Payload Concept Proposal

A.I.M. AT Xanadu

"Reflecting its magnificence"

Da Vinci School for Science and the Arts

Da Vinci Team #2

1.0 Introduction

The University of Alabama in Huntsville has challenged the participants of the 2016 InSPIRESS program to design a scientific payload that accomplishes a science objective in Titan. Titan is the largest moon of Saturn. As of now, it is the only moon discovered to have a dense atmosphere, and the only space object other than Earth to have bodies of liquid on its surface. There is a feature of Titan however, that simply has not been investigated enough, and this area is known as Xanadu. Xanadu is an area distinguished by its high reflectivity, is located in the southern hemisphere of Titan, and is estimated to be about the size of Australia. Due to the endeavors of the 2004 Cassini mission, it was revealed that Xanadu possesses albedo patterns, but it is unclear what led to their formation. Going along with the previously stated, A.I.M. at Xanadu's two science objectives will be completed by the scientific payload the "Pocket Rocket" with a purpose to: research and determine the cause of high reflectivity of Xanadu, *and* to uncover the basis for the creation of albedo patterns. The slogan "Reflecting its magnificence" adheres to both the meaning of Xanadu (a place of magnificence and great beauty), and the fact that the surface of Xanadu is reflective.

2.0 Science Objective and Instrumentation

A.I.M. at Xanadu's first science objective is to investigate the reason behind Xanadu's high reflectivity. In order to research this, Xanadu's surface must be analyzed using the instrument known as a mass spectrometer, and then the relation of chemical composition to surface reflectivity will be measured. The second science objective – researching the creation of albedo patterns – actually stems from the first objective. The albedo patterns on Xanadu might very well be the reason as to why it has a reflective surface. In order to study the formation of albedo patterns, the seismic activity of Xanadu must be measured through tectonic patterns using an inertial measurement unit (IMU). The importance of these two science objectives becomes clear when one takes into account the reflective surface of Xanadu. Never before has a reflective surface (much less the size of Australia) been discovered in space, it is now the time to find out exactly what causes such a unique phenomenon.

Table 1. Science Traceability Matrix

Science Objective	Measurement Objective	Measurement Requirement	Instrument Selected
Investigate the cause for the high reflectivity of Xanadu	**Analyze the composition of Xanadu's surface**	**Chemical composition**	**Mass Spectrometer**
Uncover the basis for creation of albedo patterns	**Study Xanadu's seismic activity to determine the composition of its subsoil**	**Tectonic Patterns**	**Inertial Measurement Unit**

Table 2. Instrument Requirements

Instrument	Type	Mass (kg)	Power (W)	Data Rate (Mbps)	Lifetime (Hours)	Frequency	Duration (Hours)
Inertial Measurement Unit	P	0.01	0.22	0.16	384	Two stage	Two stage
Mass Spectrometer	P	0.23	~1.5	2.4	0.2389	Continuous	0.2389
Antenna	S	0.10	0.02	0.25	384	Two stage	Two stage
Transceiver	S	0.08	0.17	0.25	384	Two stage	Two stage
On-board Computer	S	0.09	0.40	16000	384	Continuous	Continuous
Space Batteries	S	0.17	N/A	N/A	384	Two stage	Two stage

3.0 Payload Design Requirements

A.I.M. at Xanadu's payload development process must take the following constraints into account in order to meet the design requirements.

Project Requirements
- Up to 10kg of mass
- Maximum Volume of 44cm x 24 cm x 28 cm
- Survive the environment of Titan
- No harm done to UAH spacecraft

Functional Requirements
- Deploy from UAH spacecraft
- Provide power for basic functions of the payload
- Take measurements of Titan
- Collect data from measurements
- Transmit data to UAH spacecraft

Environmental Requirements
- Temperature: ~93 K
- Pressure: 162120 Pa
- Gravity: 1.352 m/s²
- Radiation: Payload is protected by thick atmosphere
- Chemistry: Nitrogen (N_2) and Methane (CH_4)
- Wind: 90-180 m/s

4.0 Design Choices

In order to travel to Titan, the payload must meet six functional requirements:

- Deployment
- Taking Measurements
- Data Collection
- Provide Power
- Send Data
- House Payload

UAH has given the competitors various vehicle deployment methods in order to facilitate the design process of a payload. There were three options: descent from an orbiter, hitching a ride on a balloon and gondola, and lastly, emerging from a lake lander. Since the team specifically wishes to land on Xanadu, it was decided that descending from the UAH orbiter would be the best choice.

