Senior Design Proposal
Notre Dame Rocketry: Payload Design

Darrell Adams, Annalise Arroyo, Holden Brown, Eric Dollinger, Wesley Garrison

1 Introduction

The purpose of our project is to support the Notre Dame Rocketry team's electrical design for the 2020 NASA Student Launch competition. The official competition description per NASA's website is as follows:

"The NASA Student Launch (SL) is a research-based, competitive, and experiential learning project that provides relevant and cost-effective research and development."

Specifically, our team will work to design the communication protocols, controls, software, and power distribution for the lunar rover that will be responsible for retrieving a simulated ice sample. We will also be working with other groups within the ND Rocketry Team working on mechanical aspects and deployment functions in order to effectively integrate our system. Additionally we will explore working with the other senior design team working on the rocket's telemetry systems to possibly send all our data over a common platform that they develop.

2 Problem Description

The Notre Dame Rocketry Team's payload will be required to exit the rocket after a successful landing, navigate to one of five predetermined sample locations that are each 3 feet in diameter with a colored tarp 10 feet in diameter surrounding the sample area, and collect at least 10mL of a simulated lunar ice that could be as much as two inches below the ground. After the sample is recovered, the payload vehicle must transport the sample at least ten linear feet away from the chosen recovery area. Any hardware that is used to collect the sample must be launched with the rocket. Our team will be working to design the electrical systems to accomplish these tasks and rules set forth by NASA. The official rules set forth by NASA for the general payload requirements are outlined in the competition rulebook. These requirements as well as team derived requirements for the preliminary design review are included in the Appendix below.

3 Proposed Solution

Our proposed solution is a rover that will navigate to the location of the sample which is determined using a UAV that will send GPS coordinates to the rover. Because our team is focusing on the electrical design of the rover, this proposal will not go into detail about the mechanical design. However, the rover design that has been decided among the rocketry team will be an eccentric crank rover that is especially effective at navigating difficult terrain. As part of the challenge this year, the team is aspiring to implement an autonomous system for driving the sample recovery rover by processing data such as GPS sent from a small UAV to the rover to determine the direction to drive. This UAV will also deploy with the rover after landing and will serve functionality analogous to a satellite in larger missions like those inspiring the competition. A preliminary decision flowchart for the autonomous rover is shown below in Figure 3.1 below.

