Titan Turtle

SPACE SDSU

TITAN X

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Abstract

During this modern space race, there are countless missions in development to further the human knowledge of our vast universe. Titan X has dedicated its work to discovering other existing lifeforms within our solar system, specifically on Saturn's moon, Titan. Our company decided to focus on this moon because it is

Fig. 1: Turtle Z and Hare Y Orbit around Saturn's moon, Titan

the most Earth-like body within the Solar System. If humans are to find other living organisms within reach, the celestial body most closely resembling Earth is the first place we would search. The journey to Titan is by no means an easy task, our primary and secondary loads will experience several gravity assists from Earth and Venus in order to reach Titan. Once on the surface of Titan, our amphibious rover known as Turtle Z, will endure freezing cold temperatures and a nitrogen-thick atmosphere that makes solar power a hundred times more difficult than on Earth. To combat the challenge of solar power, we are planning to install an MMRTG in our payloads to power them for about 15 years. The cold temperatures will pose challenges for the internal components of our rover, so we have proposed insulating Turtle Z with aerogel. With its robotic arm and sonar capabilities, the rover will be able to collect/examine Titan soil and map out liquid bodies on the moon. Meanwhile, our CubeSat known as Hare Y, will orbit the moon to provide us with a more detailed topography of Titan.
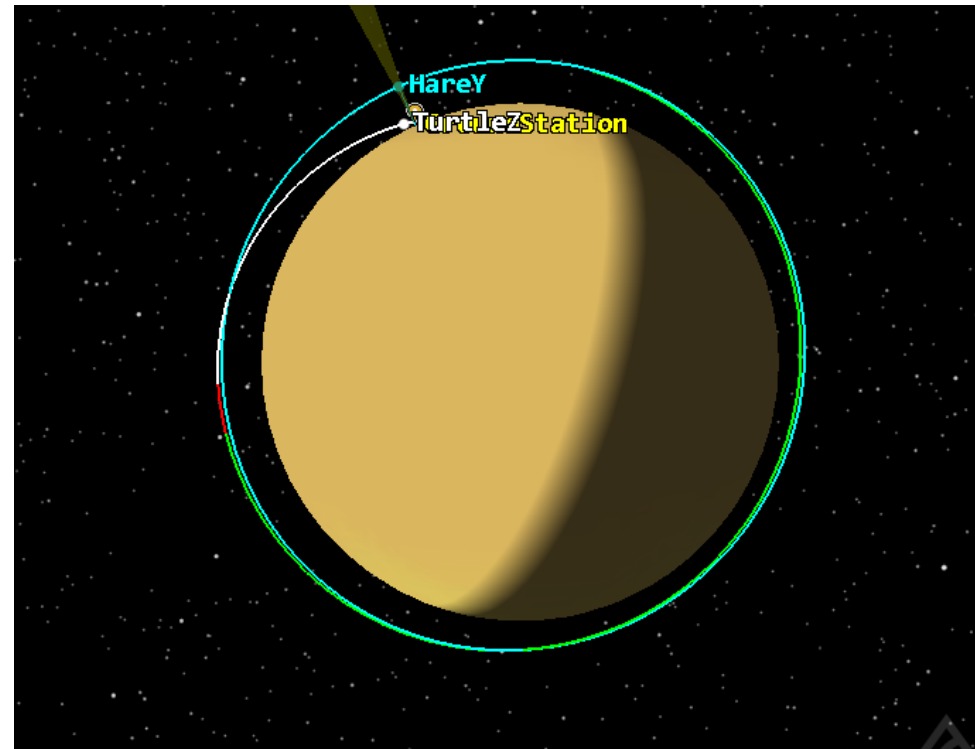
Attitude, Determination, and Control

For this mission to Titan, it is important to estimate what conditions Turtle Z and Hare Y will experience while in orbit and on the surface. Starting with Turtle Z, the surface of Titan is obscured by an opaque nitrogen-rich atmosphere. This fact knocks out the sun sensor, the star tracker, and the horizon sensor leaving only the IMU and the magnetometer as the only viable options. The strength and prevalence of Saturn's magnetic field on the surface of Titan is currently unknown but has been detected to be stronger than anticipated in Titan's ionosphere at 26 nT. This fact makes having a magnetometer on the Turtle a risky venture, so to counteract the concerns, the magnetometer will be removed from consideration only leaving the IMU for Turtle Z. Issues with gyro drift can be corrected because we can make an easy assumption that the rover can be truly motionless and therefore, we can reset the gyroscopes from time to time. Controlling the Turtle will be done by the wheels and the attached hydraulic suspensions.

