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OXYGEN ATOM REACTION WITH SHUTTLE MATERIALS AT ORBITAL ALTITUDES

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OXYGEN ATOM REACTION WITH SHUTTLE MATERIALS AT ORBITAL ALTITUDES

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OUTLINE

- EFFECTS OBSERVED FROM STS-1 THROUGH STS-4
- BRIEF DESCRIPTION OF MECHANISM
- DESCRIPTION OF STS-5 EXPERIMENT
- CONSIDERATIONS FOR THIS MEETING

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- SIGNIFICANT EFFECTS OF ENVIRONMENT ON PAYLOAD BAY MATERIALS OBSERVED ON ALL FLIGHTS
  - STS-1
    - FORWARD BULKHEAD KAPTON CAMERA BLANKET WAS MILKY YELLOW AFTER FLIGHT
    - YELLOW PAINT AGED RAPIDLY
  - STS-2
    - CAMERA BLANKETS - LOSS OF 4.8% ON KAPTON OUTER SURFACE; ALL CAMERAS AFFECTED
    - PAINT SIMILAR TO STS-1
  - STS-3
    - CAMERA BLANKETS - MASS LOSS OF 35% (0.1 MIL) ON SURFACES OF ESSENTIALLY ALL CAMERAS
    - TORLON THERMAL BLANKET BUTTON HAD WHITE DEPOSIT ON SURFACES
    - PAINT SIMILAR TO STS-1 EXCEPT WHITE PAINT ON SILL LONGERON ALSO AGING RAPIDLY

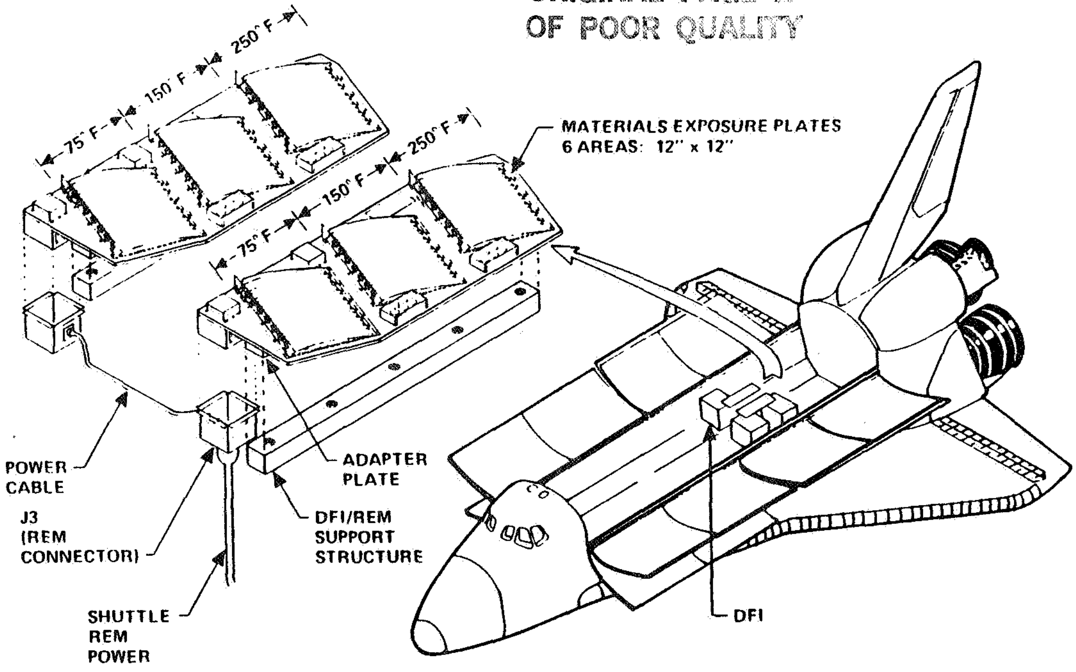
- STS-3 (CONTINUED)
  - OSS-1 KAPTON HAD LOSS OF 22% (0.22 MIL)
  - PDP SPHERES HAD COMPLETE LOSS OF AQUADAG ON UPPER SURFACES
  - OSS-1 PAINT SURFACES ALSO AFFECTED
- STS-4
  - KAPTON AFFECTS MINOR ON BOTH CAMERA AND PAYLOAD SURFACES
  - COATED KAPTON HAD RESISTANCE CHANGES
  - WITNESS SAMPLES OF FOUR MATERIALS FLOWN ON IECM HAD LOSS RANGING FROM .003 MIL FOR TEFLON TO .07 MIL FOR KAPTON AND MYLAR
  - WITNESS SAMPLES OF CARBON COATING 2000Å COMPLETELY REMOVED

