Payload Concept Proposal

Mo.L.T.E.N

Phillips High School

Team 1

1.0 Introduction

People have long looked at the sky and seen numerous fascinating events and objects in the darkness of night. The most fascinating of all these objects is the Moon. Humans have longed to go to space and explore these objects, and even step foot on the Moon. In the 20th century, a great event in the history of the world was occurring. This event was dubbed the Space Race. The Soviet Union and the United States were competing to be the first to put a man in space. Cosmonaut Yuri Alekseyevich Gagarin was the first man in space via the Soviet Union. The Soviet Union may have won this battle, but the United States was determined to win this war. This led to the creation of the United States' first federal agency dedicated solely to space exploration. This revolutionized the way the world thought about space and space exploration. The National Aeronautics and Space Administration soon began creating a mission to win this war with the Soviets. The war was won by the Americans when Neil Armstrong stepped foot on the Moon on July 19, 1969 during the Apollo 11 mission. Since this day in history, we as a race have contemplated living on the moon. The discovery of lava tubes on and below the Moon's surface has sparked the interest of scientists and astronauts to determine if these lava tubes could possibly sustain and support life from the harsh conditions of space.

Presented in this document is an outline of the payload concept proposed by Phillips High School-Team 1 Mo.L.T.E.N. to study the properties of the known Marius Hills Skylight on the North Pole of the Moon. With these two payloads named "*Chubby Cube*" and "*Shell-Razor*" Mo.L.T.E.N. is determined to study the properties of the known lava tube and test to see if it could possibly protect future astronauts from the wiles of space and sustain the life of a future moon colony. In this study, Mo.L.T.E.N. plans to test the composition and properties of the known lava tube, and study the radiation, gravity, temperature, and pressure amounts within this known lava tube. Throughout this document, detailed explanations will be given as to how we as Mo.L.T.E.N. chose these objectives through payload development, and how we came to choose the final design presented in this document.

2.0 Science Objective and Instrumentation

The science objectives chosen by Mo.L.T.E.N. for this project are all based on the possibility of one suggesting that the Moon could possibly support and sustain life. There is little to no basic information regarding lunar lava tubes and their properties. The information we have is the result of satellite imaging making it lack precision which is vital to understand specific details, such as composition, radiation levels, gravity, amount of pressure, and if the lava tube could sustain the life of a future colony. *Chubby Cube* and *Shell-Razor* aim to gather numerous readings from the exit of the orbiter unto contact with the lava tube itself. While compromising for only two objectives may take away some precision of measurement, the understanding of the known lunar lava tube on the North Pole may benefit by diversifying experiments. Finding the average temperature, pressure, gravity, and amounts of radiation will help better understand if this lava tube could support and sustain life. Determining the composition of the floor of the lava tube will help in many ways. Finding the composition will help understand if life can be supported by the lava tube due to the fact that if the ground are made of radioactive materials it will be detrimental to survival. We also want to determine if the composition of the lava tubes can aide in protection from the harmful radiation of space. If the lava tube contains diamonds, gold, silver, or other precious metals/materials, they could be mined to use on Earth. *Chubby Cube* and *Shell-Razor* complement each other very well due to the fact that if one malfunctions the other can still take readings and send data back for further research. *Shell-Razor* may only take one reading while *Chubby Cube* will take numerous readings.

Table 1. Science Objective Trade Study

FOM	Weight	Geologic Activity		Gravity/Magnetosphere		Lava Tubes/Organic Volatile Materials	
		Raw Score	Weighted	Raw Score	Weighted	Raw Score	Weighted
Interest of Team	9	3	27	1	9	9	81
Applicability to other Science Fields	1	3	3	1	1	9	9
Mission Enhancement	1	3	9	9	9	9	9
Measurement Method	9	9	81	1	9	9	81
Understood by the Public	9	9	81	3	27	3	27
Creates Excitement in Public	3	3	9	1	3	9	27
Ramification of the Answer	3	3	9	1	3	9	27
Justifyability	1	3	3	1	1	9	9
Total			222		62		270