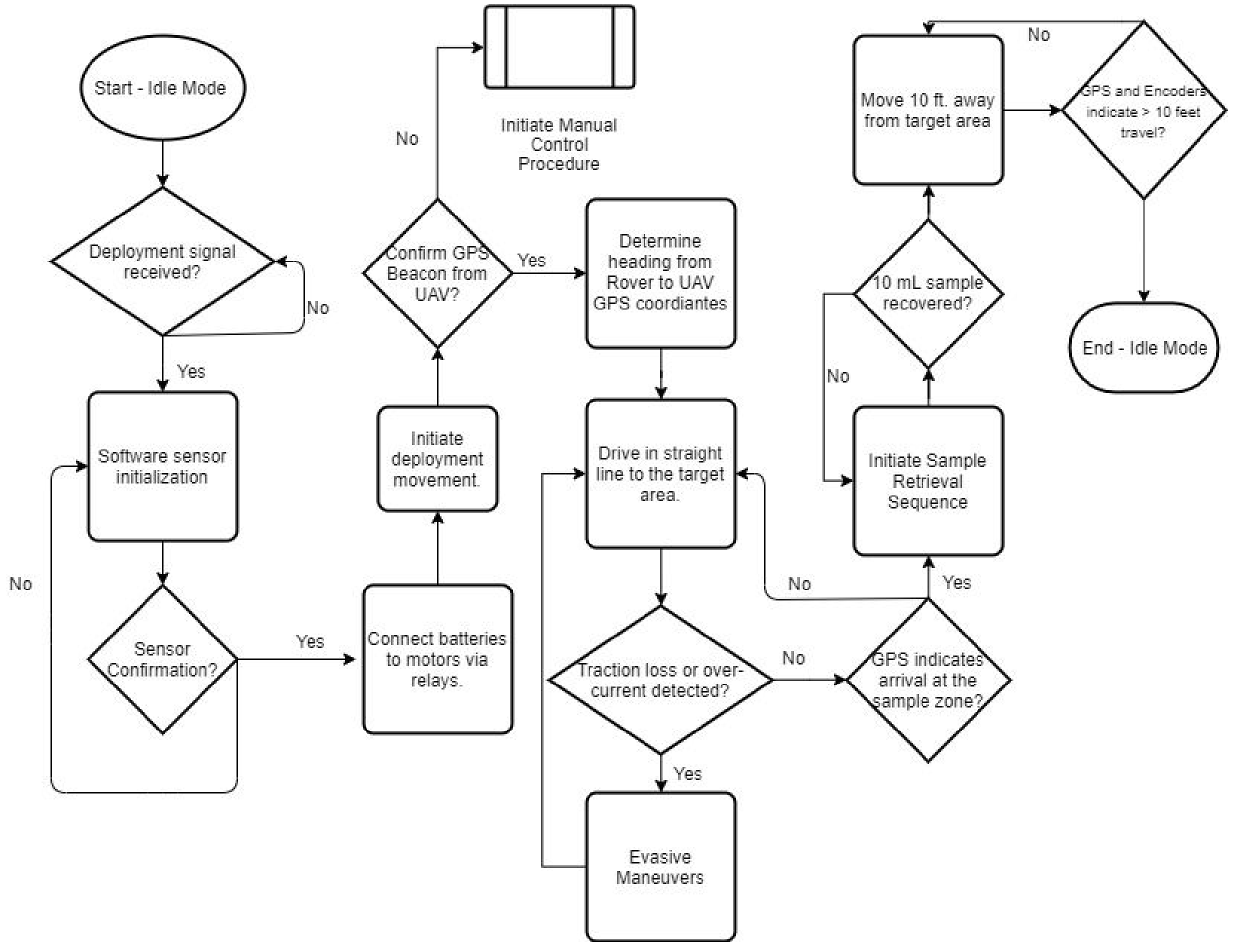


Figure 3.1. Rover Control Flow Diagram

As shown in the figure, the rover will idle until it receives the deployment signal from the ground station connecting the UAV and rover. At this point, the rover will begin initializing software and confirming sensor data. In order to isolate the motor from the batteries, there will be a relay that will close a switch to allow contact between the motor and batteries after sensor confirmation. At this point, the rover will begin navigating towards the sample retrieval site using the GPS coordinates sent from the UAV. If the GPS beacon is not received, then manual control operation will be initiated which will allow a team member to control the rover using a remote control system. As the rover navigates toward the sample zone, the accelerometer and motor encoders will be checking for loss of traction control and initiate evasive maneuvers if it is detected. When the GPS on the rover does indicate its arrival at the sample zone, it will begin sample retrieval sequence which will use a motor to power an archimedes screw that will act as an auger to dig and collect the payload sample. After a 10mL sample has been recovered, the rover will move > 10 feet away from the sample and enter idle mode, completing its task.

4 Demonstrated Features

The rover electrical design will have a number of key demonstrated features. The first key feature is to provide power distribution to the rover system capable of both powering the motors and lower power microcontroller and sensors. To preserve power, the UAV/rover payload shall be powered off until deployment, with a relay between the battery contact and the motor to prevent large scale power dissipation. This relay will be controlled by the microcontroller, and closed once the UAV/rover receives the deployment signal.

Radio communications will need to be established in order to gather GPS data from the UAV sent to find the sample area. This radio communication or another technology such as bluetooth will also need to be used to demonstrate manual control of all physical rover functionality.

The rover must demonstrate functionality of its software and physical systems in controlling the direction of the rover to drive towards the target area. Additionally, the system must demonstrate an ability to respond to changes in conditions measured by the sensors. For example the rover must be able to detect and respond to a detected jam in one of the motors and determine whether the jam can be fixed by taking an alternate route or requires emergency shutdown.

In order to complete the competition purpose, the system must demonstrate ability to retrieve and retain a 10 mL “ice” sample. Lastly, the system must demonstrate successful fail-safe functionality of the retention and deployment design when integrated into the rocket.

5 Available Technologies

5.1 Drive Motors

The primary constraints in selecting a drive motor are torque, weight, and size, particularly the length of the motor along the axis of the shaft. Two motors will be used to provide power to the drivetrain. Based on preliminary rover mechanical designs, the approximate specifications needed for each motor are summarized in table 5.1 below. These values were used in looking for a motor with similar specifications.

Motor Design Specifications	
Torque (oz-in)	100
Nominal Speed (RPM)	60
Weight (oz)	3

Length (in)	2

Table 5.1

Based on the metrics in Table 5.1, the Actobotics 98 RPM Econ Gear Motor was selected as a preliminary choice for the purpose of system prototyping. This motor meets the necessary specifications while being readily available from supplier ServoCity at a low cost, making it ideal for prototyping and final production if deemed sufficient at the time of CDR. This motor also provides a lower maximum current draw, reducing the current rating needed from the on board battery which will allow for a weight reduction when selecting a battery. The specifications are included below in table 5.2.