	IMU	Sun Sensor	Star Tracker	Horizon Sensor	Magnetometer
Price	$500 - $1,500	$2,000 - $15,000	$10,000 - $50,000	$15,000 - $50,000	~$25,000
Error Range	$0.003\text{-}1°/hr$	$0.005\text{-}2°$	$0.0003\text{-}0.01°$	$0.1\text{-}1°$	$0.5\text{-}3°$
Mass Range (kg)	1-15	0.1-2	2-5	1-4	0.3-12
Power Consumption (W)	10-200	0-3	5-20	5-10	< 1

Fig. 2: Attitude Determination Systems

For determining the attitude of Hare Y, three Sun Sensors will be utilized, each measuring the three principal axes for rotation. Sticking with a singular, yet reliable method for attitude determination reduces the satellite's weight, increases maximum rover weight, and more volume for scientific equipment. For controlling Hare Y, reaction wheels will be utilized, however these wheels will be much lighter and underpowered than traditional reaction wheels due to power constraints and the ability to plan out surface scanning procedures. A 3-axis set of magnetorquers will be present to allow momentum dumping of the reaction wheels. These will slowly discharge the momentum from the reaction wheels as Hare Y orbits Titan.

Mechanical and Structural Systems

Design Requirements and Specifications

- **Sizing:** less than or equal to 10 ft long, 9 ft wide, & 7 ft tall
  - This ensures that the Turtle will fit the size requirements that the rocket has.
- **Weight:** less than or equal to 900 kg (1984.16 pounds)
  - This ensures that the Turtle will meet the weight requirement that the rocket has.