PROPOSED MECHANISM

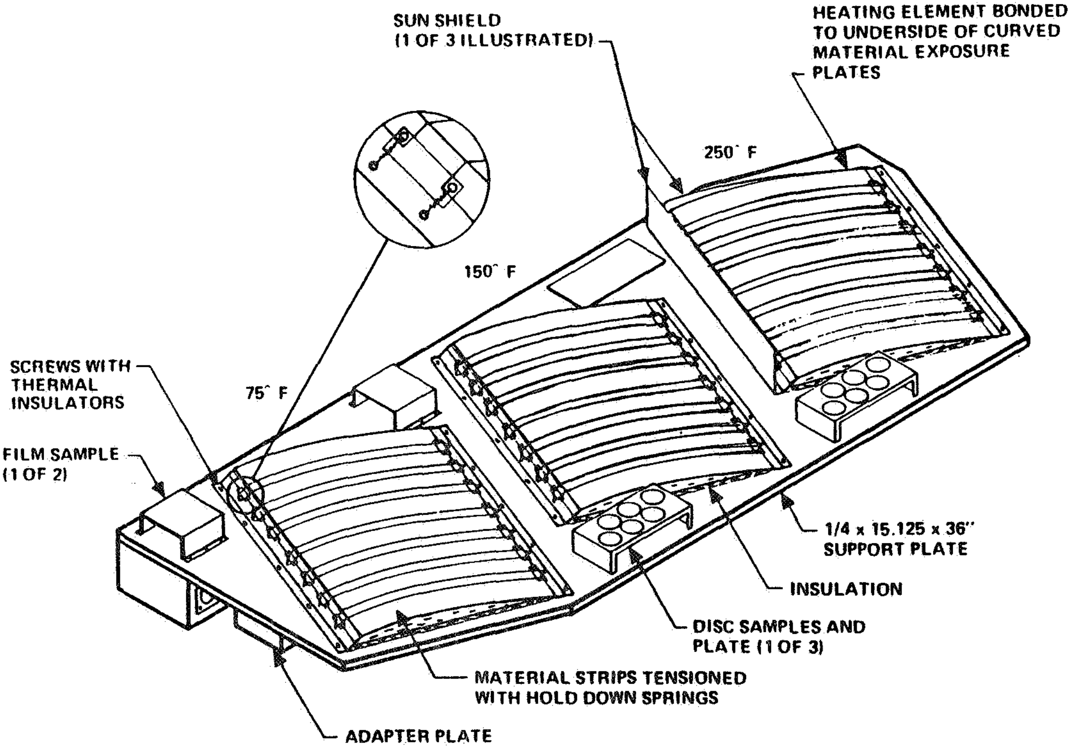
- POLYMER FILMS SUCH AS KAPTON, PAINT BINDERS, THERMAL BLANKET BUTTONS (TORLON) ARE BEING OXIDIZED BY NEUTRAL OXYGEN ATOMS PRESENT AT ORBITAL ALTITUDES (LEO)
- SOLAR EXPOSURE ACCELERATED OXIDATION REACTION AND LEADS TO SHADOWING EFFECTS
- OXIDATION PROCESS FOR MOST ORGANICS PRODUCES H_2, CH_4, AND CO WHICH RESULTS IN MASS LOSS FOR KAPTON AND LOSS OF BINDER FOR PAINTS
- OXIDATION PROCEEDS WHEN SURFACES ARE EXPOSED TO OXYGEN FLUX (VEHICLE VELOCITY VECTOR) AND SOLAR EXPOSURE
- OXIDATION GREATEST FOR TOP SUN RAM EXPOSURE