Actobotics Econ Gear Motor Specifications	
Max Torque (oz-in)	524
Nominal Speed (RPM)	98
Weight (oz)	3.25
Length (in)	2.25
Nominal Voltage (V)	12
Stall Current (A)	3.8

Table 5.2

A commercially available dual motor controller will be used in order to prototype system mechanisms and programming. The motor control driver circuitry will be included on the final PCB used for the rover control rather than using a third party prototype board, further integrating the functions of the system into a single board.

5.2 Sample Retrieval Motors

Motors will be needed in order to turn the screw for sample retrieval and also lower the screw into position. The DS04-NFC motor has been identified as a possible low weight servo motor that would meet the needs of this system.

DS04-NFC Specifications	
Max Torque (oz-in)	76.4
Nominal Speed (RPM)	45.5
Weight (oz)	1.34

Length (in)	1.57
Nominal Voltage (V)	4.8-6
Stall Current (A)	1

Table 5.3

5.3 Sensors

In order to control the rover, a number of sensors will be utilized to characterize and control the behavior of the system. Motor encoders will be used to measure the rotational response to movement commands sent by the controller. Additionally, an accelerometer will be used to determine the actual motion of the rover to compare with the motion indicated by the encoder measurements, which can be used to determine if the rover is stuck or lost traction in the mud.

A compass or magnetometer will be used to determine the current orientation of the rover. A GPS chip will be used to determine the location of the rover, and will be compared with coordinates transmitted by the UAV. This measurement in combination with the magnetometer will allow the controller to determine the direction to autonomously drive the rover within range of the sample recovery area. The GPS chip currently being considered is the TESEO-LIV3F, the specifications of which are shown in Table 5.4 below. This chip provides an accuracy of 1.5 meters which is sufficient for getting the rover onto the 10 ft. tarp of the sample recovery zone.

TESEO-LIV3F Specifications (GPS)	
Max Tracking Power (mW)	75
Standby Power (uW)	45.5
Accuracy (m)	1.5
Package (mm x mm)	9.7x10.1
Supply Voltage (V)	3.3
Tracking Sensitivity (dBm)	-163

Table 5.4

5.4 Communications

Two on-board transceiver modules are under consideration for communicating via an antenna to the ground station sending GPS data to the controller over UART communication.

For the 900 MHz band, the Microchip RN2903 module is the primary selection. This module runs on 3.3 V and has a low 2.8 mA idle current draw and 13.5 mA receiving current draw with a transceiver power of 70 mW, under the 250 mW limit. It provides more than enough range at over 9 miles in ideal line of sight conditions.

For the 2.4 GHz band, the Semtech SX1280 is a 2.4 GHz long range transceiver module ideal for low data-rate applications such as this, and provides similar specifications to the RN2903 with a lower transmission power of 18mW. As the design process progresses, the frequency band will be determined and a module will be selected.

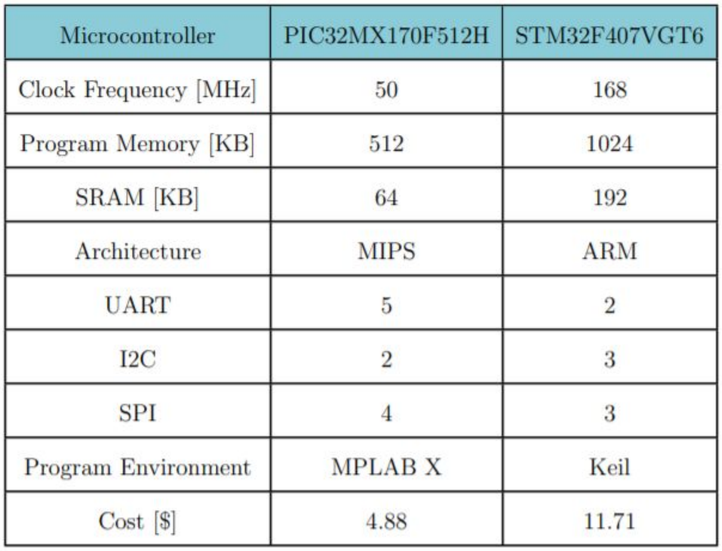
Additionally a simple whip antenna will be used to transmit and receive information for the module.

In order to provide manual control, two technical solutions are considered. The first option is to trigger manual control over the radio communication link and send the manual commands over this link. This allows to operate on a single frequency band and radio link, but adds complexity to the data processing on that line. A second consideration is to include a bluetooth module on the rover circuit and connect a bluetooth controller such as a Playstation dual shock controller to control the rover. This would allow the information conveyed from the UAV to be processed separately from the bluetooth link, which would monitor for an interrupt to trigger manual control mode, and then receive those controls over the same bluetooth link until triggered to return to autonomous mode by the manual operator.

