Mission Report 3:

Lunar Rover Design

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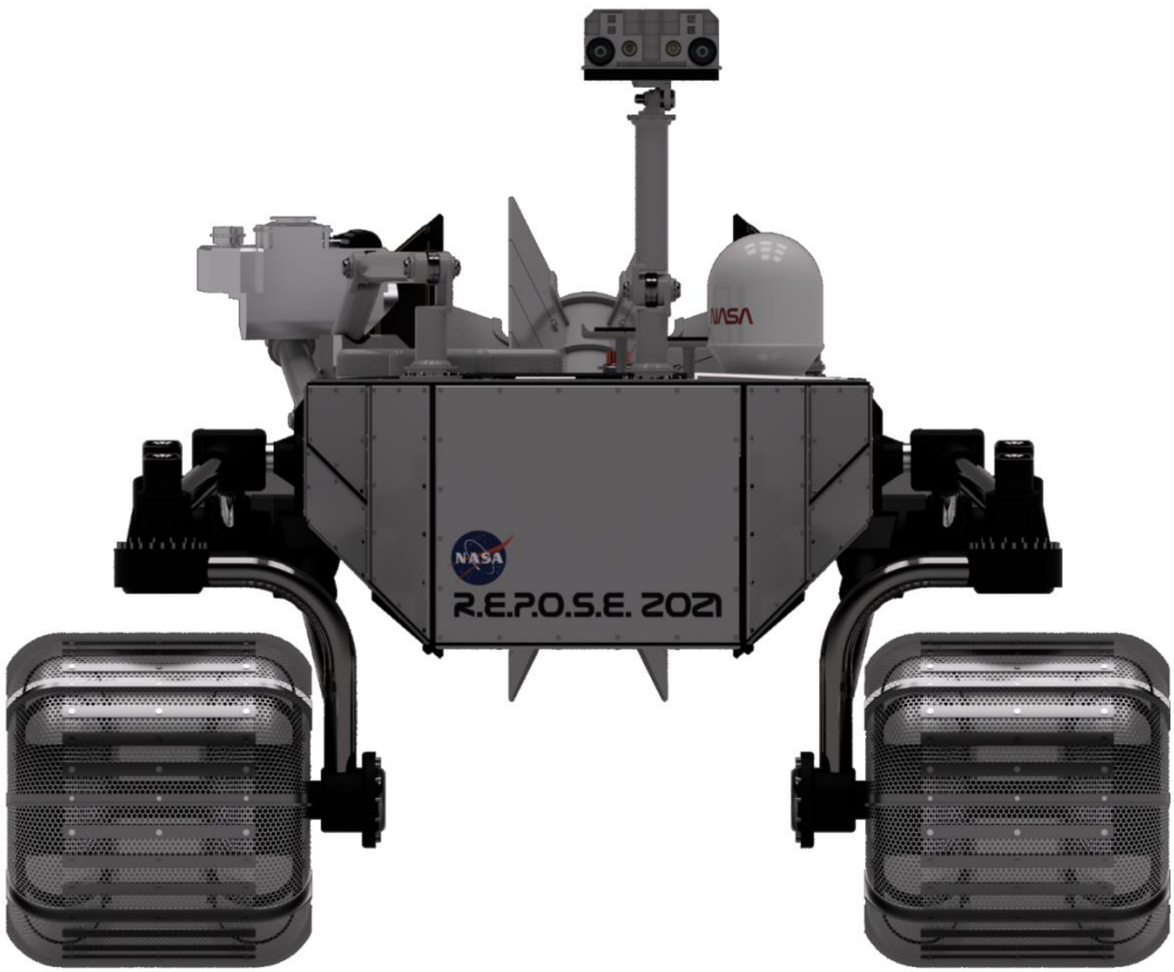


R.E.P.O.S.E.

Radio Emissions and Plasma Observation/Sampling Expedition

Repose: /rəˈpōz/ (noun) - a state of tranquility.

Main Goals

In 1972 the Apollo 16 mission returned lunar glass samples from the Moon which have been dated to around 2 million years old. Silicate crystals dating 3.9, 3.6, 3.3, and 3.2 billion years old have also been brought back. We have learned from these fragments that the Moon had a short-lived core dynamo which provided a magnetic field in the past, but no longer. This aligns with the lack of a magnetosphere present today on the Moon (Tarduno, et al., 2021).

