

RADIATION MONITORING EQUIPMENT DOSIMETER EXPERIMENT

29 f 33
Kenneth A. Hardy
USAF Armstrong Laboratory (AL/OEBSD)
Brooks Air Force Base, Texas 78235-5000
(512) 536-2613

Michael J. Golightly
NASA Johnson Space Center
Houston, Texas 77058, Mail Code SN-31
(713) 483-6190

Dr William Quam
E.G. & J. Energy Measurements, Inc
130 Robin Hill Road, Goleta, California 93117-3186
(805) 967-0456

INTRODUCTION

Spacecraft crews risk exposure to relatively high levels of ionizing radiation. This radiation may come from charged particles trapped in the Earth's magnetic field, charged particles released by solar flare activity, galactic cosmic radiation, energetic photons and neutrons generated by interaction of these primary radiations with the spacecraft and crew, and man-made sources (e.g., nuclear power generators). As mission are directed to higher radiation level orbits, viz., higher altitudes and inclinations, longer durations, and increased flight frequency, radiation exposure could well become a major factor for crew stay times and career lengths. To more accurately define the radiological exposure and risk to the crew, active, real-time radiation monitoring instrumentation must be flown capable of identifying and measuring the various radiation components. This presentation describes a radiation dosimeter instrument which has been successfully flown on the Space Shuttle, the RME-III.

The RME-III is a self-contained, portable, active (real-time) dosimeter system developed by E.G.&G., Inc. for the U.S. Air Force (USAF) and is adapted for use in measuring the ionizing radiation environment on the Space Shuttle. RME stands for "radiation monitoring equipment", the title given to 2 prototype radiation instruments successfully flown by the USAF on several pre-Challenger missions (1). These prototype instruments had relatively short battery life and very limited memory capacity; thereby, requiring an inordinate amount of crew interaction time. The RME-III was developed to incorporate the capabilities of both radiation instruments into a single unit and to minimize crew interaction times with longer battery life and expanded memory capacity. A description of the RME-III instrument and the results from flight of several Space Shuttle missions is presented in this report.

INSTRUMENT DESCRIPTION

The RME-III is a portable, self-contained, active dosimeter system. The system features a 3-channel tissue equivalent proportional counter (TEPC) which measures particle fluence and computes dose and dose equivalent at operator selected time intervals. The total accumulated absorbed dose and dose equivalent are displayed real-time on a liquid crystal display while the data and time of the interval dose readings are stored in memory modules for future analysis. Analysis of the time-resolved data permits correlation of the radiation exposure with geographic position, altitude and instrument location in the space craft. The instrument consists of 2 components: (1) the

Main Module, and (2) the Memory Module. The memory module is designed to plug into the Main Module and is exchanged with a new module when the memory capacity or primary system battery life is reached. The overall dimensions of the system are 28.6 cm x 10.2 cm x 5.1 cm. The combined total weight is 1550 g (3.3 lbs).

Main Module Description

The main module contains the analog and digital operating circuitry of the instrument and the TEPC. At the top of the module are 2 locking toggle switches. One is the system power "ON-OFF" switch. The other is a keyboard locking switch, which prevents accidental entries via the keyboard during system operation. The display is a 6.4 cm x 3.8 cm liquid crystal display (LCD), displaying 8 lines of data with 20 characters per line. The system operating parameters are entered via a 12 key keyboard. Primary operating power is provided by 5 AA alkaline batteries in the memory modules. Zinc-air batteries are used in the Main Module to maintain the instrument operating parameters and internal operating clocks during Memory Module replacement.

Memory Module Description

The Memory Module contains a 0.5 Megabyte Random Access Memory (RAM) into which the RME-III data is stored for future analysis. The RAM is also backed up by zinc-air batteries. The primary operating power for the entire system is provided by 5 AA batteries in the Memory Module, providing approximately 42 hours of continuous operation. The dimensions of the Memory Modules are 10.2 cm x 10.7 cm x 4.4 cm. The stand-alone weight of the Memory Module is 595 grams. Several Memory Modules are flown

with the Main Module on a Shuttle mission, sufficient enough to cover the entire mission.

TEPC Description

The heart of the system is the cylindrical tissue equivalent proportional counter developed by E.G.&G. The TEPC is a cylindrical (1.27 cm ID, 5.05 cm long) ionization chamber, lined with tissue equivalent plastic (type A-150), and filled with methane gas at reduced pressure (80 mmHg). The reduced gas pressure allows the chamber to simulate a tissue volume of about 2 micrometers in diameter. The TEPC is designed to measure the rate of energy loss of individual particles passing through the detector. The RME-III TEPC permits measurement of the radiation energy loss in a simulated volume on the order of the size of a typical human cell. Thus, the RME-III is a microdosimetry based instrument.

RME System Operation

The system block diagram of the RME is shown in the next figure. Pulses from the TEPC are amplified and shaped by the pre-amplifier and linear amplifier, and are fed into comparators that separate the spectrum into 3 pulse height or linear energy transfer (LET) bins: 0.35 to 6.5 keV/um, 6.5 to 30 keV/um, and 30 to 120 keV/um. Pulses greater than 120 keV/um are placed in the highest bin. The comparators in effect serve as a 3-channel pulse height analyzer. The actual counts in each pulse height bin are stored in the memory and can be used after-the-fact to more accurately estimate exposure, if required.

The instrument uses an algorithm to convert counts in each

pulse height bin into absorbed dose exposure values. For rads tissue a multiplicative constant is obtained for each of the 3 bins by exposing the instrument of Cs-137 and Cf-252 sources. The Cs-137 gamma source is used to determine the conversion constant in the low pulse height energy bin. The Cf-252 spontaneous fission source permits determination of the constants for the two higher energy pulse height bins. The constants determined by the calibration procedure are stored in the Main Module processor. The instrument calibration is checked before and after each mission.

The dose equivalent is computed by multiplying the measured absorbed dose per channel by a present quality factor. The quality factors used in the Shuttle missions presented in this report were 1 for the lowest pulse height channel, 9 for the intermediate channel, and 15 for the upper channel.

