Payload Concept Proposal

M.A.R.E

Let's get Kraken!

Vinemont High School

Team Two

1.0 Introduction

Titan, Saturn's largest moon, is the only moon in the solar system with clouds and a dense, planet-like atmosphere. Scientists believe that Titan has an atmosphere much like Earth's. It also has an orange hue, due to its dense atmosphere, which is composed of 98.4% nitrogen, 1.4% methane, and 0.2% hydrogen. This atmosphere prevented scientists from understanding what the surface was like on Titan until NASA sent a Cassini-Huygens probe to Titan and discovered hydrocarbonic lakes. UAH will be sending a spacecraft to Titan on which Team M.A.R.E.'s payload will travel to collect atmospheric and environmental measurements. Each of the InSPIRESS teams were given the option to choose two instruments from the list. One surface and one atmospheric instrument, provided by UAH. The teams are to deploy a high altitude balloon into the atmosphere from a lake based lander, which will be 200 kilometers off the shore of Lake Kraken Mare, using one of the instruments chosen by Team M.A.R.E. The team will also deploy a penetrator into the surface of Titan to measure subsurface temperature and heat flow. It will take approximately 9 to 15 years to travel from Earth to Titan, and the lifetime of the mission is to be determined by each individual InSPIRESS team. Team M.A.R.E (Measuring the Atmosphere and Researching the Environment) chose to use an acronym for their name because they will be measuring the atmosphere as well as researching the environment. They derived the slogan Let's Get Kraken from the lake on which Team M.A.R.E will be landing, Lake Kraken Mare.

2.0 Science Objective and Instrumentation

Team M.A.R.E's science objectives are to measure electric fields in Titan's troposphere to determine if they have any connection with the weather. The team will also study the features of Titan's surface at 10 meters resolution or higher. Team M.A.R.E believes that it is important to measure the electric fields in the troposphere because they want to see if the fields have any connection with the weather on Titan. To do this, the team will use the Titan Electromagnetic Environment Package. This instrument will be on constantly and it will be searching for charged electrons in the atmosphere. The package will be positioned under the balloon. In order to observe Titan's surface, Team M.A.R.E chose the Visible Imaging System. The Visible Imaging System will take constant video of the surface in order to map the geographic features of Titan. Team M.A.R.E believes that it is important to map Titan's surface because they think that new observations of the geography will contribute to the overall success of the mission. Both the atmospheric and environmental instruments will be located under the balloon. Team M.A.R.E will have thermocouples on the penetrator, which will be recording temperatures of the upper surface on Titan.

Table 1. Balloon Science Traceability Matrix

Science Objective	Measurement Objective	Measurement Requirement	Instrument Selected
Measure electric fields in the troposphere and determine connection with weather; search for induced or permanent magnetic field	Atmosphere	Must be located in the atmosphere	Titan Electromagnetic Environment Package
Detailed geomorphology at 10m resolution and higher in selected areas	Surface	Must be able to directly view the surface	Visible Imaging System

Table 2. Penetrator Science Traceability Matrix

Science Objective	Measurement Objective	Measurement Requirement	Instrument Selected
Research the upper surface	Measure Internal Temperature	Must be at least 40 centimeters below the surface	Thermocouples

Table 3. Balloon Instrument Requirements

Instrument	Mass (kg)	Power (W)	Data Rate (Mbps)	Lifetime	Frequency	Duration
Electromagnetic Environment Package	.5	3.5	$3.6x10^{-6}$	36 hours	Constant	Constant
Visible Imaging system	2	5.0	$7.8x10^{-5}$	36 hours	Constant	Constant

Table 4. Penetrator Instrument Requirements

Instrument	Mass (kg/m)	Power (W)	Data Rate (Mbps)	Lifetime	Frequency	Duration
Thermocouple	.02kg/m	NA	.0001	16 days	Constant	Constant

3.0 Payload Design Requirements

UAH gave Team M.A.R.E. certain criteria they had to meet for their mission to be a success. First, the project requirements which include the following items: having a mass that is equal to or less than 15 kg, a volume that is equal to or less than 44cm x 48cm x 28cm, as well as maintaining an internal temperature of 294K. Second, the payload design included having absolute power and connection with the UAH spacecraft, and it must cause no harm to the UAH spacecraft. They also had to have the ability to send and retrieve data. Third ,environmental requirements. Team M.A.R.E will have to survive the harsh temperatures of Titan, which are 94.3K, or -290 degrees fahrenheit. Also, they have to withstand the pressure, which on Titan is 1.5 times that on Earth. Titan also collects radiation from Saturn's radiation belt and does not release it because of how dense the atmosphere is. They must also withstand the hydrocarbonic winds that blow at two-hundred seventy miles per hour and consider a g-load of 1.352 meters per second. Overall, Team Mare has to be able to house the payload and provide power to take measurements, collect data, and send the data back.

