"Ice Ice Baby"

PAYLOAD CONCEPT PROPOSAL

Team I.C.E.

Vinemont High School

Team 1

1.0 Introduction

We are Team I.C.E. (Investigating a Cold Environment) from Vinemont High School. We were presented with the L.A.S.E.R. Mission (Lunar Analysis and Sampling for Exploration and Research) by the University of Alabama in Huntsville. We were challenged to develop and design an autonomous payload for a UAH-designed spacecraft that accomplishes a science objective to complement the L.A.S.E.R. Mission. A payload is a collection of instruments on board a spacecraft required to provide data to answer a specific scientific question. The L.A.S.E.R. Mission is focused on Earth's moon. UAH provided us with multiple science objectives from which we could choose for our mission, and we chose water-ice. Water-ice is frozen water at the bottom of craters on the moon. We chose our team name because it relates to our mission's objective of the study of water-ice. The bottom of the craters remain cold because the sun's light on the moon's south pole does not reach the bottom of the permanently shadowed craters. Our slogan is *"Ice Ice Baby"* as a pun referencing the song from 1990 by Vanilla Ice, "Ice Ice Baby." Since we are investigating water-ice, we named our payload Snowball.

2.0 Science Objective and Instrumentation

We chose from three candidate science objectives--lava tubes, internal structure, and water-ice. In our Science Objectives Trade Study (Table 1,) UAH provided us with 8 Figures of Merit (FOMs) which are factors that helped us decide which science objective on which we would base our mission. They also provided us with the weight scores. Together our team rated each FOM with a raw score of 1, 3, or 9--1 being the least important, 3 being of medium importance, and 9 being the most important. We then multiplied our raw scores by the weight scores that were provided to us by UAH to get our weighted scores. We added up all the weighted scores for each candidate science objective, and we chose water-ice because it had the highest total weighted score of 246. Consequently, our science objective is based on water-ice. Water-ice is important because in order to live anywhere, water is imperative. We will be finding the abundance, location, and composition of the water-ice on the moon. In order to find the composition of water-ice, we will be using a mass spectrometer. We will also need a thermocouple for temperature, pressure transducer for measuring the pressure, and a magnetometer for measuring the magnetism.

Table 1. Science Objective Trade Study

Figure of Merit	Weight	Water-Ice		Lava Tubes		Internal Structure	
		Raw Score	Weighted	Raw Score	Weighted	Raw Score	Weighted
Interest of Team	9	9	81	3	27	3	27

Applicability to other science fields (broadness)	1	3	3	1	1	3	3
Mission Enhancement	1	9	9	3	3	3	3
Measurement Method (easy to obtain)	9	3	27	3	27	9	81
Understood by the Public	9	9	81	9	81	3	27
Creates excitement in the public ("wow factor")	3	9	27	9	27	9	27
Ramification of the answer	3	3	9	3	9	3	9
Justifiability (nice, neat package), (self-consistent)	1	9	9	3	3	3	3
TOTAL			246		178		180

Table 2. Science Traceability Matrix

Science Objective	Measurement Objective	Measurement Requirement	Instrument Selected
Water-Ice	- Abundance - Location - Composition	- Deploy from orbiter - Minimum of 2 probes	- Mass spectrometer for composition - Thermocouple - Pressure transducer - Magnetometer

Table 3. Instrument Requirements

Instrument	Mass (kg)	Power (W)	Data Rate (Mbps)	Dimensions (cm)	Lifetime	Frequency	Duration
Mass Spectrometer	0.230	1.5	22.4	0.45 x 0.50 x 0.80	1 hr	10 min	2 min
Thermocouple	0.020/ meter	N/A	$1.0 \times 10^{(-4)}$	wire (length TBD)	1 hr	10 min	2 min

Pressure Transducer	0.131	0.04	1.0	2.2 cm dia x 8.6 cm length	1 hr	10 min	2 min
Magnetometer	0.05	1.5	0.0008	2.1 x 1.9 x 0.8	1 hr	10 min	2 min