Production Process

- **Cleanliness**
  - During the production process, the environment must be clean and free of any contaminants that might skew the results once on the surface of Titan.
  - During the loading process, the Turtle must be sanitized to ensure that no living organisms might travel with the Turtle on its voyage to Titan.
- **Functionality**
  - During the production process, testing of each instrument will be required to ensure the functionality of the components.
  - Each instrument must meet certain qualifications for duration purposes to ensure that the Turtle will work for an extended period while it is on the surface of Titan.
- **Scheduling**
  - Ensure that each deadline for the production process is met.
  - Implement extended amounts of "gap time" to ensure that in the event of a setback to the production process the overall deadline will not extend.
- **Budgeting**
  - Ensure that the budget is met during the production process.
  - Implement an overestimated budget in the event of an unavoidable price increase; for example, innovative technology that comes out that is tested and can be implemented replaces an outdated instrument, which costs more than the original instrument.
- **Final Testing**
  - Ensure that once the Turtle is fully built that it functions to the quality that is needed according to the challenges of the harsh conditions on Titan
  - Once the Turtle is tested and approved for operation, the Turtle must then be loaded into the rocket in accordance with the rocket's specifications for weight loading.
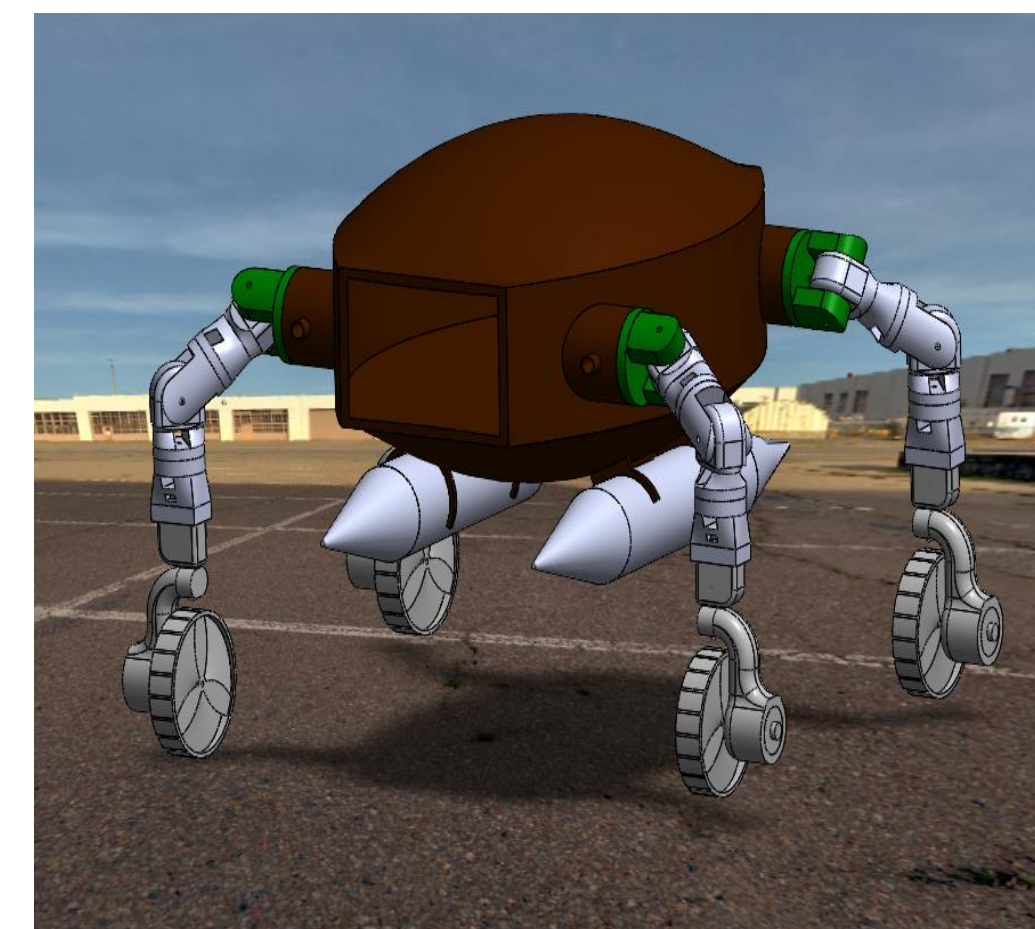

