Science on the Space Shuttle

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The nine instrument packages on the third Shuttle flight should yield important data for space plasma physicists, astronomers, life scientists and engineers and also pave the way for future scientific payloads.

THE third flight of the Space Shuttle, chiefly intended to test the orbiting portion of the Shuttle in extreme thermal conditions in space, nevertheless carries a scientific payload. The investigations will demonstrate the Shuttle's capability for research in space plasma physics, solar physics, astronomy, life sciences and technology and will also determine the effects that the presence of the Orbiter may have on its immediate environment. The information to be gathered is thus the foundation for planning of future investigations with the Space Shuttle.

The scientific payload is designated OSS-1 because the programme was originally managed by the Office of Space Science (now the Office of Space Science and Applications) at NASA headquarters. Responsibility for development of the payload was assigned to the Goddard Space Flight Center. The manager for the scientific payload is Kenneth Kissin. The OSS-1 instruments will study the Orbiter's plasma environment and the propagation of an electron beam in space, record the Sun's UV and X-ray fluxes, observe the zodiacal light and Milky Way, record interplanetary dust particle impacts, operate a sophisticated heat pipe system and also grow plants in the Orbiter's cabin. Demonstrating the Orbiter's research capability demands accurate control of the Orbiter's orientation during solar observations and use of a Remote Manipulator System to carry a package of sensors that will map charged particle and magnetic and electric field distributions around the vehicle.

The same instruments will make sensitive measurements of how the Orbiter alters its environments by the emission of particles or electromagnetic fields. Although the spacecraft has been designed to minimize such effects some, such as propellant plumes from thruster engine firings or electromagnetic radiation from the electrical circuits, are unavoidable.

All but one of the OSS-1 instruments are mounted on an engineering model of the Spacelab pallet manufactured by the European Space Agency (Fig. 1). The instruments, pallet and the various subsystems for command, data handling, power and thermal control weigh 3,132 kg. The Plant Lignification Experiment is located in mid-deck lockers of the Orbiter cabin and two OSS-1 tape recorders and two control panels are located in the aft flight deck on the upper level of the cabin. Most internal experiment operations will be carried out via commands from the investigators located at the Payload Operations Control Center at Johnson Space Center in Houston, Texas.

On the third Shuttle flight, scheduled for late March, the Orbiter will be placed in a circular orbit of 241 km with an inclination of 38°. During the seven-day flight, the Orbiter will be held in several attitudes as part of the mission's thermal test objectives. The 28-hour long orientation of the Orbiter bay towards the Sun is suitable for solar observations. The planned 80-hour long period when the Orbiter will be maintained with its nose towards the Sun is a prime observing interval for the plasma physics investigations.

The nine experiments will now be described separately.

Electromagnetic environment

During the next decade, active electron and ion beam experiments in space will become an important tool for probing the environment above the Earth's atmosphere. This region contains plasma and magnetic fields of both solar and terrestrial origin. Hitherto, actively controlled charged particle experiments carried by rockets and unmanned satellites have been used to probe the structure of the Earth's magnetic field and to create the physical conditions that led to the formation of the aurorae, seen at high latitudes[1].

The Vehicle Charging and Potential Experiment is the first opportunity to make vehicle charging and electron beam studies from a manned spacecraft. In the first instance, measurements will be made of the effect of the natural ionospheric environment on the gross electrical characteristics of the Orbiter using two pairs of charge and current probes, situated on opposite corners of the pallet, which simulate both the electrically insulating and conducting portions of the Orbiter's surface, and with a Langmuir Probe–Spherical Retarding Potential Analyser located on the sill of the pallet.

Active electron emissions will be used to change the natural electrical balance to determine how a charged Orbiter will affect electron beam and direct plasma measurements. The electron source (the Fast Pulse Electron Generator) emits a 100-mA beam of nearly monoenergetic 1 keV electrons. Pulses as short as 600 ns or as long as 109 s can be generated (Fig. 2*a*).