BASIS FOR MECHANISM

- OXYGEN ATOMS PREDOMINANT SPECIES AT LEO ALTITUDES $1 \times 10^9/CM^3$; N_2 AT ABOUT SAME CONCENTRATIONS; OTHER SPECIES FACTOR OF 100-1000 LOWER
- COMPARISON OF SEM PHOTOS FOR LAB SIMULATED SURFACE AND EXPOSED SURFACE
- COMPARISON OF MASS LOSS RATES MEASURED IN LOW TEMPERATURE ASHER (RADIO FREQUENCY EXCITATION OF O_2 GAS TO PRODUCE OXYGEN ATOMS)



MATERIAL TRAY CONFIGURATION



MATERIAL TRAY DETAIL

STS-5 SAMPLE DESCRIPTION

- TEMPERATURE CONTROLLED TRAYS
  - KAPTON
  - MYLAR
  - TEFLON - FEP/TFE
  - KEVLAR
  - EPOXY
  - POLYSULFONE
  - TEDLAR
  - PAINTS
    - A276
    - A302
    - A306
    - 401-C10
    - S13-GLO
  - GRAPHITE/EPOXY
  - GRAPHITE/POLYIMIDE
  - ALUMINUM
  - SILVER
  - OVERCOATS
    - SILICONE OIL
    - TETRAETHYLORTHOSILICATE
    - ITO
    - GOLD
    - ALUMINUM
- TEMPERATURE UNCONTROLLED AREAS
  - GERMANIUM
  - ZOT
  - SILVER FOIL
  - RTV
  - MS74
  - P1700
  - S13-GLO
  - ITO

CONSIDERATIONS FOR THIS MEETING

- INCREASED OUTGASSING RATES RESULTING IN POSSIBLE LOCALIZED EFFECTS ON EXPERIMENTS
- CHANGES IN OPTICAL PROPERTIES OF THERMAL CONTROL SURFACES (α/ϵ INITIAL = 0.4 α/ϵ EXPOSED = .7 - .8)
- PHOTO EMISSION FROM REACTION PRODUCTS

OBSERVATIONS OF OPTICAL EMISSIONS FROM STS-3

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(This paper is not available for this publication but will appear in the February issue of Geophysical Research Letters.)

OBSERVATIONS OF OPTICAL EMISSIONS ON STS-4

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OBSERVATIONS OF OPTICAL EMISSIONS ON STS-4

S.B. Mende, O.K. Garriott, P.M. Banks

August 12, 1982

INTRODUCTION

Nighttime photographs taken by the crew of STS-3 revealed that there is an observable luminosity or glow of unknown origin enveloping certain parts of the Orbiter. In photographs and payload bay TV images from STS-3 this luminosity is particularly evident on the tail section and on the aft engine pods in directions corresponding to the *windward* side of the vehicle. The study of the STS-3 photographic data is currently continuing (Banks, et al, 1982). In addition to this recent work, in the past there were observational results from Atmospheric Explorer that a fast moving spacecraft creates luminosity in the upper atmosphere (Yee and Abreu, 1982). However, the existence of the shuttle glow was not specifically predicted.

The STS-3 photographs clearly show that the luminous envelope exists above surfaces which are predominately in the forward direction with respect to the velocity vector. The occultation of an occasional star by the glow shows that the glow is a layer of 5 to 10 cm thick. The temporal fluctuation of the glow as a function of the Orbiter maneuvering system jets is also under study since short term enhancements are seen at these times. Color photographs were also obtained during the flight of STS-3, showing that the glow has a strong reddish component when compared to the normal airglow layer consisting mainly of $OI(\lambda = 5577\AA)$ radiation.

