CHAPTER III

REPORT OF THE INFRARED, ULTRAVIOLET AND SPACE PLASMA PANELS

INTRODUCTION

Following the presentation of environmental results in the Environmental Measurements Session, three Panels were convened to discuss the current status of the payload bay and the needs of Infrared, Ultraviolet and Space Plasma experiments.

A general discussion was held in each Panel which included a review of those measurements important in each area. Discussions were held on the issues of concern to each group and how these environmental conditions might impact future experiments. The discussions revealed several common issues among the three Panels, as evidenced in the following summary reports. Many recommendations were made and are given in the individual reports and in the Summary.

INFRARED PANEL REPORT

The Infrared Panel treated various issues and environmental impacts regarding infrared experiments. Various environmental factors can contribute to the ability of infrared devices flown on the Shuttle to perform the mission for which they are designed. The Panel members concentrated on what should be done to:

- improve the measurements on the spacecraft
- improve the instruments that are to be flown
- develop protective devices for the instruments
- develop any other devices that should be flown

The discussions were categorized by the panel into the following areas of concern:

- vehicle glow
- particulates
- gases
- contaminants
- thermal control.

Each of these is summarized in the following pages.

1. **Glow**

Two issues were identified by the Infrared Panel concerning the glow that is observed on the Shuttle on surfaces on the forward direction of flight. The first concern was the effect that the glow would have on optical measurements looking outward from the shuttle, specifically (a) would there be direct radiance from the glow into instruments, and (b) would there be particulate scattering of the glow radiation into the optical instruments? Clearly, a number of the characteristics of the glow need to be measured.

An important characterization of the glow is knowing what is the reaction causing it. Is it 0-0 or 0-H recombination, or some other reaction? Some of the information needed is the spectral character of the glow, i.e., is it a continuum, or does it have a line spectrum and what is the radiant intensity of the continuum and any line spectrum that may be present? These data are needed over a wavelength range from the ultraviolet out to approximately 2.5 micrometers in the infrared to answer the questions posed above.

Another factor that requires more information is the extent of the glow beyond the surfaces facing in the forward direction of flight. Even though the color film exposure was quite long (400 seconds), color film is not extremely sensitive in the yellow and red, and it is possible that the extent of the glow is greater than indicated by the color pictures. It is also not clear from the color pictures whether the maximum radiant output was at the surfaces or displaced somewhat from the surfaces towards the direction of flight.

A related issue is the air glow effects that are associated with the RCS firings, and the same types of measurements are needed on those; that is, what is the spectral content of the glow? What is its radiant intensity and its distribution around the spacecraft?

The second main concern about the glow is the question of the effect of chemical reaction on surfaces on which the glow forms. Weight loss was observed on the Shuttle flights for plastic materials, as well as formation of a chalky white coating and changes in the flexibility of the plastic materials used in thermal blankets. Tests should be made as soon as possible to determine if the glow is the cause of the changes observed in the plastic materials used in the thermal blankets to indicate whether the plastic materials should be protected with some other overlayer, or replaced with some other material. This is quite important since vaporized plastic will probably redeposit in other areas of the spacecraft, including the optics flown in the payload bay. It is well known from past flights that effluents from plastics can coat optics that, if they are also exposed to the sun, can degrade and cause overall sensitivity losses for infrared instruments.

2. **Particulates**

As with the glow, the principal need for information on the particulates is the material composition of the particulates; specifically, the volatility, conductivity, location and space in time, size distribution vs location, determination of the density of particles smaller than those detected so far, and the migration and redistribution of the particles including dwell time in the field of view of optical instruments.

Of particular concern are those particles that might reach optical surfaces and thereby deposit a residue that would not evaporate and would change the characteristic of reflecting (more than transmitting) surfaces. Since particles are observed with apparent diameters as large as 2 centimeters, these questions remain. Should optical instruments provide their own shields as a protection against such particles entering the optics, and should those shields be open and closed as events such as firing of the RCS thrusters occur?

The concern about particles also extends to spacecraft that may be launched from the Shuttle, because the plan now is to have a thermal shield for such spacecraft, but not to have a shield that would exclude particulates and gases. If these spacecraft require that optical apertures be protected and covered prior to separation from the Shuttle, this information should be known as soon as possible because of the added complexity and expense associated with shielding from any particulates that can enter optical apertures. Obviously, any action that can be taken to reduce the number of particulates in the Shuttle payload bay would be quite desirable and would reduce the necessity for added covers.