Similar to the radio communication modules, the decision on which option to pursue will depend heavily on the finalized design of the UAV frequency band and a possible ground station linking them. If bluetooth is selected, a module such as the Microchip RN4871 on-board module will provide bluetooth integration into the board for programming a connection to a wireless controller. Alternatively, commercial solutions exist from reputable vendors such as RobotShop that provide simplified bluetooth controller solutions at a low cost. One example is the Lynxmotion PS2 Controller V4 which simply plugs into a UART or other serial interface. A downside to this approach is size constraints of the receiver included and less control over the hardware.

5.5 Microcontroller

Two micro-controllers are under serious consideration. The first is the Microchip PIC32. The second option is the STMicroelectronics STM32. The primary characteristics of the controllers are shown in the table below. Many characteristics are dependent on the selected package variation of the processor, so two mid-range options offering the required serial protocols have been selected for comparison.



Microcontroller	PIC32MX170F512H	STM32F407VGT6
Clock Frequency [MHz]	50	168
Program Memory [KB]	512	1024
SRAM [KB]	64	192
Architecture	MIPS	ARM
UART	5	2
I2C	2	3
SPI	4	3
Program Environment	MPLAB X	Keil
Cost [$]	4.88	11.71

When it comes to software development, the PIC32 is a well known industry partner with stable processor performance and community development support. Comparatively, the STM32's ARM based architecture is more aligned with industry trends and provides more productive software development applications as a result. At this time, the preliminary selection is the PIC32. This is because the PIC32 would provide sufficient specifications for a lower cost both financially and in training time, as many members of the team have experience developing for PIC processors. Additionally the engineering department at the University of Notre Dame supplies a number of PIC based programming and hardware tools for lab learning and course development, so this would better align with the resources available to the team to quickly begin prototyping.

5.6 Power Supply

In order to power the drive system, sample recovery motors, and the computing architecture for the rover, two batteries will be used. As determined by the mechanical design of the rover, the batteries can be a maximum of 1lb total weight. Based on the motors under consideration, a 12V nominal voltage was selected. There will be a voltage regulator to convert to 12V to 3.3V that can power the microchip and other peripheral components.

The first option considered is using two 12V Nickel Metal-Hydride (NiMH) batteries of 1600mAh each. Their specs are below in table 5.1. Note that the specs are for one battery and 2 will be needed in parallel. Assuming a nominal current of 4A while running both motors, the runtime would be 3.6Ah/4A = 0.9 hours.

12V NiMH 1600mAh Battery Option	
Voltage (V)	12
Discharge Current (A)	1.6A Standard (1C), 16A Max (10C)
Weight (lb)	0.5

Dimensions LxWxH (in)	3.40 x 0.68 x 2.30
Cost	$22.95

Table 5.1

Battery Option 2: The second option is 2x 2200mAh Lithium Polymer batteries (LiPo). While the total energy storage is greater than necessary, it still fits within the allotted weight allocation. The specs can be found in table 5.2 below. The estimated runtime with average current of 4A is 4.4Ah/4A = 1.1 hours.

LiPo ProTek 2200mAh 35C Battery	
Voltage (V)	11.1 (12.6 Fully Charged)
Discharge Current (A)	77A Continuous (25C)
Weight (lb)	0.40
Dimensions LxWxH (in)	4.33 x 1.37 x 0.9
Cost ($)	27.49
Lead Time	1 day online, in-store pickup possible in Granger, IN

Table 5.2

Battery Option 3:

The 1500mAh LiPo E-flite Battery listed in Table 5.3 represents another LiPo option with a lower weight and financial cost with the offset of a reduced capacity. The runtime for this battery with an average current of 4A would be 0.75 hr or 45 mins. In order to facilitate the decision making process, table 5.4 below highlights the pros and cons of LiPo and NiMH battery types.

LiPo E-flite 1500mAh Battery	
Voltage (V)	11.1 (12.6 Fully Charged)
Discharge Current (A)	30A Continuous (20C)
Weight (lb)	0.31
Dimensions LxWxH (in)	4.10 x 1.35 x 0.75
Cost	$25.99
Lead Time	2-4 day shipping with $3 shipping

Table 5.3

Battery Type Comparison

LiPo Battery	NiMH Battery
Pros: ● Much lighter weight, and can be made in almost any size or shape. ● Much higher capacities, allowing them to store more energy. ● Much higher discharge rates, meaning higher current output	Pros: ● Longer lifespan than LiPos, usually into the 1,000 cycles range ● Much less sensitive, and doesn't usually pose a fire risk ● Simpler chargers and routines required for use.
Cons: ● Much shorter lifespan; LiPos average only 150–250 cycles. ● The sensitive chemistry can lead to fire if the battery gets punctured. ● Need special care for charging, discharging, and storage.	Cons: ● Much heavier, and limited on size. ● Lower average capacity, and less efficient overall. ● Lower discharge rates; they lack tremendous current output.

