# OSS-1: A Pathfinder Mission for Space Science on the Space Shuttle

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**On its third flight, the Space Shuttle carried a payload of nine scientific instruments, designated OSS-1, to demonstrate the capability of the Shuttle for research in space plasma physics, solar physics, astronomy, life sciences, and space technology and to characterize the environment associated with the operation of the vehicle. A comprehensive scientific and technical program of measurements was successfully executed during the eight-day mission. The interactive use of the Remote Manipulator System by the crew to perform space plasma measurements, the control of the Orbiter as a pointing platform, and the ability to return instruments for recalibration and reflight demonstrate a basic Shuttle capability that can be exploited in future scientific missions.**

## Introduction

THE primary purpose of the third Shuttle flight, STS-3, was to test the orbiting portion of the Shuttle, termed the Orbiter, in extreme thermal conditions in space. Nonetheless, it carried a payload of nine scientific instruments for the dual purpose of demonstrating the Orbiter's research capability in space sciences and to provide information on the effects that the Orbiter has on its immediate environment.[1] The disciplines represented by the investigations included space plasma physics, solar physics, astronomy, life sciences, and space technology. The payload was designated OSS-1 because the program was originally managed by the Office of Space Science (now the Office of Space Science and Applications) at NASA Headquarters.

The OSS-1 mission also explored many of the areas of payload and science management that will be encountered by future payloads. The development, integration, launch, and operation of the payload required close coordination between the Goddard Space Flight Center, the Kennedy Space Center, and the Johnson Space Center. In this paper we provide a description of the payload, mission operations, scientific results obtained, and conclusions that may benefit future science missions.

## OSS-1 Objectives

NASA initiated its activities in developing this scientific payload in 1976 by issuing an Announcement of Opportunity that solicited scientific investigations for the initial Shuttle test flights—the Orbital Flight Test Program. Seven investigations were selected from 120 proposed. These investigations were subsequently supplemented with two others. The investigations reflected the dual objectives of the mission and many carried out a program of scientific research as well as making sensitive measurements of how the Orbiter alters its environment by the emissions of particles, gases, or electromagnetic fields. Science objectives included studies of the Orbiter's plasma environment and the propagation of an electron beam in space by the Plasma Diagnostics Package (PDP) and the Vehicle Charging and Potential Experiment (VCAP), observations of the zodiacal light and Milky Way by the Shuttle Induced Atmosphere Experiment (SIA), observation of the sun's ultraviolet and x-ray fluxes by the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) and the Solar X-ray Flare Polarimeter (SXFP), respectively, studies of interplanetary dust particles by the Microabrasion Foil Experiment (MFE), and studies of the effect of near-zero gravity on growing plants by the Plant Lignification Experiment (PGU). Studies in the technology of a sophisticated heat pipe system for instrument thermal control were made by the Thermal Canister Experiment (TCE). Principal investigators and institutions are listed in Table 1.

Many of the same OSS-1 instruments also were used to make sensitive measurements of the Orbiter's induced environment during its usual modes of operation. Its electrical charging characteristics were measured under passive conditions and during emission of an electron beam by the Fast Pulsed Electron Generator (FPEG), a part of the VCAP experiment. A Contamination Monitor Package (CMP) was specifically included to monitor the accretion of molecular contaminants. This instrument also carried two externally mounted mirrors to assess the effects of contamination on ultraviolet (uv) reflecting optical surfaces.

## OSS-1 Payload Description

Figure 1 shows the configuration of the OSS-1 payload and supporting equipment on STS-3. One investigation, the Plant Lignification Experiment, was located in a mid-deck locker of the Orbiter cabin; the remaining investigations were located on an engineering model of the Spacelab pallet. Responsibility for development of the payload was assigned to the Goddard Space Flight Center (GSFC). The Marshall Space Flight Center had responsibility for the pallet, which was provided by the European Space Agency, the Kennedy Space Center (KSG) was responsible for launch and landing, and the Johnson Space Center (JSC) managed Shuttle and flight operations, while GSFC managed the overall mission. The principal investigators were given the full responsibility for the technical performance of their instruments and the achievement of the accepted scientific objectives. A discussion of mission management aspects of the program can be found in an earlier paper.[2]