The Fast Pulse Electron Generator will also be used to investigate the effectiveness

Table 1 OSS-1 Plasma Diagnostics Package instrumentation and measurement ranges

●Low energy proton and electron differential energy analyser	Nonthermal electron and ion energy spectra and pitch angle distributions for particle energies between 2 and 50 keV
●A.c. magnetic wave search coil sensor	Magnetic fields with a frequency range of 10–30 kHz
●Total energetic electron fluxmeter	Electron fluxes between 10^9 and 10^{14} electrons $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$
●A.c. electric and electrostatic wave analysers	Electric fields with a frequency range of 10 Hz–1 GHz S-band field strength meter
●D.c. electrostatic double probe with spherical sensors	Electric fields in one axis from 2 mV m^{-1} to 2 V m^{-1}
●D.c. triaxial fluxgate magnetometer	Magnetic fields from 12 mG to 1.5 G
●Langmuir probe	Thermal electron densities between 10^4 and 10^7 cm^{-3} Density irregularities with 10 m–10 km scale size
●Retarding potential analyser/Differential velocity probe	Ion number density from 10^2 to 10^7 cm^{-3} Energy distribution function below 16 eV Directed ion velocities up to 15 km s^{-1}
●Ion mass spectrometer	Mass ranges of 1–64 AMU Ion densities from 20 to 2×10^7 ions cm^{-3}
●Pressure gauge	Ambient pressure from 10^{-3} to 10^{-7} torr

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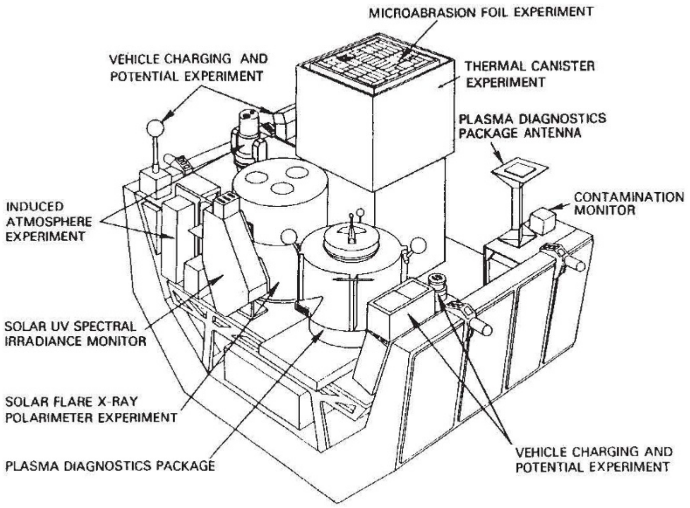


Fig. 1 OSS-1 instrumentation mounted on an engineering model pallet supplied by the European Space Agency. An additional OSS-1 experiment is carried in the mid-deck section of the Orbiter cabin.

of generating electromagnetic radiation by pulsing the electron beam at frequencies as high as 1 MHz. Several ground-based observatories will attempt to receive this radiation. Of particular interest is the extent to which VLF radiation can be generated using special electron beam modulation sequences. Detection will be attempted both at ground observatories and with VLF receivers aboard the recently launched Dynamics Explorer satellites.

Evidence will also be sought for a laboratory phenomenon termed beam-plasma discharge, in which an electron beam energizes a plasma column which then emits intense optical radiation and radio waves (Fig. 2*a*). It is thought that the electron beam initially ionizes residual gas, producing a columnar plasma. As the plasma density builds up, the beam creates electrostatic plasma waves which impart additional energy to the plasma, leading to further ionization and excitation and causing the column to emit optical and radio waves. In Earth-orbit, the different conditions may mean that beam plasma discharge does not occur — the gas density is less, the beam is not terminated by the metallic top of a chamber and the Orbiter moves the beam across magnetic field lines so that plasma may not build up. The Vehicle Charging and Potential Experiment will be used with the Plasma Diagnostics Package to tell whether beam plasma discharge is initiated by the beam from the orbiting electron generator (Fig. 2*b*).

Ionosphere studies

The Earth's ionosphere can be studied by introducing perturbations such as chemical tracers, radio waves and particle beams and by creating plasma wakes around solid bodies. The objectives of the Plasma Diagnostics Package, an assembly of electromagnetic and particle sensors, are to assess the electromagnetic and plasma environment of the Orbiter, to study the interaction of the vehicle with the surrounding plasma, to test the capabilities of the Remote Manipulator System and to carry out active beam–plasma experiments in conjunction with the Fast Pulse Electron Generator. Measurements will be made of electric and magnetic fields, plasma waves, energetic ions and electrons and plasma parameters — density, composition, temperature and directed velocity (see Table 1).

