INFRARED MEASUREMENTS OF SPACECRAFT GLOW PLANNED FOR SPACELAB 2

Giovanni G. Fazio and David G. Koch

Smithsonian Astrophysical Observatory

Abstract. A liquid helium cooled infrared telescope (IRT) will be flown in July 1985 on Spacelab 2. The instrument was designed to measure both diffuse and discrete infrared astronomical sources, including the zodiacal light, galactic, and extragalactic components, as well as to evaluate the induced Orbiter environment. The focal plane contains ten photoconductive detectors covering six broad bands from 2 to 120 microns. Each detector has a 0.6 by 1.0 deg. field-of-view optimized for detection of extended sources of IR radiation. Except for the 2-micron detector, the system noise is limited by the sky background noise.

This paper describes the measurements planned for the IRT using the 1-meter base of the Plasma Diagnostics Package (PDP), an already existing SL 2 experiment, as the glow generating surface. The measurements will be repeated changing the position of the PDP, the attitude of the Orbiter, and the ram direction in an effort to remove both the thermal component of the PDP emission and the cosmic background radiation.

Introduction

The primary intent of these observations is to obtain measurements of the glow phenomenon in the infrared produced by the base of the Plasma Diagnostics Package (PDP). The IRT is capable of obtaining data in six broad passbands: 2.0-3.0, 4.5-9.5, 6.1-7.1, 8.5-14.5, 18-30, and 70-120 microns. The two longest wavelength passbands, 18-30 and 70-120, include three detectors each. See Koch, et al. [1982] for a complete description of the instrument. Young, et al. [1981] contains a detailed description of the IR detector performance. Additional data that will be of use in interpreting the results will come from the in situ measurements by the PDP of the particles and fields associated with the ram gases. Specifically, data from the mass spectrometer will be used. Further data that will be of use are measurements available in the visible from the image-intensified camera [Mende et al., 1985]. The equatorial altitude for this mission will be 383 km and the inclination 49.5 deg.

Method of Observation

In an attempt to determine a dependence on material two observational methods will be used. One will be to see if there is any glow from the inside of the gold-coated mylar sunshade of the IRT. The other will be to look for the glow from the base of the PDP, which is covered with beta cloth and aluminum screen as the PDP is positioned near the beam of the IRT. The Orbiter Remote Manipulator System (RMS) will be used to position the PDP so that the flat base of the PDP will be in the Orbiter Y-Z plane. In both of the methods of observation described below the telescope will be fixed (stowed) and viewing along the Orbiter -Z axis (see Figure 1).

Observing Constraints

During the glow measurements, the field-of-view of the telescope must encompass regions of low infrared brightness. Such regions include the ecliptic pole or the galactic pole and must avoid regions near or crossing the galactic plane. (The preferred orbit would have the plane of the orbit pass near the ecliptic pole.) While the data are being taken the field-of-view, hence the Orbiter, must be held inertially on the sky. In addition, the data must be taken on the nighttime side of the orbit in order to observe with the lowest possible background and to permit optical photography of the glow. The velocity vector should be kept approximately normal to the base of the PDP. Data cannot be taken while near or passing through the South Atlantic Anomaly (SAA). Water dumps, operation of the flash evaporators, experiment purges,and other sources of effluent must be inhibited prior to and during data taking.

Since the thermal radiation from the PDP is substantial it will be important to have the thermal conditioning prior to and during the observing runs as nearly identical as possible.

Observing Sequence

Due to the uncertainties in both the absolute position of the PDP when manipulated by the RMS and the alignment of the telescope with respect to the Orbiter, it will be necessary to make the glow measurements by gradually cycling the PDP into and out of the field-of-view of the telescope. This will also provide a means of establishing the baseline intensity without the PDP. The intensity will be correlated with the RMS positional information. This cycling with the RMS will be repeated for each of four separate inertial positions on the sky during the 36 minutes of Earth shadow during two consecutive orbits. On the first orbit the PDP base will be pointed into the wake and on the second orbit the PDP base will be pointed into the ram, all other conditions remaining the same. During the first three inertial positions, the PDP will be moved in closer and closer to the telescope beam at about 15 cm above the sunshade aperture. During the fourth inertial position the PDP will be raised 5.7 meters above the aperture where the 1-meter PDP diameter will still fill the 15-cm telescope beam, but the thermal effects from the PDP will fill a much smaller portion of the telescope side lobes. This alternate position is shown in Figure 2. Before each RMS cycle, the cold shutter at the focal plane will be actuated to provide an absolute flux level. On the second orbit when the PDP base is into the ram, the mass spectrometer on the PDP will be pointed into the ram to provide in situ measurements of the plasma.