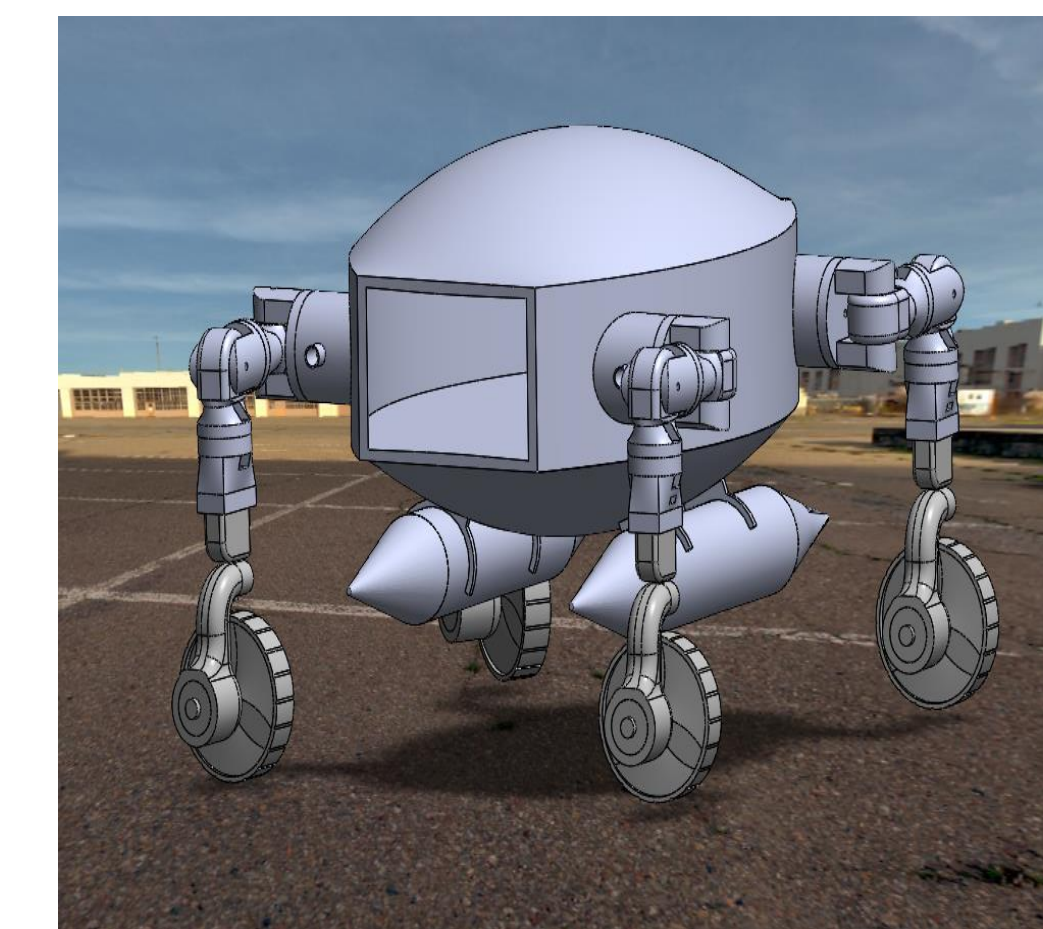Fig. 3: Turtle Z grounded configuration

Fig. 4: Turtle Z propeller configuration

Constraints and Challenges during Design and Production

- **Constraints**
  - **Sizing**
    - Ensure that the sizing of the Turtle does not exceed the maximum volume of the rocket's storage space, keeping in mind that the CubeSat (Hare Y) will also be included in the rocket as well.
  - **Weight**
    - Ensure that the weight of the Turtle does not exceed the maximum weight requirements of the rockets specified loading, also keeping in mind that the weight of the CubeSat will be included in the overall loading of the rocket.
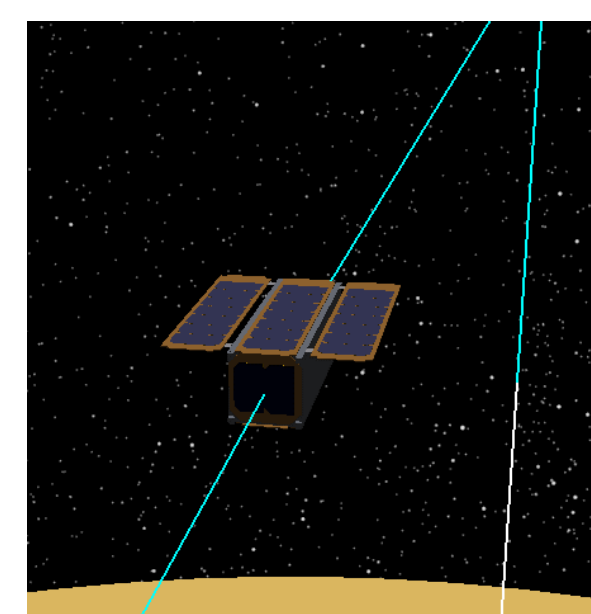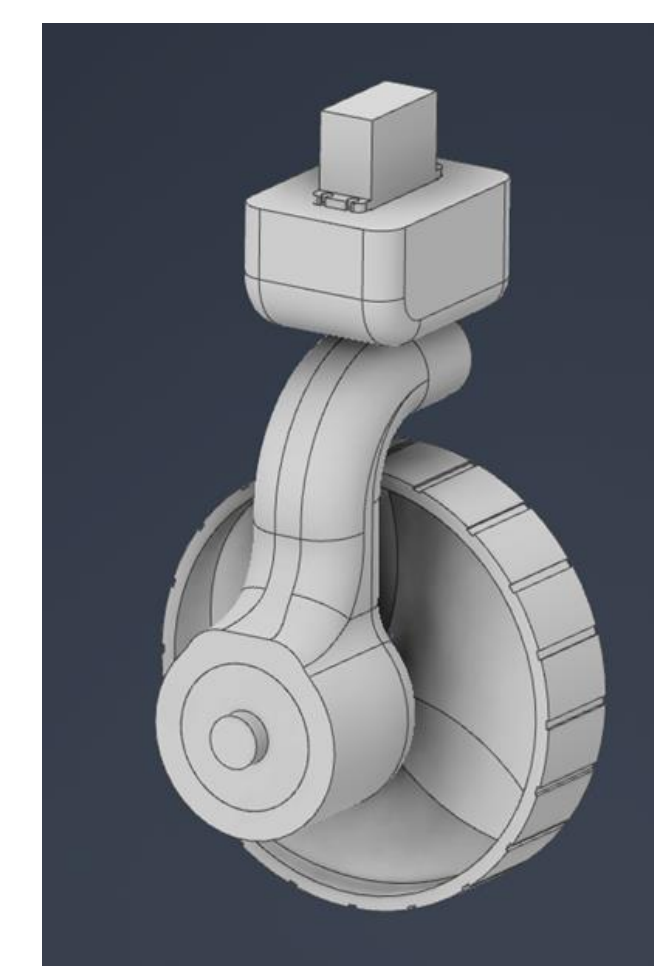

