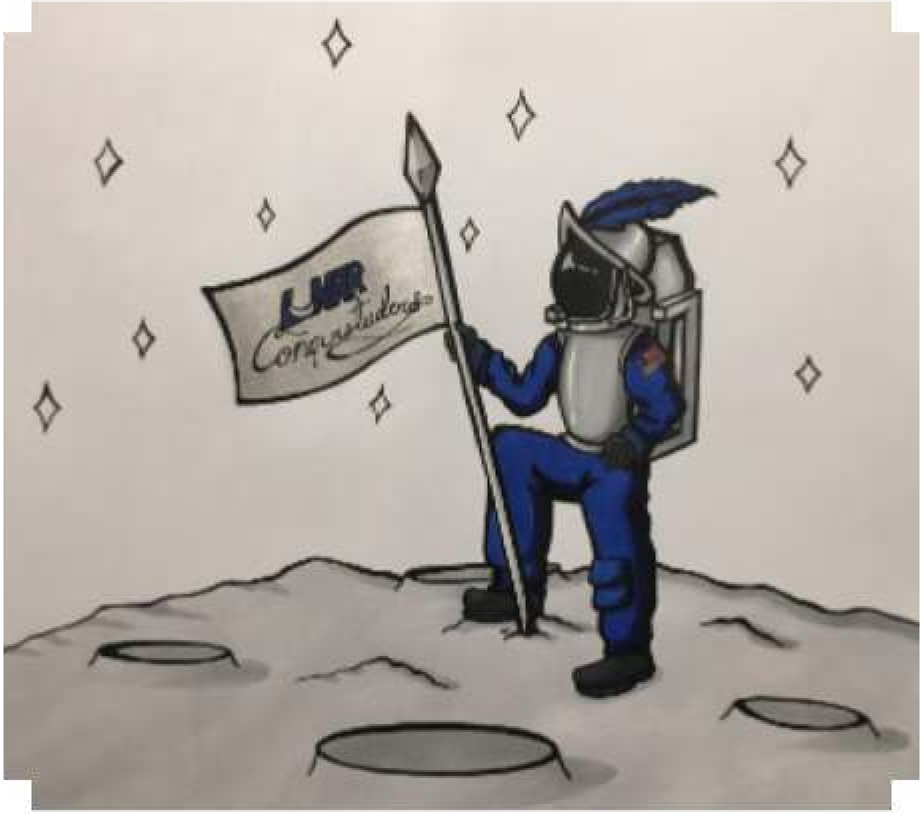
PAYLOAD CONCEPT PROPOSAL

Lunar Conquistadors

Palmetto Scholars Academy

Team 1



NO ONE EXPECTS THE LUNAR INQUISITION

1.0 Introduction

Team Lunar Conquistadors is part of the L.A.S.E.R. (Lunar Analysis and Sampling for Exploration and Research) mission with the University of Alabama in Huntsville (UAH). This mission consists of an orbiter, lander, and rover interacting with the South Pole of the Moon over the course of two years. It will start with the orbiter staying in a 100 kilometer circular polar orbit around the Moon throughout the entire mission. After six months, a lander will touch down approximately 100 miles from Shackleton Crater, which lies within the Moon's southern rotational axis. Then two months later, a rover will travel from the lander to Shackleton crater at roughly 2 kilometers per 24 hours for fifty days. The rover will then spend ten days performing science missions with an extra ten day contingency. The rover will then travel another 100 miles or fifty days back to the orbiter. Two months later, the lander will return to the orbiter, which will break obit six months after that. The payload concept chosen for the LASER mission is titled the Illuminati Payload. It is an autonomous payload aboard the rover traveling to Shackleton Crater.