Data Deconvolution

To be able to distinguish the thermal radiation of the PDP from the glow, as well as to measure the intensity scale height of the glow, the method of observation has to provide many differential experiments. These include moving the source (PDP) in and out of the telescope beam, repeating the cycles at different distances from the beam, and repeating at a different height above the aperture. Before and after each cycle the cold shutter is used to provide an absolute flux level. All of this is done first with the PDP base in the wake where there should not be any glow and only the infrared of the environment and sky is measured. Then the entire process is repeated on the next nighttime pass with the base into the ram where any difference in signal should be due to the glow. Any slight variations of the sky background due to variations in the inertial position can be corrected, since the prime objective of the IRT is to measure the large-scale structure of the sky. In addition to the many signal modulation and differentiation effects, the glow should be distinguishable spectrally from the zodiacal and the PDP thermal radiation, both of which are approximately 300 K blackbodies.

Finally, any glow off of the inner surface of the gold-coated mylar sunshade should be detectable and separable from other signals since during each cycle of the RMS, the telescope is held inertially on the sky, but during the 4 to 9 minutes of inertial hold, the orbital motion will result in the velocity vector varying from slightly into the sunshade aperture to slightly out of the sunshade. During normal IR mapping the telescope aperture will always be pitched slightly away from the velocity vector so that the inside of the sunshade is never exposed to the ram.

Expected Results

An estimate of the expected infrared flux can be made based on the following assumptions:

1. The glow is due to atomic oxygen impacting the surface at 7.7 km/sec.
2. The atomic oxygen flux at 400 km altitude is 1.5 x 10^{14}/cm^2/sec.
3. The spectral shape of the emitted radiation will resemble that of highly excited OH.
4. The decay distance from the PDP base produced by oxygen impact is 1 meter or more.

In the paper by Banks et al. [1983] the volume density of the visible photon emission was estimated to be 2 x 10^7 photons/cm^3/sec at the 280 km altitude for STS-3. This was observed in about a

0.1 micron band so that the spectral flux is 2 x 10^8 photons/cm^3/sec/micron at about 0.65 microns. If the emitting species is OH we can use Langhoff's [1983] calculated spectrum to get volume densities of 10^{10}/cm^3/sec/micron at 1.3 to 2.2 microns at 280 km and 10^9/cm^3/sec/micron at 4.5 to 6.5 microns beyond which it drops rapidly with increasing wavelength. The IRT will look through a 100-cm-thick volume of gas that is radiating into 4π sr. Therefore, the telescope should see a flux of 8 x 10^{10} photons/cm^2/sec/sr/micron at 1.3 and 2.2 microns and $I_{280} \approx 16 \times 10^9$ photons/cm^2/sec/sr from 4.5 to 6.5 microns. From ground-based measurements of STS-9 (240 km altitude) by Witteborn et al. [1985] a flux of 5 x 10^{11} photons/cm^2/sec/sr/micron at 1.6 microns was observed and the observed flux at 2.3 microns was attributed entirely to the diffuse reflection of the Earth thermal emissions. This would imply a factor of about six times more emission at 1.6 microns than expected from using Langhoff's method.

