CRYO THÉONS

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"Making our mark in the frozen abyss."

Da Vinci High School

Team 5

1.0 Introduction

Triton is Neptune's largest moon and the 7th largest in our solar system with a diameter of 2,700 km. It is also the only moon in the solar system that travels in a retrograde orbit, meaning that it orbits in the opposite direction of Neptune. Triton's surface consists of frozen nitrogen, and has many cryovolcanoes located mainly in its south pole. Cryo Théons, in cooperation with UAH, has created a payload with the mission of completing three science objectives. The team's main goal is to learn as much as possible about the cryovolcanoes on Triton and about Tritons atmosphere. Our payload, "Cronus," will arrive to its destination via the UAH Triton orbiter, and will focus on gathering information about the cryovolcano structure, cryovolcano plumes, and Tritons atmosphere. We hope that, with this payload, we will be "making our mark on the frozen abyss."

2.0 Science Objectives and Instrumentation

Our team, Cryo Théons, after careful consideration, has chosen to attempt completing three science objectives. Specifically, Cryo Théons is determining the composition of the cryovolcano plumes, the structure of the cryovolcanoes, and the atmospheric composition. Our team chose these science objectives because knowing more about what material lies beneath the surface of Triton, and what is being ejected can help us have a better understanding of its geographic composition. Learning about Tritons atmospheric composition gives us information and helps us understand Tritons surface; the atmosphere comes primarily from outgassing on the surface, and due to the fact that the only known information was obtained from Voyager 2, direct measurements could reveal great amount of information.

In order to complete our science objectives we selected some instruments in order to take measurements and collect data. We selected a mass spectrometer, thermocouple, pressure transducers, IMU, magnetometer, Langmuir probe, and a scintillation counter. Each of these instruments will measure something different on the surface or atmosphere of Triton. For example, the thermocouple will be used to find the depth of the cryovolcano, the temperature of the atmosphere, and for the temperature of the cryvolcano plumes. However, this is not the only instrument that we can use due to the fact that the temperature and position don't provide enough information. Therefore, we have various instruments each measuring different things.

Table 1. Science Traceability Matrix

Science Objective	Measurement Objective	Measurement Requirement	Instrument Selected
Cryovolcanoes	To determine the structure of Cryovolcanoes by measuring depth and properties	Collect data continuously as the payload is deorbiting.	Mass Spectrometer, Thermocouples, Pressure Transducers, IMU.
Plumes	To determine the elements in the cryovolcano plumes	Collect data continuously as the payload is deorbiting.	Mass Spectrometer, Thermocouples, Pressure Transducers, IMU, Magnetometer, Scintillation Counter
Atmospheric Measurement	To understand Triton's thin and tenuous atmosphere by measuring composition, properties, and change with time	Collect data continuously as the payload is deorbiting.	Mass Spectrometer, Thermocouples, Pressure Transducers, IMU, Magnetometer, Scintillation Counter

Table 2. Instrument Requirements

Instrument	Mass (kg)	Power (W)	Data Rate (Mbps)	Dimensions (cm)	Lifetime (min)	Frequency	Duration (min)
Thermocouple	0.010	N/A	1.0x10^(-4)	50	8.215	Continuous	8.215
Mass Spectrometer	0.230	1.500	22.400	0.45x0.50x 0.80	8.215	Continuous	8.215
Pressure Transducer	0.131	0.040	1.000	2.20 x 8.60	8.215	Continuous	8.215
Magnetometer	0.050	1.500	0.0008	2.10x1.90x 0.80	8.215	Continuous	8.215
Inertial Measurement Unit (IMU)	0.013	0.220	0.220	2.20x2.40x 0.30	8.215	Continuous	8.215
Scintillation Counter	0.027	7.500	1.500	3 cm dia x 14.3 cm length	8.215	Continuous	8.215
Langmuir Probe	0.5	0.5	0.080	4 antennas, each 0.05 cm dia x 2.5 cm length	8.215	Continuous	8.215

Table 3. Support Equipment

Component	Mass (kg)	Power (W)	Data Rate	Other Technical Specifications
On-board computer	0.094	0.400	2 x 2 GB onboard storage	Isis on board computer 400 MHz, ARM9 processor
Transceiver	0.085	1.700	Up to 9600 bps downlink; up to 1200 bps uplink	ISIS VHF/UHF Duplex Transceiver
Antenna	0.100	0.020	(see above)	Deployable Antenna System
Space Batteries	400 Whr/kg	N/A	N/A	Based on power requirements

3.0 Payload Design Requirements

Team Cryo Théons payload must meet many prerequisites in order to successfully complete the mission. These requirements include functional, project and environmental requirements. First, our payload must successfully deploy from the UAH spacecraft. It must then be able to take measurements, collect data, power itself, transmit data, and protect itself from the environment.

