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Paper Session III-B - The Prospector's Proposal: Research Advancing Survivability Through Resource Options

Devin C. Walters
Project Manager, Astronautical Engineering Majors, Department of Astronautical Engineering, United States Air Force Academy, Colorado

Howard Clark
Astronautical Engineering Majors, Department of Astronautical Engineering, United States Air Force Academy, Colorado

Alex Cos
Astronautical Engineering Majors, Department of Astronautical Engineering, United States Air Force Academy, Colorado

Matt Dubois
Astronautical Engineering Majors, Department of Astronautical Engineering, United States Air Force Academy, Colorado

D. C. Conroy
Astronautical Engineering Majors, Department of Astronautical Engineering, United States Air Force Academy, Colorado

See next page for additional authors

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Presenter Information

Devin C. Walters, Howard Clark, Alex Cos, Matt Dubois, D. C. Conroy, Doug Fullingim, Wim Libby, Joseph C. Medlin, and Vincent Reyna

THE PROSPECTOR'S PROPOSAL:
Research Advancing Survivability Through Resource Options

Devin C. Walters Project Manager
Howard Clark
D.C. Conroy
Alex Cos
Doug Fullingim
Matt Dubois
Wim Libby
Joseph C. Medlin
Vincent Reyna

Astronautical Engineering Majors
Department of Astronautical Engineering,
United States Air Force Academy, Colorado

ABSTRACT

As a group of nine Astronautical Engineering majors, we have identified a problem of great concern. It involves the scarcity of strategic materials and the possibility that our supply will be cut off. The Prospector's Proposal is our solution. This proposal involves a prospecting mission to the asteroid belt, specifically Ceres. Using heavy lift vehicles, we will put our spacecraft into orbit where it will be assembled. A nuclear drive will provide propulsion for the unmanned probe. A landing craft will transport a mobile unit to the surface. This unit will collect samples that may contain sufficient quantities of the necessary materials to justify future mining. We have set a launch date for Spring 2001.

INTRODUCTION

In 1989, the United States finds itself in a very unhealthy predicament-- it is the number one industrial nation in the world, yet it is also one of the most import dependent nations in the world. The United States imports some ninety-seven percent of the raw materials, such as bauxite, titanium, and tungsten, which are critical to both its commercial and defense industries. This forces the United States to rely on its importers, not all of them friendly or sympathetic to U.S. interests, for the maintenance of its economic and defense systems. To lessen the impact of a sudden cut-off of these materials, we offer the Prospector's Proposal.

This proposal centers around an unmanned mission to the asteroid belt. The mission begins with the use of heavy lift launch vehicles propelling our payload into a low Earth orbit. The spacecraft and fuel needed for the complete trip will be sent up in parts to be remotely assembled in orbit. Using a nuclear drive the probe will enter its transfer orbit for Ceres, the largest known asteroid. This asteroid was chosen under the assumption that the largest asteroid would have the greatest chance of having the materials we hope to find. After arriving at Ceres a lander will separate from the probe and descend to the surface. Using a mobile unit, samples will be collected from both the surface and subsurface. These samples will be returned to the lander which will rejoin with the probe in orbit with Ceres. The probe will then return to Earth orbit where the lander will again separate and begin its descent into the atmosphere. Splash down will complete the flight portion of this mission. Analysis of the returned samples will complete the overall mission. Each phase of this proposal is discussed in the following paper, with particular attention paid to those areas of specialized equipment and technology unique to this project.

Phase One: Launch to LEO

To meet the requirements of our mission, we will need to place into orbit a spacecraft consisting of a transport system, lander system, and all needed fuel and propulsion equipment. This spacecraft design has a total weight of 948.82 tons. At the present time, there is no launch vehicle in the U.S. inventory capable of this mission without having to section the spacecraft and use several small launch vehicles to put it into orbit. Therefore, the designing of a new heavy lift vehicle had to be incorporated into this project.

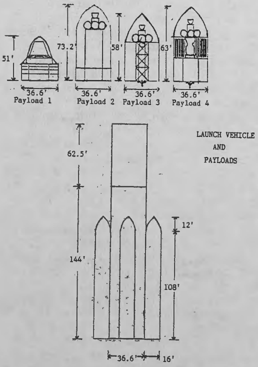

Figure 1

The launch vehicle is a three-stage, cryogenic, liquid, bipropellent rocket system capable of producing 8.0 x 10^6 pounds of thrust. The bipropellent is composed of liquid hydrogen and liquid oxygen generating a specific impulse (Isp) in the range of 360 - 455 seconds. These specifications are needed to acquire a delta V of 7550 m/sec and attain an orbit of 600 km. This design slightly exceeds the capabilities of the Soviet Energiya. Four of these launch vehicles boosting a payload of 216 to 260 tons each will be required to put the spacecraft components into orbit. Figure 1 shows the launch vehicle and the payloads for each of the launches. Two of the payloads shown have maneuvering units attatched to aid in the remote assembly of the spacecraft.