The Lunar Conquistadors' team name was chosen because the mission was to launch an inquisition of the Moon to discover its secrets and learn what is available. The logo is an image of a conquistador on the Moon holding a pike with a flag. The conquistador was chosen because the mission is to "conquer" and explore the Moon. The central crater in the image represents Shackleton Crater as it is the focus of the mission. The conquistador is missing a face because the mission is unmanned. The pack that the conquistador wears is symbolic of the compressed air from which the payload will be ejected. The feather on the conquistadors hat is symbolic of the short flight that the payload will take after being ejected. The motto is, "No one expects the Lunar Inquisition" and refers to America's return to the Moon after a long absence since the Apollo missions. Our payload's name is Illuminati since the payload's main focus of research is solar energetic particles over long periods of time, and the eye in the Illuminati symbol represents the idea of an omniscient force. The Illuminati eye also is representative of our watching the solar energetic particles over a period of time. The Illuminati themselves have been around for centuries, reconfirming the watching for a long time. Due to the nature of our payload and, the name seemed appropriate for our mission.

2.0 Science Objective and Instrumentation

Three candidate science objectives were chosen for the LASER Mission. The first candidate science objective concerns Solar Energetic Particles (SEPs). Specifically, the science objective regards how SEPs interact and change the composition of the lunar regolith. SEPs are high energy particles that are emitted by the sun. They consist of protons, electrons, and high-energy nuclei (HZE) ions. When SEPs impact the surface, two separate layers are created due to the difference in heat. The SEPs block the energies to pass between layers. Attraction builds up to overcome the cold barrier, and the subsurface becomes charged and sparks. The resultant sparks generate energy that heats up the soil to temperatures comparable to a meteor strike. The material composition and temperature is changed as a result. This is known as dielectric breakdown. Dielectric breakdown is found in Permanently Shadowed Regions (PSRs) because of the extreme cold that is typically found in PSRs.

The second science objective involves Cold Traps. In this candidate objective, the abundance and composition of water-ice and the possibility of bacterial life on the Moon are probed thoroughly. Throughout the Moon's existence, hundreds of thousands of meteors have made impacts on the Moon's southern pole. These meteors would have rained ice and water upon the Moon's surface. Most of that ice would instantly vaporize; however, some of the ice might be saved inside the extreme cold of PSR. The Lunar Reconnaissance Orbiter (LRO) has captured images of parts of the southern pole at Shackleton Crater where cold trap conditions and the possibility of water-ice exist. The LRO's Lunar Crater Observing and Sensing Satellite (LCROSS), a companion mission, impacted with the surface of the Cabeus Crater, roughly 100 kilometers from Shackleton Crater, and results indicated the presence of water and hydroxyl.

The third science objective is Atmospheric Conditions. This objective is concerned with the composition of the atmosphere of the southern pole of the Moon. The objective would compare the atmospheric conditions of the southern pole to the rest of the lunar atmosphere.

The objective will determine the composition and temperature of the lunar regolith when it interacts with solar energetic particles. The payload must be located inside a Permanently Shadowed Region because without the extreme cold, dielectric breakdown cannot occur. A slit spectrometer and Inertial Measurement Unit (IMU) were chosen as instruments for the objective. The slit spectrometer will determine the change in composition of the materials as dielectric breakdown occurs, and the IMU will allow the payload to be correctly oriented.

Table 1. Science Objective Trade Study

FOM	**Weight**	**SEPs**		**Cold Traps**		**Atmospheric Conditions**	
		Raw Score	Weighted	Raw Score	Weighted	Raw Score	Weighted
Interest of Team	9	9	81	3	27	1	9
Applicability to other Science Fields	1	9	9	3	3	1	1
Mission Enhancement	1	9	9	9	9	1	1
Measurement Method	9	9	81	3	27	9	81
Understood by Public	9	3	27	9	27	3	27
Excitement of Public	3	9	27	3	9	1	3
Ramification of Answer	3	3	9	3	9	1	3
Justifiability	1	9	9	9	3	1	1
TOTAL			**252**		**87**		**99**

Table 2. Science Traceability Matrix

Science Objective	Measurement Objective	Measurement Requirement	Instrument Selected
Solar Energetic Particles	Determine the composition and temperature of affected materials	Payload needs to be adjacent to lunar soil in a Permanently Shadowed Region	Slit Spectrometer, IMU