The environment on Triton is extremely harsh. The temperature on the surface is the coldest known surface in the solar system with temperatures of about 36 K. Tritons atmosphere is an extremely thin nitrogen atmosphere, with a surface pressure of only 14 microbars. When creating the payload, the team must make sure it can withstand the cold long enough to receive information and study the cryovolcanoes.

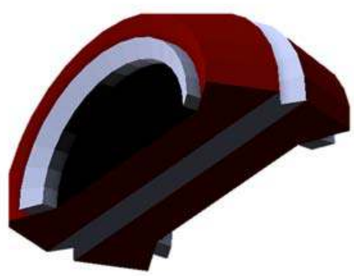
In addition, our payload must be less than or equal to 44 x 24 x 28 cm and have a mass of no more than 10 kg. Furthermore, our payload must also deploy from the UAH spacecraft without causing any harm to it. The requirements given to us by UAH Baseline Mission are vital to properly creating and designing our payload.

4.0 Payload Alternatives

Our team, Cryo Théons, has a total of four design choices, each created to carry out our team's science objectives. When coming up with our design alternatives we brainstormed rough undeveloped ideas that allowed us to explore the various options in our disposal. We were allowed to deploy from the Triton orbiter, Triton lander, or the Neptune orbiter. Two of our concepts are designed to deploy from the lander, while the other two are designed to deploy from the Triton orbiter. The vehicle that the concept would deploy from depended greatly on what worked best with our mission and the design of our various concepts.

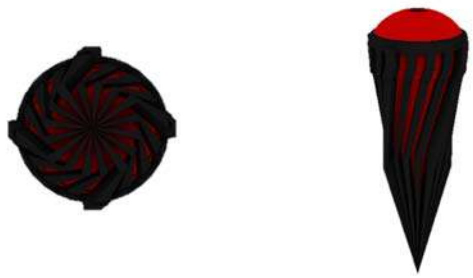
The first concept, called "Clash of Ice", was designed to deploy from the UAH triton lander and take measurements of the cryovolcanoes and cryovolcano plumes on the South Pole of Triton. This design begins to take measurements upon deployment and will continue until the end of the mission. Upon impact the payload will run out of power and the mission will conclude.

Figure 1. Clash of Ice



The second concept, called "Cronus", was designed to deploy from the UAH Triton orbiter and penetrate a cryovolcano. "Cronus" will begin to take measurements at 9 km in order to measure the plumes, since the plumes are known to reach distances of about 8km and will continue the mission after it penetrates the cryovolcano. As the payload is falling it will be taking measurements of the atmospheric composition of Triton. The mission will last as long as possible and will end when the payload runs out of power. In order to survive the force of impact it will be housed with aluminum lithium alloy.

Figure 2. Cronus



Our third concept, called "Wrath of Triton", was designed to deploy from the UAH Triton orbiter in a similar manner to Cronus. This concept is in the shape of a cube and has four landers inside the payload. The four payloads will begin to take measurements upon deployment, and will collect information on the cryovolcano structure, cryovolcano plumes, and the atmosphere of Triton. Having more than one payload will increase the odds of success.

Figure 3. Wrath of Triton

Our last concept, called "Rhea", was designed to deploy from the Triton lander. This payload will use tank tracks to get to the cryovolcano in order to complete our science objectives. The payload will take measurements of the cryovolcano plumes, and the mission will end upon impact.

Figure 4. Rhea

5.0 Decision Analysis

To help us analyze and select a payload our team created a decision matrix. The decision matrix has different criteria or figures of merit (FOM). We rated the criteria differently depending on how important we considered them in our mission. Our rating system consisted of three numbers, each representing its importance and significance: 9 “Very Important”, 3 “Important”, and 1 “least important”. When evaluating each payload concept we took into consideration the various functions each design was expected to complete and ranked them based on how well they would complete each function. The designs were carefully analyzed and considered based on possible scenarios, and in particular worse case scenarios.