RME-III Setup Menu

The RME-III is menu driven. When the RME is initially turned on the set-up menu appears as shown in DISPLAY 1. The operator can then select the following operational parameters:

- a. Time interval for dose integration. Ten seconds is the value that is used on the Shuttle.
- b. Alarm levels for total dose and dose rate. These are normally set to OFF on the Shuttle flights.
- c. Calendar Date
- d. Coordinated universal Time (UTC)
- e. Mission Elapsed Time (MET)

Normally all of the operating parameters are preset by the

ground crew at L-5 with the exception of the MET. The MET is entered by the Shuttle crewmember when the unit is turned on after launch. After presetting by the ground crew, the system is turned off and stowed in a mid-deck locker on the Shuttle. After lift-off the RME-III is removed from the locker by the crewmember, the power turned on, the keyboard unlocked and the MET entered. The crewmember then presses the START button, locks the keyboard and places the RME in the appropriate operating location. DISPLAY 3 is the display the operator normally sees during operation. The Shuttle crewmembers are trained in the operation of the RME and can be called upon to change or correct the operating parameters during flight, if required.

DATA

Data may be read out directly from any memory module by using the Main Module display and control keys. This function is a lengthy process since there are usually many sets of data (30,000 to 50,000) for a typical Shuttle mission. The normal procedure is to download the data from the Memory Modules to a personal computer (PC) after the mission. This task is accomplished by attaching the Memory Module to a special readout module which transfers the data from the Memory Module to a file in the PC via an RS-232 protocol. An 80C31 processor with data conversion algorithms is used to handle the transfer and conversion of the Memory Module data files. These files contain the raw data, the timing information (date, UTC, MET, and interval length), the absorbed dose in rads and the dose equivalent in rem for each time interval, and the integral dose in rads and rem for the

whole time the Memory Module recorded data.

The next figure shows representative data files obtained during Shuttle missions. The top file shows the data obtained at the start of one data set from a memory module. The counts in channel #1 are the low LET counts. The counts in Channels #2 and #3 are the intermediate and the high LET counts. The data in this file is representative of the count rate data obtained while traversing the equatorial latitudes, where the radiation background is due primarily to high energy cosmic rays. The middle file is an example of count rate data obtained at higher latitudes, where weakening of the Earth's magnetic field permits more cosmic ray particles to reach the Shuttle. The bottom file is an example of data collected during a pass through the South Atlantic Anomaly (SAA) on STS-31. The bulk of the dose is due to the high energy, low LET component of the inner Van Allen Belt protons, but the increased counts in the intermediate and high-LET channels indicate the presence of either high-LET, low energy protons, and/or the presence of high LET secondaries, which have a marked effect on the resulting dose equivalent.

The data for the first six Shuttle missions flown by the RME-III are summarized in Table I. Shown for comparison are the average Passive Radiation Dosimeters (PRD) doses measured on the Shuttle with thermoluminescent dosimeters by NASA/JSC. Six PRDs are routinely flown at different locations in the Shuttle. The highest doses/dose rates are measured in the high altitude missions which penetrate the SAA. In these orbits the dose contribution is due primarily to the Van Allen Belt protons. In the lower altitude orbits, the Galactic Cosmic Ray component predominates.

The data files are in ASCII or binary format and can readily be manipulated to produce plots of counts or dose vs. time or position. The next figures represent data obtained from various Space Shuttle missions displayed in this format. Figure 8 illustrates dose rate at 10s intervals vs MET for a low altitude, high inclination mission in which there is little interaction with the SAA and the exposures are dominated by the cosmic ray background. Notice the cyclic nature of the cosmic ray background with the peaks occurring at the high latitudes and the valleys at the equator caused by the geomagnetic shielding effect of the Earth. Figure 9 illustrates dose rate vs. MET for a Shuttle mission in which the altitude was sufficiently high to penetrate deeply into the SAA. Notice the peaks due to the penetration of the SAA. Dose rates on the order of several hundred millirad per hour were measured on this mission during some of the SAA passes.

The RME-III data readily lends itself to other forms of analysis. Figure 10 is a plot of dose rate as a function of orbiter geographic position (longitude and latitude) which were made from 38241 individual measurements taken during 113 hours of operation on the STS-28 Space Shuttle mission. The next figure (fig. 11) illustrates a plot of the South Atlantic Anomaly in two dimensions obtained from Space Shuttle RME-III data.

CONCLUSION AND DISCUSSION

Flight data from the Space Shuttle missions has demonstrated that a microdosimetric based radiation instrument such as the RME-III with the capability of registering counts and exposures vs. MET and UTC can be used to accurately assess dose from various sources of exposure, such as that encountered in the complex radiation environment of space. The RME-III is presently manifested to fly on STS-53 next month, and on STS-56 and -51 in 1993. Our goal is to fly

the RME-III on at least two or three more flights in 1994, the point of solar minimum. The RME-III flew its first mission on STS-27 in Dec 88 just before solar maximum. The RME-III is the only real-time radiation instrument to fly on the Shuttle from Solar Maximum to Solar Minimum. The data from all of these mission are being analyzed. The data is being used to enhance spacecraft shielding and space radiation models; and to investigate phenomena such as the drift of the SAA with time, the variation of the GCR background in LEO with the solar cycle, and diurnal (day vs. night) variations in the space radiation quality factors.

"Smart" dosimetric instrumentation such as the RME-III have definite applicability to the Aerospace operational environment. Newer instruments with larger memory capacities and greater spectral resolution are currently being developed which will ultimately be flown on the Space Station Freedom and future long duration space missions. Modified versions of the RME-III will soon be used by the Air Force to investigate the cosmic ray and solar radiation exposure of air crews at high altitudes.

REFERENCES

1. Cash, S. E., Madonna, R. G., McClellan, M. R., Steskal, M. J., and Fields, M. E. Results for Radiation Monitoring Equipment Experiments of STS-41-C, 41D, 41G, and 51A. AFTAC-TR-85-4, April 1985.