The zodiacal emission in the 4.5-8.5 micron band is about 7 x 10^9 photons/cm^2/sec/sr which is comparable to I_{280}. Since SL 2 will be at 400 km altitude, the oxygen incidence will be ten times lower, resulting in an equivalent decrease in the volume densities of photon emission. Consequently the irradiance at 400 km from "O-glow" would be $I_{400\ km} = 1.6 \times 10^9$ photons/cm^2/sec/sr. This is only 20% of the zodiacal emission expected in the ecliptic, 90 deg. from the Sun. This irradiance would be about 60% of the zodiacal emission (away from ecliptic plane) over most of the hemisphere away from the Sun. Distinguishing the O-glow from the zodiacal emission should be easy, since the O-glow is not expected to contribute to the observed flux at wavelengths beyond 15 microns. Thus the O-glow should change the ratio of the radiation in the 4.5-9.5 micron band to that in the 18-30 micron band.

Conclusions

Although the plan to make the glow measurements have evolved only recently (after the final mission plan for SL 2 was formed), the opportunity to perform these IR measurements with existing hardware in so near a term has led us to dedicate two of the 18 revs planned for IR celestial observations to making these measurements. It appears that in using the observing plan outlined above, the glow should be detectable in the near IR for the given geometry. Otherwise, the observations will put severe upper limits on the flux, limiting it to well below the zodiacal flux for the geometry described.

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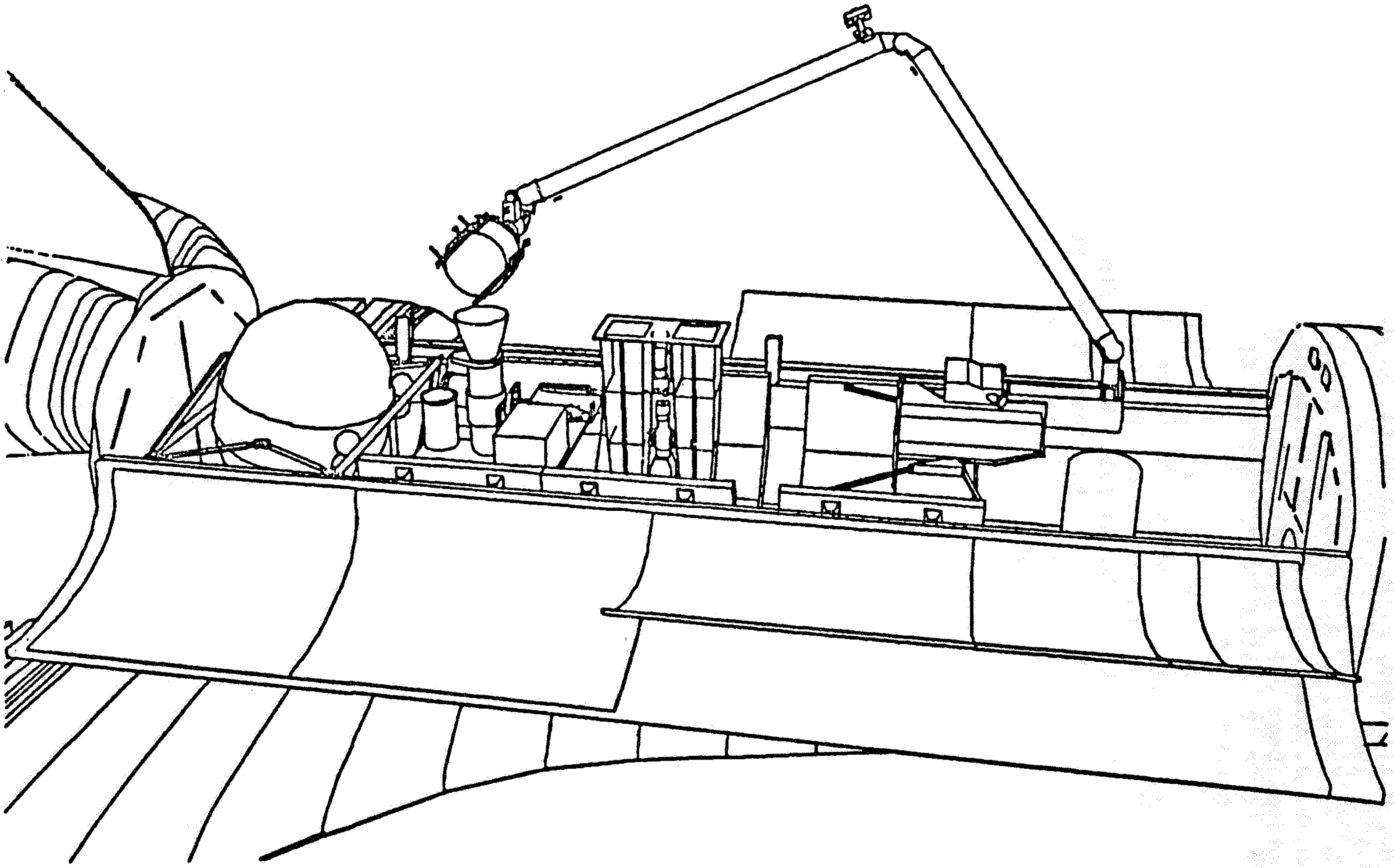