Table 5.4

Based on this comparison table it is clear that LiPo batteries are generally more advantageous because of their higher energy density and current discharge rates. The NiMH batteries can only produce a total of 3.2A each in normal operating mode and up to 7.6A may be required because each motor can draw up to 3.8A each. This would result in the NiMH battery suffering reduced battery life and raised fire safety risks when the motors are drawing near stall current. Therefore LiPo battery type will be used and the decision of whether to use the 1500mAh or 2200mAh will be made at a later date depending on weight constraints.

While the motors will run directly off the 12V batteries, the voltage will be converted to 3.3V in order to power the microcontroller and sensors. This will be done using a voltage regulator. The regulator that will be used will be one of the following:

	Analog Devices ADP7105ACPZ-3.3-R7	Texas Instruments TPS7B8233QDGNRQ1
Output Voltage (V)	3.3	3.3
Max Input Voltage (V)	20	40
Output Current (mA)	500	300

Table 5.11

For Isolation of the motors before landing and deployment, two 3.3V relays will be used to isolate the motors from our 12V power source. One relay will be used to isolate the motors that control the rover's movement and one relay will be used to isolate the motor that drives the auger for sample retrieval. The relay considered is listed below.

TE Connectivity OJE-SH-112HM,000	
Coil Voltage (V)	12
Contact Rating (A)	10
Contact Current (mA)	37.5
Type	Normally Open (NO)

In order to close the relay, 37.5mA is needed which is too high to be provided by the microcontroller. In order to combat this, the relay will be closed using the 3.3V from the voltage regulator and will be switched on with an optoisolator. The part that will be used is a Broadcom Limited ASSR-4118-503E. When a signal is applied from the microcontroller, this device will allow current to flow to the relay that will allow the motors to begin operating.

6 Engineering Content

The complexity of the problem and the proposed solution results in several fundamental design areas that are essential to the project. The design, prototyping, and testing of the rover involves work in power systems, sensor interfacing, communications, and controls.

An efficient and sufficient power system will need to be designed and tested to provide enough current and correct voltage to the motors, sensors, and microcontroller.

The rover will need a sophisticated software system that will allow it to operate autonomously by integrating the sensor measurements and communications from the ground station and UAV. In addition, a manual control mode is required and will necessitate its own controls design based on the user input.

Controls for autonomously driving the rover to the GPS coordinates of the UAV at the sample location based on the output of the processed sensor inputs will need to be developed and integrated with system controls to respond to environmental factors.

A robust and reliable communications system will need to be designed and tested to allow for data to be transmitted from the UAV and the ground station to the rover. In addition, communications hardware will need to be integrated to remotely control the rover during the manual control.

A custom printed circuit board will need to be designed to integrate all of the necessary technologies onto a minimal amount of boards depending on size constraints which are a major design constraint when designing for a system as small as this rover.

7 Conclusions

This will be no simple task. There are many electrical and mechanical design considerations that need to be taken into account and worked on thoroughly to ensure a successful launch, deployment, collection, and recovery on competition day. Integrating with designs created by other members of the Notre Dame Rocket Team presents a unique but exciting challenge that will provide learning experiences representative of integration work we will encounter in our careers.

The design must be complex enough to complete all the tasks outlined above, but simple and robust enough that it will be able to perform exactly as expected every single time. However, with careful planning, design, and execution, the project will be completed successfully.