Table 3. Instrument Requirements

Instrument	Mass (kg)	Power (W)	Data Rate (Mbps)	Dimensions (cm)	Lifetime	Frequency	Duration
Slit Spectrometer	2.5	11	0.74	20x30x10 (electronics)	169	1	168
Inertial Measurement Unit	0.013	0.22	0.16	2.2x2.4x0.3	169	1	168

Table 4. Support Equipment

Component	Mass (kg)	Power (W)	Data Rate	Other Technical Specifications
On-Board Computer (processed with board)	0.094	0.4	2 X 2 GB onboard storage	Cubesatshop.com ISIS On Board Computer 400 MHz, ARM9 processor
Batteries	4.9	N/A	N/A	400 Whr per kg
Transmitter/Receiver	0.085	1.7	Up to 9600 bps downlink; up to 1200 bps uplink	Cubesatshop.com ISIS VHF/UHF Duplex Transceiver
Antenna	0.1	0.02	(see above)	Cubesatshop.com Deplorable Antenna System

3.0 Payload Design Requirements

There are several design constraints placed upon our payload by UAH. The payload most not have a mass of more than 10 kg or exceed a volume of 44cm by 28cm by 24cm when stowed. The spacecraft must be kept operational, the spacecraft must be kept safe from harm, and data must be sent back to Earth. For the mission, the payload must take measurements, collect data, provide power, send data, and have a housing. The payload also must be able to withstand temperatures from -183℃ to 175℃. It must be able to withstand an atmospheric pressure of up to $3x10^{-15}$ atm. It must be able able to withstand the gravity of 1.622m/s^2, as well as any high solar or cosmic radiation. The payload must be able to withstand coming into contact with an elements found commonly on the Moon, such as silicon, oxygen, aluminum, calcium, iron, titanium, and possibly water-ice.

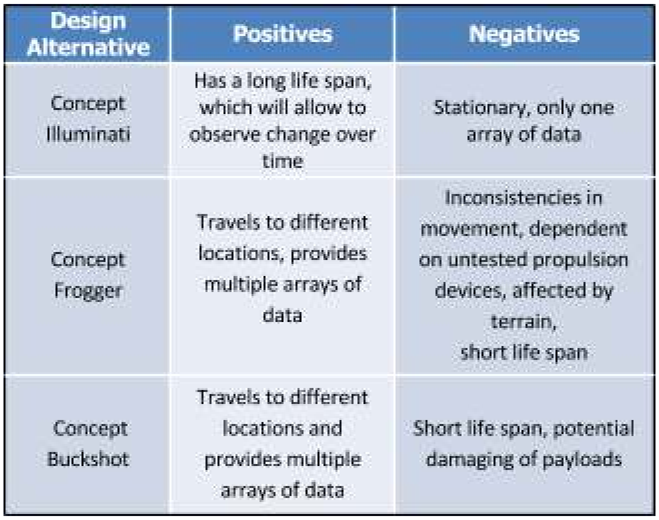
Table 5. Payload Design Requirements

Project Requirements	Functional Requirements	Environmental Requirements
Mass under 10 kg	Deploy	Able to withstand average temperatures from -183℃ to 175℃
Volume When Stored: 44cm x 24cm x 28cm	Take Measurements	Able to withstand an average atmospheric pressure of 3×10^{-15} atm (0.3 nPa)
Protection Against Environment	Collect Data	Able to withstand an average gravity of 1.622 m/s^2
Keeping Spacecraft Operational	Provide Power	Able to withstand high cosmic and solar radiation
Able to Send Information Back To Earth	Send Data	Chemical composition is silicon, oxygen, aluminum, calcium, iron, titanium, magnesium, and up to 22% water ice
Keep Main UAH Spacecraft Safe from Harm	House Payload	Almost nonexistent wind due to extremely thin atmosphere

4.0 Payload Alternatives

Three concepts were developed. The first payload design alternative is Concept Illuminati shown in Figure 1. Concept Illuminati would travel aboard the rover to Shackleton Crater. It would be ejected from the rover using compressed helium into a Permanently Shadowed Region. The payload would record temperatures and compositions of the lunar regolith with a slit spectrometer. This payload will have a longer lifespan than the rest and be able to record the changes to the regolith made over time. The housing would be made of aerogel.