The OSS-1 payload was launched on STS-3 on March 22, 1982, from KSC and was placed in a nominal orbit of 130 n. m. altitude and 38 deg inclination. The attitudes flown are shown in Fig. 2 and their actual durations in Table 2. For convenience in discussing OSS-1 observations, the STS

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**Table 1 Investigations selected by OSS for flight on the OSS-1 mission**

| Investigation | Principal investigator | Institution | Instrument acronym |
|---|---|---|---|
| Plasma Diagnostics Package | S. Shawhan | University of Iowa | PDP |
| Vehicle Charging and Potential | P. Banks | Utah State University | VCAP |
| Characteristics of the Shuttle/ Spacelab-Induced Atmosphere | J. Weinberg | University of Florida | SSIA |
| Thermal Canister Experiment | S. Ollendorf | GSFC | TCE |
| Solar Flare X-ray Polarimeter | R. Novick | Columbia University | SFXP |
| Solar Ultraviolet Spectral Irradiance Monitor | G. Brueckner | NRL | SUSIM |
| Study of the Influence of Weightlessness on Lignification in Developing Plant Seedlings | J.R. Cowles | University of Houston | PGU |
| Microabrasion Foil Experiment | J.A.M. McDonnell | University of Kent, England | MFE |
| Contamination Monitor Package | J. Triolo | GSFC (USAF) | CMP |

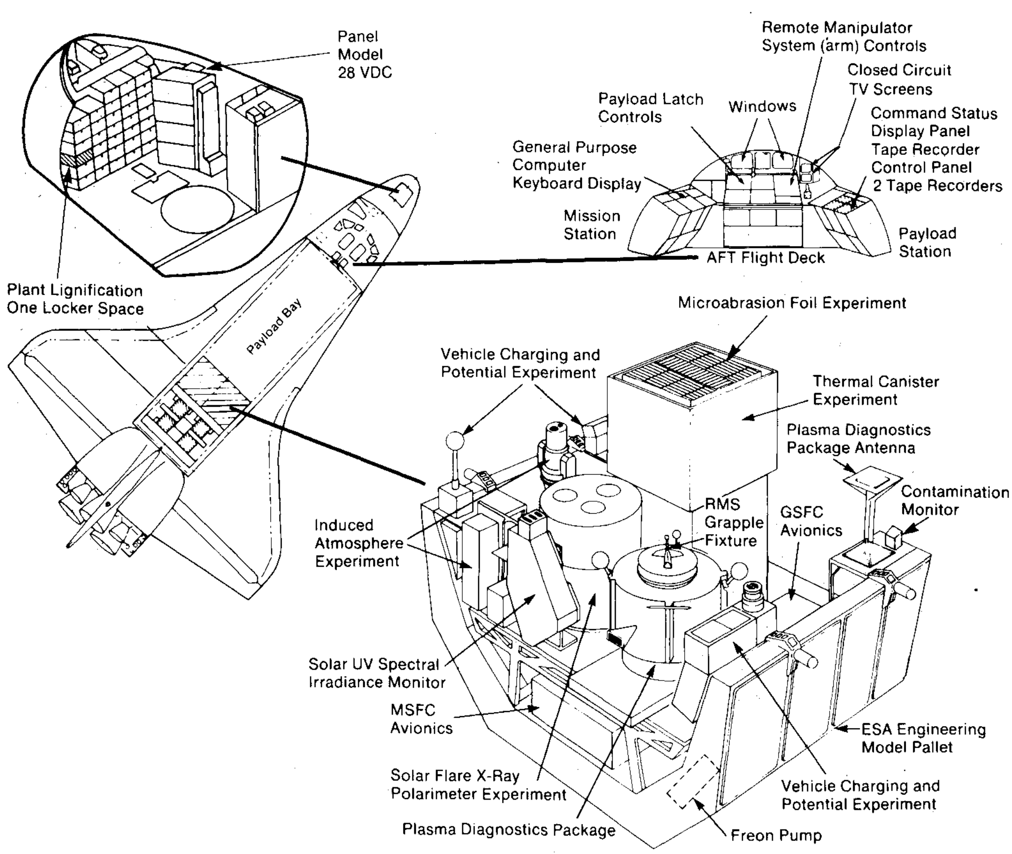


**Fig. 1 Configuration of the OSS-1 payload and its supporting equipment on STS-3.**

orientations in space are loosely referenced to the sun and Earth. The Orbiter landed at the Northrop strip dry lake bed landing site in New Mexico on March 30, 1982, where the PGU, payload tape recorders, photographic film from the SIA, and several other sensitive components were removed.