8 Appendix - NDRT Payload Requirements

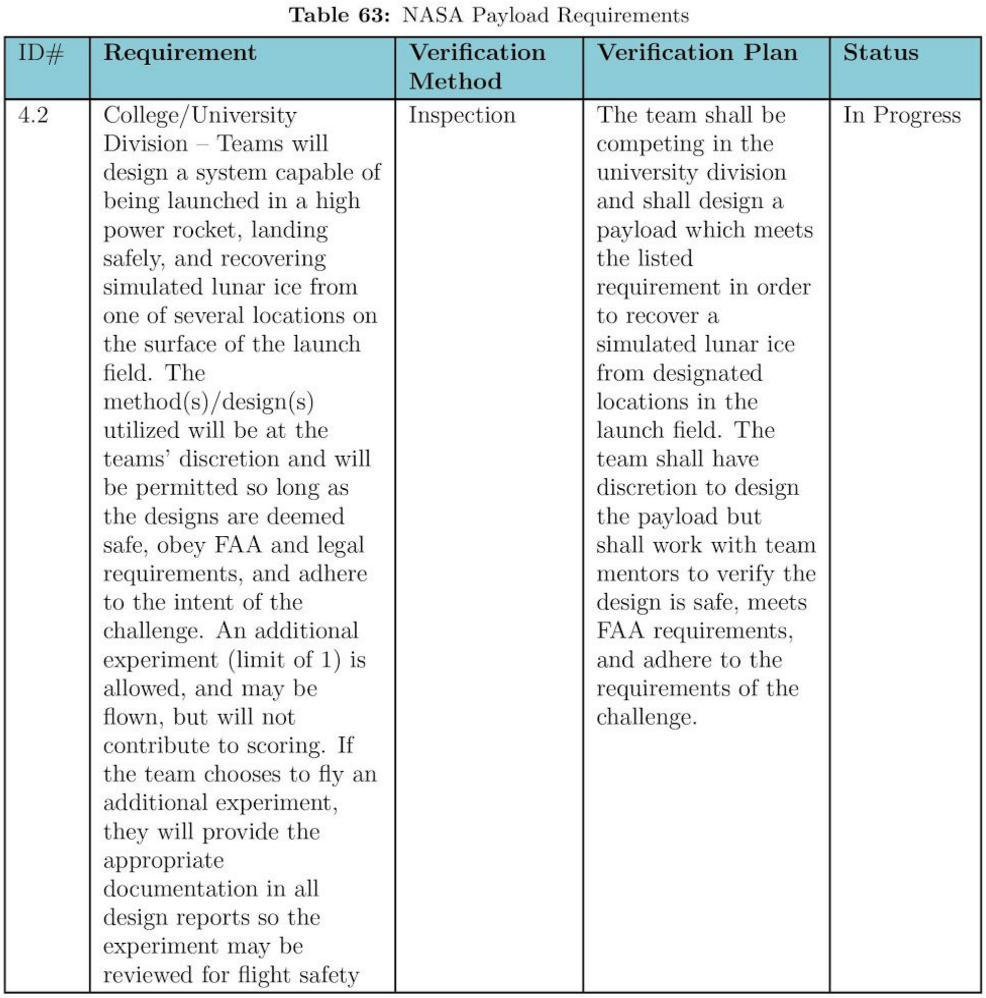


Table 63: NASA Payload Requirements

ID#	**Requirement**	**Verification Method**	**Verification Plan**	**Status**
4.2	College/University Division – Teams will design a system capable of being launched in a high power rocket, landing safely, and recovering simulated lunar ice from one of several locations on the surface of the launch field. The method(s)/design(s) utilized will be at the teams' discretion and will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring. If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety	Inspection	The team shall be competing in the university division and shall design a payload which meets the listed requirement in order to recover a simulated lunar ice from designated locations in the launch field. The team shall have discretion to design the payload but shall work with team mentors to verify the design is safe, meets FAA requirements, and adhere to the requirements of the challenge.	In Progress

4.3	Lunar Ice Sample Recovery Mission Requirements	Inspection	The payload shall be designed in adherence with the mission requirements listed.	In Progress
4.3.1	The launch vehicle will be launched from the NASA-designated launch area using the provided Launch pad. All hardware utilized at the recovery site must launch on or within the launch vehicle.	Inspection	The launch vehicle will be launched from the NASA designated launch area using the provided launch pad. All hardware utilized at the recovery site shall be launched on or within the vehicle.	In Progress
4.3.2	Five recovery areas will be located on the surface of the launch field. Teams may recover a sample from any of the recovery areas. Each recovery site will be at least 3 feet in diameter and contain sample material extending from ground level to at least 2 inches below the surface.	Demonstration	The team shall design the payload to be capable of travelling to one of the recovery areas and recover a sample extending at least 2 inches below the surface.	In Progress
4.3.3	The recovered ice sample will be a minimum of 10 milliliters (mL).	Demonstration	The payload will be designed to be capable of recovering an ice sample with a minimum volume of 10 mL.	In Progress
4.3.4	Once the sample is recovered, it must be stored and transported at least 10 linear feet from the recovery area.	Demonstration	The payload will be designed to be capable of transporting the recovered sample at least 10 linear feet from the recovery area.	In Progress