4.0 Analysis of Alternatives

After the team was given the requirements by UAH, they developed a plan as to how they would meet and exceed the requirements. The requirement for Focus Area One was that the balloon had to reach a minimum of 200 km horizontally. UAH also gave the team a choice of 3 balloon sizes and 3 payload sizes. Using these choices they had to create at least 3 different alternatives. The first Alternative was a balloon with a mass of 3,000g and a payload mass of 3kg. The second Alternative was a balloon with a mass of 600g and a payload mass of 15kg. This Alternative, however, turned out to have many problems. The neck lift was not strong enough to carry the weight of the payload, so Team M.A.R.E did not give it much consideration when making the final decision. The third Alternative was a balloon with a mass of 1,200g and a payload mass of 8kg. After further review of the individual characteristics of each Alternative, a final decision was made as to which Alternative the Team would use.

The Team took the same initiative with Focus Area Two. The requirement for this area was that the penetrator must take measurements at a depth of at least 40cm. UAH gave the team 3 diameter choices and 3 mass choices for the penetrator as a guide to help them better understand how the different masses performed when given a different diameter. Team M.A.R.E considered the choices given to them but decided to create their own mass and diameter after reviewing how their three chosen alternatives performed. None of the three Alternatives functioned quite as well as they wished, which led to the development of the fourth Alternative. The fourth Alternative had a mass of 6.349kg and a diameter of .06m which enabled it to penetrate the surface up to 50 cm.

Table 5. Focus Area #1 Results

Alternative	Neck Lift (g)	Balloon Size (g)	Payload Mass (kg)	Burst Altitude (km)	Ascent Rate (m/sec)
#1	18,750	3,000	3	100-150	1.01
#2	6,750	600	15	40-50	2.68
#3	14,000	1,200	8	60-70	2.18

Table 6. Focus Area #2 Results

Alternative	Penetrator Mass (kg)	Penetrator Diameter (m)	Starting Altitude (km)	Surface Depth (m)
#1	0.75	0.05	70	1.05
#2	2.5	0.075	35	.95
#3	5	0.125	135	1.56
#4	6.349	0.06	100-150	.49

5.0 Decision Analysis

The decision regarding the Alternative with which the team will continue forward into the mission, very well could be the most important decision chosen in the project. All dependance and faith will reside in the one chosen alternative. For this to be such an important decision, precautions must have been present in the decision. The team took precautions and gave precise scores for each alternative in 7 different and very important categories called FOMs or, Figures of Merit. The score indicators were a 1,3, and 9. In the Preference column, a 1 represents low importance, a 3 represents medium importance, and 9 represents high importance. In relation to how crucial each FOM was to the mission. All things other than the Likelihood of Meeting the Project Requirements and Likelihood of Mission Success were given scores lower than a 9 because the team believed that those two FOMs were the most critical to the project. In the three Alternative columns the same 1,3, and 9 indicators were used, although they have a slightly different representation. The numbers represent how well that Alternative met the team's desired Preference for each FOM. A 1 represented a low performance in meeting the team's desired preference, a 3 represented an intermediate performance in meeting the team's desired preference, and a 9 represented a high performance in meeting the team's desired preference. After all scoring was completed, the totals were determined by a process of multiplying each preference weight by the score indicator given for the Alternative's performance and adding each product for all FOM's for each Alternative. It was determined that Alternative 1 was the best decision for Focus Area #1.

As for Focus Area #2 they went with their own Alternative because they felt like they could better design a penetrator more suited to perform the task at hand.

Table 7. Focus Area #1 Decision Analysis

Figure of Merit	Weight	Preference	Alterative #1	Alternative #2	Alternative #3
Neck Lift	1	low	9	3	3
Balloon Size	3	medium	3	3	3
Payload Mass	3	medium	1	9	3
Burst Altitude	3	medium	9	1	3
Ascent Rate	3	medium	3	9	9
Likelihood of Meeting Project Requirements	9	high	9	1	3
Likelihood of Mission Success	9	high	9	1	3

Table 8. Focus Area #2 Decision Analysis

Figure of Merit	Weight	Preference	Alterative #1	Alternative #2	Alternative #3	Alternative #4
Penetrator Mass	3	medium	3	1	3	3
Penetrator Diameter	3	medium	3	3	3	3
Starting Altitude	1	low	1	3	1	3
Surface Depth	3	medium	3	3	1	9
Likelihood of Meeting Project Requirements	9	high	9	9	3	9
Likelihood of Mission Success	9	high	9	9	9	9