The Plasma Diagnostics Package will be operated both on the OSS-1 pallet and while deployed by the Remote Manipulator System. As the Plasma Diagnostics Package is moved in and around the Orbiter bay, measurements will be made of the ambient pressure and of the spectrum of electromagnetic interference generated by the Orbiter's electrical subsystems. The pressure profiles in time and in distance from the Orbiter are relevant for the design of instruments sensitive to gaseous contamination and those requiring low operating pressures. The sensitivity of wave receivers and of topside ionospheric sounders to be flown on future Spacelabs will be determined by the levels now measured, while measurements of electric fields and particles by the Plasma Diagnostics Package will provide an independent assessment of the charge condition of the Orbiter.

The Orbiter will move in the ionosphere, at supersonic velocity (Mach number 6 relative to the characteristic plasma sound speed or the ion acoustic sound speed[2]) and so will create a plasma wake that may be identified by plasma depletion, energization of particles and the creation of Alfvèn waves behind the Orbiter. Such processes are thought to be important consequences of the motion of other bodies through plasmas — for example, Alfvèn waves behind the jovian moon Io may accelerate the particles which cause decametric radio noise bursts[3]. Remote Manipulator System trajectories have been designed to move the Plasma Diagnostics Package through the wake boundary, thus providing direct observations of its Physical properties. When the package flies again on the Spacelab-2 mission as a subsatellite, the wake will be examined out to 20 km behind the Orbiter[4].

The combination of the Fast Pulse Electron Generator and the Plasma Diagnostics Package provides an opportunity to study the interactions of a beam of accelerated electrons with the ambient space environment (see Fig. 2*b*). Radio waves over a wide frequency range may be stimulated by both pulsed and continuous operation of the electron beam and measured with the Plasma Diagnostics Package. The two instruments will also operate together to investigate beam-plasma interactions such as the beam plasma discharge. Similar experiments will be conducted with more intense beams on Spacelab-1 and on later missions[5].

Solar ultraviolet radiation

Solar UV radiation in the spectral range 120–300 nm has an important role in the energy balance and photochemistry of the Earth's upper atmosphere. Molecular oxygen absorbs radiation at wavelengths below 242 nm, resulting in its dissociation into atomic oxygen; ozone is dissociated into molecular and atomic oxygen by UV radiation below 310 nm. These reactions

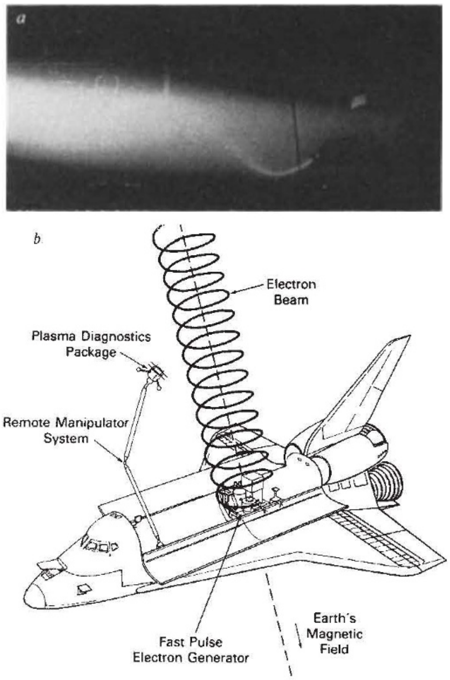


Fig. 2*a*, Photograph of light emission resulting from the interaction of electrons generated by Fast Pulse Electron Generator with residual atmosphere in a space simulation chamber at the Johnson Space Center. The column of luminosity enclosing the helical path of the primary electron beam is due to the occurrence of a beam plasma discharge for the conditions pertaining to this particular operation of the electron generator. *b*, Scheme for the joint Fast Pulse Electron Generator and Plasma Diagnostics Package operations. As the electron beam is emitted along some angle to the Earth's magnetic field, the Remote Manipulator System sweeps the Plasma Diagnostics Package back and forth across the beam region to make measurements of plasma fields and waves and of the energy distributions of electrons and ions.