Table 4. Decision Matrix

FOM	Weight	Clash of Ice		Cronus		Wrath of Triton		Rhea	
		Raw Score	Weighted	Raw Score	Weighted	Raw Score	Weighted	Raw Score	Weighted
Science Objective	9	3	27	9	81	9	81	1	9
Likelihood Project Requirement	9	9	81	9	81	3	27	3	27
Science Mass Ratio	3	3	9	3	9	9	27	3	9
Design Complexity	1	3	3	1	1	9	9	1	1
ConOps Complexity	3	1	3	9	27	9	27	3	9
Likelihood Mission Success	9	3	27	9	81	9	81	1	9
Manufacturability	3	3	9	3	9	9	27	1	3
Survive Enviornmnet	9	1	9	3	27	3	27	1	9
Instrument Security	9	3	27	9	81	3	27	3	27
Data Collected	3	9	27	3	9	9	27	9	27
TOTAL			**222**		**406**		**360**		**130**

The design that we have chosen, based on the results from the decision matrix, was Cronus. It ranked the highest on the decision matrix because it meets the criteria better, and while Wrath of Triton will collect more data, the instruments in Cronus will be safer. Rhea got scored very low because the wheels in the payload might not work due to the cold temperatures on Triton and as a result the payload will not be able to complete the mission. The analysis revealed that Cronus would be the most effective for this mission.

6.0 Payload Concept of Operations

To begin our mission, Cronus will deploy from the UAH Triton Orbiter. Once it deploys, it will enter the atmosphere where it will begin collecting data over the atmospheric composition of Triton, and other properties. This means that Cronus will be functional the moment it deploys.

When Cronus begins its descent, it will gain velocity thanks to Triton’s gravity of 0.779 m/s. Before arriving at the surface, it will collect data over the structure of cryovolcanoes, specifically the depth of said cryovolcanoes. Our team also theorizes that at the height of 9 km, which is 1 km above the maximum height that cryovolcano plumes reach, we will be able to pass through one of the plumes and collect data over the composition of said plume. In the case this does not happen, Cronus will arrive at the surface of Triton, on the inside of a cryovolcano, at a speed of

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1,067m/s. It will then bury itself underground and further its data collection on cryovolcano plumes.

7.0 Engineering Analysis

7.0 Design Analysis

In order to continue with our calculations, we needed to determine the payload's weight, dimensions, and volume. Since our payload is deploying in a downward motion, and is meant to bury into the ground to continue collecting data, we decided to assume a total mass of **10 Kg,** which is the maximum amount of mass that the payload can have.

Cronus consists of a cone-shaped bottom half, and a semi-circular top. The payload will be made out of Aluminum-Lithium Alloy, which is strong enough to resist the impact caused by the crash. The total height of the cone area would be 38.5cm, while the height of the semi-circle would be 5.5cm. The payload was also designed with extrusions in four parts of its outer layer. These extrusions will measure 2 cm, and will allow the payload to mimic rifling and stay in a smoother trajectory.

7.1 Velocity, Pressure, Acceleration and Deceleration, and G-Load

Calculating velocity came in three major stages, excluding the orbital velocity, which were the following: shooting out from the orbiter, falling and gaining speed, and finally calculating the deceleration caused by the impact on the surface. In order to get out of orbit the amount of velocity that is required is at least 1% worth of the orbital velocity. The orbital velocity in this case would be **992.169 m/s**, therefore our team decided to assume a velocity of **10m/s** for our final velocity once we shot out from the orbiter. With this we were able to find the pressure needed to achieve this velocity, which resulted in a pressure of **32,465.7 pascals.**

Afterward, we calculated the final velocity for the second stage by taking the **10m/s** as our initial velocity for our fall sequence. We found out that the only acceleration factor in this sequence would be the gravity of Triton, assuming constant gravity, which is **0.779m/s^2**. Finally, taking into consideration the distance from the orbiter to the surface of Triton, **100 Km**, after carefully following the formula $v_f^2 = v_i^2 + 2ad$, we were able to determine a final velocity of **1,067m/s.** In order to do this, we had to use vectors, one of which is the x-vector, which we assumed would most likely be the gravitational velocity, or **992m/s**, the other, the y-vector would be our velocity going down, in this case we calculated it would be **395m/s.** To find out the final velocity we used the Pythagorean Theorem and came up with the answer mentioned before, of **1,067m/s.**