3. Gases

Despite the "snow storm" effect observed after the dumping of waste water, it appears that the H_2O column densities are below original specifications and of little or no concern to the sensors on the spacecraft. It would be desirable, however, to have these H_2O column densities confirmed on successive Shuttle flights to make sure they remain below the standards.

The presence of more complex gases such as monomethylhydrazine should be measured, if possible, as a function of location and persistence after firing of the RCS system. This again may lead to a requirement for instruments that would have deployable covers that can be closed during the firings and opened at some time after the firing when the gas concentration will have reached a satisfactory level.

4. Contaminants

This area is intended to cover contaminants other than the particulates and the gases such as monomethylhydrazine. In particular, the contaminants referred to are those which are outgassed from those plastics that have shown a weight loss on the spacecraft, and those that resulted in non-volatile residues that were collected on the quartz crystal microbalances. The chemical form of the material lost from the plastic should be determined. This will have a strong bearing on the necessity for individual experiments to provide covers that can be opened and closed during the flight of the spacecraft.

If non-volatile residues are left behind on the quartz crystal microbalances, it is also possible that such residues may be left behind on optical surfaces. Attempts should be made to analyze those residues and their origin to reduce, if possible, the quantity of the material produced in the residue, and to indicate whether protective covers are needed on optical systems. Any relationship between the residues and the previously mentioned glow should be established as quickly as possible as a step in reducing the amount of the residue.

5. Thermal Control

It was reported that, in one case in the so-called "sun up" position into the payload bay, a sensor measured a temperature of 260^{o} Fahrenheit. It is not clear if an optical sensor located in the same position would reach the same temperature, but it is known that the utility of optical sensors such as mercury cadmium teluride detectors would be severely affected, if not destroyed, by temperatures as high as 260^{o} Farenheit. Further information is needed on the temperatures that would be reached in flight by sensors, and whether operational control can prevent sensors from seeing the sun directly and being overheated, or whether protective shields are needed that may have to be deployed and restored during flight.

Such temperatures would probably accelerate the mass loss observed in some of the material in the payload bay, so it would appear that operational planning is necessary to avoid prolonged exposure to the "sun up" position and temperatures as high as those measured on the previous Shuttles. Passive control of temperatures of surfaces that see the sun directly has been achieved on the Shuttle either by the Shuttle itself as a whole, or by individual experiments that are forced, because of operational constraints, to view the sun directly.

6. General Considerations and Recommendations

With minor exceptions, the major thrust of the Infrared Panel output was that better characterization is needed of all of those features of the Shuttle that may affect optical instruments. Those characteristics identified were the glow, particulates that had been observed and those that may not have been observed due to smaller size, the various gases that are produced by the RCS system and leakage from other parts of the Shuttle and other instruments on the Shuttle, contaminants that are produced by mass loss from plastics and possibly from other instruments on the Shuttle, and thermal control to prevent temperatures from reaching as high as the 260^{o} Fahrenheit that was reported.

It was the feeling of the Panel that a basic "core" package of environmental measurements should be made on every Shuttle, and in as many locations as is feasible. This package of measurements should also be supplemented in special cases when unusual experiments are flown to build up a baseline of knowledge concerning the environment of the Shuttle. This would reduce the amount of funding and effort expended to protect individual instruments to that actually needed, rather than overdoing it because of lack of knowledge of the Shuttle payload bay environment. The Infrared Panel recognized the fact that while redesign of the Shuttle is not practical in any major way, better characterization of the Shuttle environment is certainly practical - and could, in the long run, lower the cost of experiments by reducing the complexity of the protective devices that had to be provided for each experiment.

ULTRAVIOLET PANEL REPORT

The UV Panel loosely interpreted the Shuttle environment to include things other than the on-orbit environment situation. The Panel was concerned with the environment which UV payloads would encounter at Kennedy Space Center plus pre and post-flight phases.

The Panel addressed issues during pre-launch, post-launch, and the Shuttle-induced background which is a real issue for ultraviolet experimenters since there is very little information on the UV to date. In these areas of concern, other issues addressed by the Panel included problems such as optical coatings, thermal effects, pointing stability, gas cloud/charged particle emission, affects on integrated circuits, and information/data dissemination. Each of the topics of interest to the UV Panel and recommendations made are summarized in the following paragraphs.