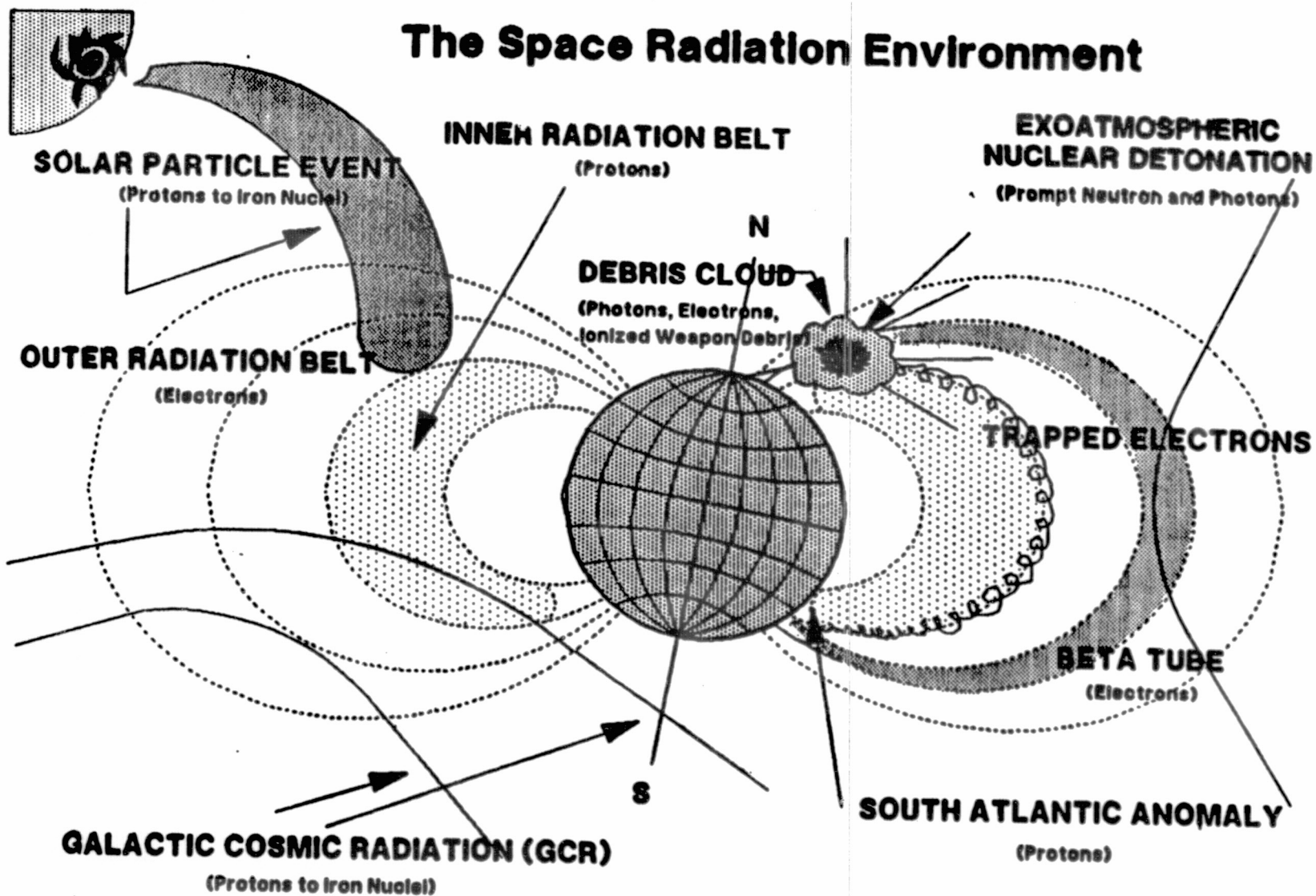
RME-III

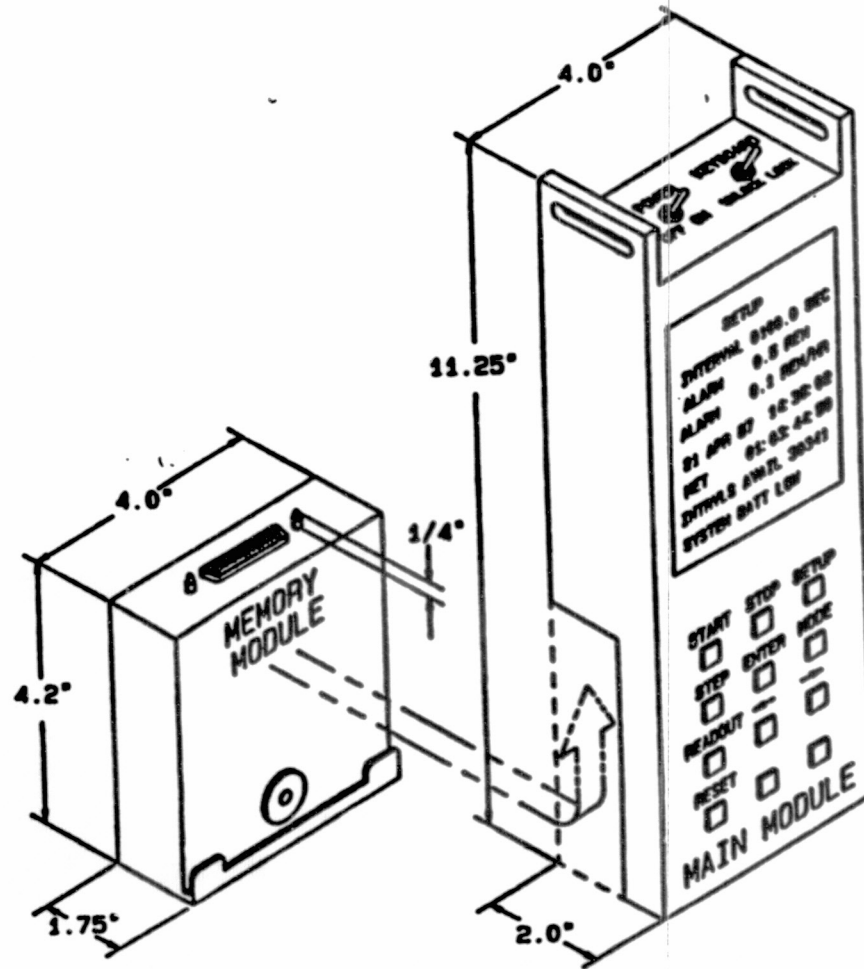
RADIATION MONITORING EQUIPMENT

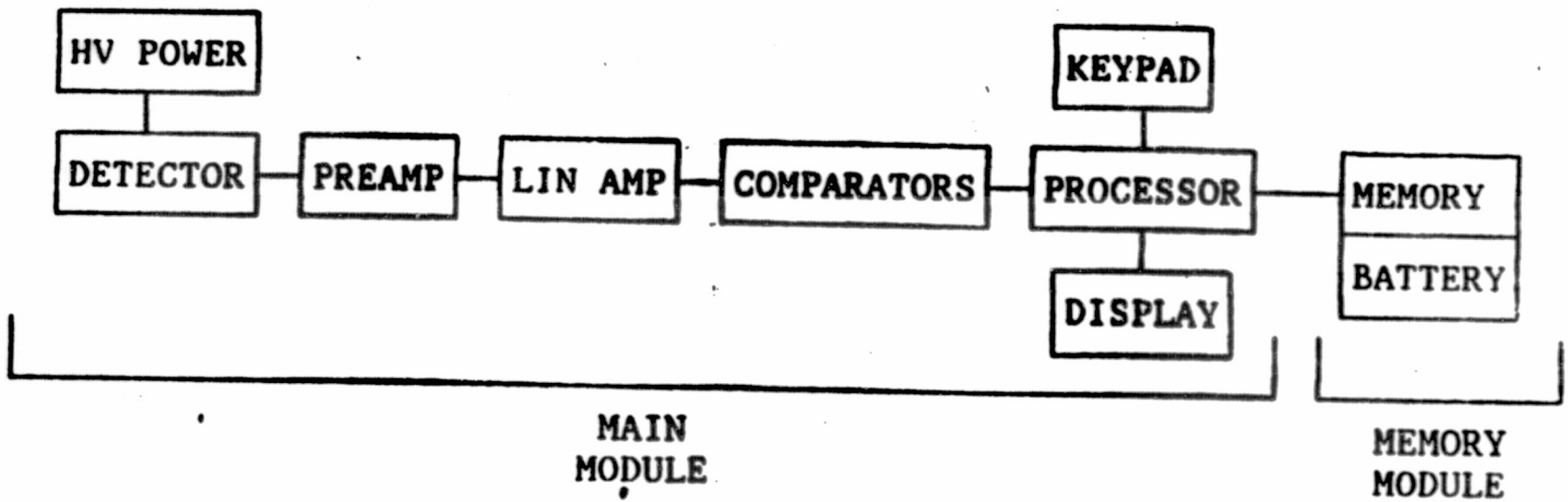
KENNETH A. HARDY

**Radiation Physicist
Dosimetry Function
Occupational Environmental
Health Directorate
USAF Armstrong Laboratory**

The Space Radiation Environment







RME III BLOCK DIAGRAM

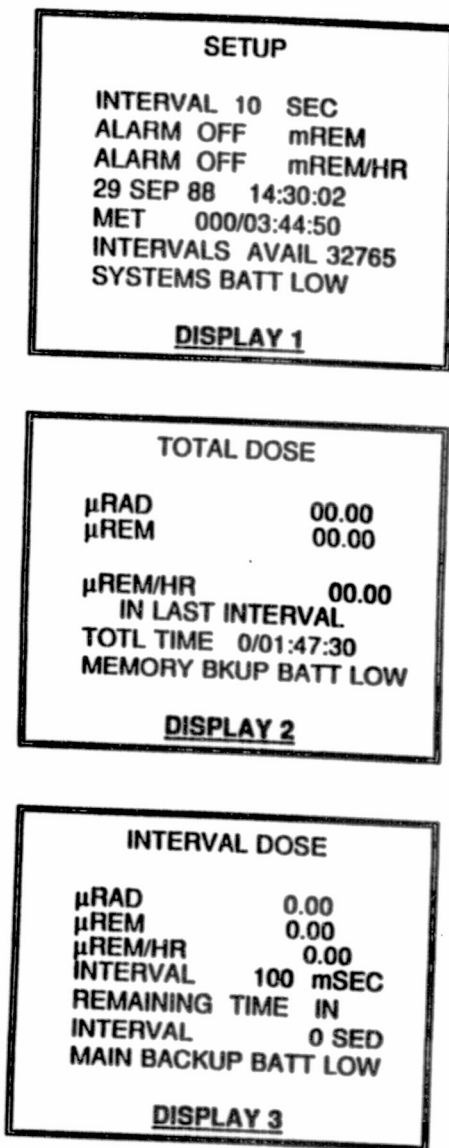


Figure 3. RME-III operating displays.

START OF FILE

MET = 002/02:33:17

GMT = 041288 17:03:50:0J10

MET	GMT	RAD	REM	COUNTS#1	CNT#2	CNT#3	INV
002/02:33:27:0	041288 17:04:00:0	2.941e-07	2.941e-07	2	0	0	10
002/02:33:37:0	041288 17:04:10:0	1.029e-06	1.029e-06	7	0	0	10
002/02:33:47:0	041288 17:04:20:0	7.353e-07	7.353e-07	5	0	0	10
002/02:33:57:0	041288 17:04:30:0	1.241e-06	5.267e-06	5	1	0	10
002/02:34:07:0	041288 17:04:40:0	5.883e-07	5.883e-07	4	0	0	10
002/02:34:17:0	041288 17:04:50:0	1.177e-06	1.177e-06	8	0	0	10
002/02:34:27:0	041288 17:05:00:0	5.883e-07	5.883e-07	4	0	0	10
002/02:34:37:0	041288 17:05:10:0	2.941e-07	2.941e-07	2	0	0	10