## Mission Operations

The timeline of OSS-1 operations to accomplish the mission objectives was constrained within the primary engineering flight objectives of testing the performance of the Orbiter under extreme thermal conditions. To achieve such extreme conditions, the attitude of the vehicle was held constant for long periods of time relative to the sun and Earth. The prolonged tail-to-sun attitude produced extremely cold bay conditions, while the bay-to-sun attitude resulted in elevated bay temperatures. All OSS-1 instruments survived, using combinations of active and passive thermal control and the Orbiter coolant loop system, where feasible.

The several Orbiter attitudes provided observing opportunities for the variety of OSS-1 instruments. The tail-to-sun and bay-away-from-Earth orientation (during a period when the moon was nearly new) provided a prime opportunity to study the faint zodiacal light and interplanetary scattered light. While in this orientation, the Orbiter was repositioned 10 deg down from a direct tail-to-sun position for a short time to allow a better measurement of the Shuttle's contaminant cloud as viewed in a near-solar direction. During the nose-to-sun attitude the Orbiter was rotated at two revolutions per orbit to provide the best opportunities to inject electrons from the FPEG along the Earth's magnetic field lines and to provide optimum ram/wake orientations relative to the Orbiter's bay. The variety of Orbiter attitudes exposed the

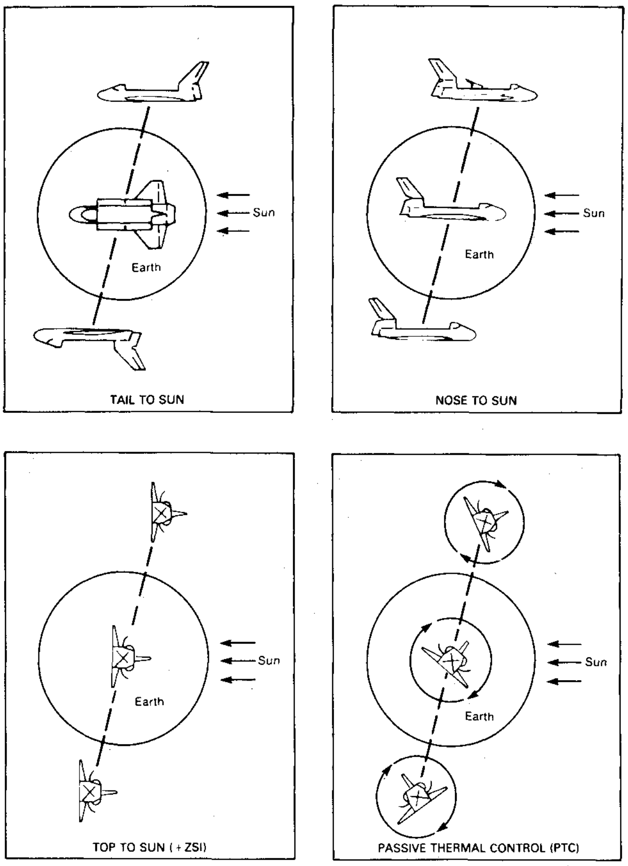


**Fig. 2 STS-3 thermal test attitudes.**

thermal canister experiment to changing thermal loads and allowed the Contamination Monitor Package to observe molecular accretion rates at different temperatures.

During the mission, several modes of instrument operation were demonstrated. Some required a minimum of in-flight support while others needed a deep involvement by the crew to maximize scientific return. In the latter category were the interactive space plasma physics experiments carried out by the PDP and VCAP, in which the crew eventually took over manual control of the Remote Manipulator System (RMS) to search for and map the properties of the electron beam produced by the FPEG. The crew also used sun-pointing signals from the SUSIM to adjust the orientation of the Orbiter so as to provide sun-centered pointing for that instrument and also executed visual, photographic, and closed-circuit television (CCTV) observations for the payload. In all cases, the necessary command sequences or other required activity were documented in a Flight Planning Annex and commented on by the flight crew, rehearsed at crew training sessions at GSFC and KSC, and used during preflight simulations at JSC.