The second concept, Concept Frogger, is shown in Figure 2. Concept Frogger would also travel to Shackleton Crater by rover and be launched with compressed helium. It would then use controlled bursts of compressed helium to “hop” inside of Shackleton Crater. A mass spectrometer and infrared scanner would record the composition and temperatures. The housing would be made of aluminum.



Design Alternative	Positives	Negatives
Concept Illuminati	Has a long life span, which will allow to observe change over time	Stationary, only one array of data
Concept Frogger	Travels to different locations, provides multiple arrays of data	Inconsistencies in movement, dependent on untested propulsion devices, affected by terrain, short life span
Concept Buckshot	Travels to different locations and provides multiple arrays of data	Short life span, potential damaging of payloads

The last concept, Figure 3, is called Concept Buckshot. Concept Buckshot would consist of multiple payloads carrying an infrared scanner and mass spectrometer in an aerogel housing. The multiple payloads would cover a large surface area inside of Shackleton Crater, but they would have much shorter lifespans.

Figure 1. Concept Illuminati

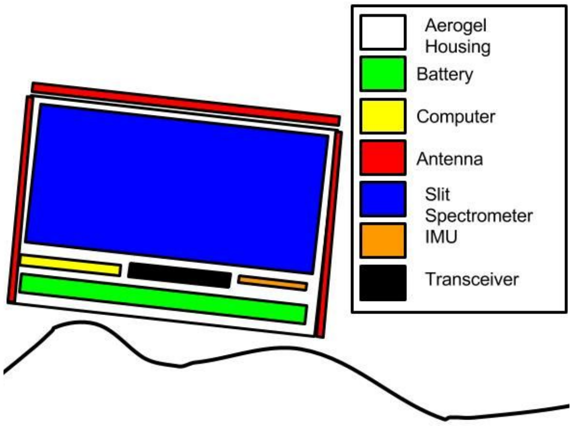
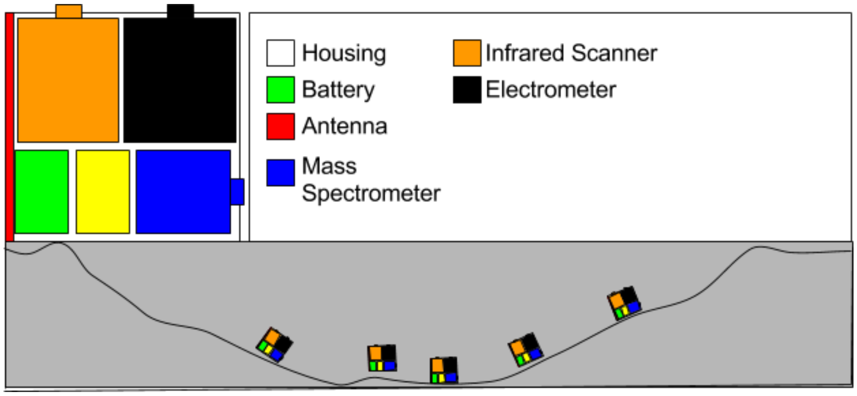


Figure 2. Concept Frogger

Figure 3. Concept Buckshot



5.0 Decision Analysis

In this decision analysis, we were given 7 FOM's by UAH and had to create three FOMs as a team and are written in blue in Table 6. We weighted the FOM's with a 1, 3, or 9, depending on how important they were to the team (1 being least important, 9 being most important). We then analyzed each FOM against each design and gave each FOM a raw score of 1, 3, or 9. We then multiplied the raw score by the weight to get a weighted score for each objective.

Once completed, we compared the totals of each payload and confirmed that Concept Illuminati was the best design to meet our team requirements and those of InSPIRESS.