Fig. 5: Hare Y orbiting Titan

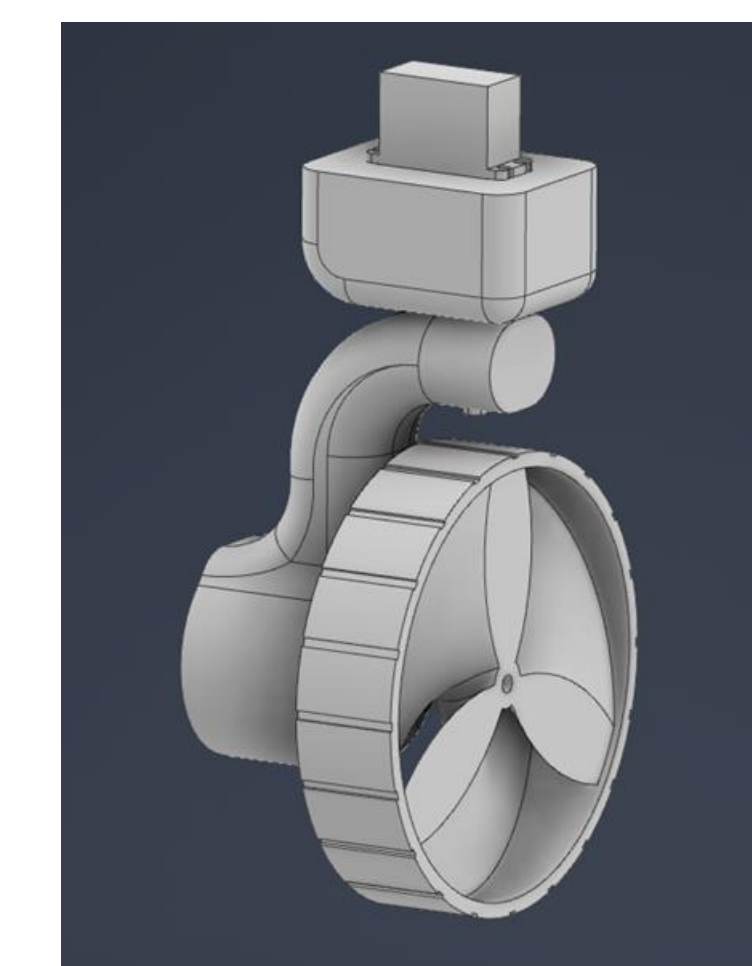Fig. 6: Wheel mechanism propeller orientation

Fig. 7: Wheel mechanism grounded orientation

Communication and Payload

There will be four components of telecommunications between Turtle Z and Hare Y. Both Turtle Z and Hare Y will have a radio modem that will have a radio frequency board as well as antennas to ensure effective transmission of radio waves. The purpose of having a radio modem in Turtle Z and Hare Y is to give them a route of communication by sending and receiving digital symbols or "packets" that can consist of 2000 eight-bit bytes. These packets can transfer images as well as information regarding the tests performed on Titan. The purpose of having antennas is to make sure there is effective transmission of radio waves between Turtle Z and Hare Y. The specifications of the radio modems and antennas are seen below in the Tables.