Phase II: Orbit Operations

Once in orbit, the spacecraft will be remotely assembled and tested for system integrity and accuracy. One of the primary systems to be tested will be the nuclear drive. Other systems to be tested will include: spacecraft environmental, NGC, and power systems.

The spacecraft engineering and environmental systems perform the function of determining the integrity of the vehicle's other subsytems. They will begin testing in orbit and continue testing throughout the mission to ensure that each major component of the vehicle is recieving sufficient power to perform its tasks. The vehicle's temperature and atmosphere will also be monitored to make sure that they are within acceptable limits. Active and passive measures will be undertaken in order to correct any deviations in the established standards. Earth based controllers will be informed of these deviations using the communication system.

Phase III: Outbound Transfer

When the on-orbit testing is completed and the orbital window opens, the nuclear drive will be fired. This burn will put the spacecraft into a hyperbolic escape orbit. This orbit will inject into a heliocentric, circular orbit with its apogee intersecting Ceres' orbit. At the point of intersection, the probe will perform a combined plane change to enter a co-orbit with Ceres. The fuel for each burn will be stored in a separate cluster of tanks, which will be jettisoned as they are emptied, reducing the spacecraft parasitic weight and improving efficiency.

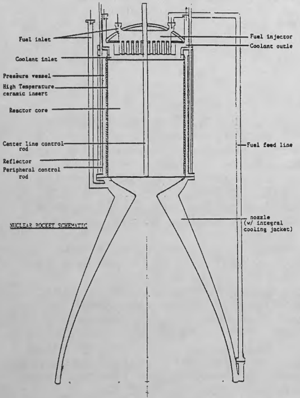

Figure 2

The engine for the spacecraft is a nuclear heat exchange drive, consisting of an nuclear pile and nozzle. Fuel is pumped into the reactor and heated. The superheated fuel is then expanded isentropically through the nozzle to produce thrust. This system was chosen for the advantages it has over chemical rockets. Nuclear rockets, as a class, have higher specific impulses than conventional chemical rockets, allowing them to use less fuel than a comparable chemical system. Also, nuclear drives can use almost any liquid as a propellant, overcoming the storability problems associated with high energy chemical propulsion systems which use cryogenic fuels. For this mission methane was selected as the propellant. Hydrogen, which would have produced a higher level of performance, was not used because it would not be storable for the three year duration of this mission.

The reactor was designed for reliable low energy performance over long periods of time, as well as for short term high energy performance during propulsion burns. The reactor shown in Figure 2 is a breeder reactor which produces more fuel for use at a later date as it operates, extending its useful lifetime. Also, breeder reactors do not require a heavy moderator, making them lighter than conventional reactors. The reactor will initially "burn" uranium-235. Some of the neutrons produced by this reaction will infect the uranium-238 that will initially moderate the U235 reaction. The uranium-238 will, after a series of intermediate reactions, become plutonium-239 which will be "burned" after the uranium-235 is exhausted. During thruster operation, the reactor heat will be carried away by the propellant. As the thruster operation is finishing, a secondary coolant must be employed. The coolant for this system is liquid sodium. It will be used to initially cool the reactor core and to provide cooling during low energy operation. Excess heat will be radiated away from the spacecraft by means of a radiator fin. Heated sodium will be used to provide power for various spacecraft systems hooking the turbines in the cooling loop to a generator. This power will be used to charge batteries on the lander and to power the environmental systems.

The spacecraft in Figure 3 is divided into two parts: the probe and the lander. As the spacecraft approaches Ceres the lander will separate from the probe and will continue on to Ceres while the probe remains in orbit to act as a relay station between the lander and Earth.

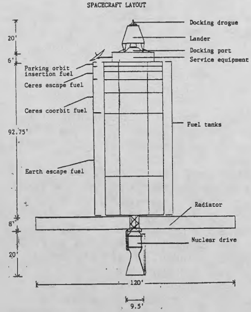

Figure 3

Phase IV: Ceres Operations

After the lander shown in Figure 4 separates from the probe, it will have an 18 hour descent to the surface of Ceres. During this time, Ceres will rotate twice. The first rotation will allow for observations to be made of the asteroid's surface. On the second rotation, the lander will touch down on a sight selected because of its apparent accessibility and location with respect to interesting features on the surface. The 18 hours will allow for the time delay involved in the transmission of the observations to Earth and the return of the commands to initiate attitude control for the lander to land on its chosen site.

Upon touchdown of the lander on the surface of the asteroid, a mobile unit will be deployed. Due to the thirty minute communication time lag, both the lander and the mobile unit must be autonomous systems, capable of remote or preprogrammed control, and with redundant features to accomplish their missions.