4.3.5	Teams must abide by all FAA and NAR rules and regulations.	Inspection	The team shall abide by all FAA and NAR rules and regulations. The team shall conduct a review with the team launch manager prior to the launch day to verify all regulations are met.	In Progress
4.3.6	Black Powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Any ground deployments must utilize mechanical systems.	Inspection	The team shall not utilize energetics for the ground depoloyment of the payload. The payload ground deployment shall utilize a mechanical system.	In Progress
4.3.7	Any part of the payload or vehicle that is designed to be deployed, whether on the ground or in the air, must be fully retained until it is deployed as designed.	Demonstration, Testing	The payload shall be designed to be fully retained until it is deployed as designed. This shall be verified in tests prior to launches and demonstrated during the demonstration flights.	In Progress
4.3.7.1	A mechanical retention system will be designed to prohibit premature deployment.	Analysis	The mechanical system designed to prohibit premature deployment shall be designed and analyzed using methods such as Finite Element Analysis (FEA) to determine forces on the system to avoid premature deployment.	In Progress

4.3.7.2	The retention system will be robust enough to successfully endure flight forces experienced during both typical and atypical flights.	Demonstration, Testing	The retention system shall be subjected to shake tests to ensure the system is capable of enduring typical and atypical flight forces while still being reusable per Req. 2.4.	Incomplete
4.3.7.3	The designed system will be fail-safe.	Inspection, Testing	The designed system shall be designed to be fail-safe to ensure that the failure of any system components does not result in the payload being damaged or released prematurely. Additionally the system shall be designed with redundancy to avoid failures.	In Progress
4.3.7.4	Exclusive use of shear pins will not meet this requirement.	Inspection	The team ackownledges that shear pins shall not meet the fail-safe requirement.	Complete
4.4	Special Requirements for UAVs and Jettisoned Payloads	Inspection	The team shall follow all requirements for UAVs and Jettisoned payloads.	In Progress
4.4.1	Any experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event.	Inspection	Any element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the event.	Incomplete

4.4.2	Unmanned aerial vehicle (UAV) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAV.	Inspection, Demonstration	Any components deployed during descent shall be tethered to the vehicle with a remotely controlled release mechanism until the RSO gives permission to release the UAV and shall be demonstrated during test flights.	Incomplete
4.4.3	Teams flying UAVs will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).	Inspection	The team shall abide by all FAA regulations and shall carefully review the regulations during each step of the development process (design, testing, pre-flight review etc.)	In Progress
4.4.4	Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.	Inspection	Any team UAV weighing more than 0.55 lbs will be registered with the FAA and the registration number marked on the vehicle.	Incomplete

Table 67: Derived Payload Requirements

ID#	**Description**	**Justification**	**Verification Method**	**Verification Plan**	**Status**
S.1	The Rover must not have an overall width larger than 6 inches	Constraining the Rover to a 6 inch maximum width gives the other subsystems a dimension to design around	Inspection	All rover body designs will be constrained to a width of 6 inches	In Progress

S.2	The Rover must be able to overcome small obstacles such as rocks, corn stalks, and crop rows	The terrain where the launch will be conducted is not flat and easy to navigate, so the Rover should be able to overcome any obstacles it may encounter	Demonstration, Testing	The translation mechanism will be tested traversing multiple types of obstacles	Incomplete
S.3	The Rover must be able to traverse through mud, puddles, corn stalks, and corn fields	The state of the terrain is variable and the rover should be designed to overcome any terrain it may experience.	Demonstration, Testing	The rover will be tested traversing through various terrains that may be present at the launch including mud, puddles, and high cut corn	Incomplete
S.4	The Rover must hold and protect the electronics in a water proof container	Making the Rover water resistant will enable it to travel through puddles rather than going around them and wasting time.	Inspection, Demonstration, Testing	All containers that will house electronics will be water tested to ensure there are no leaks and they function as intended	Incomplete
S.5	The Rover must not weigh more than 40 ounces	Constraining the Rover to a maximum weight will prevent the payload from going over weight	Inspection	An up to date weight budget of all components will be maintained to keep track of the weight of the systems	Incomplete

S.6	The Rover must have a minimum operating time of 20 minutes	A 20 minute operating time will provide adequate time for the Rover to traverse to the closest FEA	Demonstration, Testing	Operating time calculations will be conducted at various design milestones to verify the selected components will enable the Rover to operate for a minimum of 20 minutes	In Progress
S.7	The Rover must have a manual override switch	A manual override enables the operator to take control of the Rover should an error occur in the control code	Inspection, Demonstration, Testing	All control software will be required to have a manual override built into the code	In Progress
S.8	The Rover will remain dormant until receiving the initiation signal from the UAV	A low power mode will conserve the battery life of the Rover prior to deploying	Demonstration, Testing	Various testing will be conducted with the Rover in the low power mode to ensure that no external force or signal will bring the Rover out of the dormant state	Incomplete

