection to MC in the moments that follow the error. Should the rover fail to do so after some attempts, the rover will boot into safe mode once again, this time prioritizing two-way communication control. Should all attempts to make a successful connection fail, the rover will enter the lowest tier of communication which entails one way communication from the rover to MC. In the event of a thermal runaway, the rover will boot into safe mode, like before, this time keeping a close monitor on power consumption and battery pack status. Should the battery deteriorate to a more critical state, the rover will power down main power and proceed with a reserve battery. Simultaneously, the rover ejects all hazardous matter in a safe direction and manner, ejecting the power housing as well to mitigate any effects of harmful waste in the atmosphere of the target surface.

3.3. Payload Integration



4. Payload Design and Science Instrumentation

4.1. Selection, Design, and Verification

4.1.1. System Overview

Power:

- Power will be supplied to the spacecraft by solar panels. The solar panels will generate 250W of power each to the spacecraft per hour exposed to sunlight. There will be 9 solar panels total. The amount of time spent in the sunlight will dictate the total power that the battery will receive after every charge. Power will be supplied to the payload instruments (3.6 kW), sample analysis lab (200 W), thermal sensors (5 mW) and the communication antennas (107 W).

Thermal:

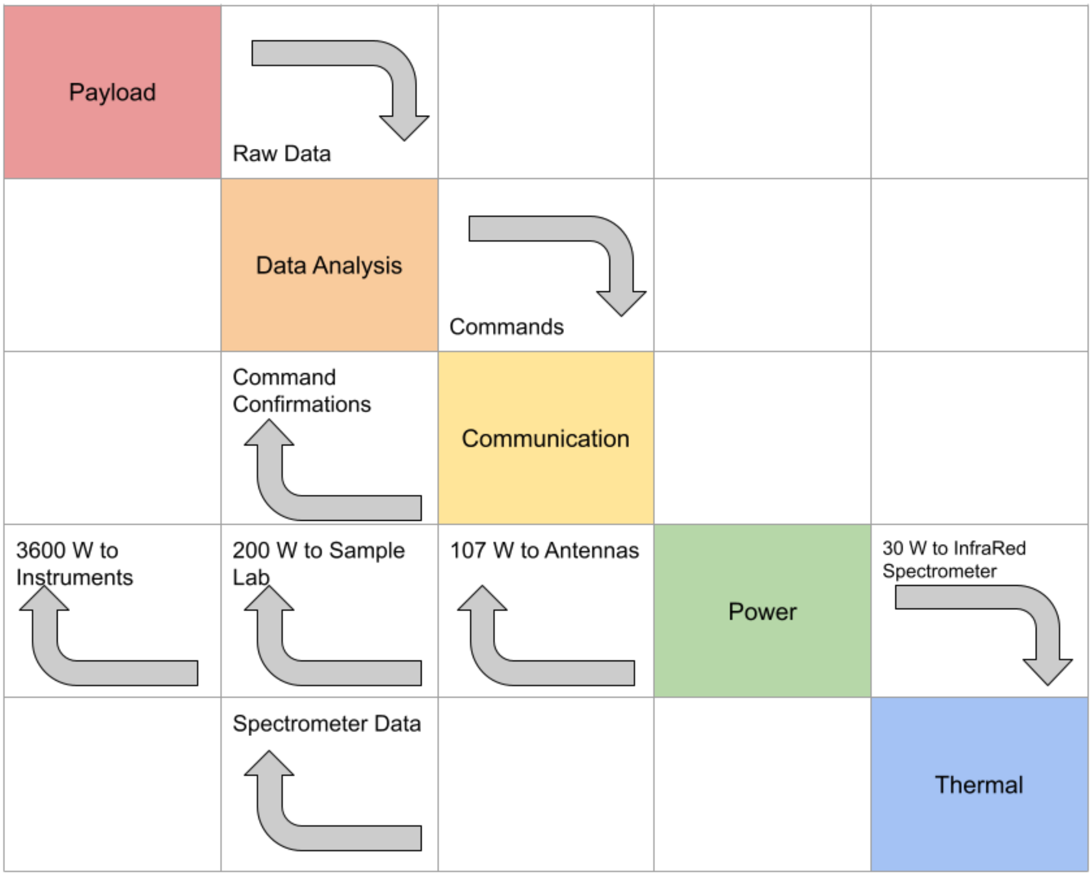
- The InfraRed Spectrometer will send raw data to the Sample Analysis Lab. It will receive power generated by the solar panels.

Data Analysis:

- Data will be collected and handled in the Sample Analysis Lab. This lab will receive data from the payload instruments and thermal spectrometer. It will receive power from the solar panels. The lab will also receive recognition of completed tasks from the antennas.

Communications:

- Communications will receive commands from the Data Analysis Lab. In return, the communications systems will send confirmation messages back to the data analysis systems. There will be three antennas used for communication, a high gain antenna, a low gain antenna, and a UHF antenna. The communications systems will receive power generated from the solar panels. 100 W to power the high and low gain antennas and 5-7 W to power the UHF antenna.



4.1.2. Subsystem Overview

Power

The main source of power for the spacecraft will be the battery. This will store energy gathered from the solar panels. The battery will power all other components of the spacecraft, including the payload instruments, cameras, sensors, and other moving parts.

Thermal

The infrared spectrometer is the main instrument in the thermal subsystem. This will be used to map out ice water below the lunar surface. This will be powered by the battery/solar panels.

Data Analysis

The regolith and ice drill, scoop, and sample analysis lab fall into the data analysis category. These instruments are responsible for gathering and analysing the samples collected. The sample analysis lab is the main source of analysis. It will be the place where the samples are stored and analyzed.