Table 2. Science Traceability Matrix

Science Objective	Measurement Objective	Measurement Requirement	Instrument Selected
Environment and Properties	-Temperature -Radiation -Pressure -Gravity	-In Marius Hills Skylight Lava Tube on North Pole -Constant temperature, gravity, and radiation readings until probe hits the bottom	-Geiger Counter -Thermocouples -IMU
Composition	- Det. Composition of lava tube floor	-In Marius Hills Skylight Lava Tube on the North Pole - One time reading after penetration and/or skim of lava tube floor	-Mass spectrometer

Table 3. Instrument Requirements

Instrument	Mass (kg)	Power (W)	Data Rate (Mbps)	Dimensions (cm)	Lifetime	Frequency	Duration
Geiger Counter	0.368	6	2.4	14.3 x 8.3 x 3.5	From entry of skylight to destination	Continuous	Continuous
IMU	0.013	0.22	0.160	2.2 x 2.4 x 0.3	From entry of skylight to destination	Continuous	Continuous
Thermocouples	0.007	N/A	1.0×10^{-4}	33	From entry of skylight to destination	Continuous	Continuous
Mass Spectrometer	0.230	1.5	22.4	0.45 x 0.50 x 0.80	From entry of skylight to destination	1 Time Reading	N/A

Table 4. Support Equipment

Component	Mass (kg)	Power (W)	Data Rate	Other Technical Specifications
On-Board Computer	0.094 (double)	0.4 (double)	2 X 2 GB onboard storage	ISIS On Board Computer 400 MHz, ARM9 processor
Transceiver	0.085 (double)	1.7 (double)	Up to 9600 bps downlink; up to 1200 bps uplink	ISIS VHF/UHF Duplex Transceiver
Antenna	0.100 (double)	0.02 (double)	(See above)	Deployable Antenna System
Batteries	0.359	143.52 W-hr	N/A	400 kg/W-hr

Our project requirements include a maximum mass of 10 kilograms, a stowed volume of 44cm x 24cm x 28cm, survive environment, and do not harm to the main spacecraft. The functional requirements were to deploy, measure, collect data, send data, provide power, and house the payload. The environmental requirements are for the Marius Hill Skylight. They include a temperature of less than -247 ˚C, pressure of 1 x 10^{-8} Pa, gravity greater than 1.62 m/s^2, and radiation of no more than 0.463 milliservants per hour. The average human is subjected to approximately 3 milliservants per year.

3.0 Payload Alternatives

Team Mo.L.T.E.N. designed four alternative concepts in order to find any fault with the initial design that may be addressed more efficiently and effectively than was before. All concepts were designed to meet the requirements mentioned above.

Figure 1. Probe 1, Concept 1

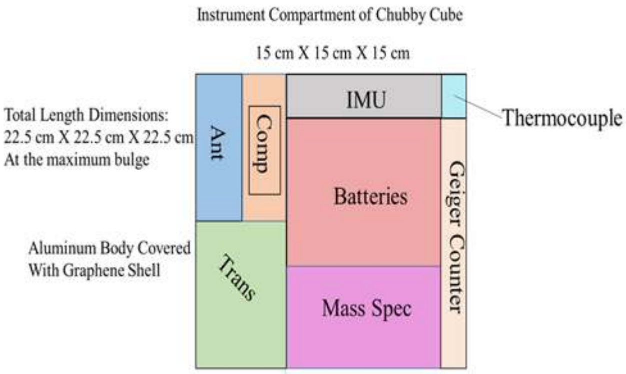


Figure 2. Probe 1, Concept 2

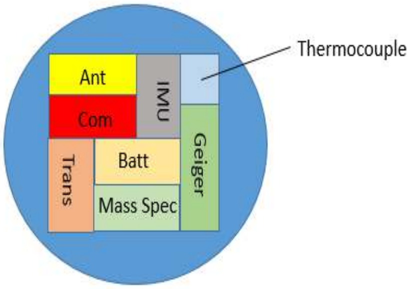


Figure 3. Probe 2, Concept 1

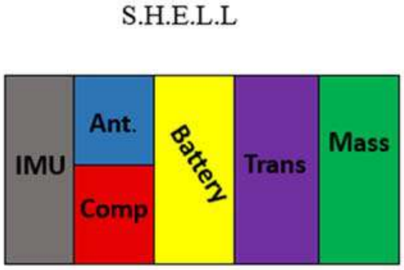
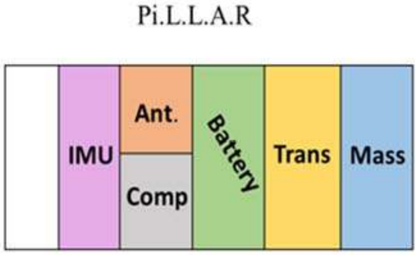


Figure 4. Probe 2, Concept 2



4.0 Decision Analysis

Upon refining the four concepts, the design team put them through the Decision Analysis Tables below. The team concluded that the Science objective, likelihood project requirement, likelihood mission success, instrument protection, and durability were the most important FOM's (figure of merit) because without meeting them the mission could not proceed successfully as planned.

