IMPETUS User Manual

December 9, 2023

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1 Introduction

1.1 Overview

Welcome to the Asteroid Exploration Rover User Manual. This document serves as a comprehensive guide to understanding and operating our state-of-the-art rover designed for exploring asteroids in our solar system.

1.2 Mission Objectives

The mission objectives of the asteroid exploration rover are rooted in scientific exploration. The rover has been meticulously crafted to achieve the following goals:

- Conduct detailed surface analysis.
- Examine geological features and composition.
- Capture high-resolution images for imaging and mapping.
- Collect samples for analysis and potential return to Earth.

2 Rover Overview

2.1 Physical Structure

The rover boasts compact dimensions of 3 meters in length, 3 meters in width, and 3 meters in height. With a weight of 1573.4 kilograms, it is designed to optimize mobility and functionality on the asteroid's surface. Crafted from advanced lightweight yet durable materials, the rover's outer shell is primarily composed of [thermosetting polymers, Aluminum, Carbon Composite, Radiation-Resistant Materials] to withstand the challenges of space exploration.

2.2 Mobility System

The rover features a hexapod mobility system, equipped with six independently controlled legs. The outer four legs are dedicated to propulsion, providing controlled movement, while the inner two legs serve as stabilizers to enhance stability on uneven asteroid terrains. Designed for adaptability, the hexapod structure enables the rover to traverse diverse terrains with stability. Each leg is equipped with adaptive limbs, allowing the rover to adjust to the varying surfaces it encounters during exploration.

2.3 Power System

The power system of the asteroid exploration rover is a critical component that ensures sustained operations and data collection during the mission. The rover employs a combination of solar panels and nuclear energy to provide a reliable and robust source of power in the challenging conditions of space.

The rover is equipped with high-efficiency solar panels strategically placed on its surface. These solar panels harness solar energy from the sun, converting it into electrical power to meet the rover's energy needs.

In addition to solar power, the rover is equipped with a nuclear energy source, providing a supplementary and reliable power supply. This integration is essential for ensuring continuous operation during periods when solar energy may be insufficient, such as in shadowed regions or during extended missions in the asteroid's night.

2.4 Communication Systems

The rover features a sophisticated remote control interface that enables users to command and navigate the rover from a remote location. The interface provides real-time feedback on the rover's status and allows for seamless control during its mission. Communication systems facilitate efficient data transmission, allowing the rover to send captured images, scientific data, and other relevant information back to Earth. These systems are optimized for reliability and speed, ensuring the seamless transfer of mission-critical data.

3 Key Features

3.1 Computer Vision System

This system enables the rover to recognize and classify various objects on the asteroid's surface, including rocks, craters, and potential scientific points of interest. The neural network models have been trained on a diverse set of images to ensure robust object identification.

3.2 Self-Healing Materials

The rover is equipped with self-healing materials that serve as a protective layer against potential damage from micro-meteoroids, cosmic radiation, and other environmental hazards encountered during its mission on the asteroid. These materials possess the unique ability to autonomously repair small cracks and damages, ensuring the rover's structural integrity and functionality over an extended period.

The self-healing capability relies on advanced polymer composites. These composites typically include polymers with embedded microcapsules or vascular networks containing a healing agent. When the material is damaged, these capsules rupture, releasing the healing agent into the affected area, where it reacts to repair the damage.we will be using materials as **thermosetting polymers, Aluminum, Carbon Composite, Radiation-Resistant Materials .**

The selected polymers are designed to withstand the harsh conditions of space, including extreme temper, vacuum, and exposure to radiation. This involves testing materials in vacuum chambers, subjecting them to radiation sources, and simulating the temperature fluctuations of space environments.

The self-healing materials will be integrated into multi-layered structures where outer layers provide additional protection against harsh environmental factors .

3.3 Samples collection

Impetus is equipped with advanced sensors and instruments to identify potential mining sites on the asteroid based on mineral composition, accessibility, and economic viability. The rover utilizes tailored mechanisms such as drilling, blasting, and surface excavation techniques to physically extract desired materials. Carefully designed equipment, including robotic arms and sample tubes, allows for precise collection and sealing of rock and soil samples. With integrated instruments, the rover can perform on-site analysis of sample composition and characteristics, while a secure storage system preserves the samples for future analysis.