On-orbit operation of the OSS-1 payload was supported around the clock by GSFC and principal investigator teams located at the Payload Operations Control Center (POCC) at JSC in Houston, Texas. Payload monitoring and control was maintained through the JSC Mission Control Center. Nominal payload operations and procedures as well as contingency and malfunction procedures were detailed in a Flight Operations Support Annex that formed the common basis for ground operations throughout the mission. Although payload personnel at the POCC were not in direct communication with the astronauts, space-to-ground voice loops were available to all POCC positions for monitoring the astronauts' activities in support of payload operations.

During the several prelaunch simulations at JSC, in which a fully operational POCC, MCC, and flight crew participated,

**Table 2 Orbiter's attitude durations for the STS-3 mission**

| Attitude | Planned, h | Actual, h:min |
|---|---|---|
| Tail to sun | 34 | 29:57 |
| Nose to sun | 60 | 80:20 |
| Top (Bay) to sun | 26 | 37:00 |
| Passive thermal control | 24 | 40:09 |

all on-orbit procedures were simulated at least once. These simulations were essential preparation for real-time operations and replanning activities. Written instructions to the flight crew were required for all checklist changes to the mission plan. Consequently, POCC personnel were continually engaged in the real-time replanning loop.

The following successful, extensive real-time replanning tasks were accomplished during the STS-3/OSS-1 mission:

1) Interchanging flight day 3 and flight day 4 to provide the crew with an additional day of rest before deploying the Plasma Diagnostics Package on the Remote Manipulator System.

2) Adding an extra day in orbit at the end of the mission because of landing conditions (i.e., high winds and dust) at White Sands Missile Range, New Mexico.

3) Working around all OSS-1 payload-related and STS-3 Orbiter-related anomalies.

4) Using the RMS elbow video camera to scan the top of the OSS-1 payload for verifying that the fragile Microabrasion Foil Experiment sensors and the Solar Flare X-ray Polarimeter windows had remained in their prelaunch conditions. This unplanned use of the RMS demonstrated the astronauts' adaptability in maneuvering the RMS early in the mission.

## Summary of OSS-1 Results

### Observations of the Orbiter's Environment

*Measurements of the Electromagnetic and Charged Particle Environment*

Comprehensive measurements of the electromagnetic and plasma environment of the vehicle and the vehicle's interaction with the surrounding plasma were made by the PDP, both in the Orbiter payload bay and above the bay while deployed by the Remote Manipulator System. Results are discussed by Shawhan, Murphy, and Pickett,[3] Shawhan Murphy, and Fortna,[4] and Murphy and Shawhan[5] in this issue. During daylight, the PDP and the Spherical Retarding Potential Analyzer of the VCAP experiment detected a cloud of ions and electrons around the Orbiter that was significantly different than the ambient ionospheric plasma. This cloud is attributed to gases and vapors emanating from the Orbiter and ionized by the Sun's ultraviolet radiation.

*Measurements of Orbiter Electrical Charging Characteristics*

The VCAP investigations showed that the Orbiter undergoes rather normal charging effects, remaining relatively constant at $-1$ to $-2$ V, except during FPEG operations. Even then, electron beam emission during sunlit portions of the orbit resulted in little, if any, charging of the vehicle. However, during darkness, the VCAP charge probes, with surfaces simulating conducting and insulating Orbiter surfaces, were at times driven to saturation ($>50$ V). This had no effect on Orbiter operations and the use of higher power electron emitters on future flights is considered feasible.[6] An unexpected result from time-exposure photographs and low-light level CCTV images used to observe the electron beam was the appearance of a glow on the ram side of Orbiter surfaces.[7] Experiments have been carried out on subsequent STS flights to characterize the spectrum and origin of this radiation further.[8] Its occurrence suggests that either very low-light level astronomical instrumentation should be pointed well away from Orbiter surfaces during observations, or the Orbiter should be flown at higher orbits for such missions.

*Evaluation of the Orbiter-Induced Particulate Environment*

The SIA investigation detected sunlight scattered by particulates that presumably originated from the Orbiter during sunlit portions of the orbit.[9] The brightness of this scattered background generally diminished as the mission progressed. Unexpected light levels recorded during spacecraft night are attributed to large-scale diffuse glows associated with the vernier thruster firings and a surface glow on the Orbiter as has been mentioned above. Detailed correlation with the operations timeline of Orbiter systems is being carried out and will provide guidelines for the operation of low-light level instruments on future missions.