take place at altitudes from 30 to 160 km in the Earth's atmosphere. Ozone is formed from molecular and atomic oxygen by a catalytic reaction which involves trace species such as NO, NO_x or Cl. Quantitative description of these reactions requires precise knowledge of the absolute amount of solar UV radiation as a function of wavelength. Although many attempts have been made to measure this quantity, large experimental discrepancies still exist[6] (Fig. 3). The objective of this first flight of the Solar Ultraviolet Spectral Irradiance Monitor experiment is to establish a more accurate base of solar UV irradiance measurements with an absolute error of 10 per cent or less over the wavelength region 120–400 nm. During the STS-3 flight, it will accumulate approximately 20 hours of solar measurements, compared with 5 minutes during a typical sounding rocket flight.

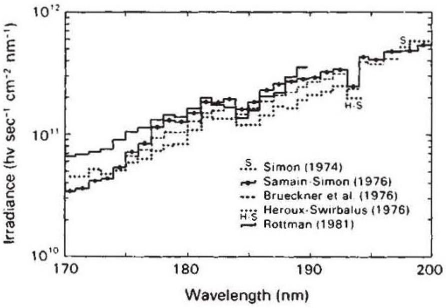
Calibration is important. The instrument carries two independent spectrometers and an in-flight calibration light source which allows tracking of any sensitivity change due to vibration at lift-off or contamination during flight. Its seven detectors will allow cross-checks of possible detector changes. It can be operated in broadband (5 nm) or narrow band (0.15 nm) modes over the wavelength region 120–400 nm. During 17 orbits amounting to approximately 28 hours, the bay of the Orbiter will be pointed to the Sun by the crew, using Sun sensors mounted on the Solar Ultraviolet Irradiance Monitor and measurements of solar intensities will be interleaved with periodic in-flight calibrations[7].

The measurement of the solar UV irradiance on OSS-1 is only the first step of a programme to measure the variability of the solar UV radiation over an 11-year solar cycle. This variability has been estimated to be less than 20 per cent in the 170–210 nm region and less than 2 per cent in the 210–300 nm region[8], and Fig. 3 shows that a decisive improvement of accuracy is needed if the Sun's UV variability is to be determined.

Solar flares

Although it is known that there are high-energy electrons in the Sun's atmosphere during solar flares, fundamental questions remain about the nature and location of the mechanisms by which the electrons are energized and their energy dissipated. It is, however, believed that a flux of magnetic energy from the solar interior provides the energy for these events, and that interactions of the accelerated particles with the Sun's atmosphere dissipate this energy, leading to observable flare phenomena including X-ray emission. Similar bursts of energy observed by the Einstein Observatory from other stellar objects have established that flares are relatively common. Hard X rays emitted during flares carry unique information about the motion of the electrons producing the radiation[9]. A definitive observation of the state of polarization of the radiation could provide important data to test theoretical models of the flare phenomenon.

Fig. 3 Recent measurements of solar UV irradiance in the spectral region between 170 and 200 nm (after ref. 6).



The Solar Flare X-ray Polarimeter on OSS-1 aims to observe flare X rays emitted between 5 and 30 keV and to measure their polarization as a function of time and photon energy. The instrument uses blocks of metallic lithium surrounded by xenon-filled proportional counters as detectors. If polarized, the incident X rays will be scattered preferentially by the lithium into directions normal to the plane of the electric vector of the incoming radiation. To avoid instrumental effects that have plagued previous measurements, the instrument uses three independent sets of scattering blocks and detectors, with each unit rotated by 120° with respect to the other two about a line passing through the Sun. A minimum of two units is necessary to determine the magnitude and orientation of polarization; the use of a third provides redundancy and increased effective area[10].

The instrument will be aimed at the Sun by orienting the entire bay of the Orbiter and it is planned to maintain the Orbiter in this orientation for approximately 28 hours. Solar flares occur only sporadically on the Sun, so that the observation of flare emission is not assured. However, the instrument has sufficient sensitivity that even a small event can yield a usable signal. Such events can be expected to occur about once a day on average.