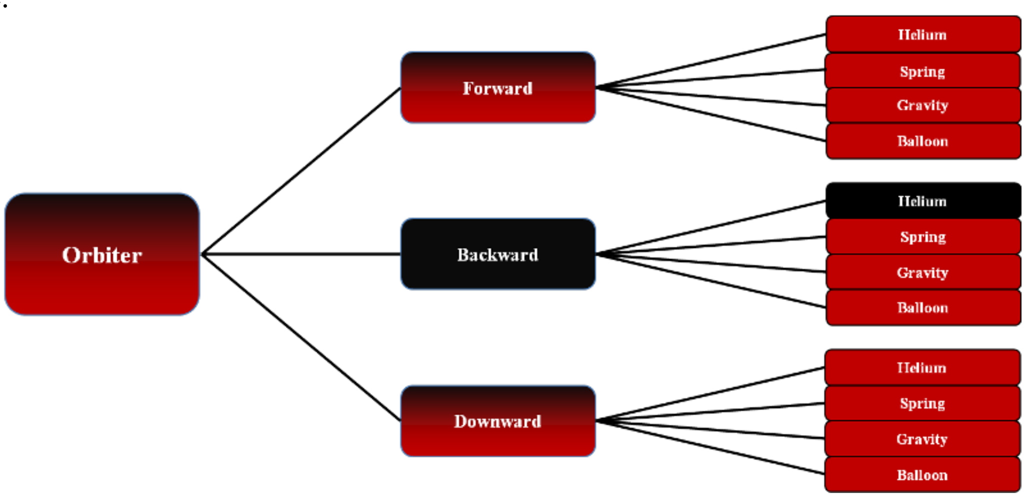

Figure 1. Mission Trade Tree

After the decision to be located within the orbiter, UAH then had the options of deploying, forward, backward, or downward using helium, a spring, gravity, or a balloon. A.I.M. at Xanadu decided to deploy backward in order for the payload to launch accurately into Xanadu. The team also decided upon using helium because it would be the easiest method to calculate, and at the same time, effective to the point of launching a probe into space. Figure 1 above denotes this by having "Backward" and "Helium" outlined by black. Moving on, the payload will take measurements from Titan using the mass spectrometer, and the inertial measurement unit. Afterwards, the data will be collected by the on-board computer, and sent to the UAH spacecraft with the antenna. Power to the payload will be provided by internal batteries, and the payload will be housed using a combination of: carbon fiber, titanium, and insulation foam. With all this being said, it is rest assured that A.I.M. at Xanadu meets the six functional requirements to carry on with the mission.

5.0 Preliminary Design

A.I.M. at Xanadu came up with two prototype designs, both designed to accomplish the same science objectives.

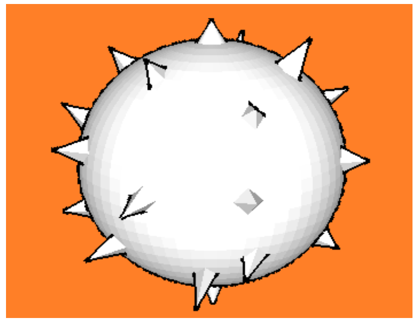

Figure 2. "Spike Ball"

The first design shown above in Figure 2, the "Spike Ball" is a spherical shaped probe with spikes beaming from its center as a source of stability to be used when landing on the surface of Titan. A sphere was chosen since the instruments could be kept well protected and insulated in the center.

Table 3. "Spike Ball" functional requirements

Function	Instrument
Deployment	Backward, Helium
Take Measurements	Mass Spectrometer, Inertial Measurement Unit
Data Collection	On-board computer
Power	Internal Battery
Send Data	Antenna, Transceiver
House Payload	Titanium Shell

The second concept shown in Figure 3 below, the "Pocket Rocket" is a more standard rocket shape, set to mimic the more conventional rockets sent into space by NASA. This shape was decided upon due to the ease of sending it out onto space. The nose cone-tip, and side fins, allows the rocket to minimize drag, and as a result, have a relatively stable flight towards Titan. By adding titanium to its tip, it is ensured that the rocket will land on the titanium, preventing any damage to the instruments held within.