And, at the location humanity first set foot on the lunar surface, Apollo 11 established Tranquility Base, gathering 21.5kg of rock samples for testing back on Earth. With a return to Mare Tranquillitatis through the REPOSE mission we may be able to provide further insights into magnetic properties of impact glass (through hyper-velocity micro impacts), and the interaction of hot plasma ionic discharge at hyper-velocity impact sites (in excess of 11km/s). The data garnered from such a mission may yield further understanding of magnetic field decay, transient magnetic field generation, and possible insights into Earth's magnetic anomalies, such as the South Atlantic Anomaly, and the possibly imminent magnetic pole shift.

Earth has lost 9% of its overall magnetic field within the last 200 years (The European Space Agency, 2020). Additionally, the South Atlantic Anomaly, a section of the Van Allen radiation belt which has reduced in magnetic intensity between South America and Africa, has formed and has increased four-fold in size within that same time period (Amit, Terra-Nova, Lézin, & Trindade, 2021). A full answer to these questions may be garnered from another lunar mission for which it is hoped live data can be gathered from immediate area impacts in real-time.

According to an online forum response, Robert Frost, Instructor and Flight Controller in Flight Operations Directorate at NASA, states that, "the Moon gets hit by about 2,800kg of meteor material per day." Given the surface area of the Moon (3.793×10^7 km^2) it should not be considered a primary mission to record a live impact event (depending on the sensitivity of equipment used). However, the data yielded from such an event may outweigh the possibility of a live event.

As a secondary goal, working directly with the possibility of a real-time impact occurrence, REPOSE would gather data in regards to radio frequency interference derived from hypervelocity impacts that vaporize, ionize, and produce a radially expanding plasma that can generate electrically harmful radio frequency emissions (Goel, Tarantino, Lauben, & Close, 2015). This can trigger electrostatic discharge which can be damaging to delicate electrical equipment (Schimmerohn, n.d.).

With further understanding of these plasma states we may be able to better understand how to harden electrical equipment for future deep space and planetary missions. Furthermore, tying all this data together we may find methods by which we can detect these impacts at the moment of occurrence, increasing the reaction time of astronauts in responding to micrometeorite habitat penetration and environmental loss.

As all three objectives work closely with each other (magnetic field research, radio frequency mapping and data gathering from real-time impacts, and habitat protection from micrometeorite impacts) it can be seen as three objectives with one main goal, the study of real-time impact glass creation through hot plasma interaction via hyper-velocity micrometeorite impact.

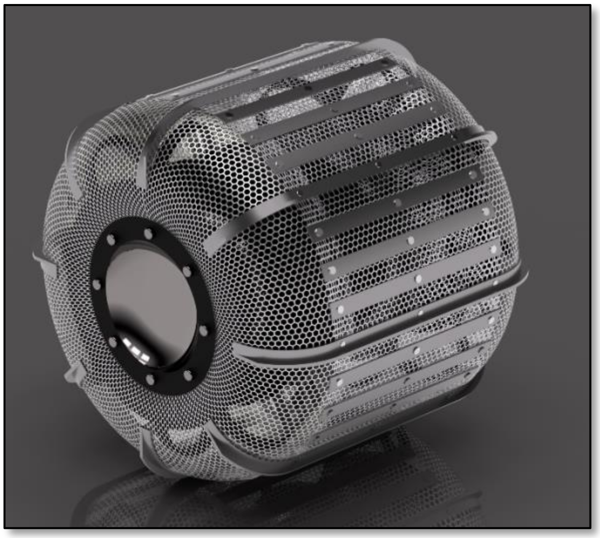
As a quaternary function this mission will use a robotic arm mounted with an electromagnetic tool allowing for the recovery of lunar material, specifically micrometeorites from 50µm and 5mm, and classification and composition analysis correlated with their magnetic field strength, location, and other local readings.

Finally, as a means of general public engagement, and program visibility, the Pancam mast can be made (indirectly, and briefly) available to the public for a series of 5-10 focused pictures from a location immediately around, and visible to, the rover in its current work location once every 24 hours, based on website interaction and polling of the public via online voting. Given a panoramic shot users can choose one of a number of interesting landscape features to receive more focused photography which will be uploaded to this same engagement website the following day.