*Evaluation of Molecular Accretion on Orbiter Surfaces*

The CMP measured varying molecular accretion rates on exposed surfaces, depending upon the Orbiter's bay temperature in relation to the temperature of collecting surfaces. These are summarized in an accompanying article in this issue.[10] Accretion rates at a 15°C collector temperature in a cold Orbiter bay, typical of astronomical telescopes in orbit, were as low as 1 Å/h. These rates increased appreciably when the Orbiter bay was oriented toward the sun. An additional experiment evaluating the contamination of $MgF_2$-coated mirrors was performed in conjunction with the CMP.[11] Several aluminized and magnesium fluoride ($MgF_2$)- coated mirrors were flown, both exposed and covered, on the surface of the CMP. Comparison of their ultraviolet (between 1150 and 2200 Å) reflectivities before and after flight showed no evidence for permanent Shuttle-induced deterioration of reflectivity.

**Scientific Observations Demonstrating the Orbiter's Research Capabilities**

*Studies of the Orbiter-Magnetoplasma Interaction Within 15 m of the Orbiter*

The PDP and VCAP separately and jointly investigated the interactions of the vehicle with the surrounding ionosphere. Among the affects detected was a large cavity of diminished plasma density trailing the Orbiter during dark periods of the orbit[6] and a broad spectrum of electrostatic noise generated by the Orbiter's motion through the ionosphere.[3] However, natural ionospheric noise emissions could be detected above this background level.

The VCAP electron beam experiments represented the first of a series of active space plasma physics experiments planned for the Shuttle. Both CCTV and photographs revealed a rapid diminution of the luminosity of gas excited by the primary electron beam in the first several meters of propagation from the FPEG.[7] The beam was modulated in controlled sequences and the response of the ionosphere measured as has never before been possible. The PDP, maneuvered both in programmed sequences and manually on the RMS, mapped the properties of the electron beam and the electric and magnetic fields produced by the pulsating beam.[12] A plasma column of energized ambient ions and electrons about 6 m in diameter, the electron gyrodiameter for 1 keV electrons spiralling around the Earth's magnetic field lines, was detected. The presence of energized ions indicates a plasma heating process perhaps similar to that in geophysical processes in aurorae.

*Observations of the Brightness, Polarization, and Color of the Diffuse Astronomical Background*

During nighttime portions of the orbit, the Shuttle-Induced Atmosphere Instrument was able to record the zodiacal and diffuse galactic light when sources of induced light such as thruster firings were not present.[9] Coordinated observations were conducted with a ground-based observatory on Mt. Haleakala, Maui, Hawaii. A comparison of space and ground observations will provide direct information on the level of atmospheric air glow continuum emission and atmospheric extinction and scattering in astronomical measurements made from Earth. These combined data will form a baseline for past and future terrestrial observations of the light of the night sky.

*Accurate Photometric Observations of the Solar Ultraviolet Spectrum*

The planned spectral scans of the sun's ultraviolet spectrum could not be accomplished because of a malfunction of the scan drive system in the SUSIM. Nonetheless, the planned calibration sequences were successfully carried out and the requisite photometric stability and accuracy of the instrumentation successfully evaluated.

The use of the Orbiter as a pointing platform, whose direction of pointing was updated by the crew using data from the instrument, was highly successful.[13] At the beginning of the period of bay-to-sun attitude, the SUSIM sun sensors indicated deviations from their preflight alignment to the Orbiter's navigational base of only 0.01 deg in pitch (within measurement error) and 0.04 deg in yaw, demonstrating that gravity release deformations of the Orbiter structure were appreciably less than the worst-case predicted values. The residual SUSIM solar offset was nullified by the crew by appropriately biasing the Orbiter navigational base. Over a period of 12 h of solar pointing, interrupted only when the vehicle passed into the Earth's shadow, the SUSIM-to-Orbiter alignment changed by about 0.05 deg in pitch and even less in yaw, implying a minimal amount of structural distortion in the Orbiter due to asymmetric solar heating.