The three FOMs created by the team were Mission Duration, Data Collected, and Environmental Disruption and are colored blue on Table 6 below. Mission Duration dealt with how long each concept would be able to record data. Data Collected concerns the amount of data collected over the mission. Environmental Disruption weighs how much each concept disrupts the lunar environment and thus has an impact on the data. We gave the FOMs of Mission Duration and Environmental Disruption a weight of 1 because they were factors that needed to be taken into account, but they weren't vital to mission success. We gave the FOM of Data Collected a weight of 3 because large amounts of information are valuable when collecting data. The FOMs that distinguished our winning Illuminati design were overall likelihood of mission success, likelihood of achieving project requirement, and science objective. The team agreed that Illuminati was the most compliant design that had the best chance to succeed, and the decision analysis quantitatively reflected that consensus.

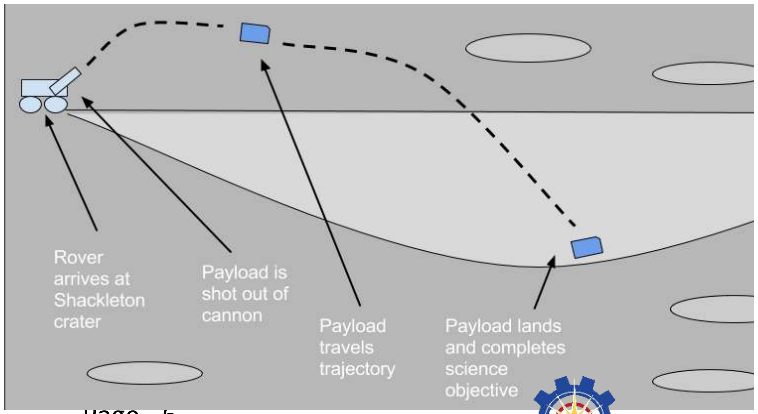
Table 6. Payload Decision Analysis

FOM	**Weight**	**Concept illuminati**		**Concept Frogger**		**Concept Buckshot**	
		Raw Score	Weighted	Raw Score	Weighted	Raw Score	Weighted
Science Objective	9	9	81	3	27	3	27
Likelihood of Achieving Project Requirement	9	9	81	3	27	3	27
Science Mass Ratio	3	9	27	1	3	3	9
Design Complexity	1	9	9	1	1	1	1
ConOPs Complexity	3	3	9	1	3	1	3
Overall Likelihood of Mission Success	9	9	81	1	9	3	27
Manufacturability	3	9	27	1	3	3	9
Mission Duration	1	9	9	1	1	1	1
Data Collected	3	1	3	1	3	3	9
Environmental Disruption	1	9	9	1	1	1	1
TOTAL			**336**		**78**		**114**

6.0 Payload Concept of Operations

The payload operations begin when the UAH lunar rover arrives at the rim of Shackleton Crater. Immediately afterwards, the payload is launched out of the barrel via helium and bounces into Shackleton. Then the payload will gradually bounce to a stop and carry out its science mission over 168 hours. After this time span the payload's mission

Figure 4. Concept of Operations



will come to an end as it transmits the received data over the last hour of its life.

7.0 Engineering Analysis

No calculations were necessary for initial conditions, but assumptions were necessary to ensure that the mission would commence properly. Those assumptions included that the UAH rover would successfully travel to Shackleton Crater in four months; that the inclination of the rover would be no more than 12 degrees constantly; that the deployment barrel would function properly; and that the rover would be stationary during deployment. Next, we performed calculations for deployment, payload trajectory, battery mass, and ending conditions (buckling pressure and drag force) of our payload. The battery mass is calculated by using a constant function of all instruments and support equipment and the specific amount of time each payload would be on. For the initial conditions, the payload will be aboard the rover. The rover will be still with an inclination swing of no more than twelve degrees in either direction. Using the cross sectional area, mass, and length of our payload, we can calculate pressure for deployment, the trajectory, and the g-load for the ending conditions. For these calculations, it is assumed that there will be no friction, constant pressure, constant gravity, a perfect fit, no terrain inconsistencies, and a constant speed.