1. Integration During Pre-Launch

The Ultraviolet Panel paid particular attention to the integration of experiments at KSC prior to launch. The Panel addressed the need for defining the special integration procedures, such as cleanliness, in the Payload Integration Plan (PIP). The feeling from the integration people at KSC seems to be "Put it in your plan if you think you will need it."

One of the key problems raised was the cleanliness level which must be maintained for optical, UV and X-ray coatings. The general feeling is that just because there is a certain "visual cleanliness level" does not mean that the optical coatings are not contaminated. Visual inspection does not guarantee that there is no molecular surface contamination.

The Panel expressed the desire that a better cleanliness criterion be expressed that would translate into specifications driven by science objectives.

One other key problem addressed by the Panel in the optical and ultraviolet area was the routine "last access to the payload" situation. The last opportunity for an experimenter to have access to his instrument may be five weeks before launch. This is a major issue. As an example of interest, astronomical photographic emulsions fog rapidly if left at room temperatures. If hypersensitized within a few days of use and kept cool (0-10^{o}C), improvements of three to four times sensitivity can be realized.

While the experimenters would like to use these emulsions (III AS, III AF, etc) in Shuttle experiments, the environment on board the Shuttle is not adequate.

Other issues expressed by the Ultraviolet Panel related to integration at the KSC and whether sufficient testing, integration and storage facilities exist for those instruments that will fly multiple flights. Would there be clean facilities where optics, perhaps detectors, could be changed at KSC. At the present time, experimenters are concerned with even getting access to change electronic boards. The Panel felt KSC facilities need to be evaluated systematically from a user viewpoint.

2. **Post-launch Environment**

The post-launch environment issues raised by the Ultraviolet Panel were cleanliness and thermal control, how fast the experimenter can get to critical components including photographic films before thermal fogging is significant. Rapid removal of the critical items will be required for many scientific experiments.

3. **Shuttle-Induced Background**

The shuttle-induced background is just now being addressed; we do know it comes from several already known sources. The photographs obtained to date are demonstrative of some problems. From the STS-3, significant red emission is known to exist near Shuttle surfaces. A correlation with exposure to the ram velocity vector is now known.

The UV Panel was concerned that similar velocity vector induced emissions will occur in the optical region possibly in the near ultraviolet region, but especially in the infrared region.

The Panel recommended that a study of this problem be done with high priority, since there are many shuttle payloads, including OSS-3, that are anticipated to go down to sky background. The shuttle-induced emission will greatly impact science goals.

4. **Vernier Thruster Firing**

The vernier thruster firings contaminate both by the chemical cloud properties and the pointing disruptions. There is insufficient information on cloud dissipation to the level where observations can be done in the ultraviolet and optical. Settling times of pointing systems are only modeled at this time.

Some of the STS-3 measurements indicated background enhancements during vernier thruster firings, even overhead the payload bay. The Panel is concerned as to how far into the ultraviolet these emissions extend, how bright they are, and what techniques could be employed to minimize the background.

Experimenters need a warning signal in the data channels in order to protect the experiment and/or accumulated data from thruster contamination. This problem was pointed out five years ago but to no avail. Many experimenters have reiterated that the need still exists because experimenters could have time to drop voltages on detectors and even close shutters. The Panel recommended that this issue be reconsidered by NASA.

Another issue was the number of thruster firings which would occur. This is a serious problem for a pointed system as the frequency of firings could be often enough that the pointing never settles down.

5. **Water Dumps**

Similar issues were raised by the Ultraviolet Panel concerning water dumps and flash evaporator operations. NASA needs to schedule water dumps and flash evaporator use around experiment timelines. Moreover, experimenters must be aware of the schedule and should receive data line signals during the operations.

6. **Optical Coatings**

Although the OSS-1 witness mirror tests of MgF_1 overcoated aluminum showed no deterioration, there were some questions raised by the Panel because the witness plates were not thermally monitored. They may have been as hot as 50-degrees Centigrade and very little adhesion of contaminants would have occurred. The Panel recommended that further experiments be flown with better control of conditions.

Much more information is needed about mirror coatings in the extreme ultraviolet. The Panel was concerned knowing that osmium, which oxidize rapidly at the Shuttle orbital altitude. Other mirror coatings, including iridium, need to be tested in Shuttle and the Long Duration Exposure Facility.