Table 4. Support Equipment

Component	Mass (kg)	Power (W)	Data Rate	Other Technical Specifications
On-Board Computer	0.094	0.4	2 x 2 GB onboard storage	On Board Computer 400 MHz, ARM9 processor
Transmitter /Receiver	0.085	1.7	Up to 9600 bps downlink; up to 1200 bps uplink	VHF/UHF Duplex Transceiver
Antenna	0.100	0.02	Up to 9600 bps downlink; up to 1200 bps uplink	Deployable Antenna System
Batteries	0.01	N/A	N/A	Mass calculated by each team, based on power requirements

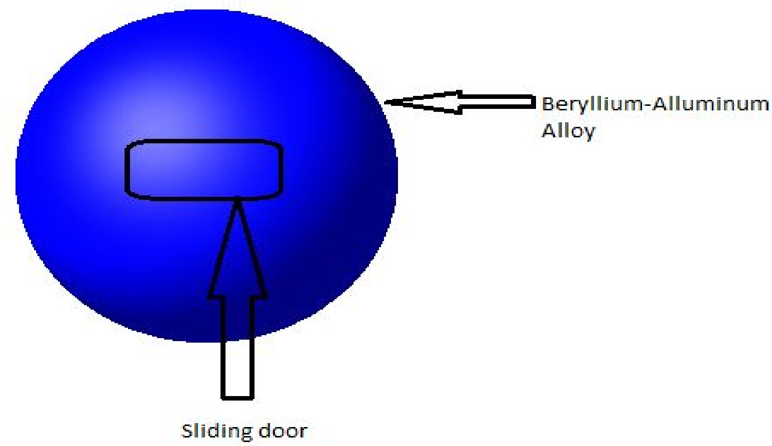
3.0 Payload Design Requirements

We were given six payload design requirements by UAH. We must deploy from the UAH spacecraft, take measurements, collect data, send data, provide our own power, and house the payload. They also gave us four payload constraints. First, the mass cannot exceed 10 kg. Second, the volume when stowed cannot exceed 44 cm by 24 cm by 28 cm. Third, it cannot cause any harm to the main UAH spacecraft. Finally, it has to survive the moon's environment. Temperatures on the moon are as high as 123℃ and as low as -153℃. The moon's pressure is 2.961×10^{-15} atm. Since there is no atmosphere on the moon, cosmic rays and solar flares are very harsh on its surface. Our payload is required to survive these harsh conditions on the moon.

4.0 Payload Alternatives

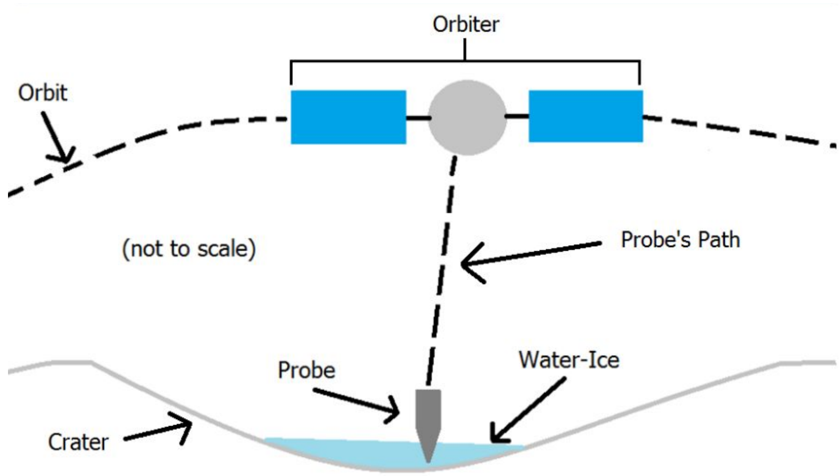
Our team designed two concepts. We named our first concept, Snowball. Using Snowball, we will be deploying two probes backwards from the UAH orbiter to de-orbit to the lunar surface. Each probe has a different crater as a target. These probes will be deployed at a 3° angle to allow them to "bounce" into the center of a crater. Inside the probes, the instruments will be put on one side to make the probe top heavy allowing the probe to stop on the side of the instruments. Once stopped, the small door will slide open and allow the instruments to make contact with the moon's surface and start taking measurements of the abundance, location, and composition of the surrounding area. After 12 minutes of taking measurements, the probe will send data back to the orbiter, and it will send data back to Earth. The probe will then shut off.