Zodiacal light

The zodiacal light arises from sunlight scattered or absorbed by interplanetary dust particles, the characteristics of which have been partly defined by rockets and unmanned Earth-orbiting satellites[11]. Observations of colour, polarization and angular dependence are needed to determine dust particle size and composition[12]. Unfortunately, accurate data are scarce. Thus, polarization results at different wavelengths are often combined. There are some observations of brightness, but few of polarization and colour in regions off the ecliptic, closer than 30° to the Sun and near the anti-solar point — the regions which contain the most information on the dust. The Shuttle Spacelab Induced Atmosphere Experiment will provide observations to determine more precisely the position of maximum concentration of interplanetary dust and will search for evidence of different particle characteristics for dust near the Sun.

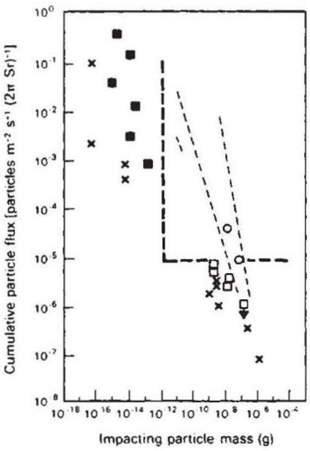


Fig. 4 Measurements of near-Earth microparticle fluxes by various techniques: ■, impact plasma sensors; ×, capacitor discharge sensors; ○ recovered surface examination; □, perforation of pressurized cylinders; dashed lines, models derived from microphone sensors. The area to the upper right of the heavy dashed line is the sampling regime of the Microabrasion Foil Experiment on OSS-1. The cumulative particle flux is the flux of particles above a specific mass. Adapted from ref. 14.

Although astronomical observations from space avoid the effects of the Earth's atmosphere, the observing platform releases particulates which may form a local contaminant cloud that will also scatter sunlight into the detector. The presence of such an induced atmosphere can be established by comparing observations made when the spacecraft is in sunlight and in the Earth's shadow. The photopolarimeter system on OSS-1 will measure the light scattered from any local cloud of particulates and will record the brightness, polarization, colour and angular dependence of the diffuse astronomical background (zodiacal light and background starlight) at visual and near IR wavelengths.

The instrumentation to be used is the spare unit of the Skylab S073 photopolarimeter and bore-sighted 16 mm camera. The system, which includes an optical train, optical filters for 10 wavelength bands between 400 and 820 nm, a polarization analyser, a brightness calibration source and a photoelectric sensor, can carry out observing sequences according to pre-programmed routines. Although the instrument was operated on Skylab, difficulties with the airlock precluded observations closer than 80° to the Sun. A new gimbal mount has been designed for this mission, allowing the instruments to be scanned in a vertical plane running fore and aft along the Orbiter axis. The instrument will view the entire sky between 20° and 120° from the Sun. Limited observations will also be possible at larger angles.

Interplanetary dust

Direct sampling of interplanetary particulate matter has been carried out from balloons, U-2 airplanes, rockets, Earth-orbiting spacecraft[13]. Remote measurements have been made with sensors in Earth orbit and interplanetary space[14]. Even impact craters in lunar samples have provided valuable information. A wide range of particle masses, down to 10^{-15}g have been observed, with the cumulative particle flux increasing strongly with decreasing mass (Fig. 4). While comets are thought to be the most likely source of interplanetary dust, direct measurement of particle composition could discriminate between cometary and asteroidal sources for the dust.

The Microabrasion Foil Experiment aims 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. The sensor, attached to the thermal blanket on top of the thermal canister experiment, consists of approximately 1 m^2 of 5μm thick aluminium foil bonded to a gold-coated brass support mesh bonded to a Kapton sheet to form a double layer detector.

Differing types of impacts may be recorded. A particle of mass $< 10^{-12}$g will form a hypervelocity impact crater on the foil surface, without penetrating the foil. More massive particles will penetrate the foil forming a characteristic 'penetration profile', dependent on the particle's incident velocity. Particles penetrating the foil may survive intact to produce a single impact crater on the rear Kapton sheet, or the particle may split into fragments and produce a corresponding number of impact craters on the sheet. Low density "fluffy" particles readily fragment whereas high density iron or stony micrometeorites survive almost intact.

Unlike the other experiments, the Microabrasion Foil Experiment is passive. Post-flight measurements of the craters with scanning electron microscopy and energy dispersive X-ray microprobe analysis of residues will provide information on elemental composition, density and shape, and thus on the origin of these particles.