7. **Contamination of Other Materials**

Photographic emulsions were another area of interest to the Panel since experimenters need to know what emulsions are not affected by the Shuttle environment. Some films have been flown on OSS-1, but there are no results at this time.

The Panel recommended an experiment be developed to determine if emulsions can be hypersensitized in the payload bay on orbit.

8. **Shuttle Gas Cloud/Charged Particle Environment**

Some problems were identified by the Panel regarding upstream ram pressure and its effects on UV detector pumps. Windowless UV detectors will be flown on the OSS-3 mission. The ion pumps for these detectors are designed to pump pressures at 10^{-6} Torr and are rapidly used up at higher pressures.

The pressures reported from prior flights indicate that the Shuttle may never fall below the 10^{-6} Torr pressure. Obviously, if the pump is working continuously at a higher pressure, its lifetime is going to be limited. The problem becomes very serious as the ion pump may not last through the mission.

More information is needed about the payload bay gas pressure and whether or not these pumps are adequate.

Another issue for the Panel was the effect that charged particles will have on photographic emulsions, on detectors, and on certain optical surfaces. More information is needed.

9. **Thermal Environment**

The payload bay thermal environment is of concern to the Panel. An example is the environment the OSS-3 payload may encounter.

The OSS-3 payload consists of three co-aligned telescopes mounted on a MSFC - designed cruciform. The cruciform is mounted on the Instrument Pointing System (IPS) and the payload utilizes Spacelab hardware and avionics. The payload shares flights with deployable satellites. During the first few days when the satellites are deployed and tested, the

IPS remains stowed. Two of the telescopes will be in a very hot payload bay situation. The key issue is will they survive. The thermal problem might be resolved if the IPS could be deployed, looking out of the bay, so that all of the instruments had a much more benign environment.

The Panel recommended that this issue and related thermal problems be worked through over the next few years.

10. **Pointing Stability**

Pointing stability is a problem that has been compounded by the fact that the Shuttle is not stable in an inertial environment that it continuously uses vernier thruster to keep it stabilized.

At this time it is not known how many firings must occur per orbit for inertially pointed experiments. Estimates are that between 60 to 400 firings may occur per orbit. The IPS settling time may be as long as 15 seconds. With 400 thruster firings per orbit, the IPS may never settle down to a quiescent situation. The OSS-3 science goals require arc second pointing stability. Internal motion compensation will be required for the quiescent stability. The Panel recommended that consideration be given to reducing the thruster firing per observation.

11. **Control from Aft Flight Deck**

While operations and control are not really contamination, concern was expressed about the need for interactive control. If an experimenter can control automatically as well as from the aft flight deck and from the ground, then the unanticipated situations can be met much more successfully.

Experience gained through Spacelab 1 and 2 missions would provide a much better feeling on just how much control an experimenter will indeed work from the aft flight deck and from the ground. It should reveal how much the experiment can be changed orbit by orbit. The Panel felt this could make the difference between success and failure for a mission.

12. **Integrated Circuits**

Experimenters flying new experiments on the Shuttle are increasingly relying on state-of-the-art integrated circuits. Few devices are flight-qualified and indeed many may be susceptible to soft or hard failures due to radiation or energetic particle hits.

The Panel recommended that experiments be developed to test various integrated circuits both for short missions and for long duration exposure facilities.

13. **Management Consideration**

The Ultraviolet Panel recommended that there be an organization designated within NASA Headquarters that has the responsibility to follow the contamination control on the Shuttle, provide funding where it would be very useful to get more information, and effectively improve the contamination situation. The Panel felt that NASA would obtain a more postive response from the science and engineering community if they know that the contamination problem is being worked upon and being improved.

SPACE PLASMA PANEL REPORT

The Space Plasma Panel covered areas related to the plasma environment of the Shuttle, the electromagnetic interference generated by the Orbiter and its payload, and the electrical interaction of the Orbiter with the surrounding atmosphere. The Panel was also concerned about the environment as it affects instrumentation used for plasma measurements. The discussions and presentations made during the Workshop established many of the characteristics of the Shuttle environment and led to a number of recommendations from the Panel.