Figure 1: Mining Drills

3.4 Shields for Sensitive Components

The rover is equipped with deployable shields designed to safeguard sensitive components, including cameras, sensors, and solar panels. These shields are crafted from radiation-resistant materials to protect against cosmic radiation and are capable of retracting to allow unobstructed operation during scientific observations. The shields serve as a crucial defense mechanism, ensuring the longevity and functionality of the rover's essential instruments in the challenging conditions of space.

3.5 Six-Legged Mobility System

The rover features a hexapod (six-legged) mobility system designed for stability and adaptability on the asteroid's surface. The four outer legs are dedicated to propulsion, providing controlled movement, while the two inner legs act as stabilizers. This configuration ensures stability on uneven terrains, allowing the rover to navigate with precision. Actuated joints, brushless DC motors, and adaptive control algorithms collectively enable the rover to adjust its posture, enhancing its maneuverability and stability in diverse environments.

3.6 Adaptive Limbs

Adaptive limbs refer to limbs or appendages that can adjust their shape, position, or movement to adapt to different environments or tasks. These limbs are designed to provide flexibility, versatility, and improved performance in various situations.

By adjusting their shape, position, or movement, adaptive limbs enhance the rover's mobility, enabling it to explore rough terrains with improved efficiency and safety.

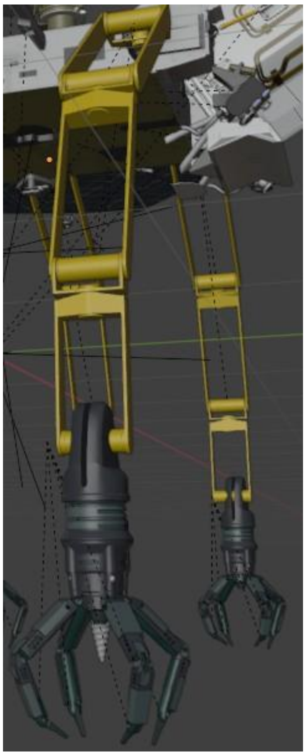

Figure 2: Adaptive Limbs

3.7 Communication System Integration

The primary task of a rover is to gather scientific information. This needs to be transmitted to Earth, and commands need to be transmitted to the rover. The rovers have two antennas to communicate with Earth.

1. **High-gain antenna** : This antenna can adjust its direction to send information directly to an antenna on Earth. It's like a focused beam of information that can travel long distances quickly. This antenna allows the rover to send data back to Earth at a faster rate.

2. **Low-gain antenna** : The low-gain antenna is different. It doesn't need to be pointed in a specific direction. It can send and receive information from any direction, but at a slower rate compared to the high-gain antenna. It's like a more general way of communication, but it's not as fast as the high-gain antenna.

Communication is limited by the Friis equation. Data rate is proportional to transmitter power and square of antenna dish diameter and frequency. Very high frequency operation can reduce power requirements, but is limited by falling electronic efficiencies and dimensional tolerances of the orbiter receiving antenna.

In that sense, communication through relay systems such as Reconnaissance Orbiter or Mars Odyssey Orbiter can provide much powerful connection with earth.

On Earth, the Deep Space Network will receive the signal and relay it to the mission control facility.

3.8 Solar Panel Integration

The distance between the asteroid belt and the sun, in the order of 2-3 astronomical units (AU), necessitates efficient operation of the solar arrays under the low intensity, low-temperature (LILT) conditions.

The solar array is planned to provide power under greatly varying illumination and temperature conditions. The sun intensity will vary approximately from 136.7 mW/cm2 to 15.2 mW/cm2 (i.e., 1 - 3 AU), while the calculated operating temperature of the solar array varies from +60°C to -88°C. Solar arrays populated with advanced triple-junction (ATJ) solar cells are selected to provide primary electrical power for the space exploration mission.