Physical Specifications

Chassis: The WEB, or Warm Electronics Box, will be constructed using 5052 aluminum alloy for its fatigue strength, durability, lightness, and ability to endure excessive vibrations. The WEB will be reinforced, internally, with a square tube frame designed to provide multiple mounting points for mission hardware while providing a rigid platform for the upper instrument deck, the MAST camera assembly, the robotic arm, and the mobility components. The extreme outside dimension of the WEB is 894mm wide x 1,529mm long x 424mm tall, sitting 500mm above the ground at its lowest point.

Mobility Design – REPOSE will use an iteration of the same rocker-bogie found on predecessor designs on the Spirit, Opportunity, Curiosity, and Perseverance. However, in a departure from the pipe-stock-milled wheels of the previous rovers, and with a nod to the Lunar Rover, the rocker-bogie design will be a mated double torus configuration secured to solid hubs internally and a 5052-aluminum alloy hexagonal mesh securing the component tori together.



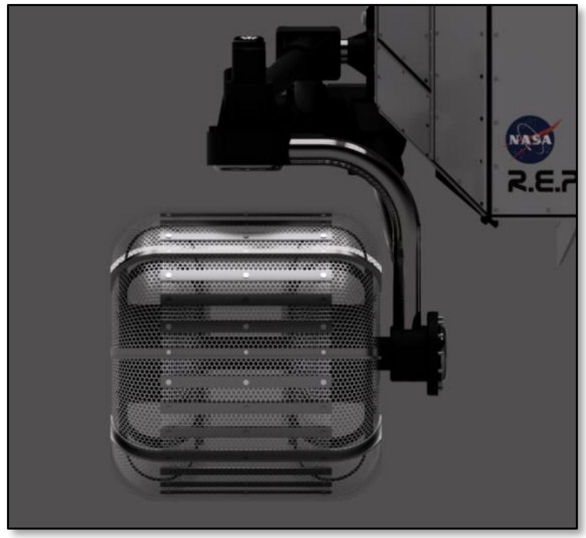


Figure 1- Oblique view of the double torus design wheel assembly. (Note the negative deflection bars mounted internally.)

Figure 2 - Wheel assembly as mounted to the rover as view from the front.

Each wheel measures 0.5 meters in diameter by 0.5 meters wide. Like the Lunar Rover REPOSE will include a ring inside each torus every 45° to negate extreme negative deflection of the outer surface. Additionally, tread plating is used to keep the wheel from sinking into the lunar surface, and have been mated to a small vertical body as a means of traction control. The hexagonal pattern of the wheel also increases grip in the lunar soil, facilitating movement on inclined and oblique surfaces. Because of the wheel design and rocker-bogie combination the rover can climb obstacles up to 1 meter in height, and can tackle moderate inclines with little difficulty.

As the front and rear wheels on either side of the rover extend past the front and rear of the WEB it was important to take into consideration the overall length of the vehicle from the outside of the wheel cleats as the extremum between the front and rear of the rover. While the wheels are

500mm in diameter the wheel cleats add an additional 10mm to either side. Given the mission parameter of 2.43 meters I have chosen to place the center of the rear bogie axle and the forward bogie axle a distance of 1.91m apart, leaving the central bogie at an equidistance of 955mm from either axle, and a total end-to-end distance of 2.41m in length. This allows for full range of motion of the forward and rear axles given the maximum oblique distance of each wheel at 645mm. As the wheels also extend past the sides of the rover the outer dimensions in that direction have been measured from the extremum of the wheel hubs spanning 1.82m wide total. As the Pancam height exceeds the required 1.21m requirement the upper mast arm is able to pivot and rest against the body of the rover for transportation, meeting height requirements. Upon touchdown the mast is raised into a vertical position for the remainder of the mission.