*Search for X-Ray Polarization During Solar X-Ray Bursts*

The presence or absence of polarization in the hard x-ray flux emitted from solar flares provides a sensitive means of establishing the trajectories of high-energy electrons during the flare event. This information can, in turn, be used to infer the physical processes that initially accelerated these particles. During the bay-to-sun attitude, the SXFP recorded the x-ray emission from eight solar flares with a signal-to-noise ratio of 25 or better. Data analysis was complicated by a prelaunch degradation of a portion of the detector system. However, this was resolved through use of redundant observations made by the instrument and reasonable assumptions on the level of polarization expected from flares near the center of the sun. The resulting data set provides a level of polarization sensitivity never before obtained.[14] It is concluded that polarization of hard x-rays, if present at all, is very low, and inconsistent with flare models that hypothesize collimated beams of energetic electrons accelerated in the solar corona and impinging on the denser, lower layers of the sun's atmosphere.

*Measurement of the Physical and Chemical Properties of Cosmic Dust*

The Microabrasion Foil Experiment used a new type of thin-foil passive sensor to measure the high-velocity microparticle flux in near-Earth orbit for particle masses greater than $10^{-12}$ g to investigate the density distributions of the impacting particles and to study their chemical properties by analysis of residues remaining in the impact craters. Four hypervelocity impact perforations were found in the foil using scanning electron microscopy.[15] The calculated microparticle flux based on these data is a factor of five lower than the currently accepted near-Earth flux model for particles of $10^{-12}$ g. The recondensed debris found at three of the four perforation sites is being studied, using energy dispersive x-ray microprobe analysis, to obtain information on the chemistry of these interplanetary particles. An additional, unanticipated result of the experiment was the capture by the foil of several rod-like particles that may have originated in the glass fiber-reinforced "Beta-cloth" used in insulating blankets on the pallet. These observations are discussed by Dixon, Carey and McDonnell[16] in this issue.[16]

*Evaluation of Lignin Formation in Plants Grown in a Weightless Environment*

To investigate the growth of plants in a weightless environment, a special plant growth unit was designed for and carried in one locker space in the mid-deck area of the Orbiter cabin. The flight crew monitored the functions of this unit and, twice a day, reported the chamber temperatures. These temperatures were then applied to a laboratory control group of plants grown under identical conditions to those in space except for the presence of gravity. Three types of plants, mung bean, oat, and pine seedlings, were successfully grown in the weightless environment. In space, most of the plants grew toward the light, although some mung beans grew at skew angles, indicating that light is not a complete substitute for gravity. The space-grown plants were generally shorter. The roots in the space group of plants were also shorter and less numerous than the control group. Approximately 26% of the oat roots and 38% of the mung bean roots grew upward and many of these extended above the growth medium. Hence, neither light nor water was adequate to orient the roots in the space-grown group.[17] A statistically significant reduction of 25% in the total lignin content was recorded for the space-grown mung beans. The overall reduction for oat and pine seedlings was 7 and 4%, respectively, but the top sections of the flight stems of pine, which had the most development in space, contained 15 to 20% less lignin than the 1 *g* controls.[18]

**Evaluation of Technology that May Have Application to Future Experiments in Space**

The Thermal Canister Experiment successfully demonstrated the application of controllable heat pipes in a zero *g* environment to maintain simulated instruments at selected temperatures. The unit successfully operated in each of the four Shuttle attitudes, which represented a wide range of thermal loading on the TCE. During transitions from one extreme to another, the control systems of the variable conductance heat pipes adjusted their operation so that the internal thermal environment of the canister remained constant even though external conditions were changing. Details of these measurements are reported by Ollendorf[19] in this issue. The performance of the system in space exceeded its performance in prelaunch testing and conclusively demonstrated that such a technology can be used to shield sensitive instruments from the harsh and variable environment of space.

## Conclusions

The OSS-1 payload on STS-3 contributed to the objectives of the Orbital Flight Test Program by effectively using the vehicle as a platform for space observations and contributing to an assessment of the Orbiter's induced environment. The resulting measurements demonstrated that the presence of the Orbiter and its interactions with the ambient ionosphere can have an impact on certain sensitive observations. Depending on the measurement, attention must be paid to the attitude of the vehicle relative to its direction of motion, viewing directions of optical observations relative to vehicle surfaces, and the operation of Orbiter control systems. With reasonable precautions, however, many science and application disciplines will find the Orbiter a suitable platform for research, enhanced by the capability of control by man in space.

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