Communication

The antennas and cameras/sensors are the parts that are responsible for communication between the rover and headquarters. The antennas will send the analyzed data from the rover to headquarters. The cameras and sensors will allow headquarters to see what the rover is encountering, which is very valuable information. Together these parts will give people back on Earth an idea of what the rover is seeing and discovering about the lunar surface, specifically in the Shackleton crater.

4.1.3. Manufacturing Plan

The engineering team has designed some of the science-capturing equipment to be made in-house and some to be purchased off the shelf on a case-by-case basis. Considering many lunar rovers missions have already taken place, the main structural chassis, panoramic camera, spectrometer, antennas, and battery does not need major time and money allocated to its development. It will be a modified version from previous versions. Same with the lunar rover wheels. NASA has already developed wheels designed to tread the lunar regolith, providing cost savings for this mission.

The solar panels are off the shelf parts well, with specific panels purchased per requirements for the mission. The lunar ice drill, scoop, and analysis lab are custom parts with major funding allocation as the nature of the mission is the first of its kind.

4.1.4. Verification and Validation Plan

Vigorous verification and validation will be necessary to prove that each subsystem of the rover will fulfill its designed task. The full assembly will be placed in a field where the lunar terrain will be simulated and will be driven to test suspension, and tread on the wheels. Additionally, each particular component will be tested in its own testing lab with a required working confidence interval of 99.5%.

4.1.5. FMEA and Risk Mitigation

Strategies for risk mitigation were developed using the Failure Modes and Effects Analysis to identify the potential failures. Risk mitigation strategies were used to assess potential risks and what the team could do to mitigate the risks. To ensure all team members were aware of the FMEA and Risk Mitigation processes such as identifying any unnecessary risks, analyzing the risk, proceeding with the appropriate action, monitoring splintering risks, and finally controlling the risk.

4.1.6. Performance Characteristics

Team 26 has carefully chosen systems and scientific instruments that have previously been designed and used for in past NASA missions, Because of this heritage it is already known that these systems and scientific instruments are capable of functioning properly on the Moon's environment.Due to the moon being relatively close to the Earth sending information from the Moon using the equipped antennas would be accomplished within seconds. This will allow the driver of the lander to have better response times when operating the vehicle from Earth.