Specifications	Hare Y Radio Modem	Turtle Z Radio Modem
Mass	105.9 g	265.2 g
Dimensions	3.2" x 2.5" x .9"	4.2" x 2.8" x 2.1"
Operating Voltage	+7.5 Volts	+7.5 Volts
RF Center Frequency	459.7MHz	459.7 MHz
RF Transmit Power	100mW	100 mW
RF Channel Bandwidth	25KHz	25kW

Fig. 8: Radio Modem Specifications

Specifications	Hare Y Antenna	Turtle Z Antenna
Overall Length	45 cm	33.6 cm
Materials	Fiberglass, Aluminum, Teflon, Coaxial cable	Fiberglass, Aluminum, Teflon
RF Center Frequency	459.7 MHz	459.7 MHz
RF Bandwidth	700 KHz	16 MHz
RF Gain	1.4 dB	1.4 dB

Fig. 9: Antenna Specifications

Ground Station

The launch vehicle used for this mission will be the Falcon Heavy. Even though the Falcon Heavy has fewer total flights, it has the ideal payload capacity for this mission in comparison to Falcon 9. Falcon Heavy is inspired from Falcon 9, however; it is a heavier lift version of it by utilizing a stronger Falcon 9 first stage and two added Falcon 9 first stages which act as boosters. The vehicle is also partially reusable, which is an added benefit to its choice. The launch site for the vehicle would be the same as the Falcon Heavy in 2018 – Cape Canaveral Space Force Station LC-39A in Brevard County, Florida.

Radioisotope Power System

Our mission's primary and secondary payloads include a rover and CubeSat. Traditionally, rovers such as Mar's Perseverance and CubeSats such as the FireSat use solar panels to harness solar power. As mentioned above, solar power at Titan is non-existent. To combat this problem, Turtle Z will be powered by an MMRTG. However, since an MMRTG is rather large, our CubeSat, Hare Y, must be powered by another power source.

Hare Y will be powered by a radioisotope heater unit-based radioisotope power system (RHURPS). This system is effectively a miniature MMRTG, also utilizing thermoelectric heat to convert into electricity. The only difference is the size and use of lithium-ion batteries. A standard RHURPS is about 6.2cm by 13.4cm. With this sizing, a two-unit (2U) CubeSat frame can house the RHURPS, batteries, charger card, and charging cable.

