

ASTEROID EXPLORATION AND UTILIZATION

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Abstract

The Earth is nearing depletion of its natural resources at a time when human beings are rapidly expanding the frontiers of space. The resources possessed by asteroids have enormous potential for aiding and enhancing human space exploration as well as life on Earth. Project STONER (Systematic Transfer of Near Earth Resources) is based on mining an asteroid and transporting raw materials back to Earth. The asteroid explorer/sample return mission is designed in the context of both scenarios and is the first phase of a long range plan for humans to utilize asteroid resources. Project STONER is divided into two parts: asteroid selection and explorer spacecraft design. The spacecraft design team is responsible for the selection and integration of the subsystems, consisting of GNC, communications, automation, propulsion, power, structures, thermal systems, scientific instruments, and mechanisms used on the surface to retrieve and store asteroid regolith. The sample return mission scenario consists of eight primary phases that are critical to the mission.

Introduction

The Earth is nearing depletion of its natural resources at a time when human beings are rapidly expanding the frontiers of space. The resources which may exist on asteroids could have enormous potential for aiding and enhancing human space exploration as well as life on Earth. With the possibly limitless opportunities that exist, it is clear that asteroids are the next step for human existence in space.

The final report comprises the efforts of NEW WORLDS, Inc. to develop a comprehensive design for an asteroid exploration/sample return mission. This mission is a precursor to proof-of-concept missions that will investigate the validity of mining and material processing on an asteroid.

Scenarios

Project STONER (Systematic Transfer of Near Earth Resources) is based on two utilization scenarios: 1) moving an asteroid to an advantageous location for use by Earth and 2) mining an asteroid and transporting raw materials back to Earth. The asteroid explorer/sample return mission is designed in the context of both scenarios and is the first phase of a long-range plan for humans to utilize asteroid resources.

The final report concentrates specifically on the selection of the most promising asteroids for exploration and the development of an exploration scenario. Future utilization as well as subsystem requirements of an asteroid sample return probe are also addressed.

Project STONER is divided into two primary areas: asteroid selection/mission design and explorer spacecraft design. The asteroid selection team has narrowed the possible 4800+ known asteroids to ten, considering physical attributes of each candidate asteroid as well as mission trajectory and ΔV requirements. From that group of ten, a final asteroid was chosen for more in-depth study.

The mission design team formulated mission scenarios and -- working with the other teams -- investigated possible problem areas and contingency plans. In the design of the spacecraft, subsystems that have been studied are: GNC, communications, automation, propulsion, power, structures, thermal systems, scientific instruments, and mechanical retrieval devices.

Spacecraft Overview

The Hawking spacecraft, designed to study an asteroid and return a sample to Earth, was named after Steven F. Hawking as a tribute to his continuing efforts to expand the limits of man's understanding of the universe. The Hawking is an adaptation of the Mariner Mk II series of spacecraft. Utilization of the Mariner Mk II design can accelerate development of the spacecraft and significantly reduce cost.

The Hawking spacecraft consists of three component vehicles: orbiter, lander, and the sample return craft (SRC); the spacecraft is shown in

Figure 7. Each of these vehicles has specific mission objectives and contributes directly to the fulfillment of the primary mission goal: return a sample of asteroidal material to the earth for analysis. Analysis of the samples is crucial in determining the composition of different taxonomic classes, and is a necessary step before utilization of asteroids can begin.

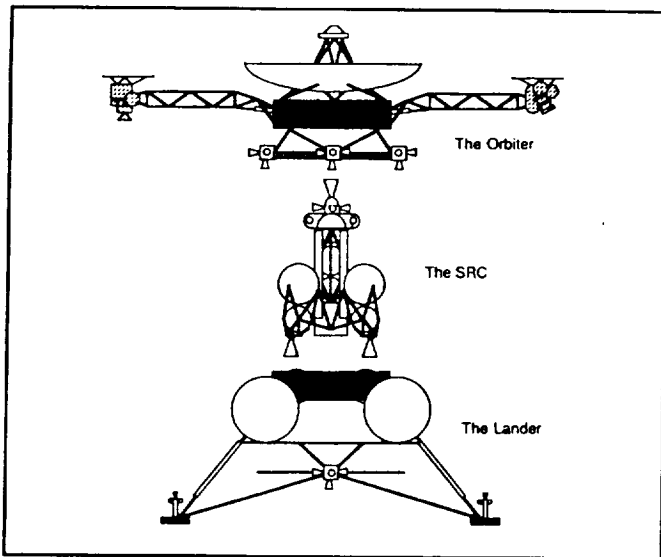


Fig. 7 The Hawking spacecraft

Mission Phases

The sample return mission scenario consists of nine phases, the successful completion of each being critical to the overall mission.