Because of the importance of shuttle glow as an optical contaminant to the high sensitivity astronomy or aeronomy experiments which will be carried on future shuttle missions, further experiments to study the glow were carried out on STS-4. Owing to

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the short time between STS-3 and STS-4, it was not possible to introduce a complete spectroscopic experiment to study the vehicle glow. Consequently, a simple experiment using a 300 line per mm grating was proposed in combination with the same cameras which recorded the glow on STS-3. Close cooperation between all levels of NASA permitted us to procure the diffraction grating, schedule the photography, train the crew, and perform the experiment on STS-4 in a period of four weeks. In this report we provide the preliminary findings from these second generation experiments.

MEASUREMENT TECHNIQUE

The main object of the experiment was to obtain the optical spectral distribution of the glow. Because of the brief time available we had to minimize our impact on the flight hardware. We used the previously flown 70 mm Hasselblad camera with a 100 mm focal length lens. This same camera was used for the glow photography on the STS-3. The camera was mounted in the aft flight deck window on brackets and a window shade was used to screen out undesirable light contamination from the cabin.

The only item specially procured and delivered for the STS-4 experiment was the optical grating. The 300 lines per mm grating was purchased from Diffraction Products, Inc., Woodstock, Illinois and was used as an objective grating in front of the camera optical system, thereby making the camera into a slitless spectrograph. The optical path of the system is illustrated in Fig. 1. The camera and lens were pointed toward the tall, narrow tail section (vertical stabilizer) with the aft engine pods included in the frame. With the grating ruling approximately parallel to the vertical stabilizer, a "zero order image" will be located on the film at the same location as if the grating were absent. For this grating, however, most of the light is diffracted into a bright first order image to the right of the fainter zero order image. For a moderately bright object (such as a star), zero order image, first, and second order spectra may be observed. It is important to detect the zero order image because the distance on the plate from the zero to first order image defines the wavelength. If the spectrum consists of a continuum emission then the first order image is widely spread and represents a convolution of the image intensity and the spectral profile. With good signal to noise ratio such a diffuse image can be processed to yield the high resolution spectra.

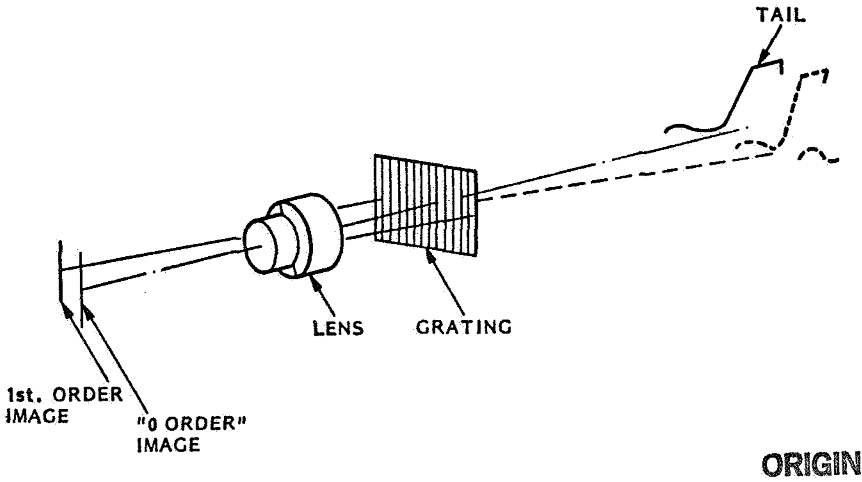

Figure 1

CALIBRATION

Two kinds of calibrations were performed with a camera and grating combination. In one test performed prior to flight, we photographed a mercury lamp in a full scale JSC Orbiter trainer. In this situation it was possible to simulate the actual distances from the camera to the anticipated light-emitting portions of the vehicle tail. The mercury lamp was masked off to produce a slit and enabled us to calibrate the spectral resolution of the system. From photographs it was verified that the spectral dispersion of the system was closely in agreement with the theoretical prediction which assumed the use of a grating with 300 rulings per mm. The system could separate, in second order, two lines which were at $\lambda = 5764Å$ and $\lambda = 5790Å$ i.e., only 26Å apart. In the first order the resolution, therefore, is about 30-50Å.