4.2. Science Value

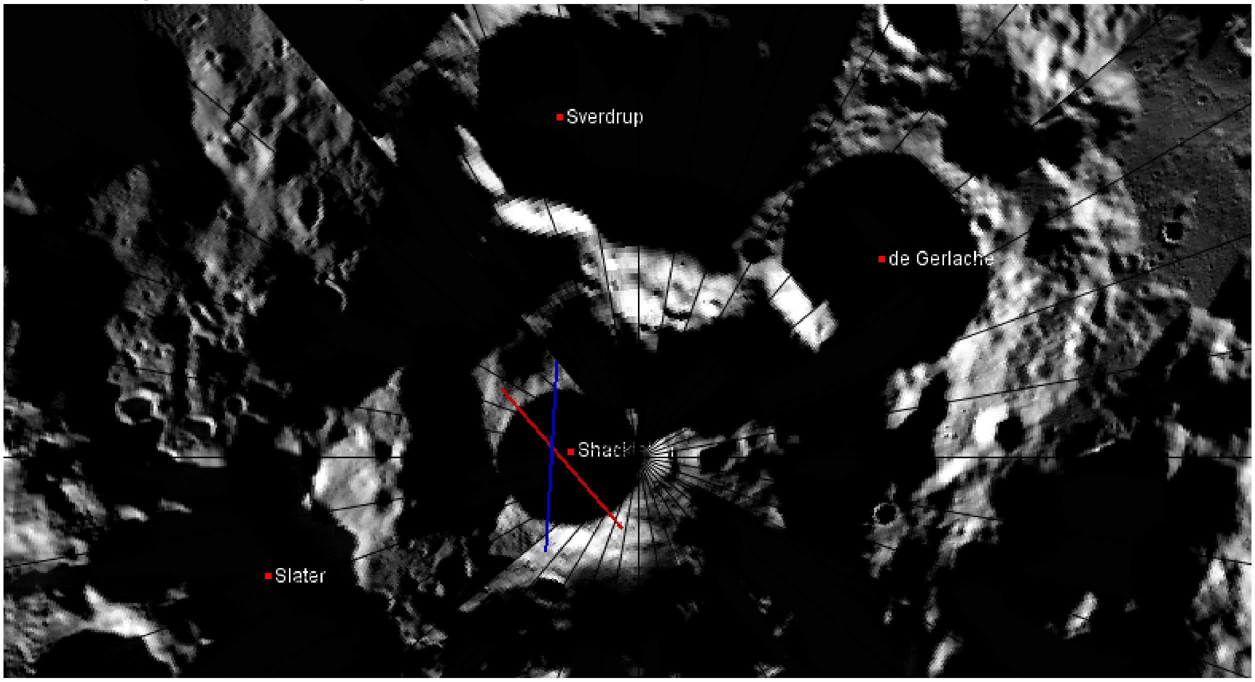
4.2.1. Science Payload Objectives

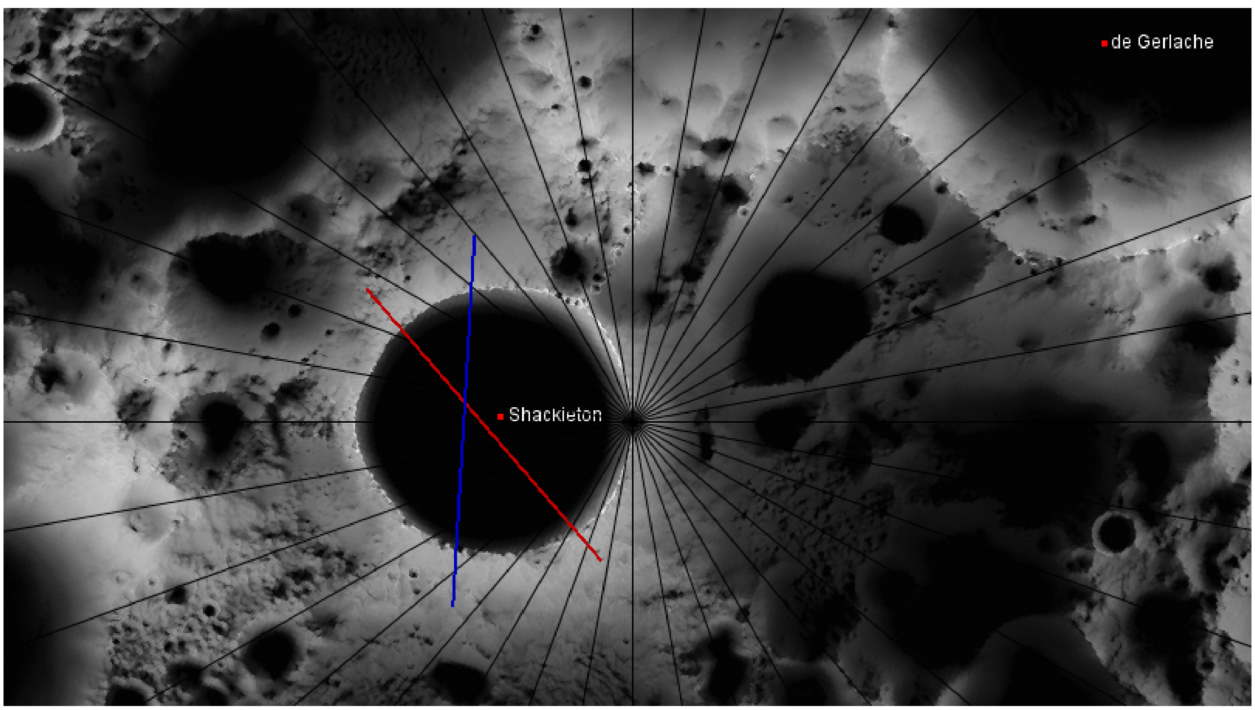
The goal of this mission is to establish a good foundation, the mission's lander constraints are to keep within a mass of 180 kg, a volume configuration of 60.1 cm x 71.1 cm x 96.5 cm or less, and a budget cap of $200 million or less. Our design will also need to be able to land successfully, resist dust build up for the duration of the mission, successfully navigate the lunar surface, establish communications, and collect and analyze samples of the lunar regolith.

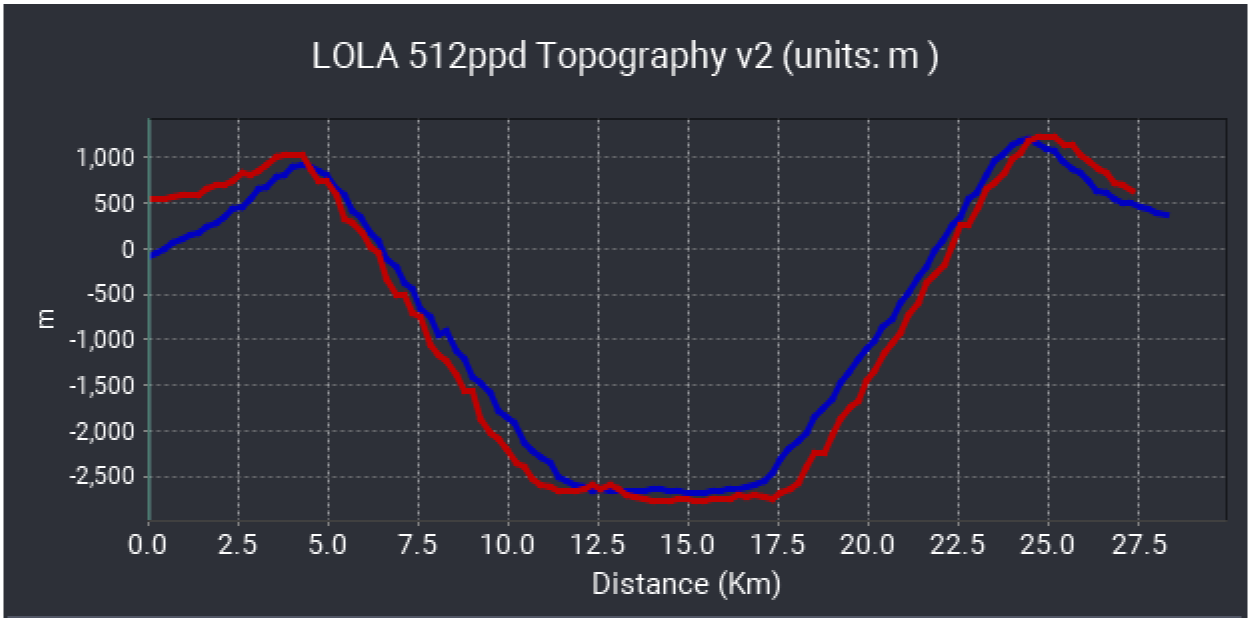
- Scientific instruments will not exceed 50 kg of lander weight
- Mission lander is to detect and map ice-water within 1 m beneath the lunar surface
- Precise landing of lander on to chosen lunar site

4.2.2. Creativity/Originality and Significance

Team 26 chose Shackleton crater as the mission's landing site. The interior of this crater is permanently in shadows that lies within the southern region of the lunars surface. Apart from Shackleton’s interior being submerged in the dark, its rims are continuously exposed to sunlight. Due to this occurrence the mission's lander could use the craters rims to recharge itself using the equipped solar panels after searching for ice-water within the shadowed region of the crater. Although Shackleton crater is steeper than other craters located near the southern region of the Moon, the mission's lander would still be capable of driving under the craters surface conditions due to the height not drastically steepening when coursing across the crater.