002/02:34:47:0	041288 17:05:20:0	7.353e-07	7.353e-07	5	0	0	10
002/02:34:57:0	041288 17:05:30:0	5.883e-07	5.883e-07	4	0	0	10
002/02:35:07:0	041288 17:05:40:0	4.412e-07	4.412e-07	3	0	0	10

Figure 4a. Count rate data at equatorial latitudes (STS-27)

002/03:45:37:0	041288 18:16:10:0	2.353e-06	2.353e-06	16	0	0	10
002/03:45:47:0	041288 18:16:20:0	3.088e-06	3.088e-06	21	0	0	10
002/03:45:57:0	041288 18:16:30:0	2.647e-06	2.547e-06	18	0	0	10
002/03:46:07:0	041288 18:16:40:0	3.236e-06	3.236e-06	22	0	0	10
002/03:46:17:0	041288 18:16:50:0	2.794e-06	2.794e-06	19	0	0	10
002/03:46:27:0	041288 18:17:00:0	3.088e-06	3.088e-06	21	0	0	10
002/03:46:37:0	041288 18:17:10:0	3.741e-06	7.767e-06	22	1	0	10
002/03:46:47:0	041288 18:17:20:0	3.530e-06	3.530e-06	24	0	0	10
002/03:46:57:0	041288 18:17:30:0	3.530e-06	3.530e-06	24	0	0	10
002/03:47:07:0	041288 18:17:40:0	2.500e-06	2.500e-06	17	0	0	10
002/03:47:17:0	041288 18:17:50:0	3.383e-06	3.383e-06	23	0	0	10
002/03:47:27:0	041288 18:18:00:0	3.377e-06	3.677e-06	25	0	0	10

Figure 4b. Count rate data at high latitudes (STS-27).