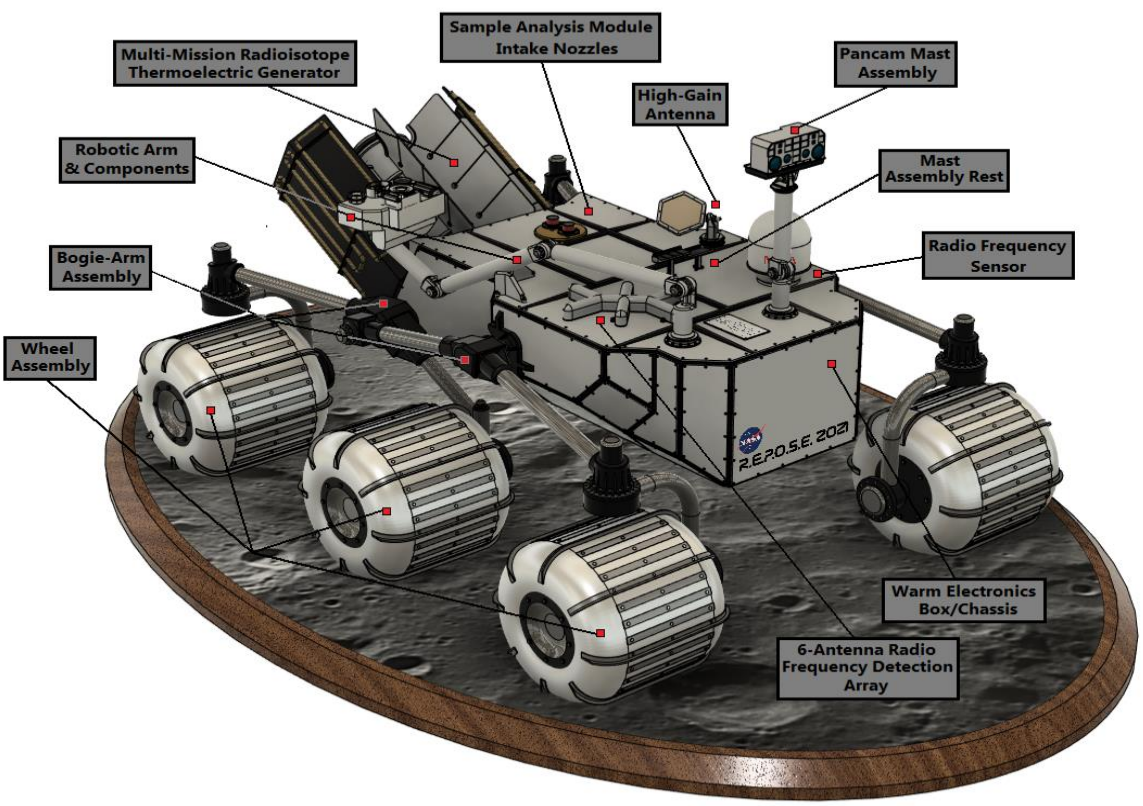
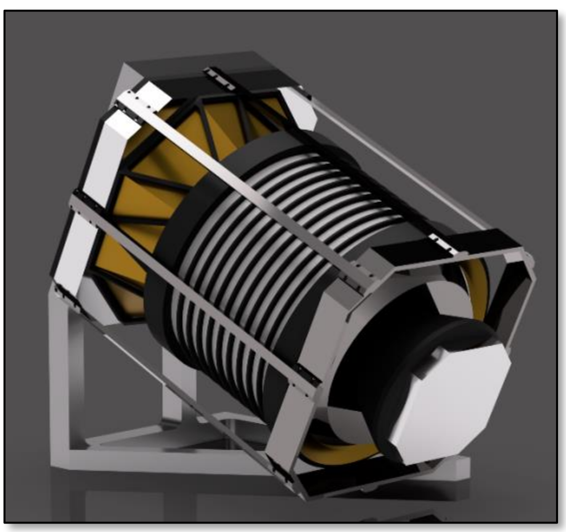


Figure 3 - Oblique model of REPOSE Lunar Rover with external labels.

Instrument Package

Hyper- Velocity Impact Hot Plasma Charge Detector (HVIHPCD) – Attached to the robotic hand the Plasma Charge Detector is 55mm Ø across, nested into the hand, with 27.75mm protruding from the body, and a height of 80mm. The detector is a 16 well channel electrostatic analyzer. This allows for different types and levels of energy detection within the plasma body to be directly examined to allow for the measuring of flux, composition, energy distribution, and temperature of ions and electrons within the hyper-velocity impact event upon plasma creation (Goel, Tarantino, Lauben, & Close, 2015). This will allow for cross-interfacing with the B-Field Magnetic Spectrometer through the Instrument Data Processing Unit (IDPU) to correlate the data into specific tasks with the outcome of hard data points regarding magnetic field creation and real-time tracking of magnetic fields and radio frequency emissions.