4.2.3. Payload Success Criteria

The success of the mission will be if the rover is able to land successfully, power on and establish communications with headquarters. The mission will be successful if the rover is able to travel to 100 sampling areas, take samples from the lunar surface in the Shackleton crater, analyse amounts of water ice in the samples, and report data back to Earth. The mission will be a failure if the spacecraft cannot land successfully on the lunar surface and establish connection with Earth. The mission will also be considered a failure if the rover scoop and drill cannot properly obtain samples or if the sample analysis lab fails to calculate the abundance of ice water within said samples.

4.2.4. Experimental Logic, Approach, and Methods of Investigation

1. Run through appropriate calibration tests to ensure all scientific equipment is working properly. Solar panels will provide power for all systems.
2. Determine and map out a 100 square meter area of testing around the interior of the Schackleton crater.
3. Utilize the panoramic camera to get a visual of the surrounding area.
4. Send movement commands from headquarters to the rover using the antennas located on top of the rover. Move the rover toward the mapped out area. Use caution when navigating terrain.
5. Once the rover reaches an area marked for analysis, send a stop command from headquarters.
6. Command the rover to rotate the ice drill into the vertical position. Place the ice drill on the lunar surface and drill a 1 meter deep hole.
7. Command the rover to stop drilling and retract the drill.

8. Maneuver the arm with the scoop to the drilled area. Use the scoop to collect debris.
9. Maneuver the scoop with the collected debri to the sample analysis lab that is attached to the back of the rover. Place the sample in the lab.
10. Utilize the InfraRed Spectrometer with the sample. Thermal imaging will pick up whether hydrogen samples encountered belong to water molecules (H2O) or to hydroxyl (OH).
11. InfraRed Spectrometer will send out confirmation signals to the analysis lab.
12. The analysis lab will send information to headquarters.
13. Clear analysis lab of any debri.
14. Repeat steps 3 - 13 until sample area is completed.

4.2.5. Testing and Calibration Measurements

Calibration of Panoramic Camera: Acquire multiple images from the same point of view. To minimize parallax, take the pair of rotated images with near and far objects. Analyze the order between two images. If the order is the same, there is little to no parallax. Otherwise, shift manually until the effect disappears. Then, use refined rotation to find matching points in a gridded area. Compare the quality of the homologous structures to each other. Use a mathematical calibration method to get a calibration value.

Calibration of InfraRed Spectrometer

Items needed:

1. Polystyrene film
2. Reference spectra of polystyrene

Setup:

1. Turn on the spectrometer and let it warm up for at least 10 minutes to stabilize the source. An unstable source creates an unreliable spectra.
2. Place a piece of polystyrene film in the sample holder. Run through a test with known spectra to use a standard.
3. Retrieve the spectra from the polystyrene sample. Compare it with the known standard reference of InfraRed Spectrometer.

Analysis:

1. Check and make sure all expected peaks exist. The peaks must line up with wavelengths of absorption.

2. Check and make sure the strength of the signal is within 95 percent of maximum strength.

Checklist:
1. If the strongest peak is more or less than full scale, adjust appropriately to deliver the correct signal strength.
2. Calibrate the InfraRed Spectrometer frequently. Users should calibrate at least before and after a task is completed.

Calibration of Solar Panels

Sunlight:
1. Before calibration, analyze whether the panels are getting enough access to sunlight. Performance will vary based on the amount of access to sunlight.

Inspect the Inverter:
1. The inverter is an important part of the solar panels. It converts the direct current into alternating current electricity.
2. Check inverter indicator lights.
    a. Red/Orange lights: Inverter is experience potential problems

Evaluate solar meter:
1. Solar panels should have a solar meter that is an output of systems production.
2. Evaluate the display of total kilowatt-hours. If they are increasing, then the panels are working properly. Otherwise, there is probably an error causing the panels not to work properly.

Test other instruments:
1. The solar panels power the rover. Attempt to move or operate other instruments on the rover to test if there is proper power.

Calibration of Analysis Lab:

Base/Controlled sample:
1. Test the functionality of the lab by placing controlled substances in the InfraRed Spectrometer. The lab should send back expected results.

Calibration of Regolith and Ice Drill:

Orient the drill head:

1. Orient the drill head to the nearest camera. Evaluate blade and head for any damages that may have occurred on landing.

Check for maneuverability:

1. Make sure the drill can move in the directions and angles it is supposed to be capable of doing.

Check for power:

1. Make sure the drill is getting the proper amount of power by drilling a selected test area.

Calibration of Scoop:

Orient the scoop:

1. Orient the scoop into the view of the nearest camera. Check for any damages that may have occurred on landing.

Check for maneuverability:

1. Make sure the scoops arm can move properly around the rover.

Check for power:

1. Make sure the scoop is getting the prower by scoping a selected test area.
2. Maneuver the arm to the analysis lab and release the scoop into the analysis area.

Calibration of Antennas:

1. Ensure all commands are being taken in from headquarters and all signals are reaching headquarters with accurate information.