2/7:39:38:0	900426 20:13:37:0	1.660e-03	1.963e-03	11058	53	10	10
2/7:39:58:0	900426 20:13:47:0	1.655e-03	2.001e-03	10985	68	8	10
2/7:39:58:0	900426 20:13:57:0	1.701e-03	2.018e-03	11318	61	8	10
2/7:40:8:0	900426 20:14:07:0	1.704e-03	2.063e-03	11310	69	9	10
2/7:40:18:0	900426 20:14:17:0	1.694e-03	2.074e-03	11229	72	10	10
2/7:40:28:0	900426 20:14:27:0	1.741e-03	2.167e-03	11514	81	11	10
2/7:40:38:0	900426 20:14:37:0	1.699e-03	2.036e-03	11286	68	7	10
2/7:40:48:0	900426 20:14:47:0	1.691e-03	2.118e-03	11173	77	13	10
2/7:40:58:0	900426 20:14:57:0	1.659e-03	1.973e-03	11026	69	4	10

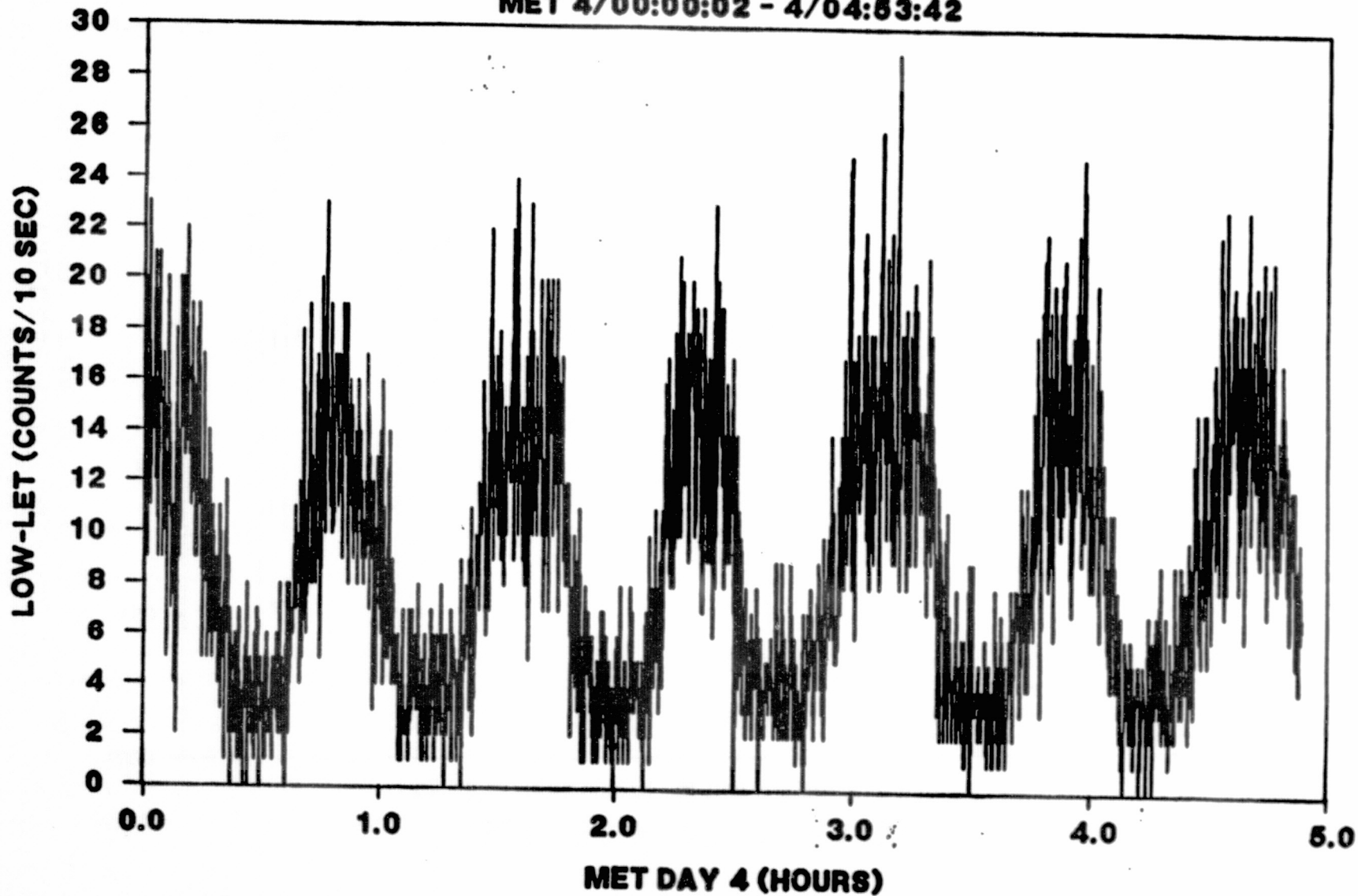
Figure 4c. Count rate data in South Atlantic Anomaly (SAA) measured on (STS-31).