The second set of calibrations was taken post-flight. During this calibration we obtained photographs of a light source of known spectral luminosity per angstrom as a function of wavelength. This measurement provided us with the absolute sensitivity of the grating camera system as a function of wavelength.

Following verification of the grating characteristics and measurement of its resolution, a wavelength calibration was performed using the nominal 100 mm focal length of the camera lens. Using the test prints, the system magnification was measured and actual wavelength scales could be determined by comparing distances of the film and final print.

FLIGHT OPERATIONS

From the STS-3 experiments we know that the shuttle glow is essentially subvisual, detectable only by low light level TV cameras or long exposure photography. (Some of the best STS-3 color photographs were taken with exposure durations of 50 seconds). Since the diffraction grating will produce additional transmission losses as well as spectral dispersion across the film, and the flight itself was to be conducted at a substantially higher altitude than STS-3 (about 300 km instead of 240 km), it was concluded that very long exposures would be necessary on STS-4. Photographic sensitometry data provided by the Johnson Space Center (courtesy of N. Lamar) showed that the problem of reciprocity failure in the 2485 black and white flight film is quite severe and an extension of the exposure time produces only moderate gains.

A second factor involved operational constraints. The schedule of STS-4 was such that the orbit was essentially always in moonlight except for about 12 minutes each orbit during the first few days of the flight. Furthermore, the crew was heavily scheduled at this time in payload activities. Acting together, these constraints severely limited our ability to schedule many sessions with very long exposure durations. Consequently, we settled on a sequence consisting of 400, 100, 25 and 5 second exposures .This schedule virtually filled the entire 12 minute shadow period of an orbit. Two such operation sequences were scheduled. Because of the tight timeline, it was not possible to schedule any other experiment periods for photography without the grating for data to compare with STS-3. During the time when there was ground contact with the spacecraft we were able to monitor the progress of the experiment, which was carried out by T.K. Mattingly, the STS-4 flight commander.

During the first observation session, the full complement of pictures was taken. Mattingly reported during this session that he saw visible light by eye during the firing of the vehicle attitude control system, but otherwise no glow could be seen, even with the on-board closed circuit TV system. Mattingly also reported that during the last part of the session there was evidence of sunrise.

During the second photographic session, conducted on the next orbit, pictures were taken according to the scheduled checklist in the order given above. No discrepancies were noted and no comments were made by the crew. However, the last picture was omitted from the sequence as a consequence of sunrise contamination.

RESULTS

The best picture obtained from the flight was obtained during the 400 second exposure at the start of the first observing session. This result is shown in Figure 2. A second image, obtained with a 100 second exposure showed similar features but was too underexposed for effective analysis. The third and fourth exposures, of 25 and 5 seconds duration, respectively, show brighter images of the tail section in the first order spectrum with light at much shorter wavelengths (4000 to 5000Å) produced by faint sunrise illumination.