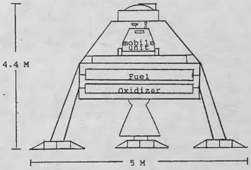

Figure 4

The lander has its own navigation, guidance, and control systems that allow it to maintain its orientation during any one of its flight phases. Engineering instrumentation and passive and active thermal control systems, as on the probe, will monitor and maintain a suitable environment for proper lander function. A communication system that allows the mobile unit to determine its position relative to the lander is also incorporated, along with the equipment necessary to maintain communications between the lander, mobile unit and Earth-based controllers. The propulsion system used on the lander must meet the design requirements for active transport and attitude control of the lander system. Due to the required restart capability of the rocket engine, a chemical system consisting of a bipropellent, hypergolic fuel was chosen. The fuel for the propulsion system will be stored for a minimum of three years, prescribing the need for a storable fuel. The fuel chosen is a mixture of hydrazine and nitrogen tetroxide, because it meets these requirements and provides the needed specific impulse. The propulsion system consists of one main rocket motor and four smaller motors with nozzles in five directions to allow for attitude control in any direction. All of the nozzles are made of stainless steel and use a double helix for regenerative cooling. Fuel will be stored in four tanks (two large and two small) and will be emptied by a pressurized air, bladder system. All of the power requirements will be met primarily by a large solar array, with a battery system used for back-up.

The mobile unit will be used to accomplish the primary mission of collecting soil samples for later analysis on Earth, a mobile unit will be deployed. Due to power constraints, sampling tests will be integrated with the enviornmental control so that power can be most efficiently used. In order to move, the mobile unit must overcome the forces of gravity and internal gearing friction. An electric motor will be utilized to produce the required torque, yet not at such a magnitude to cause the treads of the mobile unit to spin.

The mobile unit to be used is shown in Figure 5. Once this unit has been deployed on the surface, communication and path determination become the major concerns. The communication system consists of dish and rod antennas and a video camera. As the mobile unit traverses the surface of the asteroid, pictures will be sent back to Earth for analysis of areas of terrain which might be of particular interest. In order to avoid dangerous crevices or obstacles such as sharp inclines, declines or otherwise radical changes which may be encountered during the thirty minute communication time lag, a slope detector will automatically stop the mobile unit. The mobile unit will have a pre-programmed path consisting of four clover leaf loops, subject to change at Earth-based discretion. On each of the loops, roughly one quarter of the sought five hundred pounds of samples will be collected.

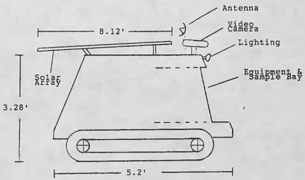

Figure 5

The central goal of the mission will be accomplished by using three methods of sample collection. The first will be electrostatic precipitation. Soil dust and small ocks will be magnetically attracted to a ten foot electromagnet which will be deployed behind the unit. In the case that surface samples cannot be collected in this way, a grinding system will scrape small amounts of the surface into a storage cannister which will be exchanged for an empty cannister after each loop. As a last resort, a diamond tipped drill will be used to loosen even the most dense soil. On the spot composition testing will be accomplished with a small ND YAG Diode pumped laser and a mass spectrometer. In this way, Earth-based controlers can gain limited insight into areas where collection should be concentrated.

The specified operations of the mobile unit will be accomplished by two robotic arms housed in the equipment bay. The laser, grinder, drill, and a collection tube will all be attachments to the mechanical arms. One arm will have gears which can generate high speed rotations while the other arm will fuction as a hand to hold the collection tube. The soil samples, which are stored in the the four cannisters, will be placed into the lander and sent back to Earth while the mobile unit remains on the surface of Ceres. After the samples have been collected and stored in the lander, the lander will reuse its descent engine to boost it back into orbit to rendezvous with the probe.

Phase V: Return to Earth

After the lander docks with the probe, the nuclear drive will be restarted. The spacecraft will burn into a return Hohmann trajectory. This trajectory will terminate via a hyperbolic approach into a 600 km orbit around Earth.

Phase VI:Deorbit/ Recovery

After a 600 km orbit with Earth has been established, the lander will separate from the probe to begin its descent into the atmosphere. The probe will shut down its systems and remain in orbit to be used on later missions. At this point the primary fuel tanks on the lander will be jettisoned to prevent possible explosions during reentry. The asteroid samples will descend through the atmosphere using the lander vehicle as a sheild against atmospheric heating. Using a parachute to control the descent, the lander will splash down at a predesignated point to be recovered for testing. This completes the outline of the Prospector's Proposal.

Conclusion

By no stretch of the imagination does this paper attempt to suggest that we should immediately dart off to the asteroid belt to solve our strategic materials dependency problem. On the contrary, it is intended to point out a problem that is going almost completely unnoticed and a possible solution which also incorporates several new technologies that would need to be developed. The Prospector's Proposal provides a valid reason for the development of these systems that would not only fulfill the requirements of this mission but others as well. We hope we have identified areas where our space program could be improved and used to further the interests of the United States and suggest that the U.S. put its technological might to use and achieve the things it is capable of.

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