4.2.6. Precision of Instrumentation, Repeatability

InfraRed Spectrometer:

1. Precision
   The precision of the InfraRed spectrometer will need to be within 1% of the actual value. This will be validated by the testing prior to launch.
2. Repeatability
   In order to improve repeatability, each sample should have 3 separate readings taken with the final value being an average of the three values. This will allow a higher confidence in the accuracy of the measurements.
3. Recovery

Due to the cost, a full duplicate of the spectrometer is not feasible, the best course of action will be to thoroughly test the current spectrometer and being able to recover the spectrometer in case of a failure.

Drill

1. Precision
   The drill will need to be able to provide regular and consistent samples for the spectrometer. The drill will also need to be able to provide a large amount of samples for the spectrometer. The drill should have a failure rate of 0.1% or lower to ensure that it will last for the duration of the mission
2. Repeatability
   The drill should be able to provide quality samples to the spectrometer. In the case of a bad sample being drawn then the rover should be able to draw a new sample from the adjacent regolith
3. Recovery
   Due to the cost limitations having two drills would be infeasible, since this is the case, the drill will need to be thoroughly tested before launch. In the case of total failure the rover could switch to collecting surface samples instead of subsurface samples.

Scoop

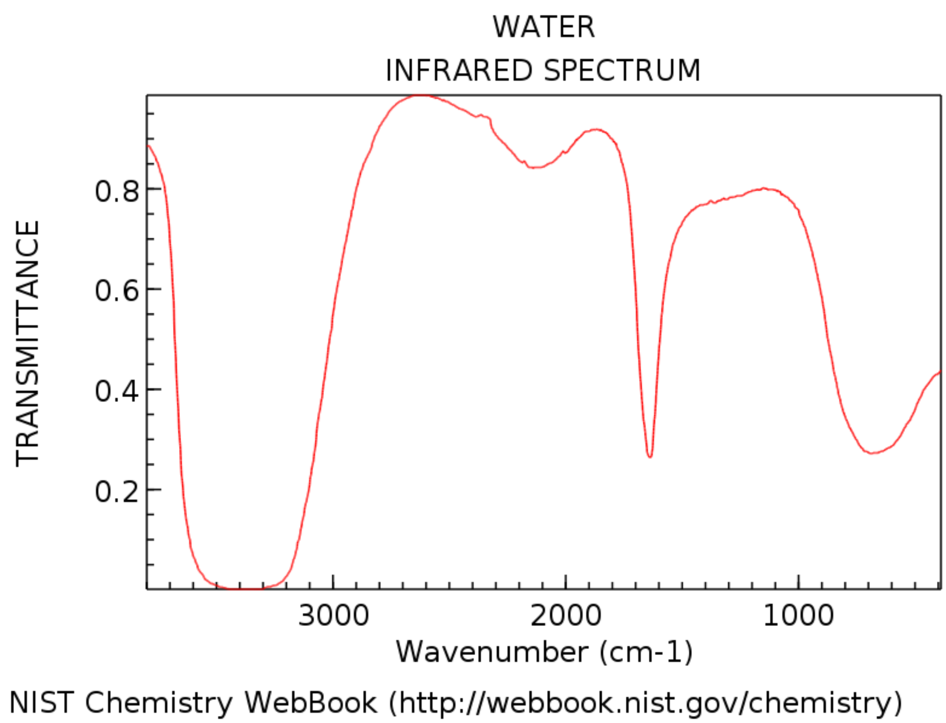
1. Precision
   The scoop will need to reliably transfer samples from the drill to the spectrometer. The scoop will need to be thoroughly tested and it’s failure rate should be brought down to 0.1% or less.
2. Repeatability
   In the case of a failed transfer the scoop could attempt a second transfer with the current sample or if needed, the rover could collect a new sample from nearby regolith.
3. Recovery
   Due to the increased cost of another scoop it is infeasible to carry an additional scoop on board. The scoop should instead be thoroughly tested before flight.

Antennas

1. Precision
   The antennas should be able to reliably establish connection with orbital satellites in order to communicate with Earth. The rover should be able to establish a connection of high enough quality in order to allow for real time driving and operating of the rover.
2. Repeatability
   The antennas should be able to maintain a strong connection with the orbiting satellites and the Earth
3. Recovery

In the case of a complete loss of signal the rover should enter a safe mode and attempt to reestablish connections with the satellite. If needed a satellite could try to send information about current satellite locations to the rover in hopes the rover could establish a link with a satellite.

4.2.7. Expected Data & Analysis



5. **Safety**

5.1. Personnel Safety

5.1.1. Safety Officer

The personal safety officer for Team 26 is Rashed Khraisat. His responsibilities are:

a. Making sure the factor of safety of the structure is above 3.
b. Welds, nuts and bolts, and hydraulics are included in this factor of safety.
c. Keeping any active chemicals in safe locations.
d. Any moving parts are kept at proper temperatures to prevent material compromisation.

e. All tasks performed during fabrication follow health and safety guidelines, such as wearing proper PPE, do not disregard spilt liquids, be cautious of flammable materials, only trained personnel may use machinery.
f. Safety training for everyone in the facility on how to react in case of an emergency.

5.1.2. List of Personnel Hazards

The hazards that humans might face during this mission are as follows

1. Misuse of Machinery
   a. The misuse of machinery (used for building and testing parts) could result in injury.

2. Part Malfunction
   a. During the building and testing phases, tools and parts of the rover might malfunction, inflicting harm on those nearby.