Table 1. RME-III Shuttle Data

Shuttle Mission *****	Orbital Parameters *****	RME run Time (hrs.) *****	RME Total Dose (mrad) *****	RME Total Dose Equiv. (mrem) *****	Average Q.F. *****	Av. PDR Dose (mrad) *****
STS-27	Inc.: 57 deg. Alt.: 450 km circular	101.5	157.9	247.3	1.566	256.4
STS-28	Inc.: 57 deg. Alt.: 300 km circular	116.1	63.4	109.2	1.722	119.9
STS-33	Inc.: 28.5 deg. Alt.: 230 km x x 555 km elliptical	102.7	370.7	427.7	1.154	762.8
STS-36	Inc.: 62 deg. Alt.: 240 km circular	104.6	20.9	33.5	1.603	32.5
STS-31	Inc.: 28.5 deg. Alt.: 685 km circular	112.9	2033.5	2486.5	1.223	1380.9
STS-41	Inc.: 28.5 deg. Alt.: 300 km circular	85.3	12.0	16.1	1.346	17.8

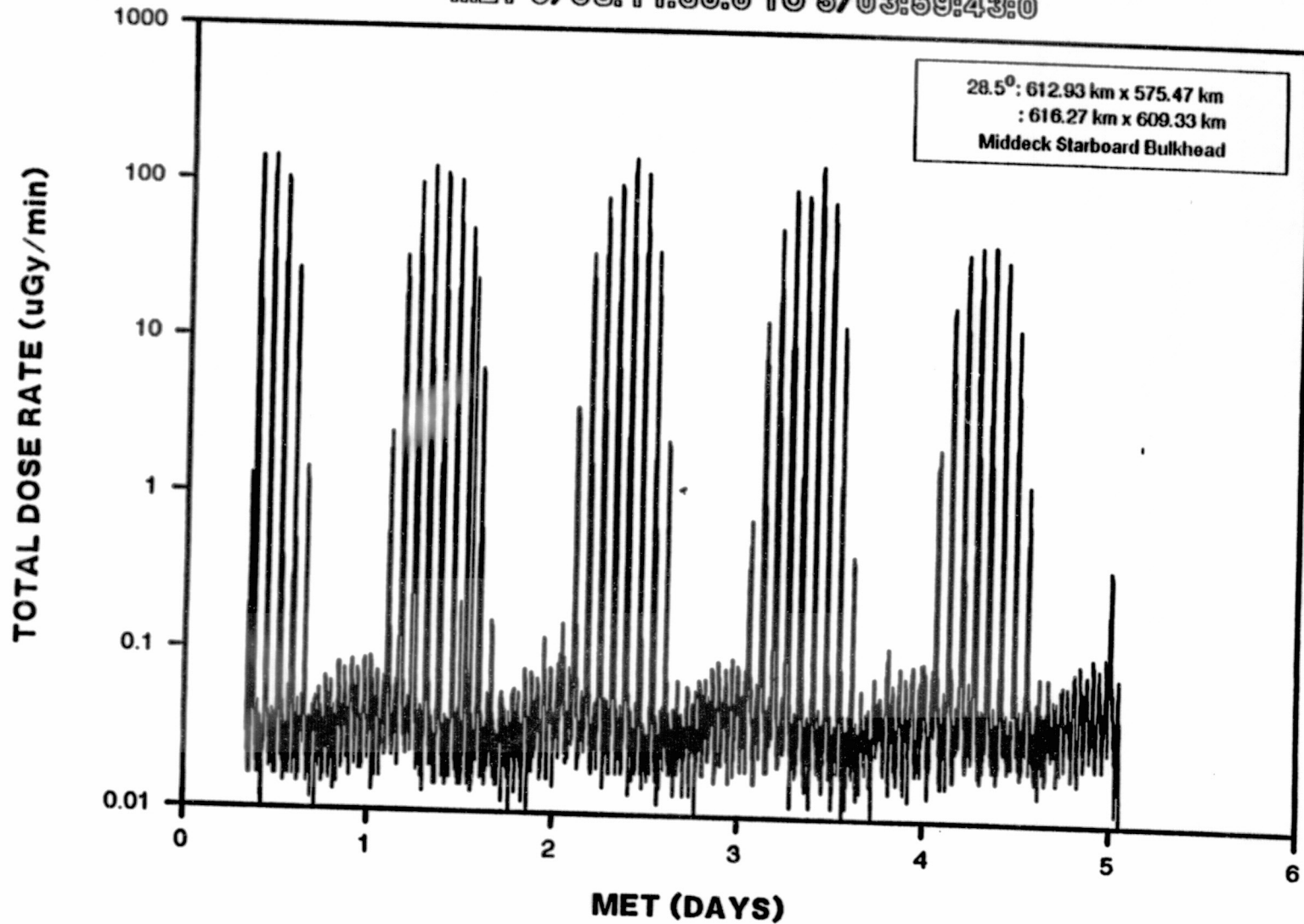
STS-28 RME-III DATA

MET 4/00:00:02 - 4/04:53:42



STS-31 RME-III DATA

MET 0/08:11:36:0 TO 5/03:59:43:0



STS-28

RME-III Measured Dose Rate

NOTES
08 AUG 89 -- 13 AUG 89
SPACECRAFT ALTITUDE = 306 KM
ORBIT INCLINATION = 67.0 DEGREES
RME DATA PLOTTED FOR THE TIMES
MET 0/ 6:58:13.0 TO 4/17:17:52.0