The last thing that we found out was the deceleration caused by the impact when our payload crashes and begins to bury underground. Because our payload will be stationary once it arrives at the surface of Triton, we assumed that our final velocity for this stage would be **0m/s,** and our initial velocity would be **1,067m/s,** our final velocity for the previous stage. With this information, we were able to find our deceleration of **-56,925m/s^2**, and by dividing this deceleration by the gravity of Earth we see the amount of G's that our payload will be experiencing, which is about **5,802g's**.

7.2 Penetration Distance

We researched the penetration distance equations, and were able to find an equation, which was easy to follow and simple to understand its components. The formula is $D = 0.000018SN(M/A)^{0.7}(v - 30.5)$. Where **S** is our penetrability number, which is **10**. **N** is our Nose cone coefficient, which we assumed was **1**. **M** is our payload mass, and, as mentioned before, we assumed maximum mass of **10 kg**, in order to be able to bury underground. Finally, **A** which is the Cross-sectional area, or the widest area in our payload, which we calculated to be **0.035m^2**, by following the Penetration Equation, we were able to estimate a penetration of **9.77m**.

7.3 Battery Mass

To find battery mass, we looked up the power required for each instrument. We added the power needed for each instrument in order to find the total power required for our mission, the total power is **13.38 W**. We then found our total operation time by using the total time of our mission. We then multiplied our operation time in hours, which is **0.1369 hrs.,** by the total power, this gave us **1.832 hrs. x kg.** We then used the battery mass formula which is $m_{batt} = \frac{(total\ power\ requiered\ W*hr)}{400\ W*hr/kg}$. After solving for the battery mass, we obtained a mass of **0.00458 kg.** This would be considered as our minimum battery mass needed to complete our mission successfully. In case our batteries are not enough, our team decided to add the remaining mass of the payload to batteries. Therefore, our total battery mass is **6.661 kg.**

7.4 Time

After finding the distance, the different velocities, acceleration, and assuming *No Drag*, we were able to find the amount of time that it would take for our payload to arrive to the surface. By following the formula $v_f = v_i + at$ we were able to estimate the amount of time, although it does not consider the depth of the cryovolcano itself, the estimate that we were able to come up with was **8.215mins**, which roughly translates into **8 minutes 13 seconds**, this time is assuming *No Drag*, as stated before.

8.0 Final Design

Cryo Théons' final design consists of a version of Cronus which will be deployed from the UAH Triton Orbiter. Once it enters the atmosphere it will begin to gain velocity. While this is going on, it will be measuring the depth of a cryovolcano via the IMU. This payload was designed with creases on the sides to mimic rifling, this will help the payload maintain its trajectory, and will make it easier for the payload to arrive safely to its destination.

Cronus has measurements of 24 x 24 x 44 cm. While in the UAH Triton Orbiter, Cronus will be non-functional; it will begin collecting data as soon as it is deployed from the orbiter. As it enters the atmosphere it will collect different types of atmospheric data, such as its composition, and other properties.

Cronus will not slow down, this was decided by our team in order to be able to bury and continue to collect data. This was also decided because it is expected that the Aluminum-lithium alloy housing will survive the strain caused by the impact of the crash. Although it is provable that it will not be destroyed upon impact, in the case that Cronus gains too much speed and is destroyed, Cronus will have collected enough data over the cryovolcano's structure and the composition of the atmosphere. With this data, we are able to guaranty that the mission will not be a failure, under any circumstance.

Figure 3. Cryo Théons Mission

Table 5. Final Design Mass Table

Function	Component(s)	Mass (kg)
Deploy	N/A	N/A
Measure	Mass spectrometer, thermocouple, pressure transducer, IMU, magnetometer, scintillation counter, and Langmuir Probe	0.961
Collect Data	On board computer	0.094
Provide Power	Space batteries	6.661
Send Data	Transceiver and antenna	0.185
House/Contain Payload	Aluminum lithium alloy	2.099
Total		10