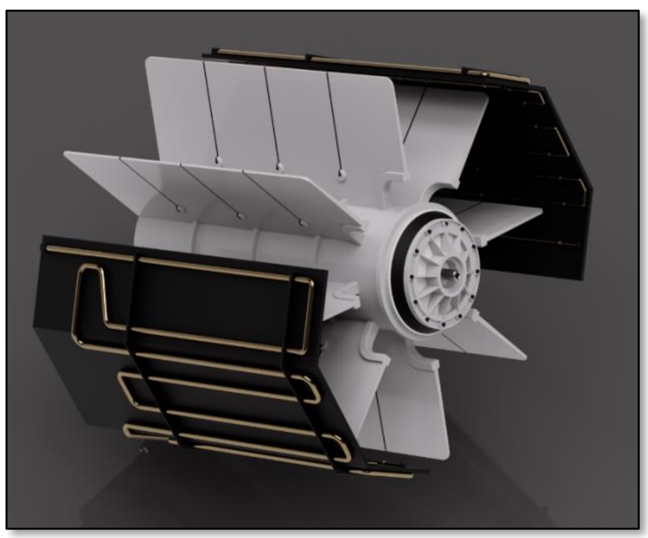


Figure 4 – B-Field Magnetic Spectrometer with aluminum mounting bracket.
Figure 5 – Multi-Mission Radioisotope Thermoelectric Generator with Heat Exchange Shields.

EMF/RF/ELF Radio Frequency Detection Suite (ERFDS) - In conjunction with the HVIHPCD the ERFDS will use active frequency detection through modulated radio frequency currents between 0.5Hz and 150Khz in the extra-low and radio frequency bands. Additional magnetic field data points are also obtained through this device in the range of 0 milligauss to 500 milligauss. Through a modified array of six 10 cm antennae located at various points 0.8cm – 3cm distant from each other (Schimmerohn, n.d.) on the body of the rover, in conjunction with a radio frequency sensor, radio signals can be intercepted through electron interaction within the metallic frame which create tiny oscillating currents which are then transmitted back to the ERFDS which routes them to the IDPU as data points.