6.0 Engineering Analysis

For the team to make a conclusion on the final design for Focus Area One, multiple steps were taken. Before any further calculations could take place, the total flight time of the payload had to be calculated. To determine this, a simple calculation underwent. The team used the distance equation(d=v/t) and revised it to meet their needs. The team solved for time using the equation t=d/v. With the team's unique burst altitude in place for distance and their unmatched ascent rate substituting velocity, the team got an astounding flight time of thirty six hours. Once the total flight time was found the next step was to calculate the amount of space battery mass needed for the Titan Electromagnetic Environment Package, Visible Imaging System, and the other balloon instruments. After that was completed, the total mass for Focus Area One was determined by adding the mass of the balloon, the mass of all necessary instruments, the mass of the housing, and the determined amount of space batteries. Following all mass related calculations, the distance the balloon would travel horizontally was determined. In order to do this, the team used wind speed data previously collected by Huygens, and chose a range of low to high wind speeds for their burst altitude. The team calculated a low horizontal distance of 2,557 km from the shore and a high horizontal distance of 3,467 km. From this calculation the team agreed that they could release their penetrator anytime after 8 hours of flight and meet the project requirements for both the distance traveled from the center of the lake as well as penetration depth.

In order for the team to make a decision on their final design on Focus Area Two they had a number of steps to take. The first thing they had to accomplish was to determine the weight of the penetrator. In order to do that, they had to find the weight of space batteries and instrumentation. Once they found those, they gave the penetrator's payload housing enough mass to survive impact. Then they determined the diameter so they could calculate how far the penetrator would travel into Titan's surface. In order to calculate surface depth they used this formula

D(in meters)=.000018(surface penetrability number)(nose cone coefficient)(mass/cross-sectional area)^0.7(velocity-30.5)

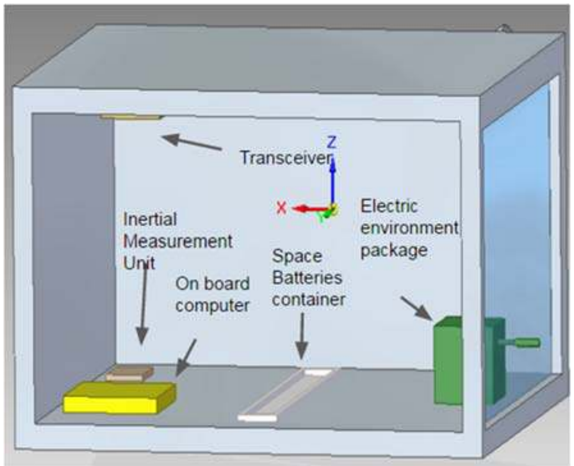
7.0 Final Design

Team M.A.R.E's final design will include a high altitude weather balloon that will reach a height of 132 km into the atmosphere while also traveling between 2,733 km and 5,551 km horizontally. The weather balloon will be attached to a payload housing, enclosing a Visible Imaging System, Titan Electromagnetic Environment Package, and penetrator. Both the Visible Imaging System and Titan Electromagnetic Environment Package will be collecting atmospheric and surface data for the entire 36 total hour flight time of the balloon. Once the balloon approaches burst altitude at 132 km, the penetrator will be released and after penetration will collect internal temperatures at 50 cm for 16 days. A vast amount of new data would be collected from this mission using the team's chosen instruments. The team believes their mission will be a great success and will contribute to scientific advancement better than any other combination of instruments.

Figure 1. Team M.A.R.E's Mission

Table 9. Final Design Mass Table

Function	Mass (kg)
Deploy	3.1
Measure	2.541
Collect Data	.188
Provide Power	3.015
Send Data	1.9
House/Contain Payload	4.256
Total	15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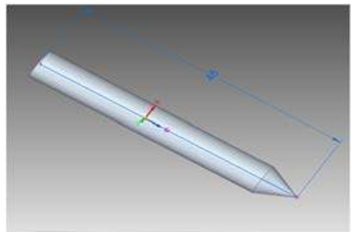

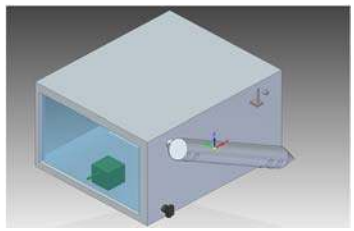

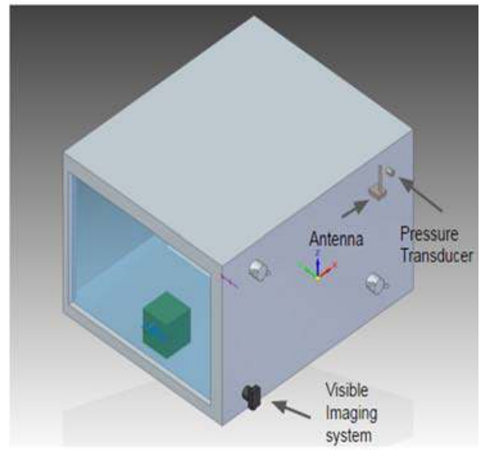
Antenna
Pressure Transducer
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