Table 7. Engineering Analysis Calculations

Design Stage	Variable	Equation	Calculation	Result
Deploy-ment	P_a=Pressure A=barrel area m=mass v=velocity d=barrel length	$v_f^2 = v_i^2 + 2(\frac{PA}{m})d$	$28.556^2 = 0^2 + 2(\frac{P*.0627}{7.9767}) * .44$	110,000= Pa V_f=38.98368 m/s
Trajectory	v=velocity d=distance traveled TOF=time of flight a=acceleration	$v_f^2 = v_i^2 + 2ad$ $\therefore d = \frac{v_f^2 - v_i^2}{a}$ $v_f = v_i + at$ $t = \frac{v_f - v_i}{a}$ $\therefore TOF = 2$	$d = \frac{0^2 - 7.391^2}{-1.622}$ $TOF = 2(\frac{0-7.391}{-1.622})$	tof=4.557sec d=33.679m
Ending Condition	g=g-load a=acceleration d=distance to stop v=velocity g_{earth}=earth gravity	$v_f^2 = v_i^2 + 2ad$ $g - load = \frac{a}{g_{Earth}} = \frac{a}{9.81}$	$= \frac{(\frac{0^2 - 7.391^2}{2*10})}{-9.8}$	g=0.2782

Table 8. Battery Mass

Equation	Calculation	Result
$m = \frac{(ab+cd+ef..)W*hr}{400\ W*hr/kg}$	$\frac{((0.4*168hr)+(1.7*1hr)+(0.02*1hr)+(0.22*168hr)+(11*168hr))}{400\ W*hr/kg}$	4.8847 kg

8.0 Final Design

Team Lunar Conquistador's Illuminati Payload (Figure 6.) is a rectangular payload designed for a long lifetime. The housing material is aerogel for increased protection and lightness. Aerogel is a synthetic, lightweight material that is a solid with extremely low density and low thermal conductivity. It can withstand extreme cold temperatures and is four times better at insulation than fiberglass. The rectangular shape is used to provide increased compactness. The housing holds a slit spectrometer to be used to complete our science objective of studying how dielectric breakdown and solar energetic particles affect the lunar regolith. There is a 1.3cm hole to allow our slit spectrometer collect data. The antennae is wrapped around our payload to increase the compactness. The slit spectrometer is located nearest the walls of our payload. The payload 30cm x 23.5cm x 27.5cm.

Figure 5. Team Lunar Conquistadors' Mission

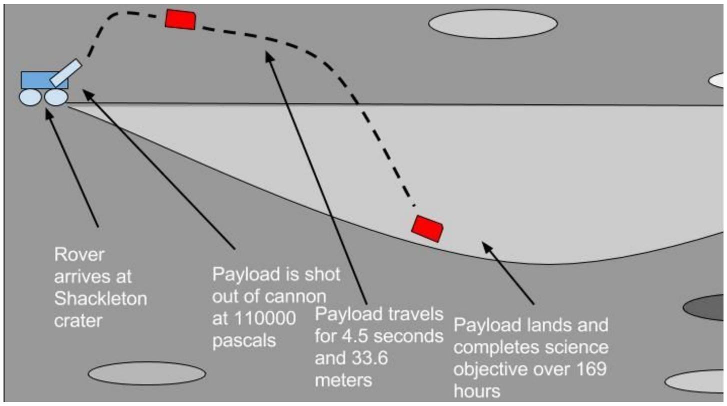


Figure 6. Payload Model

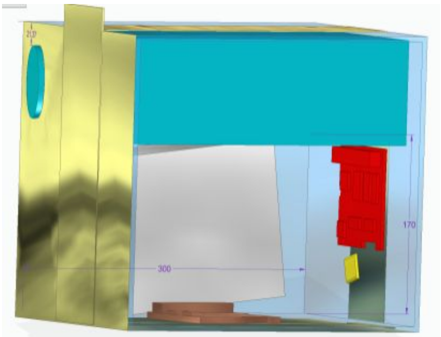


Table 9. Final Design Mass Table

Function	Component(s)	Mass (kg)
Deploy	Barrel	1.5
Measure	IMU	0.013
Collect Data	Slit Spectrometer	2.5
Provide Power	Batteries	4.9
Send Data	Antenna	0.085
House Payload	Exterior Casing	0.7
Total		**9.8**