For probe one, we found many problems with *L.E.N.S.E.*, including how the probe struggle with protecting our science instruments, the higher possibility of it be stranded on the lunar surface, and we as a team neglected the fact that there is no air resistance on the Moon when designing *L.E.N.S.E. Chubby Cube's* positives outweighed its negatives because although it may weigh more and be bulkier than *L.E.N.S.E.* it is durable, more mobile, and has a higher possibility of carrying out our mission. *Chubby Cube* scored higher than *L.E.N.S.E.* in the areas that we as a team decided were the most vital to ensure our mission's success.

Table 5 Payload Decision Analysis for Probe 1

FOMs	Weight	L.E.N.S.E.		Chubby Cube	
	1, 3, or 9	Raw Score	Weighted Score	Raw Score	Weighted Score
Science Objective	9	3	27	9	81
Likelihood Project Requirement	9	9	81	3	27
Science Mass Ratio	3	1	3	3	9
Design Complexity	1	9	9	9	9
ConOps Complexity	3	1	3	9	27
Likelihood Mission Success	9	1	9	9	81
Manufacturability	3	3	9	9	27
Deployment	1	9	9	9	9
Durability	3	1	3	9	27
Instrument Protection	9	1	9	9	81
TOTAL			**162**		**378**

Table 6 Payload Decision Analysis for Probe 2

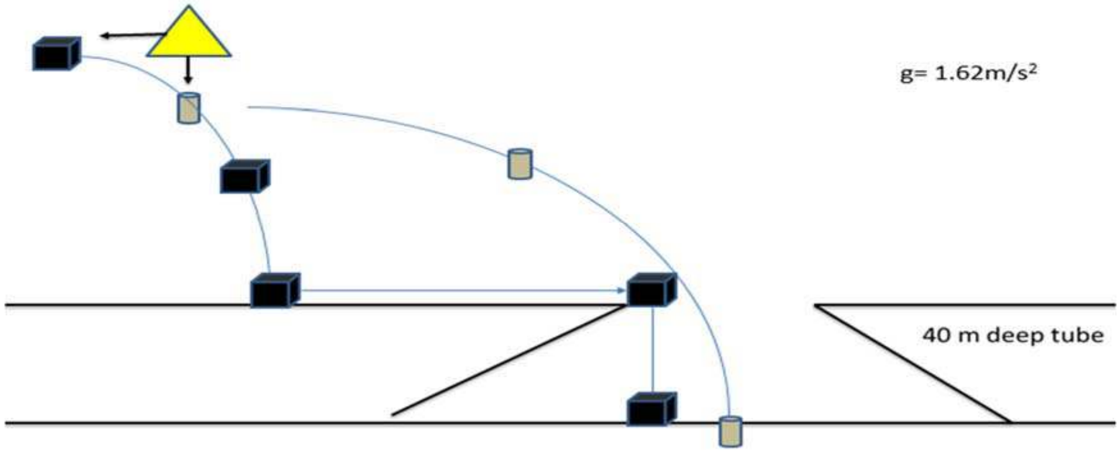
FOMs	Weight	S.H.E.L.L.		Pi.L.L.A.R.	
	1, 3, or 9	Raw Score	Weighted Score	Raw Score	Weighted Score
Science Objective	9	3	27	3	27
Likelihood Project Requirement	9	9	81	9	81
Science Mass Ratio	3	3	9	3	9
Design Complexity	1	1	1	3	3
ConOps Complexity	3	1	3	3	9
Likelihood Mission Success	9	9	81	9	81
Manufacturability	3	3	9	9	27
Penetrability	3	9	27	3	9
Durability	9	3	27	1	9
Deployment	3	3	9	3	9
TOTAL			**274**		**264**