S.9	The UAV must be no larger than 4 in x 4 in	This constraint enables the UAV to fit inside the payload bay without the need for moving arms	Inspection	All UAV frame designs will be constrained to a width of 6 inches	In Progress
S.10	The UAV frame must protect the battery	Damage to the battery can result in catastrophic failure so the risk for damage should be mitigated	Inspection, Demonstration	All UAV frame designs will be required to have no moving parts and all components will need to be statically secured	In Progress
S.11	The UAV must weigh under 2.4 ounces	Constraining the UAV to a maximum weight will prevent the payload from going over weight	Inspection	An up to date weight budget of all components will be maintained to keep track of the weight of the systems	In Progress
S.12	The UAV must have a minimum flight time of 10 minutes	A 10 minute flight time will provide adequate time for the UAV to search the area around the Rover	Demonstration, Testing	Flight time calculations will be conducted at various design milestones to verify the selected components and the selected frame design will enable the UAV to fly for a minimum of 10 minutes.	In Progress

S.13	The UAV must use a commercial flight controller	Using a commercially available flight controller expedites the flight software development process	Inspection	Only commercial flight controllers will be accepted when reviewing proposed electrical designs for the UAV	In Progress
S.14	The UAV must have a manual override switch	A manual override enables the operator to take control of the UAV should an error occur in the flight code	Inspection, Demonstration, Testing	All flight software will be required to have a manual override built into the code	In Progress
S.15	The Sample Retrieval system must recover a minimum sample size of 15 mL	Having a sample size target over the required sample size will ensure the retrieval of a 10 mL sample	Demonstration, Testing	All sample retrieval designs will be required to hold a 20 mL sample. The system will be extensively tested to ensure it consistently retrieves a sample no smaller than 15 mL.	In Progress

S.16	The Sample Retrieval system must be able to correctly orient itself for retrieval operations	A self orienting sample retrieval system will allow the rover to be in an position when the sample retrieval system is operating	Demonstration, Testing	The retrieval system will be extensively tested to verify it can correctly orient itself to perform the retrieval operations consistently and reliably	Incomplete
S.17	The Sample Retrieval system must retain and protect the recovered sample from spillage and contamination	Securing the sample once it is collected will ensure successful deliver of the sample from the FEA	Inspection, Demonstration, Testing	The sample container will be water tested to ensure no contaminants can leak into the container and the container will be tested through sample retrieval simulations to ensure no amount of sample can spill out of the container during the translation of the rover	Incomplete

S.18	The Sample Retrieval system must interface with the Rover electronics	This will reduce system complexity and reduces the risk of failure	Demonstration, Testing	The sample retrieval team will communicate regularly with the rover electronic team to ensure that the retrieval system can integrate into the electronic system of the rover	In Progress
S.19	The Sample Retrieval system must be easily integrated with the Rover frame	This will reduce system complexity and reduces the risk of failure	Inspection, Demonstration	The team is utilizing Fusion 360 and cloud based models to ensure all assemblies use up to date models and all systems integrate together	In Progress
S.20	The Deployment system must have multiple failsafes	Multiple failsafes will ensure system success despite a component failure within the system	Demonstration, Testing, Analysis	All designs of the deployment system will include a minimum of two redundant locking mechanisms for restricting motion of components in the bulkhead of the vehicle	In Progress

S.21	The Deployment system must be able to correctly orient the Rover and UAV regardless of the landing position of the upper section of the vehicle	The orientation of the Rover is paramount to mission success and must operate successfully	Demonstration, Testing	The orientation system will be extensively tested with the bulkhead section of the vehicle to ensure that it consistently and reliably orients the Rover and UAV for multiple orientations and landings of the bulkhead section of the vehicle	Incomplete
S.22	The deployment system must restrict motion of the Rover and UAV in all directions until the deployment sequence is initiated	Flight stability of the vehicle is dependent on all components in the payload bay remaining locked in place	Demonstration, Testing	All designs of the deployment system will be required to restrict motion of the Rover and UAV in the X, Y, and Z directions. Additionally, all motion restricting designs will be extensively tested to verify proper functionality	In Progress

S.23	The target detection system must correctly identify the closest FEA	This will minimize travel time and distance for the Rover	Demonstration, Testing	The target detection software will be tested to consistently locate the closest FEA during multiple simulations in which fluorescent material will be placed on multiple types of terrain.	Incomplete
S.24	The target detection system must identify the corner of the FEA that is furthest from the Rover	This will reduce the risk of the Rover driving over the UAV	Demonstration, Testing	The target detection software will be tested to correctly and reliably identify the corner of the FEA that is furthest from the Rover.	Incomplete