WATER-I MISSION CONCEPT: WATER-RICH ASTEROID TECHNOLOGICAL EXTRACTION RESEARCH K. Molag[1], B. de Winter[1], Z. Toorenburgh[1], B.G.Z. Versteegh[1], W. van Westrenen[1], K. du Pau[1], E. Knecht[1], D. Borsten[1], B.H. Foing[1,2], [1]Vrije Universiteit Amsterdam, de Boelelaan 1105, 1081 HZ Amsterdam, the Netherlands (k.molag@student.vu.nl, b.de.winter@student.vu.nl), [2]ESA ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, the Netherlands (Bernard.Foing@esa.int).

1. Introduction

As part of a Introduction to Planetary Science course in their BSc programmes in Earth Sciences, groups of students from Vrije Universiteit Amsterdam, the Netherlands were given the task of designing a planetary science mission to a target of their choice, with a nominal 1 billion US dollar budget. This abstract summarizes the mission proposed by one of the student teams. Their mission, WATER-I, aims to harvest water from a carbonaceous asteroid.

2. Background

A better understanding of the feasibility of mining near-Earth asteroids is crucial, as in the near future economically viable extraction of elements such as potassium, phosphorus and platinum-group elements (PGE's) from terrestrial reservoirs may become impossible. Significant amounts of these elements may be found on near-Earth asteroids, along with water. Water is a key resource - it can potentially be processed to yield hydrogen fuel to power rockets. Devoting of a planetary science mission to a near-Earth hydrous C-type asteroid will give more insight as to whether it is possible to extract water from such an asteroid and convert the water into rocket fuel. The OSIRIS-REx mission (Origins, Spectral Interpretation, Resource Identification, and Security - Regolith Explorer) [1] will approach a near-Earth asteroid in August 2018 and aims to return a pristine carbonaceous asteroid sample, and part of our proposed mission is based on aspects of the OSIRIS-REx design.

The aim of WATER-I (Water-rich Asteroid Technological Extraction Research) mission, is to mine water on a near-Earth C-type asteroid and demonstrate the feasibility of eventually creating a mobile 'gas station' in space. Such a facility would not only be of interest for commercial mining operations (fueling return flights to Earth with mined resources) but could also be of interest for governmental space agencies to enable further scientific exploration of the solar system.

The WATER-I mission will be a follow up of NASA's OSIRIS-REx mission. The missions' objective will not only be to obtain water from a water-rich asteroid but also to process it in situ within a regenerative fuel cell (RFC-) system [2]. Within a RFC-system, electrolysis powered by solar panels splits the water into hydrogen and oxygen, producing hydrogen fuel in a fuel cell. For this particular mission, the fuel will be ignited to fly back to Earth. Once this technique has been demonstrated, larger-scale follow-up missions could open the door to outer parts of space.

3. WATER-I mission objectives

Elaborating on the OSIRIS-REx mission, WATER-I will focus on extracting water from a carbonaceous near-Earth asteroid by asteroid capture. The mission is divided into three parts: 1. Remote sensing - suitable asteroid targeting; 2. Asteroid capture and optical mining; 3. Water processing in a RFC-system. The timespan of the WATER-I mission will approximately be 7 years. Using a Ariane 6 launching system, the WATER-I spacecraft will use the gravitational field of the Earth to reach the targeted asteroid. Based on the OSIRIS-REx mission [1], the journey back will take about 2.5 years. The launch date of the WATER-I mission will be in January 2025, after the return of OSIRIS-REx mission to Earth in September 2023. The complete WATER-I mission profile which aims to bring the capsule back to Earth safely on self-produced hydrogen fuel is as follows:

01/2025	Launch: new-generation launcher Ariane 6
07/2027	Detailed survey targeted asteroid
07/2028	Approach targeted asteroid and asteroid capture/water mining/fuel production
07/2029	Start return to Earth
01/2032	End of mission

The costs of the WATER-I mission will be comparable to the OSIRIS-REx mission. However, as more instruments are added to the WATER-I spacecraft, such as the RFC-system, bigger solar panels and the asteroid capturing system, additional costs have to be taken into account.

4. Spacecraft

The combined launch mass of the WATER-I spacecraft is estimated to be between 9000 and 10000 kg. The estimated dry mass of the WATER-I spacecraft will be around 6000 kg, based on NASA's APIS and OSIRIS-REx missions [1, 3]. For the launch the new generation Ariane 6 launch system with four booster rockets will be used [4], divided into three stages. First the four boosters launch the spacecraft into orbit around the Earth, at which point the bottom part is detached from the main rocket. The second and third stage bring the spacecraft into orbit of the targeted asteroid using cryogenic liquid oxygen and hydrogen propulsion. When the spacecraft has the right speed and orientation the propulsion parts are split from the spacecraft. After that small corrections can be done with propellants in the spacecraft.

Two solar panels with a surface area of around 15 m^2 will provide the spacecraft with energy, for communication devices and to start-off electrolysis. During the flight towards the targeted asteroid, solar energy is captured and stored within the spacecraft. When the spacecraft approaches the asteroid, it changes direction to enter an orbit very similar to that of the asteroid. The asteroid can then be captured by the spacecraft and together they will continue to orbit the Sun during water extraction [3].

To fly back to and land on Earth, a sample return capsule based on the OSIRIS-REx design is used, which includes a heat shield and parachutes. The communication and navigation devices used will be comparable to those used for the OSIRIS-REx mission as well. The spacecraft will communicate to Earth with a High Gain Antenna [1]. A Tagcam [1] will be used for navigation of the spacecraft to and from the targeted asteroid and Earth.

5. WATER-I mission instruments

A suitable asteroid target is selected through infrared spectroscopy from space telescopes, such as the IR spectrograph of NASA's Spitzer Space Telescope [5]. Selection is based on elemental composition and orbital parameters. A suitable asteroid is water-bearing and requires minimal fuel to reach.

The scientific payload holds three spectrometers, which are used to analyze the surface composition of asteroid targets. Cosmic rays interacting with the asteroid surface up to a depth of a few meters produce X-rays, gamma-rays and neutrons. These can be analyzed by X- and gamma-ray and neutron spectrometers to detect elemental compositions of the surface. Since neutron emission is influenced by hydrous compounds, neutron spectrometry can be used to detect water abundances [6]. Instruments similar to those mentioned by Hansson et al. [6] may be used for the WATER-I mission. Their average weight is 4 kg per instrument.

Another instrument present on board will be an altimeter, similar to the OSIRIS-REx Laser Altimeter [7], which weighs 22.9 kg. It will be used to manoeuvre around the asteroid and make topographic measurements.

The water is extracted from the asteroid by optical mining. The asteroid is enclosed by an instrument that resembles NASA's APIS (Asteroid Provided In-situ Supplies) [8, 9]. Sunlight is concentrated into a high-energy beam that is pointed at the asteroid within the capsule. As a result, volatiles, including water, evaporate from the rocks, but stay inside of the instrument. Water condenses within and can be collected and used in the RFC-system.

The RFC-system [2] will produce hydrogen and oxygen through a solar powered electrolyzer.The fuel cell within this system will yield energy to power the electrolyzer, future mining facilities and communication devices. As well, hydrogen and oxygen will be ignited in a propulsion tank as fuel.

A return capsule similar to the OSIRIS-REx SRC (Sample Return Capsule) [1] will be used for the WATER-I mission. This capsule relies on heat shields and parachutes to fly the instruments back to Earth.

References

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