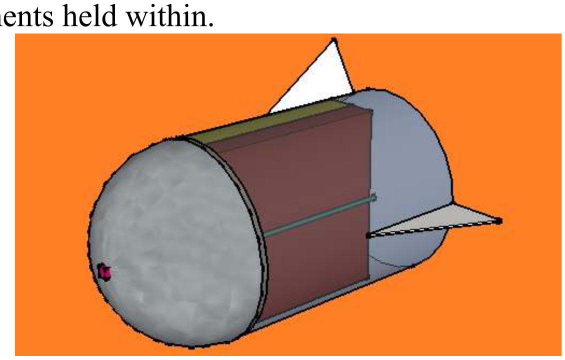

Figure 3. "Pocket Rocket"

Table 4. "Pocket Rocket" functional requirements

Function	Instrument
Deployment	**Backward, Helium**
Take Measurements	**Mass Spectrometer, Inertial Measurement Unit**
Data Collection	**On-board computer**
Power	**Internal Battery**
Send Data	**Antenna, Transceiver**
House Payload	**Carbon Fiber Shell, Titanium Tip**

6.0 Design Analysis

Table 5. Figures of Merit

FOMs	Weight	Spike Ball		Pocket Rocket	
	1, 3, or 9	Raw Score	Weighted Score	Raw Score	Weighted Score
~~Science Objective Success~~	~~9~~	~~9~~	~~81~~	~~9~~	~~81~~
Likelihood Project Requirement	9	3	27	9	81
Science Mass Ratio	3	3	9	1	3
Design Complexity	1	3	3	9	9
~~ConOps Complexity~~	~~1~~	~~9~~	~~9~~	~~9~~	~~9~~
Likelihood Mission Success	9	3	27	9	81
Manufacturability	9	1	9	3	27
~~Life Expectancy~~	~~3~~	~~9~~	~~27~~	~~9~~	~~27~~
Instrument Protection	3	9	27	3	9
Data Recovery	9	3	27	9	81
TOTAL			246		435

In order to determine the most suitable design to accomplish A.I.M. at Xanadu's science objectives, the team decided to use a design analysis based on Figures of Merit or FOMs (pictured above in Table 5). The team has to assign a score of 1, 3, or 9 to each figure as a weight, depending on how important the team believes that figure to be. Once a score has been decided upon, the two concepts are then graded on how effectively they clear each figure of merit with a 1, 3, or 9. Afterwards the two scores are multiplied to give a weighted score to each design. Once all the weighted scored have been decided on, they are all added up to give a final design score. Using this method it was found that the “Pocket Rocket” accomplishes the team’s mission more effectively, ending with nearly double the points of the “Spike Ball.”

7.0 Final Design

After deciding that the “Pocket Rocket” is the definitive concept to accomplish A.I.M. at Xanadu’s science objectives, it was then time to check if the design clears all the design requirements. Table 6 below shows how the final design will meet the sic functions set by UAH, at the same time, showing how much mass each component will be. A single probe of the “Pocket Rocket” design will be a total of 2.93 kilograms which is then rounded to 3 kilograms for convenience. Moving on from there, since UAH allows for a maximum of 10 kilograms on the space craft it was decided to have 3 probes of the final design for a total mass 9 kilograms.

Table 6. Final Design Mass Table

Function	Component(s)	Mass (kg)
Deploy	Helium	0.00008
Measure	Mass Spectrometer, Inertial Measurement Unit	0.06013
Collect Data	On-board computer	0.38400
Provide Power	Internal Battery	0.45200
Send Data	Antenna, Transceiver	0.00760
House/Contain Payload	Carbon Fiber Shell, Titanium Tip	2.03300
Total		2.93, rounded to 3

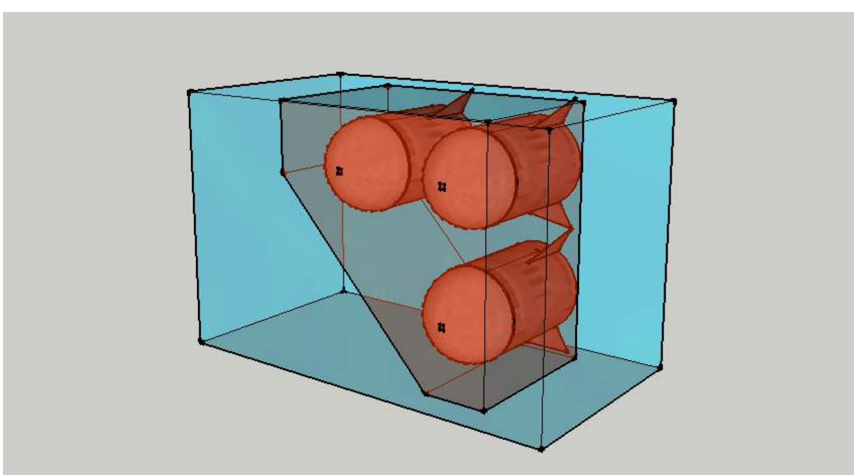

Figure 4. A.I.M. at Xanadu’s final payload concept