Plant lignification

Although few plants have been grown in space, Russian experiments have demonstrated that near-zero gravity disorients root and shoot growth, enhances plant sensitivity to substrate moisture conditions and generally results in a high mortality rate. However, little is known about the physiological changes that occur. Understanding of gravity's effects on plant growth and metabolism will provide an insight into plant physiology and aid development of an effective biological life support system.

After cellulose, lignin is the most abundant carbon compound in plants and provides both their strength and form. As gravity is believed to be a primary controlling stimulus for lignification the Plant Lignification Experiment will evaluate how near zero gravity affects the quantity and rate of lignin formation in different plant species during early stages of development.

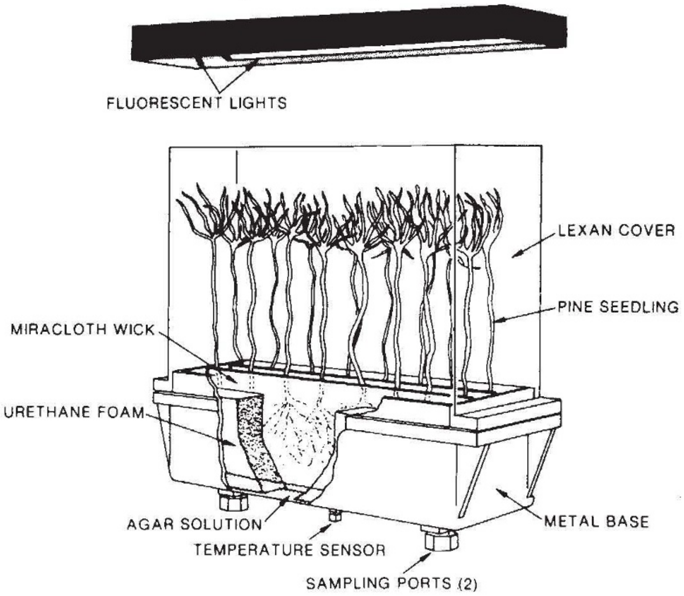
Of the major groups of higher plants the gymnosperms will be represented by slash pine, the monocotyledonous angiosperm by oat, and the dicotyledonous angiosperm by the mung bean. All are compact species that may be grown in the limited space and relatively low light levels provided by the compact flight Plant Growth Unit. Oat and mung bean seeds and young pine seedlings will be planted in the growth chambers (Fig 5) before launch so that most seedling development will take place in a weightless environment. Electronics for controlling and monitoring temperature and light cycles are incorporated into the Plant Growth Unit. At the latest convenient time (about 7 hours before launch) the unit will be carried on board and installed in a mid-deck locker of the Orbiter cabin, where it will remain throughout the flight.

On landing, the Plant Growth Unit will immediately be removed from the Shuttle, the plants photographed, and the gaseous atmosphere of the plant chambers analysed. The seedlings will then be removed and analysed for lignin content.

Control experiments, with the plants growing in a 1-*g* environment, will be conducted after the flight using the flight hardware and flight environmental data. Lignin data from the flight and control plants will be compared for patterns of lignin deposition to assess whether lignin is reduced in plants grown in zero gravity.

Because the reduced flight time of the previous Orbiter flight prevented completion of the Heflex (plant) Bioengineering Test that it carried, this experiment has been added to the current flight and is also carried[16] in the Orbiter cabin. The test is being conducted specifically to determine the optimal soil moisture conditions for germination and growth of the sunflower ***Helianthus annus*** in near zero gravity. It is a prelude to a plant growth experiment to be conducted on the first Spacelab mission to be flown on the Shuttle in 1983.

Fig. 5 View of a growth chamber, one of six used in the Plant Growth Unit of the Plant Lignification Experiment.



Thermal canister

The long-term use of Space Shuttle means that many scientific and technical investigations can be performed in the Orbiter bay. However, the extreme thermal environmental conditions ranging from equivalent sink temperatures of + 100°C in full Sun, to -100°C, in shadow may cause problems. In the past such conditions were accommodated using coatings, insulation and heaters. With the Shuttle, an instrument designed for one set of conditions may have to survive in an entirely different environment if flown again with different orbit attitudes. If a thermal enclosure were provided which decoupled instruments from the wide extremes in external tempeature whilst maintaining them in a benign environment, simpler thermal designs for instruments, with limited maintenance between flights, might be realized.