Fig. 1. View of the Spacelab 2 payload showing the Plasma Diagnostics Package being positioned above the Infrared Telescope by the Remote Manipulator System. The velocity vector is from wing-tip to wing-tip.

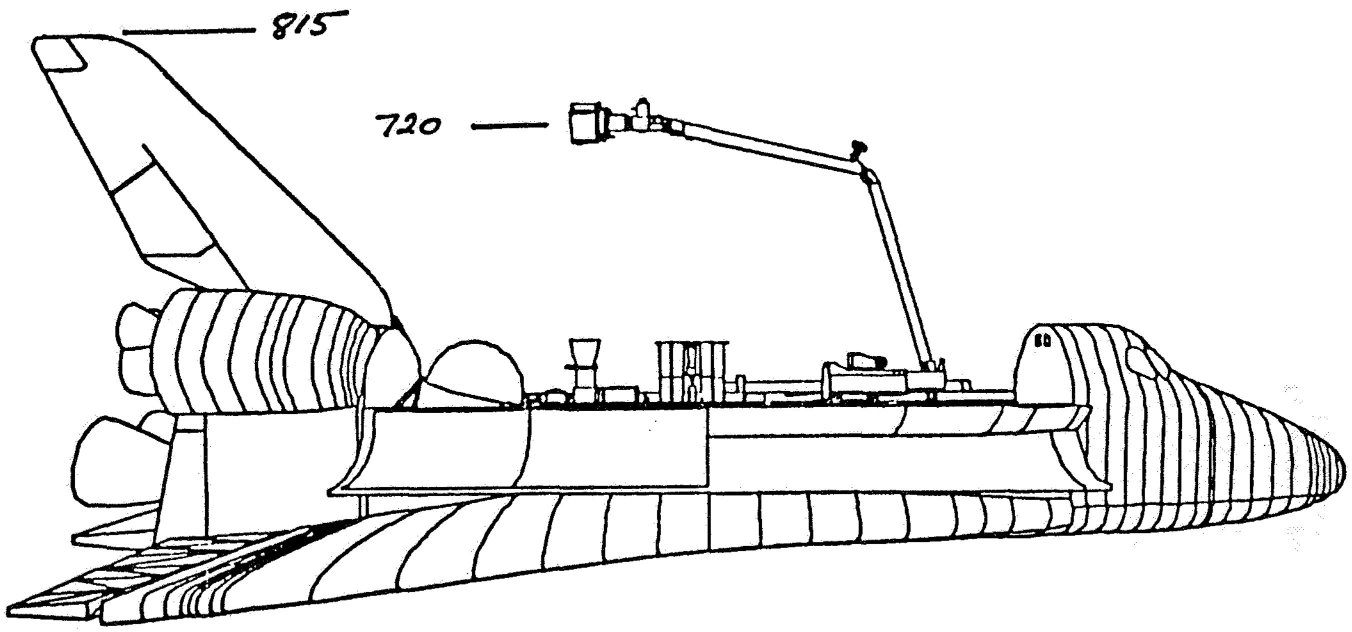

Fig. 2. View of the PDP position during the fourth inertial hold/RMS cycle.