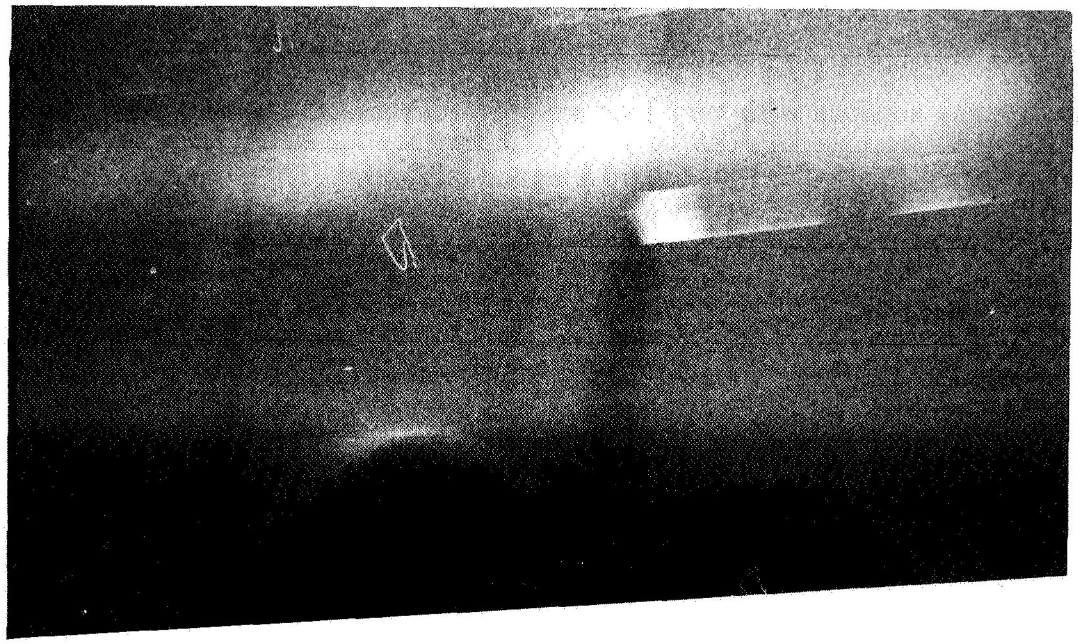

Figure 2

Examination of Fig. 2 reveals many interesting, complex features. Immediately apparent to the eye is what appears to be a dark image of the tail section and two engine pods of the Orbiter near the center of the frame. This dark feature corresponds to the first order image at wavelengths just below the optical pass band of the window-camera system. The zero order image is observed faintly near the left edge of the photograph. The general luminosity of the picture may be caused by a vernier thruster from the orbiter. It should also be noted that the diffuse, rope-like brightness running from left to right across the image is probably a result of stray light within the aft flight deck area. The three major portions of this light seem to correspond to the zeroth, first, and second order images of this source.

Although no bright glow is visible on the starboard or windward side of the tail (to the left in this aft-looking photograph), an area of dispersed glow is visible on the top of the starboard, aft engine pod. Also, the photograph will permit the spectrum of the thruster firing to be estimted, as described below.

Consider first the emission spectrum of the thruster firing, which we assume produces the general light emission around and even behind the spacecraft. To produce the faint, dark image in zero order, a major part of the light must be coming from behind the vertical stabilizer to show it in shadow. Remembering that most of the light is diffracted into first order and that the first order image is the convolution of the spatial image with the spectral profile, the only way to produce a narrow, dark first order image is to have a relatively narrow spectral emission. From the displacement of the dispersed shadow we conclude that the observed thruster emission extends from about 7200 to 8000Å, with the long wavelength cutoff established by the observing system, rather than the emission itself. Figure 3 provides a plastic overlay to Fig. 2 showing both the first order image and the wavelength calibration used to determine the various optical emission spectra.

