A conventional Mercury sample return mission requires significant launch mass due to the large ΔV required for the outbound and return trips, and the large mass of a planetary lander and ascent vehicle. Solar sailing can be used to reduce lander mass allocation by delivering the lander to a low, thermally safe orbit close to the terminator. Propellant mass is not an issue for solar sails so a sample can be returned without resorting to lengthy, multiple gravity assists. The initial Mercury sample return studies reported here were conducted under ESA contract ESTEC/1635449-MLR, PI Colin McInnes, Technical Officer Pier Fafaker1,2. Updated solar sail capabilities were developed under the Ground System Demonstration program, funded by the NASA’s In-Space Propulsion Technology (ISPT) Program.


INTRODUCTION

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MISSION DESIGN

A square solar sail is envisaged, using tip vanes for attitude control, sized to provide adequate slew rates for the planet-centered mission phases. The spacecraft (sail payload) is mounted centrally, within the plane of the solar sail, so that both faces of the core structure are free to be used as attachment points for the solar sail. Characteristic acceleration of 0.25 mm/s² is desirable to be competitive with solar electric propulsion (SEP) and chemical mission trip times. This is enabled by a sail surface area of 2.85 m². From this initial orbit, the sail sail descends to a 100 km polar orbit to allow the solar sail orbit plane to match the 100 km polar orbit of the rendezvous vehicle, final proximity maneuvering takes place along with sample place along with sample container.

SCIENCE OBJECTIVES

It is important to ascertain the surface age of Mercury to understand its geologic history, however accurate rock dating of Mercury surface samples is only possible on Earth. A high-resolution descent. Sample pre-selection and pre-analysis will be conducted in-situ during landing site characterization using a robotic arm and small mobility device (20 m range).1

SAIL DESIGN

A square solar sail is envisaged, using tip vanes for attitude control, sized to provide adequate slew rates for the planet-centered mission phases. The spacecraft (sail payload) is mounted centrally, within the plane of the solar sail, so that both faces of the core structure are free to be used as attachment points for the solar sail. Characteristic acceleration of 0.25 mm/s² is desirable to be competitive with solar electric propulsion (SEP) and chemical mission trip times. This is enabled by a sail surface area of 2.85 m². From this initial orbit, the sail descends to a 100 km polar orbit to allow the solar sail orbit plane to match the 100 km polar orbit of the rendezvous vehicle, final proximity maneuvering takes place along with sample place along with sample container.

TECHNOLOGY DEVELOPMENT

NASA’s In-Space Propulsion Technology (ISPT) Program is investing in technologies that have the potential to revolutionize the robotic exploration of deep space. For robotic exploration and science missions, increased efficiencies of future propulsion systems are critical to reduce overall life-cycle costs and, in some cases, enable missions previously considered impossible. The ISPT Program is developing technologies from a Technology Readiness Level (TRL) of 3 through TRL 6.

Solar sail propulsion uses sunlight to propel vehicles through space by reflecting solar photons from a large, mirror-like sail made of a lightweight, strong material. Because the Sun supplies the necessary propulsive energy, solar sails require no onboard propellant, thus reducing payload mass. With photonic pressure providing continuous thrust, sailcraft can conduct missions not available with conventional or electric propulsion:

- high-inclination orbit maneuver plane changes
- fast-flybys missions to the outer planets or extra-solar system
- orbit in non-Keplerian orbits (above the pole of a planet) and hover indefinitely at a point in space

Over a two and one-half year period dating from 2003 through 2005, ISPT matured solar sail technology from laboratory components to full systems, demonstrated in relevant space environment as could feasibly be simulated on the ground. Two 20 meter square solar sail designs were manufactured, subjected to launch vibration and ascent vehicle profiles and deployed under high vacuum at NASA Glenn Research Center’s Plum Brook Space Power Facility.1