Phase 1: Hawking is launched into LEO orbit aboard an existing launch vehicle.

Phase 2: Hawking is injected into the interplanetary transfer trajectory by its upper stage.

Phase 3: During the interplanetary cruise, the spacecraft performs radio science experiments and studies of the solar wind.

Phase 4: Hawking inserts itself into the asteroid's orbit, positioning itself several asteroid radii ahead of the body and slightly to the sun side. This position allows the spacecraft to map the asteroid, determine its rotational axis, and locate scientifically interesting features, all to help determine a desirable landing site.

Phase 5: Once a landing site is chosen, the lander/SRC separates from the orbiter. The orbiter remains several asteroid radii away to serve as a relay for the lander/SRC and to provide reconnaissance for the rovers. The lander/SRC approaches and docks with the asteroid using its attitude control thrusters.

Phase 6: Samples of scientific interest are identified and retrieved by either the robotic arm or the rovers, and placed in the SRC.

Phase 7: The SRC is launched from the lander in a non-destructive manner (i.e., springs, pneumatic pistons) so the lander can remain intact to perform more analysis of the asteroid. At an altitude of approximately 0.5 km above the lander, the SRC rotates and fires the booster's engines to inject itself into the transfer trajectory back to Earth.

Phase 8: After the injection burn, the booster stage is jettisoned (Figure 8) and the communication antenna and solar panels are deployed (Figure 9). During the interplanetary cruise of the SRC, the integrity of the sample is maintained by minimizing g-loads during maneuvers and keeping the sample at a low temperature.

Phase 9: Upon arrival at Earth, the SRC inserts itself into a highly elliptical orbit. After accurate ground-based orbit determination, the SRC circularizes into LEO where it waits for pick-up by either the Space Shuttle or Space Station Freedom.

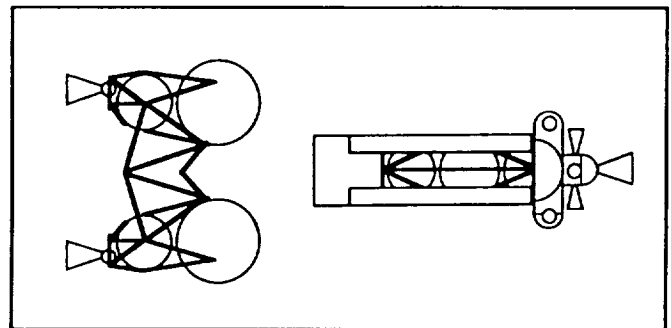


Fig. 8 The separation of the SRC from its booster

Benefits

There are many benefits to be gained from studying asteroids. Presently these bodies have been almost totally neglected in the exploration of the solar system. It is believed that because of their primitive state they hold clues to the formation of the solar system. Also, utilization of

asteroids as a future space-based source of raw materials could reduce the total cost of future space missions.

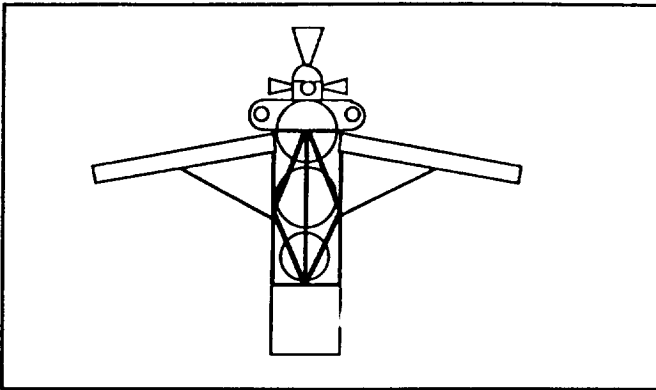


Fig. 9 Deployment of the communication antenna and solar panels of the SRC during the return trip