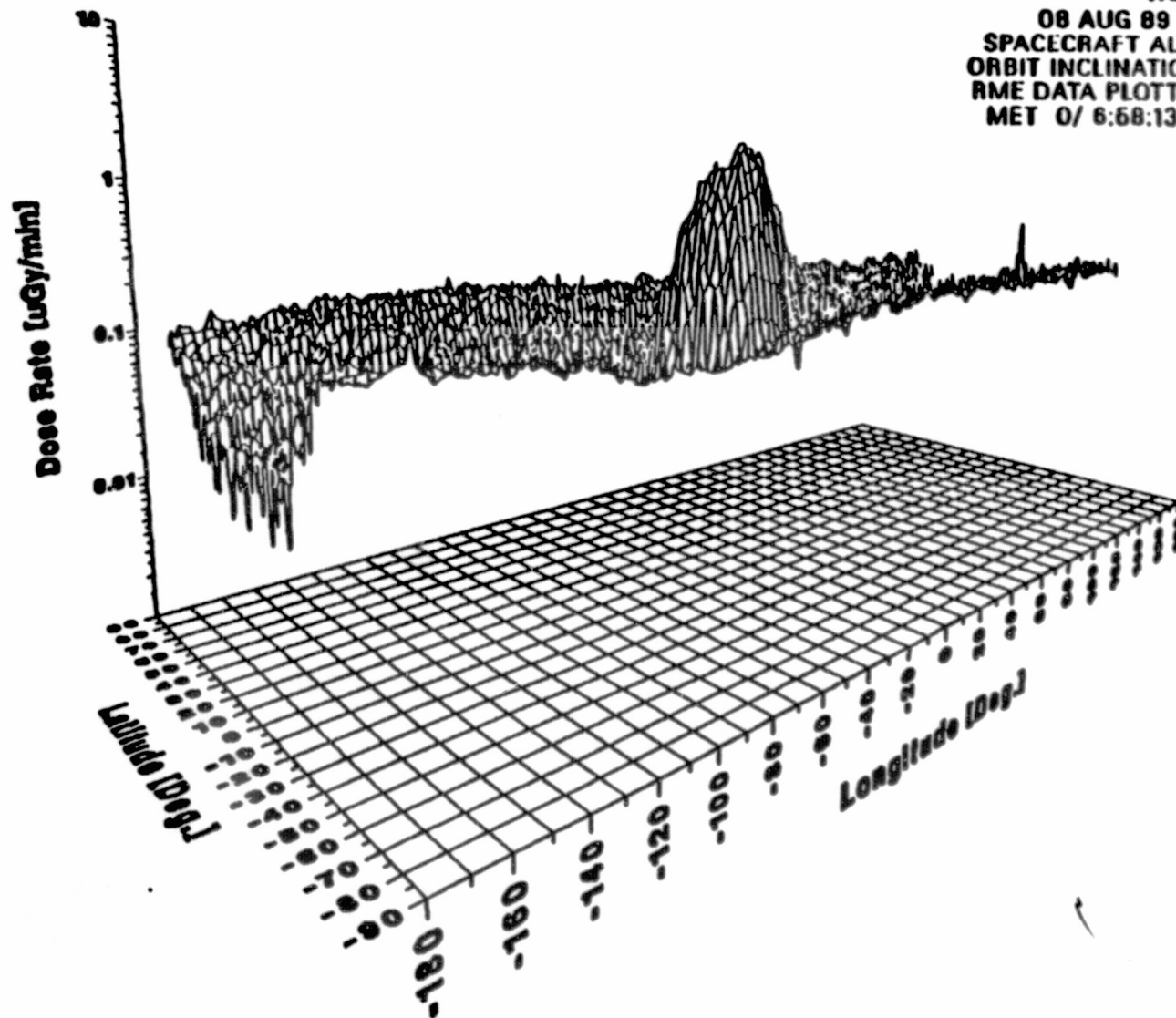
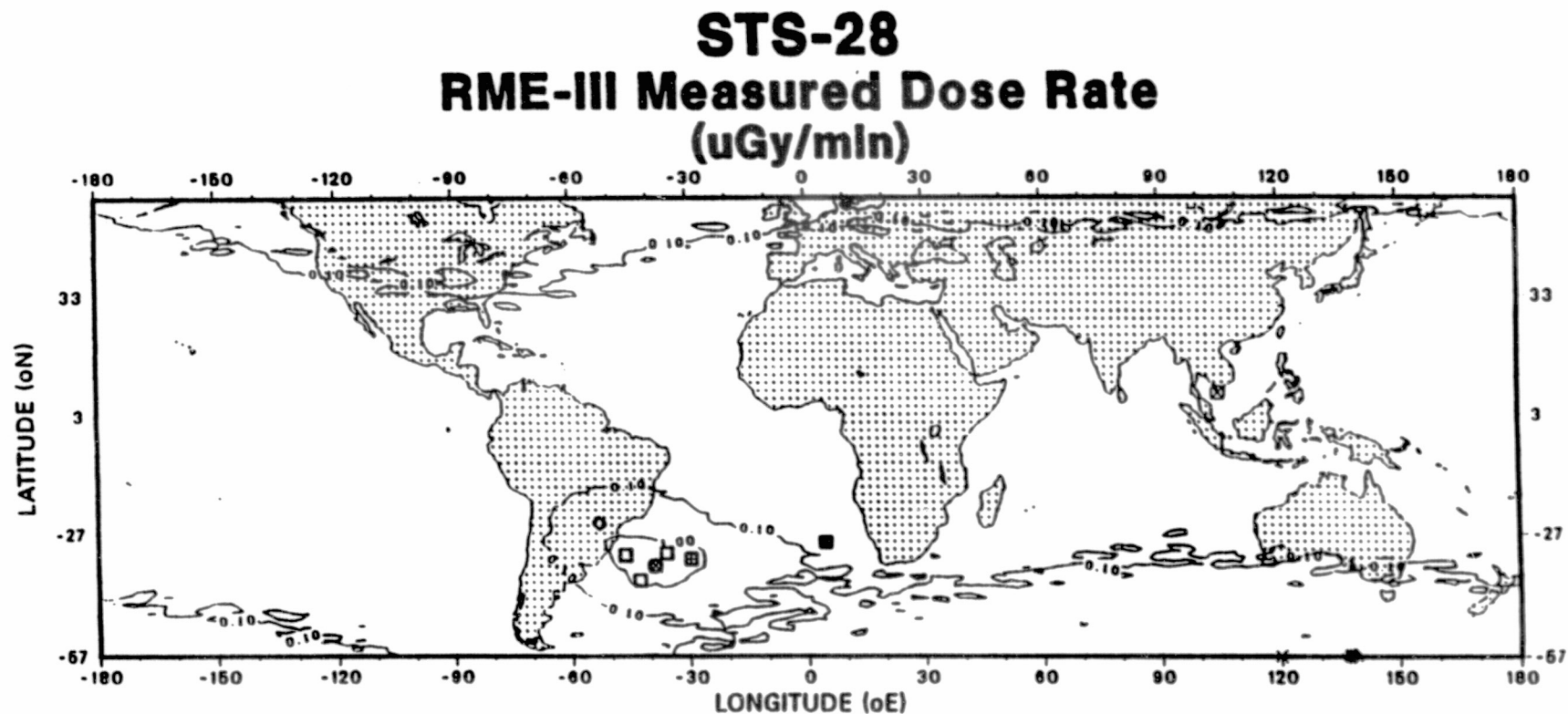


Fig. 1. Isodose contours derived from the STS-28 RME-III data. The contours were derived from 38,000 data points which were smoothed over a 249 x 249 element latitude-longitude array.