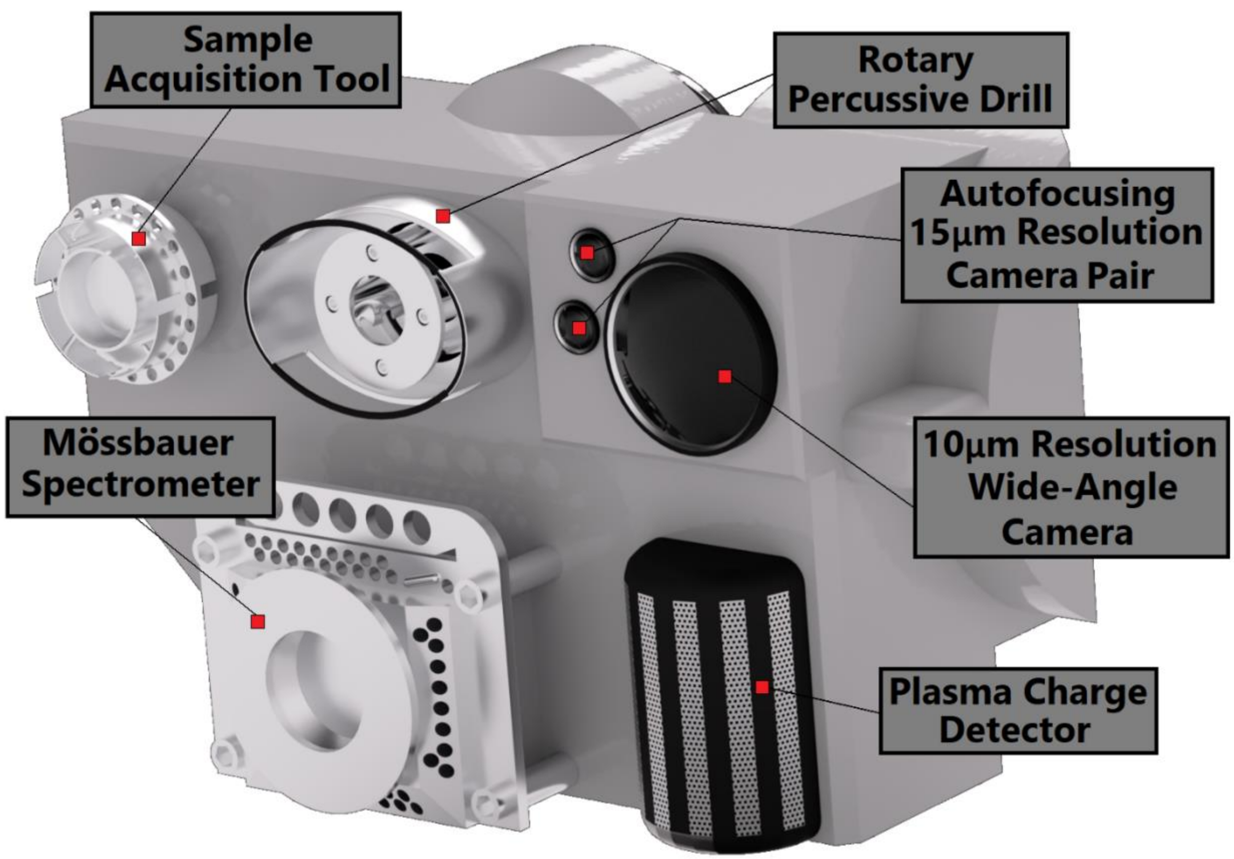
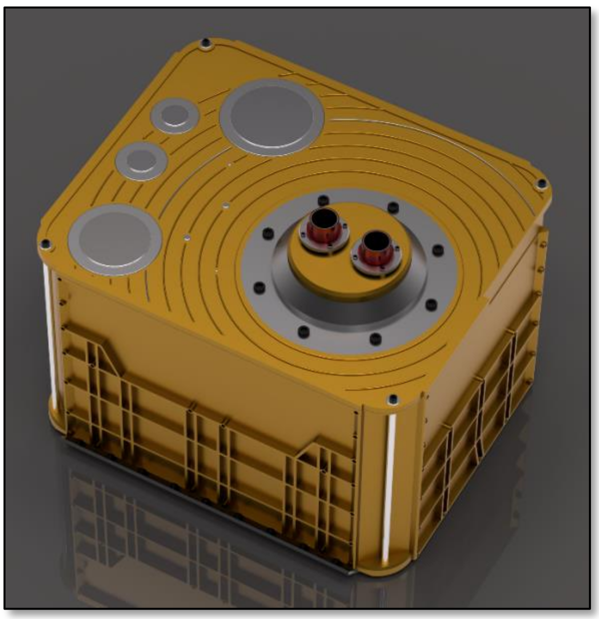


Figure 6 – Robotic Tool/Turret/Hand with multiple tool labels.

B-Field Magnetic Spectrometer (BFMS) – As the magnetic fields of interest will be created through induction it's appropriate to focus only on b-field magnetism. As such this spectrometer will be used in conjunction with the HVIHPCD through the IDPU to directly measure b-fields created through hot plasma events which magnetize elements within newly created impact glass at the impact site. Much like the Alpha Magnetic Spectrometer (AMS-02) currently mounted to the International Space Station, the BFMS will hold a permanent neodymium-Iron-Boron magnet (NASA, 2013) that will draw in particles from the local environment immediately in front of the magnet as data sets for calculating field strength, and decay. Mounted at a 25° angle pointing down towards the bow, it is able to capture events in a large cone in front of the rover. While the BFMS is 395mm in length it requires 440mm along its axis as angling the instrument adds length; the width and height are $260mm^2$.



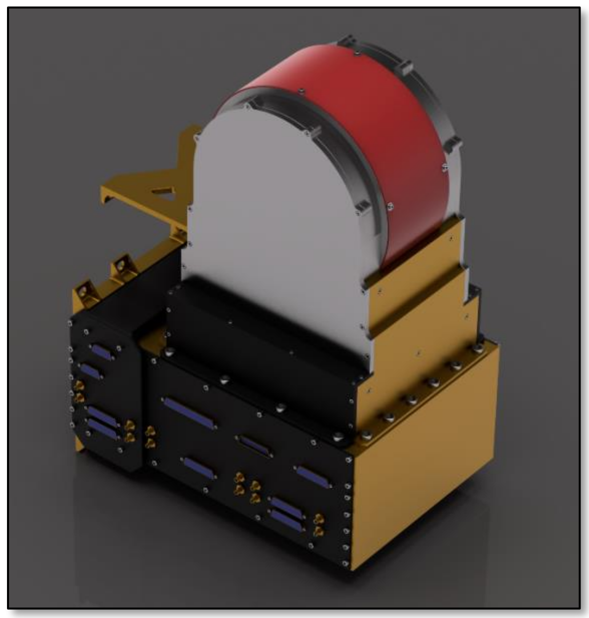


Figure 7 - Sample Analysis Module. (Note the planet-to-planet scale solar system map inlay).