To this end the Thermal Canister Experiment aims to determine whether a device using controllable heat pipes could maintain simulated instruments at several selectable temperature levels in zero gravity, and under widely varying internal and external thermal loads. It is hoped to demonstrate ±3°C temperature stability at various control points in the canister while dissipating up to 400 W in cold Orbiter attitudes (bay away from the Sun)

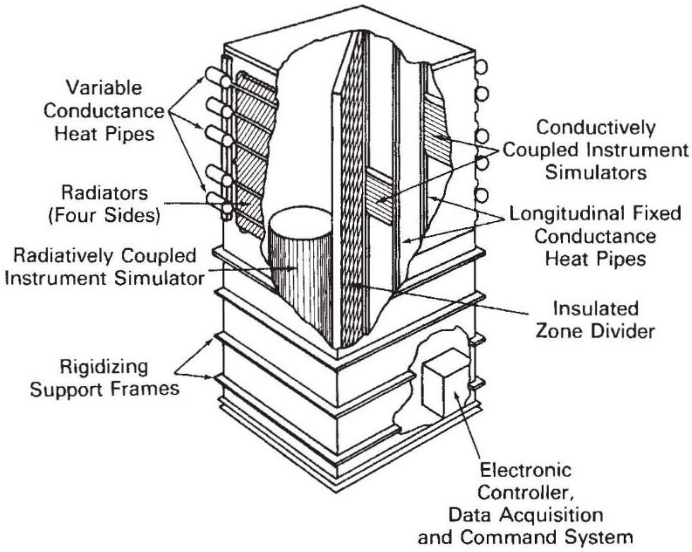


Fig. 6 Cutaway view of the Thermal Canister Experiment showing controllable heat pipes. In flight conditions, the lower half of the unit is covered with multi-layer insulation to provide a measure of isolation from temperature extremes in the Orbiter bay.

and 100 W hot (bay towards the Sun) conditions.

The Thermal Canister Experiment (Fig. 6) consists of a rectangular enclosure 3m high × 1m long × 1m wide with its aluminum sides equalized in temperature by a system of longitudinal fixed conductance heat pipes. These heat pipes collect the thermal energy dissipated internally by electrical heaters simulating instruments in operation and the energy absorbed from direct and reflected sunlight. This heat is then conducted to variable conductance heat pipes mounted to external radiators at the upper end of the canister and radiated to space. The heat pipes are long narrow closed chambers with internal capillary wicking which provides pumping action. The wick is saturated with a volatile liquid (ammonia) in equilibrium with its vapour. Heat transport is established by applying heat at one end (the evaporator) and providing cooling at the other end (the condenser) with the heat being trasferred as latent heat of vaporization. The flow path is completed by capillary forces in the wick.

The variable conductance heat pipes are more complex than the fixed conductance type in that they contain a non-condensible gas (nitrogen) stored in a reservoir at the condenser end of each pipe. As the temperature of the evaporator end of the pipe falls a heating element raises the temperature of the reservoir, causing the gas to expand into the condenser, blocking the condenser region and effectively stopping heat pipe action. The length of condenser rendered inactive depends on the temperature level along the pipe. Conversely, with increasing evaporator-end temperature, the gas will recede into the reservoir making more active area of the radiators available for heat rejection to space. The signal for activating the reservoir heaters is supplied through a feedback loop consisting of a temperature control sensor and either a hardwire proportional controller or a computer-driven controller. The sensors are attached to the canister side walls or on simulated instruments located in two different zones separated by an insulating barrier. The simulators are either radiatively or conductively coupled to the canister walls.

During the mission, it is planned to: (1) operate the canister over set points (5–25°C) located on the walls and on the simulators themselves; (2) change the internal dissipation (in the simulators); and (3) demonstrate control in maintaining the two zones at differing temperatures. The system can be operated by a proportional controller maintaining a specific temperature at one sensor, or by a microprocessor that uses all available data to maintain the overall temperature of the canister at some level, in balance with the environment, irrespective of the preselected set point.