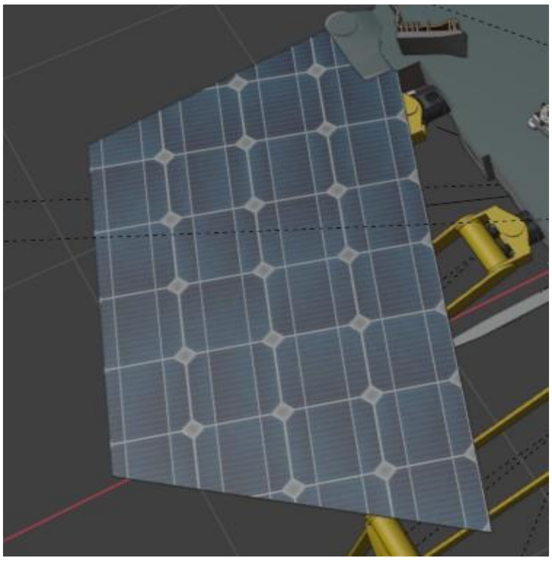

Figure 3: Solar pannel

3.9 Nuclear Energy Integration

In the asteroid belt, solar energy sometimes does not provide the power that we need. The light just does not get to those locations like we would need it. Impetus carries a radioisotope power system. This power system produces a dependable flow of electricity using the heat of plutonium’s radioactive decay as its ”fuel.”

1. **Radioisotope Power System** : The Perseverance rover utilizes a radioisotope power system called the Multi-Mission Radioisotope Thermoelectric Generator (MM-RTG).

2. **Heat from Plutonium Decay** : The MMRTG harnesses the heat generated by the natural radioactive decay of plutonium to produce electricity. This process is known as thermoelectric conversion.

Figure 4: Enter Caption

3. **Charging Batteries** : The electricity generated by the MMRTG is used to charge the rover's two primary batteries. These batteries store the electrical energy for use when needed.

4. **Heat Generation** : In addition to producing electricity, the MMRTG also provides heat to keep the rover's tools and systems at their correct operating temperatures.

5. **Longevity** : The MMRTG is designed to operate for an extended period. It is expected to provide power for at least 14 years.

4 Operating the Rover

4.1 Autonomous Mode

The autonomous mode harnesses the power of the Computer Vision System for independent exploration. During autonomous operation, the rover uses advanced algorithms to navigate the asteroid's surface, identify scientifically relevant objects, and adjust its movements based on environmental conditions.

4.2 Camera and Sensor Controls

1. **Panoramic Camera** : Each rover has a panoramic camera mounted on its mast. This camera provides a larger view of the surrounding geology. It is located about 5 feet (1.5 meters) off the ground and can take color images.

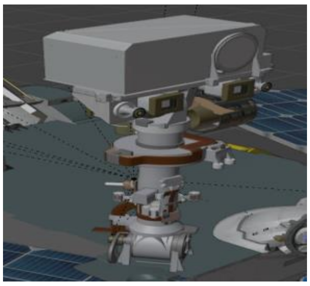

Figure 5:
High resolution camera

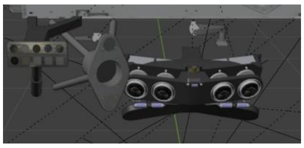

Figure 6 :
Sensors

2. **Microscopic Imaging Tool** : The rovers also have a microscopic imaging tool that allows scientists to carefully investigate rock formations and variations. This tool provides detailed close-up images of the rocks, helping scientists understand their structure and composition.

3. **CCD sensors**: They capture detailed images of the asteroid surface by converting light into electrical signals. These sensors, known for their sensitivity in low-light conditions, play a vital role in rapid data transfer, aiding the rover in scientific exploration and terrain analysis .

4.3 Computer Vision System Interface

The rover's Computer Vision System is a cutting-edge technology that employs Convolutional Neural Networks (CNNs) and advanced image processing algorithms.

To maximize the benefits of object recognition, operators should regularly review and update the object database. The system logs recognized objects, allowing users to analyze and prioritize specific features for further investigation. Object recognition can significantly enhance mission efficiency by autonomously guiding the rover toward scientifically relevant areas.

4.4 Emergency Procedures

A designated button triggers an emergency shutdown, bringing the rover to a controlled stop. This is essential for preventing further damage in situations such as system malfunctions or imminent hazards.

5 Glossary of Terms

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