Figure 1. Concept 1 (Snowball)



Our second concept is called Snow Cone. The probe's design is a hollow cylinder with a solid cone top. The cylindrical body of the probe is where all of our instruments would be housed. This design would have 2-3 probes, and it would launch from the orbiter into our target craters on the south pole of the moon. The probe would partially bury itself into the surface of a crater, then the cylinder would open up, allowing the instruments to be exposed to the surface of the crater. The instruments then take measurements of the surrounding soil, checking for water-ice as well as atoms of hydrogen and oxygen. When it is finished taking measurements, the probe would send all of the data it collected back to the orbiter, which would then send the data back to Earth. After the probe sends the data to the orbiter, it will then shut off, or "die silently," and remain inanimate in the bottom of the crater.

Figure 2. Concept 2 (Snow Cone)



5.0 Decision Analysis

We evaluated the Figures of Merit (FOMs) displayed in Table 5. UAH provided the team with seven FOMs to evaluate, and the team created an additional three. These three figures were quantity of data collected, durability, and accuracy. We chose these three FOMs because we wanted to get as much data as possible. Our probes need to be durable because we want our probes to survive the impact experienced when hitting the surface of the moon. Accuracy is important because we are trying to land in craters. If we are not accurate and miss the craters, we will be unable to complete our science objective. The FOMs were evaluated on a scoring scale of 1, 3, or 9; 1 being the least important, 3 being of medium importance, and 9 being the most important. To determine the total points, the team multiplied each weight number by the concept's raw score. The resulting sums were added together to find the highest scoring concept, which was Snowball with a score of 450.

Table 5. Payload Decision Analysis

Figure of Merit	Weight	Group 1 Concept "Snowball"		Group 2 Concept "Snow Cone"	
		Raw Score	Weighted	Raw Score	Weighted
Science Objective	9	3	27	9	81
Likelihood Project Requirement	9	9	81	3	27
Science Mass Ratio	3	9	27	3	9
Design Complexity	3	3	9	3	9
ConOps Complexity	3	3	9	3	9
Likelihood Mission Success	9	9	81	9	81
Manufacturability	3	9	27	3	9
Quantity of Data Collected	9	9	81	3	27
Durability	9	3	27	9	81
Accuracy	9	9	81	3	27
TOTAL			450		360

6.0 Payload Concept of Operations

In our mission, we will be starting on the orbiter which will be assumed to be at a perfect 100 km circular polar orbit around the moon. Our targets are two craters on the surface of the moon: Shackleton and Shoemaker. To begin our mission, we will deploy backwards from the orbiter from a barrel to de-orbit to the surface of the moon. Upon impact of the surface, our probes will skip along the bottom of the crater to a stop. When the probe stops, it will open a small door to allow the instruments to touch the surface. Once exposed, the instruments will begin taking samples of the composition, pressure, and temperature of the lunar surface. Our two probes will be on the moon taking measurements for a total time of 12 minutes before shutting down.

7.0 Engineering Analysis

After the evaluation of the Figures of Merit, we made the decision to deploy "Snowball." There are several other evaluations that were calculated for I.C.E.'s engineering analysis. These certain evaluations would be that of calculating the initial conditions, deployment from the UAH spacecraft, payload trajectory, ending conditions, and required battery mass. These calculations can be observed in Table 6.