Contamination monitoring

Payloads operating in the bay of the Orbiter will be exposed to a variable gaseous environment. In addition to outgassing of the vehicle and the payloads themselves, the operation of altitude control systems, the venting of relief valves and the dumping of water for thermal control of the vehicle all represent molecular sources that may affect sensitive instrumentation, particularly equipment at cryogenic temperatures. Measurements have been planned for the series of four orbital test flights using the Induced Environment Contamination Monitor provided by the Marshall Space Flight Center and located, on this flight, behind the OSS-1 pallet in the Orbiter bay. Particulate measurements will be provided by the Shuttle/Spacelab Induced Atmosphere Experiment. A molecular contamination monitor on the OSS-1 pallet provides information on molecular species around the OSS-1 instruments, supplementing measurements from the Induced Environment Contamination Monitor.

The Contamination Monitor Package, sponsored by the United States Air Force, contains four temperature-controlled Quartz Crystal Microbalances which measure the accreted mass of molecular fluxes. These microbalances are identical to those contained in the Induced Environment Contamination Monitor but their operation can be monitored and the data analysed during the flight. Their temperatures may be reset by command after initial results have been analysed to optimize the operation of the sensors.

The instrument will monitor the mass accretion of condensible volatile materials during ascent, on-orbit operations and descent. After the mission, the data on mass build-up will be correlated with payload activities, Orbiter operational events, performance of other OSS-1 instruments and Induced Environment Contamination Monitor results. The activation energy of the major species of the accreted materials can also be estimated.

While minimal impact is expected for most instruments that may fly on Shuttle, long-term exposures of particularly sensitive optical components or cryogenic surfaces to the Orbiter environment may require special precautions.

Future prospects

The OSS-1 instruments will point the way to future developments in the use of the Shuttle for space science investigations. Two of the OSS-1 instruments will fly again on the Spacelab-2 mission: the Plasma Diagnostics Package will be released from the Remote Manipulator System to become a subsatellite and make measurements of the spacecraft wake at distances up to 20 km behind the Orbiter, while the Solar Ultraviolet Irradiance Monitor will be mounted on a solar pointer to continue UV irradiance measurements through the solar cycle. The data from other experiments will be used to design large UV and IR telescopes and other instruments for future flights in the Orbiter. Ultimately, the Shuttle program will include discipline-dedicated flights and the development of space platforms serviced by the Shuttle.

1. Grandal, B. (ed.) *Artificial Particle Beams Utilized in Space Plasma Physics* (Plenum, New York, 1982).
2. Samir, U. & Stone, N.H. *Acta Astronaut.* **1**, 1901–1141 (1980).
3. Gurnett, D.A. & Goertz, C.K. *J. geophys. Res.* **86**, 717 (1981).
4. Shawhan, S.D., Burch, J.L. & Fredricks, R.W. *AIAA Paper 82-0085*, Florida (1982).
5. Raitt, W.J. *et al. AIAA Paper 82-0083*, Florida (1982).
6. Simon, P.C. *Solar Phys.* **74**, 273 (1981).
7. VanHoosier, M.E., Bartoe, J.-D.F., Brueckner, G.E., Prinz, D.K. & Cook, J.W. *Solar Phys.* **74**, 521 (1981).
8. Cook, J.W., Brueckner, G.E. & VanHoosier, M.E. *J. geophys. Res.* **85**, 2257 (1980).
9. Elwert, G. & Haug, E. *Solar Phys.* **20**, 413 (1971).
10. Lemen, J.R. *et al. Solar Phys.* (submitted).
11. Weinberg, J.L. in *Lecture Notes in Physics* Vol. 48. (eds Elsässer H. & Fechig, H.) 3–18 (Springer, Berlin, 1976).
12. Giese, R.H., Hanner, M.S. & Leinert, C. *Planet Space Sci.* **21**, 2061 (1973).
13. Brownlee, D.E. in *Cosmic Dust* (ed. McDonnell, J.A.M.) 295–336 (Wiley, New York, 1978).
14. McDonnell, J.A.M. in *Cosmic Dust* (Wiley, New York, 1978).
15. Leinert, C. *Space Sci. Rev.* **18**, 281 (1975).
16. Taranick, J.V. & Settle, M. *Science* **214**, 619 (1981).