Mass Estimate:
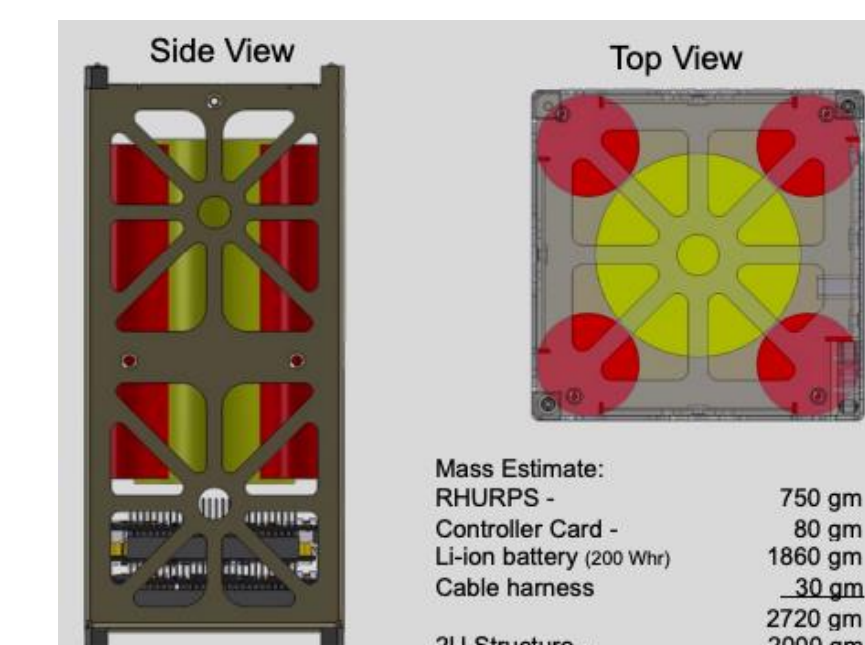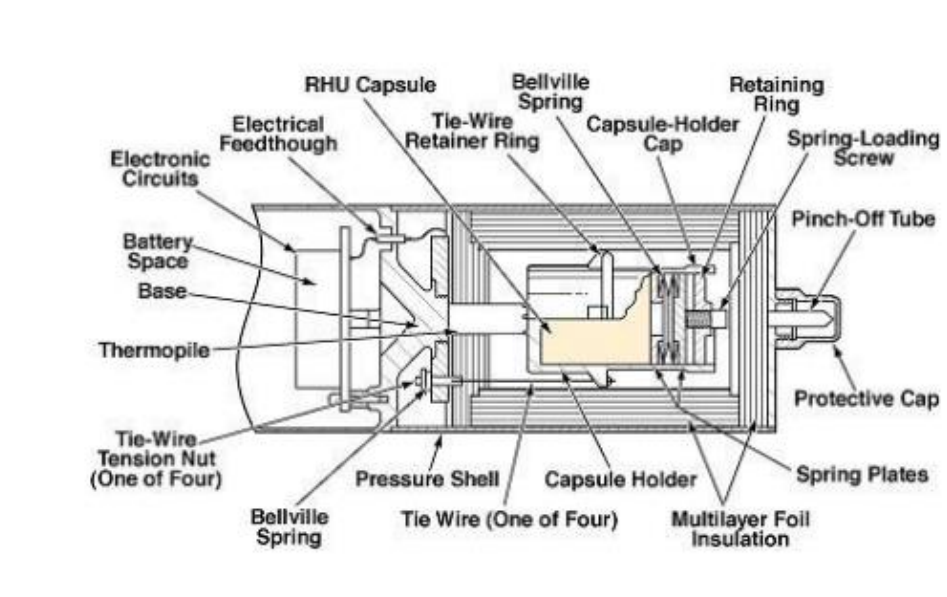|	
RHURPS -	750 gm
Controller Card -	80 gm
Li-ion battery (200 Whr)	1860 gm
Cable harness	30 gm
2U Structure -	2720 gm
	2000 gm

Fig. 10: 2U CubeSat Power System   Fig. 11: Hi-Z RHURPS System

Thermal Subsystem

The following calculations were obtained concerning the Thermal Subsystem: solar constant at Saturn, and the albedo radiation flux. For the operating temperature, T, is dependent on the Titan Blackbody value of T obtained (-38.63 °C) the ideal coating used will be polished beryllium. This will be coupled with our doubled walled insulation and the internal RTG, helping the rover operate at ideal temperatures in the

Specification	Value
J_{PT} (Titan Blackbody)	$1.5213\ Wm^{-2}$
J_S (Solar Constant at Saturn)	$15.0819\ Wm^{-2}$
J_a (Albedo Radiation Flux)	$0.4751\ Wm^{-2}$
T (Operating Temperature)	$-38.6327\ °C$

Fig.10: Thermal Subsystem

Mission Phases

Phase 1: Transportation

- Slingshot around Venus and Earth to travel from Earth to Titan

Phase 2: Landing/Orbit

- Disconnect Turtle Z from vehicle and use parachute to descend to the surface. Launch Hare Y into orbit around Titan

Phase 3: Exploration

- Navigate through Titan's terrain, collecting samples of the soil, atmosphere and from Lake Kraken

Phase 4: Data Processing

- Process data and send back to earth via communication systems

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Acknowledgements

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