Table 6. Engineering Analysis Calculations

	Assumptions	Equation & Answer	Variables Explained
Initial Conditions	• Perfect Circular Orbit • Payload is Stationary	$v = \sqrt{\frac{GM}{r}}$ v = 1633 m/s	$G = 6.67 \times 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$ $M = 7.34767309 \times 10^{22}$ kg r = 1,837,400 m
Deployment	• No friction • Gravity neglected • Perfect fit	$v_f^2 = v_i^2 + 2ad$ $v_f = 16$ m/s	$v_i = 0$ m/s $a = 333.03794149\ m/s^2$ d = 40 cm
Trajectory	• No drag • Constant gravity	$v_{fy}^2 = v_{iy}^2 + 2ad$ $v_{f,y} = 569$ m/s	$v_{i,y} = 0$ m/s $a = 1.62\ m/s^2$ d = 100,000 m
Time of Flight	No Assumptions	$v_f = v_i + at$ t = 351 s	$v_f = 569.2$ m/s $v_i = 0$ m/s $a = 1.62\ m/s^2$
Ending Conditions	• Probe comes to a stop at 100 m	$v_f^2 = v_i^2 + 2ad$ $a = 1619\ m/s^2$	v = 0 m/s v = 569.2 m/s d = 100 m

G-load	No Assumptions	$g - load = \frac{a}{g_{Earth}} = \frac{a}{9.81}$ g-load = 165 G's	a = 1619.9432 m/s^2
Batteries	No Assumptions	$\frac{ab + cd + ef + ...}{400\frac{W\cdot hr}{kg}}$ m = 2.33 g	ab = Power X Operational Time

8.0 Final Design

The final design of our payload is a spherical probe. Initially, the team wanted to send four probes to four different craters. Further into the design process, we realized we could have only two. After we calculated the mass of the beryllium-aluminium alloy shell and added the masses of all the instruments, the weight limit of 10 kg was exceeded with four probes. The probes will begin on the orbiter. As they orbit around the moon, they will deploy backwards, causing the probe to de-orbit to the moon's surface and land inside each of the two craters we chose, Shackleton and Shoemaker. Once the probes come to a stop, a door is going to slide open and our instruments are going to be able to take their measurements. After the probes are finished taking the temperature, pressure, and composition of the surrounding area, the data will be sent back to the orbiter and then to Earth. Finally, they will permanently shut off.

Figure 3. Team I.C.E.'s Mission

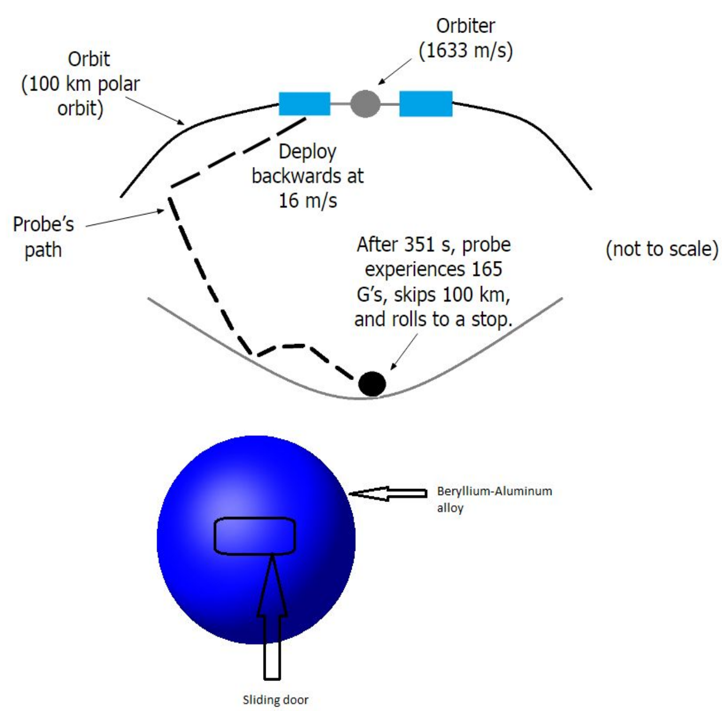


Table 7. Final Design Mass Table

Function	Component(s)	Mass (kg)
Deploy	Helium pressure through barrel	3.74244
Measure	Mass Spectrometer Thermocouple Pressure Transducer Magnetometer	2.526
Collect Data	On-Board Computer	0.564
Provide Power	Batteries	0.02
Send Data	Transmitter/Receiver, Antenna	1.11
House/Contain Payload	Beryllium-Aluminum Alloy	1.98632
Total		9.94876