When designing what essentially will be our one shot missile in order to take a deep sub-surface composition reading in the lava tube, we went for more of a stylish look to match an acronym rather than a design that would just serve its purpose. *S.H.E.L.L.* would have a shorter body than that of its counterpart and would have a harpoon shaped tip. *Pi.L.L.A.R.* would be nearly identical to the three-dimensional shape known as an obelisk. We wanted both probes to be housed in a retracted state on the orbiter which could lead to many malfunction issues. *S.H.E.L.L.* was going to have a tip that bloomed after impact with the lava tube in order to expose our instruments to the lunar regolith. This could lead to several mechanical malfunctions. *Pi.L.L.A.R.* would be hard to rifle during deployment due to its squared shape. After plugging in our scores for each design into the Payload Decision Analysis, we noticed how close the final scores actually were. The design team then collaborated in order to find a solution to this issue. After careful deliberation, the idea to combine parts of both *S.H.E.L.L.* and *Pi.L.L.A.R.* was brought before the entire team. After more discussion, we decided to put the body of *S.H.E.L.L.* with a conic version of the tip of *PI.L.L.A.R.* along with its length advantage into this new design, thus *Shell-Razor* was born.

5.0 Payload Concept of Operations

Both of our probes will begin the mission on the orbiter and then will be de-orbited to the Moon's surface. However, this will be the only similarity in their journey until they reach their final destination in the depths of the Marius Hills skylight. *Chubby Cube* will be deployed backwards from the orbiter in order to achieve a smaller impact angle so it may skip across the lunar surface, steadily decelerating, before finally falling into the lava tube. While floating through the lava tube, *Chubby Cube* will take numerous readings before finally resting at the bottom. Once there, it will take a surface composition reading, and then its mission will be complete. *Shell-Razor* will be rifled downward from the orbiter in order to achieve a steeper impact angle therefore it can penetrate into the ground in the depths of the lava tube. Once it has plummeted the 100 kilometers into the ground of the lava tube, *Shell-Razor* will take one deep, sub-surface composition reading, and then its mission will also end.

Figure 5 Concept of Operations for Deployment



6.0 Engineering Analysis

After the decision analysis *Chubby Cube* was chosen and we decided to combine the strong aspects of *S.H.E.L.L.* and *P.I.L.L.A.R.* to form *Shell-Razor*. Deployment from the orbiter for both probes will be achieved by two separate means. *Shell-Razor* will be deployed through a tube downward and *Chubby Cube* will be deployed through a tube backward from the orbiter. These decisions were made to allow for the probes to reach the Marius Hills Skylight at the appropriate angle, velocity and location. Deployment downward allows for *Shell-Razor* to penetrate the surface. By deploying *Chubby Cube* backward, we will reduce its velocity and allow for it to skip the surface and slow to a velocity that is conducive to tumbling down the path of the lava tube.

The analysis on engineering proceeded. *Chubby Cube* was determined to be more likely to survive the impact due to its shape and *Shell-Razor* allowed for a more durable and controlled penetration. *Shell-Razor* has a possibility of failure due to its impact velocity. We determined the impact angle to be slightly greater 20 degrees which is critical to it penetrating the lave tube and not skipping the surface. The opposite is true for *Chubby Cube*. It must strike the surface at an angle less than 20 degrees in order to reach a velocity of 1m/s before plunging into the Marius Hill Skylight. The g-load for *Shell-Razor* is also of concern due to the velocity at impact. Due to these concerns, we decided to add a mass spectrometer to *Chubby Cube* to allow for analysis of the composition deep in the lava tube.

When considering the mass requirement, adjustments were made to allow for the combination of the suggested probes into *Shell-Razor*. *Chubby Cube's* mass was to remain as planned, therefore the design for *Shell-Razor* had to meet the available mass. The tungsten tip was kept due to its strength. This also led to the choice to use Aluminum 2014 which had a lower mass than the previous material suggested.