3. Location of Chemicals
   a. Flammable and other active chemicals should be properly stored and disposed of.

4. Proper Worker Management (especially with regards to breaks)
   a. Manufacturing environments are naturally hot considering the total energy output of machinery, so cooldown breaks are key for the health of the workers.
   b. Tired workers are more likely to overlook mistakes in repetitive tasks, so a mixture of task assignments is a good idea.
   c. Maintain good communication so that in the case of a near miss or an actual emergency everyone can understand what is going on and react as per training.

5.1.3. Hazard Mitigation

Misuse of Machinery

a. Make sure all personnel involved in using dangerous machinery have the proper training and certification needed.

Part Malfunction

a. All staff working with tools and testing parts will be required to wear PPE (personal protective equipment) and trained on how to follow safety protocols.
b. Maintain F.O.S of 3 to prevent part breaks during manufacturing.
c. Filet all corners so not to cut or scrape anyone.

Location of Chemicals

a. All staff working with chemicals will be properly trained and provided with the correct spaces for safe disposal of chemicals. In addition, the staff will be required to wear the correct PPE to ensure safety.

Proper Work Management (especially with regards to breaks)

a. In order to ensure worker safety, there will be a strict break schedule enforced by the overseer of the area. This will ensure workers get the necessary cool down time in order to be mentally ready to make the decisions that need to be made. This will ensure no costly or dangerous mistakes will occur.

5.2. Vehicle/Payload Safety

5.2.1. Environmental Hazards

The environment of the lunar surface/space poses hazards to the spacecraft. They are as listed below.

1. Regolith
    a. The dust and debris on the lunar surface has the potential to get stuck in the spacecraft, causing malfunctions or damage.
2. Low Temperatures
    a. The area will not be as warm as Earth. This will be important to consider with regards to the brittleness of the spacecraft. The low temperatures of the shadowed craters can cause materials of the spacecraft to behave differently and this must be taken into account.

5.2.2. Hazard Mitigation

1. Regolith
    a. There will be extensive testing done on Earth to ensure that the parts of the spacecraft will be resistant to different materials (dust, rocks, etc.). This will be done over an extended period of time to prove that the rover and its parts can withstand the length of the mission and more. Materials will be used to simulate the lunar surface and will need to be tested in temperatures that are similar to that of the shadowed regions of the Shackleton Crater.

2. Low Temperatures
    a. Proper testing of materials at estimated temperatures will be done. This will include testing at extremely low temperatures due to the cold nature of the shadowed craters of the moon. Since the moon has no atmosphere, there is no need for a heat shield to protect the payload instruments from heat damage.

6. Activity Plan

6.1. Budget

	# People on Team	FTE Year 1	FTE Year 2	FTE Year 3	FTE Year 4	FTE Year 5	FTE Year 6
Science Team:	4	1	1	0.5	0.25	0.25	0.25
Engineering Team:	7	0.25	0.25	0.75	1	1	1
Administrative Team:	7	1	1	1	1	1	1

NASA L'SPACE Mission Concept Academy Budget - Sky Walkers

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	$ 160,000.00	$ 80,000.00	$ 80,000.00	$ 80,000.00	**$ 1,040,000.00**
Engineering Team	$ 140,000.00	$ 140,000.00	$ 420,000.00	$ 560,000.00	$ 560,000.00	$ 560,000.00	**$ 2,380,000.00**
Administrative Team	$ 560,000.00	$ 560,000.00	$ 560,000.00	$ 560,000.00	$ 560,000.00	$ 560,000.00	**$ 3,360,000.00**
Total Salaries	$ 1,020,000.00	$ 1,020,000.00	$ 1,140,000.00	$ 1,200,000.00	$ 1,200,000.00	$ 1,200,000.00	**$ 6,780,000.00**
Total ERE	$ 284,682.00	$ 284,682.00	$ 318,174.00	$ 334,920.00	$ 334,920.00	$ 334,920.00	**$ 1,892,298.00**
TOTAL PERSONNEL	$ 1,304,682.00	$ 1,304,682.00	$ 1,458,174.00	$ 1,534,920.00	$ 1,534,920.00	$ 1,534,920.00	**$ 8,672,298.00**
TRAVEL							
Total Flights Cost	$ -	$ -	$ -	$ -	$ -	$ 2,736.00	**$ 2,736.00**
Total Hotel Cost	$ -	$ -	$ -	$ -	$ -	$ 6,600.00	**$ 6,600.00**
Total Transportation Cost	$ -	$ -	$ -	$ -	$ -	$ 564.00	**$ 564.00**
Total Per Diem Cost	$ -	$ -	$ -	$ -	$ -	$ 9,756.00	**$ 9,756.00**
							$ -
Total Travel Costs	$ -	$ -	$ -	$ -	$ -	$ 19,656.00	**$ 19,656.00**
OTHER DIRECT COSTS							
Total Outsourced Manufacturing Cost	$ 80,000.00	$ 110,000.00	$ 160,000.00	$ 160,000.00	$ 210,000.00	$ 260,000.00	**$ 980,000.00**
|> Science Instrumentation	$ 70,000.00	$ 100,000.00	$ 150,000.00	$ 150,000.00	$ 200,000.00	$ 250,000.00	**$ 920,000.00**
|> Other COTS Components	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	**$ 60,000.00**
Total In-House Manufacturing Cost	$ 20,000.00	$ 50,000.00	$ 50,000.00	$ 50,000.00	$ 100,000.00	$ 100,000.00	**$ 370,000.00**
|> Materials and Supplies	$ 20,000.00	$ 50,000.00	$ 50,000.00	$ 50,000.00	$ 100,000.00	$ 100,000.00	**$ 370,000.00**
Total Equipment Cost	$ 310,000.00	$ 310,000.00	$ 410,000.00	$ 1,010,000.00	$ 1,010,000.00	$ 410,000.00	**$ 3,460,000.00**
|> Manufacturing Facility Cost	$ 300,000.00	$ 300,000.00	$ 400,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 400,000.00	**$ 3,400,000.00**
|> Test Facility Cost	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	**$ 60,000.00**
In-House Manufacturing Margin	$ 165,000.00	$ 180,000.00	$ 230,000.00	$ 530,000.00	$ 555,000.00	$ 255,000.00	**$ 1,915,000.00**
Total Direct Costs	$ 1,879,682.00	$ 1,954,682.00	$ 2,308,174.00	$ 3,284,920.00	$ 3,409,920.00	$ 2,579,576.00	**$ 4,200,000.00**
Total MTDC	$ 1,414,682.00	$ 1,489,682.00	$ 1,693,174.00	$ 1,769,920.00	$ 1,894,920.00	$ 1,964,576.00	**$ 740,000.00**
FINAL COST CALCULATIONS							
Total F&A	$ 141,468.20	$ 148,968.20	$ 169,317.40	$ 176,992.00	$ 189,492.00	$ 196,457.60	**$ 1,022,695.40**
Total Projected Cost	$ 2,021,150.20	$ 2,103,650.20	$ 2,477,491.40	$ 3,461,912.00	$ 3,599,412.00	$ 2,776,033.60	**$ 16,439,649.40**
Total Cost Margin	$ 606,345.06	$ 631,095.06	$ 743,247.42	$ 1,038,573.60	$ 1,079,823.60	$ 832,810.08	**$ 4,931,894.82**
Total Project Cost	$ 2,627,495.26	$ 2,734,745.26	$ 3,220,738.82	$ 4,500,485.60	$ 4,679,235.60	$ 3,608,843.68	**$ 21,371,544.22**