The discussions were categorized into the following topics:

- Vehicle Glow
- Electromagnetic Interference
- Pressure Environment
- High Voltage Systems
- Ground Contamination
- Data and Information.

Each of these is summarized below.

1. Orbiter Surface Glow

The first item of concern to the Plasma Panel was related to the vehicle glow detected on STS-3 and STS-4 and the glow process studies. The Orbiter surface glows as a result of impact by the ambient ionosphere on the surface of the vehicle with optical emission of undetermined brightness and an undetermined mechanism. The issues addressed were whether or not the glow could be seen on round objects and whether or not the glow is related to the thruster firings. Thus, the recommendation of the Plasma Panel was related to further understanding of the glow. The Panel recommended that the effort to understand the processes responsible for the surface glow observed on STS-3 and STS-4 be greatly intensified. Investigations aimed at studying this phenomenon should be given the highest possible priority on forthcoming Shuttle flights.

2. Electromagnetic Interference (EMI)

The measurements made with regard to the electromagnetic interference emission levels onboard STS-3 were of concern to the Plasma Panel since the electromagnetic interference (EMI) generated by the Orbiter and the payload is about 20 dB below the current specification.

The Panel felt that a large part of the EMI that was measured was actually generated by the payload. Accordingly, there is a relatively benign environment; but to take advantage of it, payloads must be coordinated. This coordination should be done at an early stage. The Plasma Panel recommended that user input within any particular proposed Shuttle payload should be coordinated to facilitate electromagnetic compatibility with the least degree of EMI limitations across the board.

3. **Pressure Burst**

The results from STS-3 revealed that pressure bursts produced by firing of the Reaction Control System (RCS) jets reached levels of 10^{-5} torr. This level is a problem when particle detectors and other instruments which use high voltages are operated in the payload bay.

The Panel recommended that the pressure environment in the payload bay and its dependence on angle of attack, thruster firings, and other pressure modifying events be measured with a suitable time resolution on subsequent flights to permit a better characterization of the pressure environment.

4. **High Voltage Systems**

Results from STS-3 have demonstrated that "active" experiments utilizing electron beams can be successfully operated in the payload bay with particle detectors and plasma wave diagnostic measurements performed in and near the payload bay. Changes in vehicle potential were observed, with the highest values occurring at night.

Orbits flown to date have been low inclination orbits. Polar orbit environments will be substantially different, particularly the flux of energetic particles from auroral beams which will bathe the entire Orbiter. The Panel recommended that measurements similar to those flown on STS-3 should be made in polar orbits.

The Panel also felt that parametric studies should be made pursuant to increasing the effective conducting area of the Orbiter, to allow the use of higher current beams in the future. Since future payloads will incorporate exposed high voltage systems, it is necessary to understand the operation of HV systems in the Orbiter environment.

5. **Ground Contamination**

High levels of contamination were present in the ground facilities during integration of the payload, although there was no detected impact on the on-orbit operation of any of the instruments. The Panel is concerned about the risk of payload equipment degradation or failure induced by contamination during payload preparation, particularly in the Orbiter Processing Facility.

The Panel recommended that efforts to characterize and document contamination during payload preparation should be continued, and that improvements should be made to facilities, where practical, to reduce the contamination levels. The Panel also recognized that shortened exposure to the environment reduces contamination and encourages improved scheduling of payload flow through the preparation facilities.

6. **Data and Information**

Many of the questions raised by participants during the workshop could be answered with data already obtained. The Panel felt that continued support for data analysis is needed and recommended that results be incorporated into modeling codes, specifications, and reports disseminated to the user community.

The Panel also recommended that an Environment Information Directory of available documentation concerning the Shuttle and Spacelab environments be made available quickly to users. The directory should include reports, specifications, guidelines, measurements, models, analyses, and the Operational Information (OI) downlink measurements list. An annotated bibliography of this documentation should be made available as soon as possible and be kept current with updates on a timely basis.

The Panel considered the need for this information to be of the highest priority and fundamental for future use of the Shuttle and Spacelab. The Panel further recommended that investigators on future Shuttle and Spacelab missions be provided realtime access to the OI measurements list. The experience of investigators on the orbital flight test missions has demonstrated the need for realtime Orbiter data provided to the Instrument Ground Support Equipment. Some of the operational changes developed as a result of the first four missions require detailed and timely knowledge of Orbiter operations including trajectory, attitude, thruster firings and water dumps.