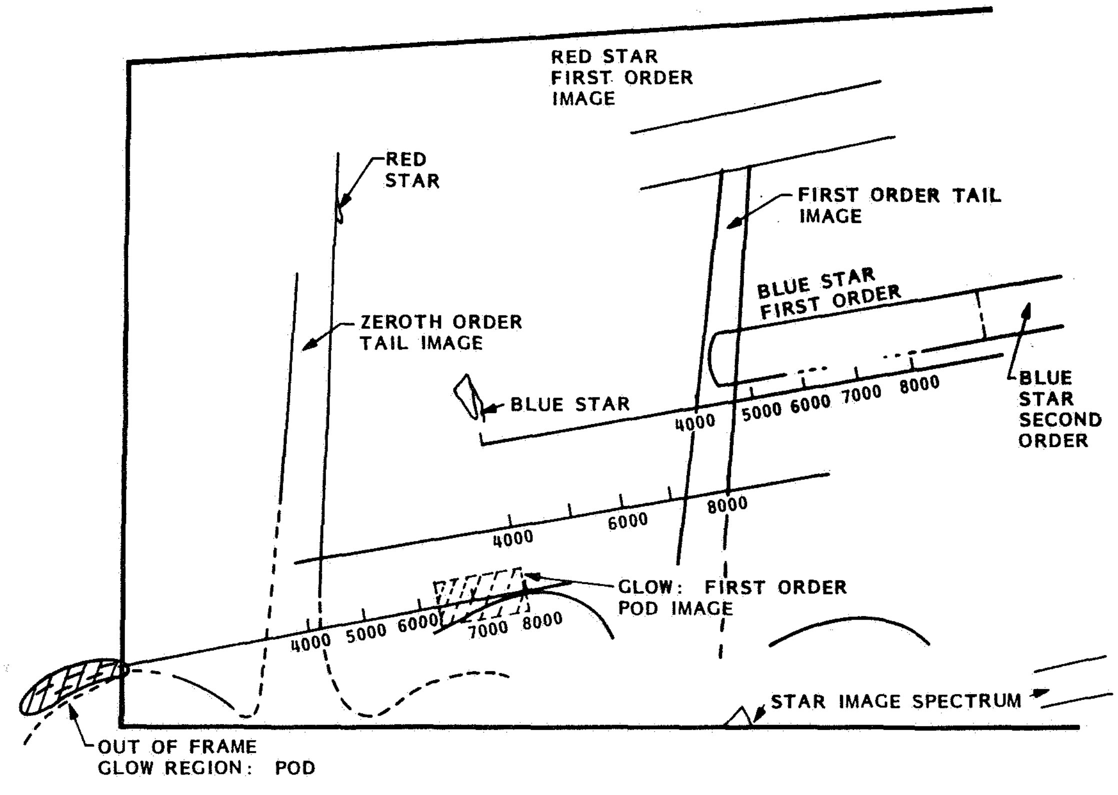

Figure 3

Data on the actual vehicle-associated glow comes from the apparent bright emission located on the starboard engine pod of the first order image. Unfortunately, in zeroth order this glow is just outside of the field of view of the photograph. Nevertheless, we can extrapolate its location using the known locations of the tail and the pods in zeroth order. This has been done on the overlay of Fig. 3 and a wavelength scale extending from 4000 to 8000Å is shown. From these data, it appears that the vehicle glow has a spectrum which extends from a short wavelength limit of about 6300Å up to the long wavelength measurement limit of 8000Å. More detailed information about this spectrum may be possible to obtain from microdensiometer traces along the spectrum brightness.

A separate source of luminosity visible in Fig. 2 arises from several stars. The bright, narrow track near the center of the image shows the apparent motion of a star during the course of the 400 second exposure. The spectrum of this star extends to the right of the zero order image and, using the scale provided by Fig. 3, shows strong emission in the blue portion of the spectrum. In addition, the second brightening to the right of the first order image is the second order image, again showing the strong blue emission. The calibrated wavelength scale given on Fig. 3 shows that the main optical output of this star lies between 4400 and 5500Å with the shorter wavelength end of the spectrum probably limited by the camera system.

Another star is visible in Fig. 2 just to the right of the zero order image of the tail. In this case the star is partially obscured by the tail itself. This accident has helped to provide information about the location of the zeroth order image of the tail and the location of the starboard engine pod. The spectrum of this star extends in first order to the right of the zero order image and shows an emission strongly weighted towards long wavelengths. Part of the second order image is also present. Both of these stars (and a third) show identical tracks, indicating the vehicle was in slow rotation, with directional changes at three points caused by (presumably) short vernier thruster firings.