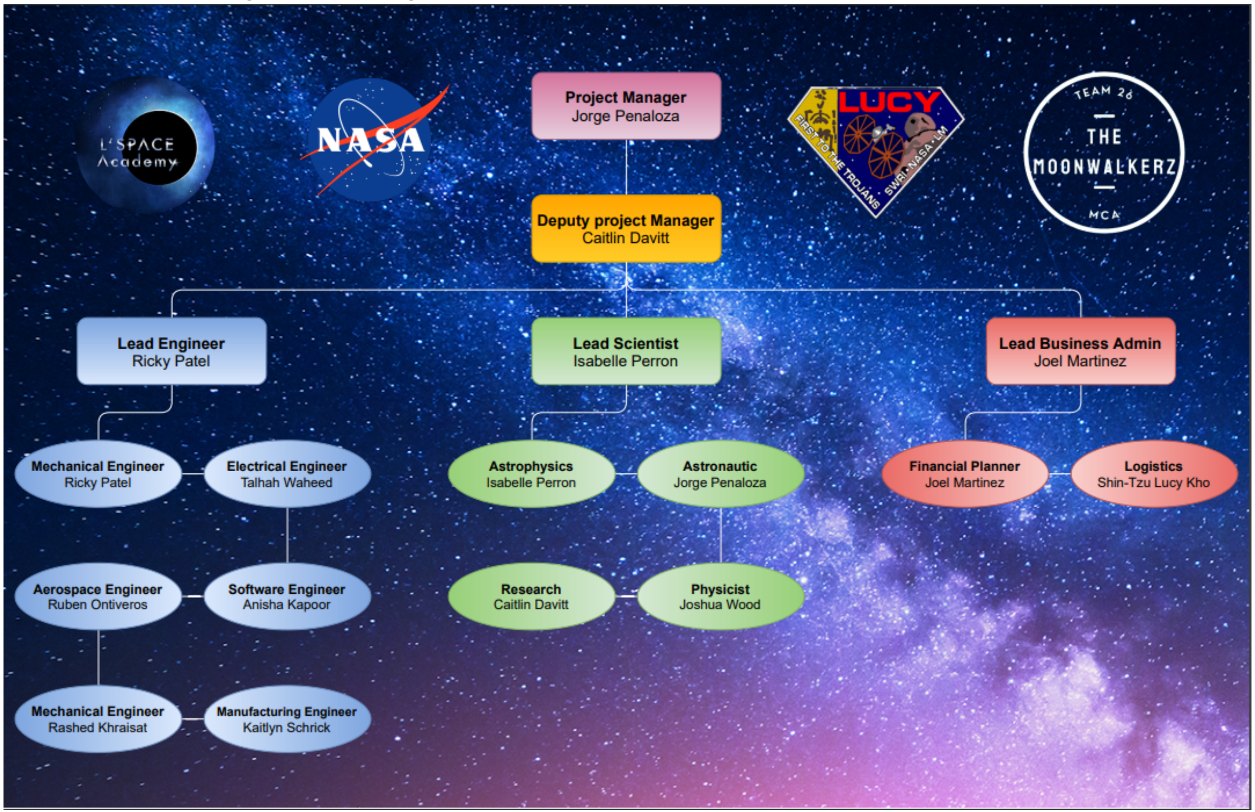
6.2. Schedule

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Science Deliverables**					
1.1	Research Execution Methods and Requirements for Surface Mission	Caitlin D, Joshua W	6/7/21	6/12/21	5	100%
1.2	Determine Scientific Insturnents for Payload	Isabelle, Joshua, Jorge, Caitlin	6/7/21	7/1/21	24	100%
1.3	Research Lunar/Space Environment	Isabelle, Jorge, Joshua	6/18/21	7/8/21	20	100%
1.3.1	Choose Candidate Landing Site in Lunar South Pole Region	Isabelle, Jorge	7/8/21	7/15/21	7	100%
2	**Engineering Deliverables**					
2.1	Scope // Goal Setting // Risk Management // Budget	Anisha	6/18/21	7/19/21	31	100%
2.2	Comm Team- Reseach bandwidth, transmitter, and nasa frequencies. Also pick what parts will be needed.	Joel	6/18/21	7/19/21	31	100%
2.3	Structures Team- Chassis, material, housing internal components	Ricky	6/18/21	7/19/21	31	100%
2.4	Power Team- Research types, cost, feasibility, safety, size, weight	Talhah	6/18/21	7/19/21	31	100%
2.5	Entry, Decent, Landing- Type of entry (propulsive, bouncy ball), suspension systems (absorbing shock)	Kait	6/18/21	7/19/21	31	100%
3	**Business Deliverables**					
3.1	Cost for launch travel	Joel	6/7/21	6/26/21	19	100%
3.2	Reseach all costs of scientific instruments, payload, and assembly for lander/orbiter	Joel, Jorge	7/1/21	7/15/21	14	100%
3.3	Calculate total cost for salaries for personnal	Lucy	6/7/21	6/26/21	19	100%
3.4	Complete budget template	Joel, Lucy	6/10/21	7/19/21	39	100%
3.5	Caluclate total manufacturing cost	Lucy	6/10/21	7/19/21	39	100%
3.6	Calculate total mission cost	Joel, Lucy, Jorge	6/10/21	7/19/21	39	100%

6.3. Outreach Summary

Science, Technology, Engineering, and Mathematics (STEM) skills are key to the United States (U.S) current and succeeding prosperity. Not only is this important for students pursuing STEM related careers, but also for students pursuing non-related STEM careers. Within today's society many careers require a solid STEM foundation, such as engaging in health care, understanding the U.S economy, or even understanding the Earth's geography. In order to spread STEM awareness an outreach program will be organized prioritizing STEM awareness and importance to highschools across the U.S. The focus on highschoolers is to pursue the country's youth and encourage the drive for honing their STEM skills regardless of the major they wish to pursue. To accomplish this goal the outreach program will conduct competitions that will allow students to engage with their STEM skills and imagination. To increase interest the competitions will award students with prizes such as tickets to a live rocket launch or a tour across a NASA facility. In addition to reaching out to students, NASA's Youtube channel could post a promo video of the mission and what it will accomplish to NASA's youtube channel. This would allow for a lot of outreach to NASA's subscriber base and allow for a lot of outreach particularly for the younger demographics. Not only would this type of outreach engage the community to get involved with STEM, it would also show people why what NASA is doing is so important. Good outreach for this mission would gain the approval of the taxpayers who help fund missions like this one. By advertising this mission and getting the public involved, it will create a drive for missions like this to continue.

6.4. Program Management Approach



Team 26 was organized through the L'SPACE academy. The team members' roles were selected by learning about each individual's skill sets and strengths. All members work together, but the work is divided up into 4 groups, the engineering team, science team, business administration team, and the leadership team. The science team was in charge of determining payload instruments, choosing the landing site and date, and filling out all sections of the PDR relating to science topics. The engineering team was responsible for designing the rover and payload instruments in a CAD software program as well as choosing manufacturing and testing sites for their parts.The business team was responsible for drafting a budget and schedule for the project. The leadership team exists to ensure that everyone is working together effectively, ensure necessary collaboration, and to provide constructive feedback.

Leadership positions were assigned through voting. Each member who was interested in a leadership role gave a short presentation on why they were qualified and what they hoped to bring to the team. Then, anonymous voting was used to pick the members of the leadership team. Members of the leadership team were expected to be able to answer questions, schedule meetings within their subteam and go over feedback given by the team's mentor. Tasks were assigned by the Project Manager and the Deputy Project Manager.

During the duration of this project, all communication was done through the website Discord. Different text channels were set up for communicating with each other as well as voice/video channels for faster and easier communication. Whenever there was conflict on what to do throughout the academy, members would have a discussion on what the best options were to continue forward. Then, the members of Team 26 would have a vote to decide what the best choice was for the good of the team.

7. Conclusion

The goal of this mission is to be able to map water ice in the permanently shadowed regions of the lunar south pole. Team 26 is aiming to determine the abundance of water ice in the top meter of the regolith to ~+-1% accuracy and have a spatial sampling of around 100 meters. This will help future humans by mapping the areas with the most water for in-situ resource utilization of a future lunar base.

The scientific instruments for the spacecraft can be broken down into a few categories. The instruments that will be in charge of collecting and storing power are the solar panels and battery, respectively. The power stored in the battery will be used to power all other parts of the rover. The payload instruments are the regolith and ice drill, the scoop, and the sample analysis lab. Samples collected with the drill and scoop will be analyzed in the sample analysis lab and this data will be sent to the antennas. Then the antennas, part of the communications subsection, will send the data collected back to headquarters, where it can be further analyzed. The cameras and sensors attached to the rover are also a part of the communications subsystem. Finally, the InfraRed Spectrometer will be used to map out the area of the lunar surface where ice water is abundant.

The next steps for this project include refining the PDR and filling in any spaces that need more detail or clarity. In addition to this, the rover model would be tested more and updated as is deemed necessary. As the rover is updated, the CAD would become more detailed and defined. If there was more time to work on this project, Team 26 would most definitely manage their time more efficiently. Not enough time went into going over the feedback given by the mentor and this caused time issues at the end of the project. In addition to this, the team would assign more concrete tasks to individuals instead of assigning more open ended tasks. This would cause less confusion among the individual team members and would result in more cohesive work.

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