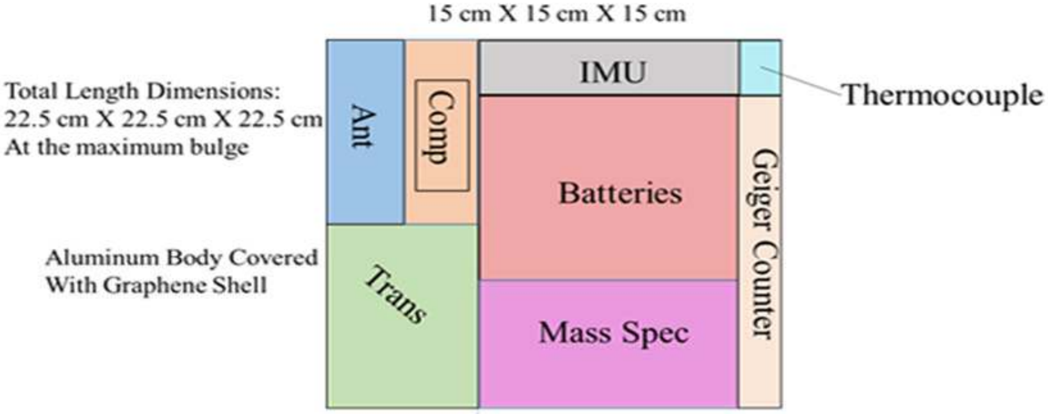
Sufficient power to run all support and required components was considered. We decided to use batteries with a 12 hour life-span to allow for extra reading although the mission duration is small. We have included a total of 143.5 Watt hours to be used by both probes. This will provide needed power for all instrumentation for the life of the mission and to meet our ending conditions.

7.0 Final Design

The final designs chosen by team Mo.L.T.E.N. were *Chubby Cube* and *Shell-Razor*. *Chubby Cube* and *Shell-Razor* ride with the UAH orbiter to the Moon, and are both deorbited from the orbiter to the Marius Hills Skylight on the North Pole of the Moon by using helium provided by UAH. After deployment, *Chubby Cube* will skip the lunar surface until entrance of the skylight and take numerous temperature, pressure, radiation, and gravity readings throughout its journey in the lava tube until it comes to a rest at the bottom. Once there, the probe will take a surface composition reading, then it will send all data collected back to the orbiter, which in turn will be transmitted to Earth. Once deployed, *Shell-Razor* will plummet from the orbiter into the depths of the lava tube. Upon impact with the bottom of the lava tube, if *Shell-Razor* survives this impact, it will then take a one-time deep sub-surface composition reading to compare to *Chubby Cube's* surface composition reading. Then (assuming survival), *Shell-Razor* will transmit this data to the orbiter, which will be sent to Earth.

Figure 6. Mo.L.T.E.N.'s Final Payload Designs

Instrument Compartment of Chubby Cube



Shell-Razor

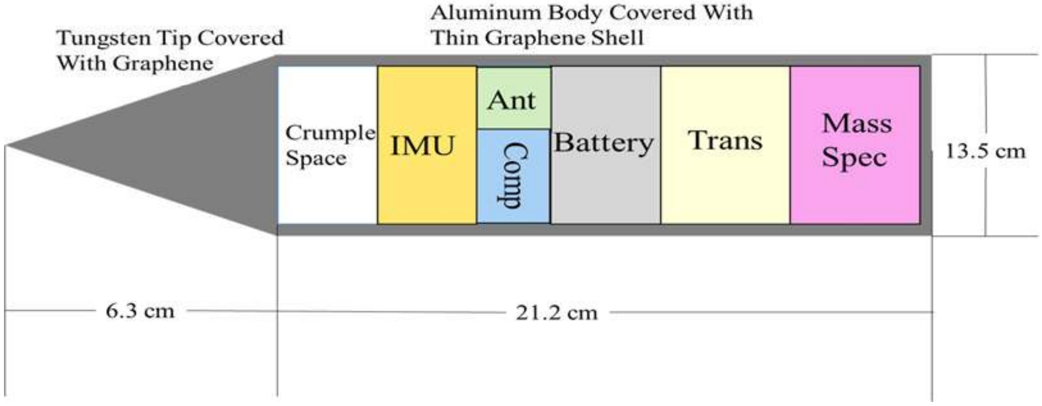


Table 7. Final Design Mass Table

Function	Component(s)	Mass (kg)
Deploy	Aluminum 2014 Tubes	1.06
Measure	Science Instruments	0.863
Collect Data	Computer	0.188
Provide Power	Batteries	0.359
Send Data	Transceivers, Antenna	0.37
House/Contain Payload	Payload Materials	6.35
Total		9.19