Figure 8 - Internal Data Processing Unit responsible for processing and correlating all data from and to the rover.

Instrument Data Processing Unit (IDPU) – At 295mm tall x 230mm long x 158mm wide this compact body holds a number of critical analytical instruments, while others interface with it to provide data correlation and processing of the information collected by those various other instruments. Much like the satellite THEMIS this rover will use a Low Voltage Power Supply (LVPS) that will take power from the Multi-Mission Radioisotope Thermoelectric Generator

(MMRTG) and convert it into the various power needs associated with each particular instrument within the rover (NASA, 2007). The Power Control Board (PCB) will be used to do the switching of the voltages between the IDPU as it steps down the current and the instruments requiring power. The most crucial component within the IDPU being the Data Controller Board, containing the system processor, which receives and executes commands from mission control, gives commands to individual instruments, retrieves, formats, and stores data from the instruments, and then sends them back to Earth (NASA, 2007) via the Deep Space Network.

Robotic Component – As can be seen in the illustration below, the rover has a multi-jointed robotic arm that is stored above the rover and can swivel around to deploy the arm over the side, or rear, of the rover. Given the multi-jointed mid-section the robotic arm has high articulation. Mounted at the end are various sensors facilitating the rover's mission objectives. In addition to this sensor suite is a specialized tool which allows for the retrieval of micrometeorites for in-situ compositing and analysis via a resistant electromagnetic coil incased within a non-magnetic body. These samples are then deposited within the Sample Analysis Module accessed through the top of the rover which then processes each sample for various data sets. Suffused with a carbon nanotube electrode network allowing for the cycling of ionic charge throughout the body of the tool to forcefully expel any particles attached to the tool (Schwan, Wang, Hsu, Grün, & Horányi, 2017). It can be used in various ways to remove the samples from the tool; while removing the electromagnetic charge will clear the sample while maintaining a majority of the finer particles on the tool it may sometimes be necessary to deposit the surrounding samples with the micrometeorites. To do this the electromagnet would first be cycled off, then the tool would be ionically charged to release all matter from the tool surfaces, depositing it within the collection device. In conjunction with the wide range of articulation of the robotic arm and the ability to repel dust from surfaces the arm can be used to clear problematic dust from lenses or other surfaces that may require in-situ maintenance.

NASA Center Contributions

Jet Propulsions Laboratory (JPL) – JPL has been involved in Moon landings since the Surveyor 1 lander set down on the Moon in 1966. And, they have played a major role in the rover program since its inception. Raising the benchmark to a new high they have deployed Ingenuity from the underside of Perseverance, bringing the first ever rotor-bladed flight vehicle to a non-Earth environment (JPL/NASA, 2019). It is clear that JPL is, hands down, the go-to for rover design and assembly. As such their engineers will modify the design to fit stress, weight, size, power drain, and temperature constraints, among others. Upon completion of the design work the JPL technician crew, with a world-class crew of skilled workers, will be ready to assemble the individual components into a Moon-ready scientific instrument.

Goddard Space Flight Center (GSFC) – In 2020 Goddard was responsible for the Osiris-Rex Asteroid Sample Return Mission, the TESS Transiting Survey, the Lunar Reconnaissance Orbiter, Operation IceBridge, and various other data collection missions. This center was also responsible for the creation of thirteen specialized tools which are currently in use aboard the International Space Station (NASA - Goddard Space Flight Center, 2021). The HVIHPCD, BFMS, ERFDS, and IDPU can all be developed through Goddard with the highest expectations of quality craftsmanship, in conjunction with the Planetary Magnetospheres Laboratory, will allow for new possibilities in autonomous research in-situ beyond the expectations of the current mission as the experts in solar system magnetic fields, planetary dust, and plasma environments.

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