CONCLUSIONS

The present results indicate that it is possible to obtain spectral measurements of optical emissions in the vicinity of the Orbiter using a simple grating-camera system. During STS-4 the absolute intensities of vehicle glow emissions appear to have been substantially lower than were observed on STS-3. Nevertheless, is was again observed that the glow occurred on surfaces of the Orbiter exposed to the passing atmosphere on the vehicle's windward side. It is likely that the lower emission intensities are a result of lower neutral gas densities at the STS-4 orbit altitude.

The spectral measurements provide important information about the spectral content of the glow; i.e., it extends from a lower wavelength of about 6300Å upwards towards the infrared. Such an emission would be consistent with an atomic oxygen interaction with the surface of the vehicle, but is in no way definitive that this is actually the process involved. These results also are in agreement with the earlier Atmospheric Explorer results of Yee and Abreu (1982) obtained at a much lower altitude.

An unexpected benefit of the present observations has been the opportunity to measure the spectral character of thruster light emission. This luminosity has a character substantially different from that of the vehicle glow and extends from a longer wavelength lower boundary on into the infrared. It appears likely that more details of the thruster optical emission spectrum can be obtained on future flights using this technique.

In summary, both of the important optical emissions associated with the Orbiter appear to have their peak intensities at the long wavelength end of the spectrum. From the present data it is difficult to identify particular molecular process leading to the emissions themselves. However, quantitative analysis of the results is underway and results from this will be reported soon.

DECAY OF GLOW ON TAIL AFTER THRUSTER FIRING
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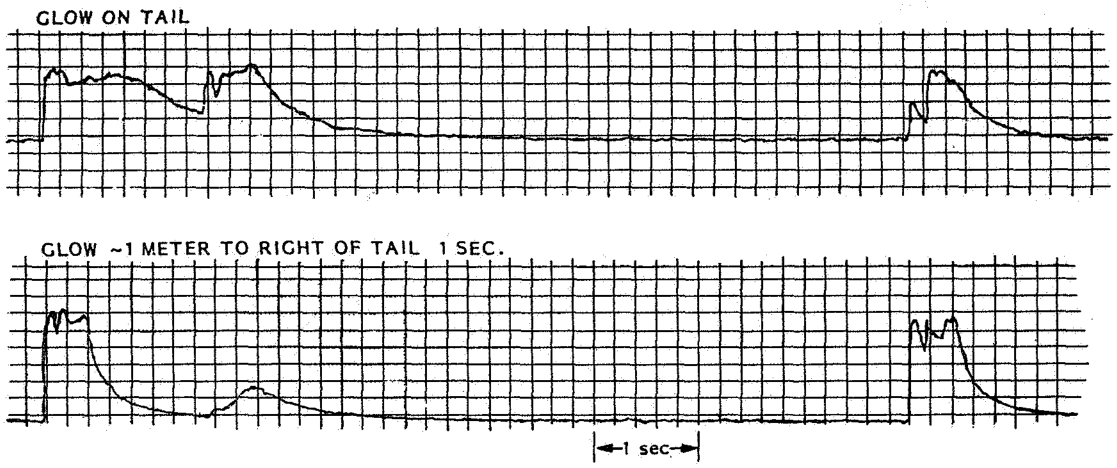

Acknowledgments

The authors are indebted to the many people who supported this experiment. Personnel at both NASA Headquarters and Johnson Space Center have made many important and timely contributions which enabled us to fly equipment in a very short period of time. We gratefully acknowledge the initiative and enthusiasm of the mission manager E.L. Michel which has been essential to the successful conduct of the experiment. Special mention should be made of spacecraft commander T.K. Mattingly of the Orbiter crew and Mr. N. Lamar and Mr. J. Holland of the photographic section of the Johnson Space Center.

References

Yee, J.H., and V.J. Abreu, *J. Geophys. Res.*, *87,913,1982.*