NOTES

MISSION DURATION: 08 AUG 89 -- 13 AUG 89
 ORBITAL INCLINATION: 67.0 DEGREES / AVERAGE ALTITUDE: 302 KM
 PLOTTED DATA SET DURATION: MET 0/ 6:58: 3 TO 4/17:17:52
 RECORDS IN DATA SET: 38240
 MAP PROJECTION: CYLINDRICAL EQUIDISTANT
 DATA SMOOTHING GRID (LATxLON): 249 x 249
 FLUX CONTOURS: $\mu\text{Gy}/\text{min}$ AT $\times 10$ INTERVALS
 MAGNETIC FIELD MODEL: IGRF 1985
 MAGNETIC FIELD EPOCH: 1989.7

DATA SUMMARY

MAXIMUM DOSE RATE: 2.40 $\mu\text{Gy}/\text{min}$
 MAXIMUM SMOOTHED DOSE RATE: 1.84 $\mu\text{Gy}/\text{min}$
 MAXIMUM DOSE EQUIVALENT RATE: 4.17 $\mu\text{Sv}/\text{min}$
 MAXIMUM L-LET COUNT RATE: 262 cnts/10 sec
 MAXIMUM M-LET COUNT RATE: 7 cnts/10 sec
 MAXIMUM H-LET COUNT RATE: 3 cnts/10 sec
 RANGE OF B VALUES (gauss): 0.2067 -- 0.6768
 RANGE OF L VALUES (Earth RadII): 0.95 -- 10.78

M.J. GOLIGHTLY/NASA JSC SN31/(713) 483-6190



Spacecraft Interactions and the APE Experiment



R. A. Viereck, E. Murad and C. P. Pike / Phillips Lab, Boston
S. B. Mende, and G. B. Swenson / Lockheed, Palo Alto
F. Culbertson, R. Springer, S. Lucid, K. T. Thornton / NASA

Outline

- Purpose:** To Understand the optical emissions that arise from the interactions between spacecraft in low earth orbit and the ambient atmosphere.
- Procedures:** Instrument Description
Experiment Description
- Results:** Shuttle Plume Emission
Shuttle Glow
Airglow
- Conclusions:** Lessons Learned
Future Experiments



Flight Experiments Technical Interchange Meeting



Purpose:

Satellite Assessment:

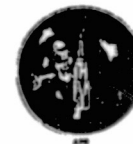
Optical Signatures for Targeting and tracking

Understanding the Physics that give rise to the spectral, spatial, and temporal variations in the optical emissions around space craft.

Characterizing the spectral, spatial, and temporal variations in the background airglow emissions

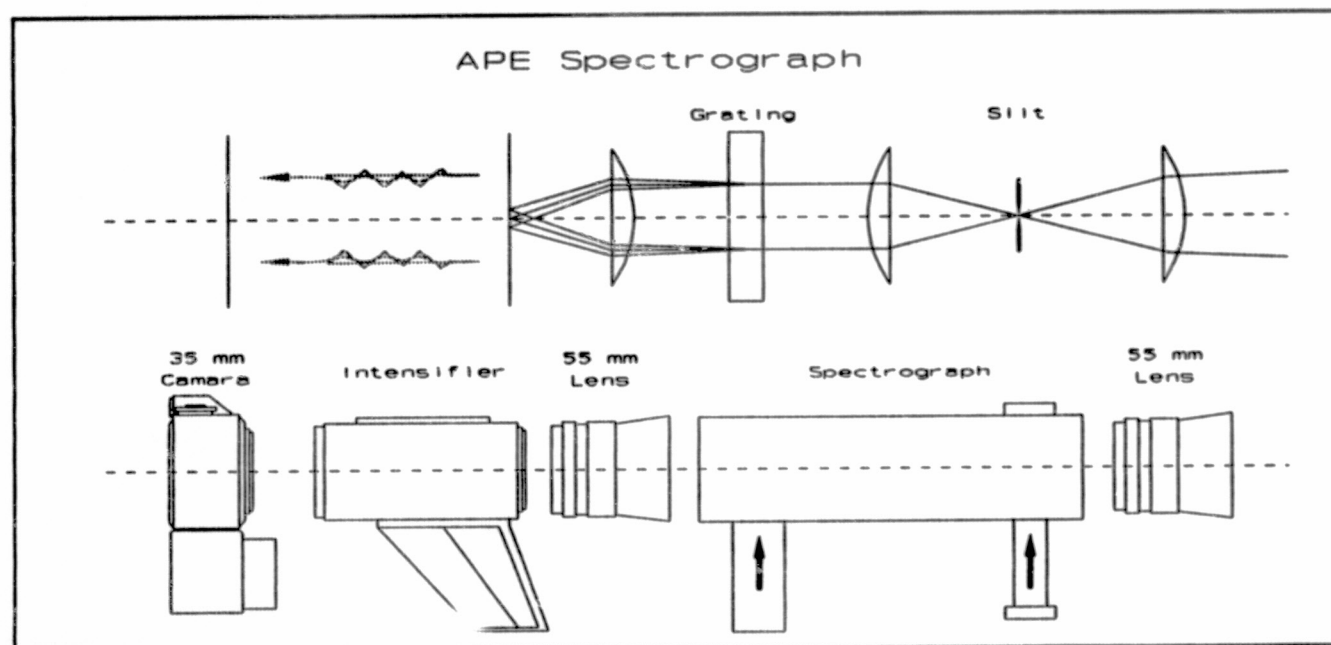


Flight Experiments Technical Interchange Meeting



Instrument Components:

Lenses (2)	50 mm, f-1.2. (NASA Provided Hardware)
Slit	25 by 0.03 mm, 1.1 nm resolution
Grating	600 lines/mm, blazed at ~500 nm
Intensifier	S-20, 25 mm photocathode
Camera	Nikon 35 mm (NASA Provided Hardware)
Film	1600 ASA, Kodak Ektapress, color negative





Flight Experiments Technical Interchange Meeting



Experiment Description:

Thruster Plumes

- Spectral Assessment

- Near vs far field observations

- Ram angle Dependence*

- Comparison with other space observations and with ground*

Shuttle Glow

- Spectral Assessment

- Thruster Effects*

- Altitude Effects*

Airglow Observations

- Spectral Assessment

- Identification of Emissions and emission altitudes

* Future Experiment or Analysis



Flight Experiments Technical Interchange Meeting

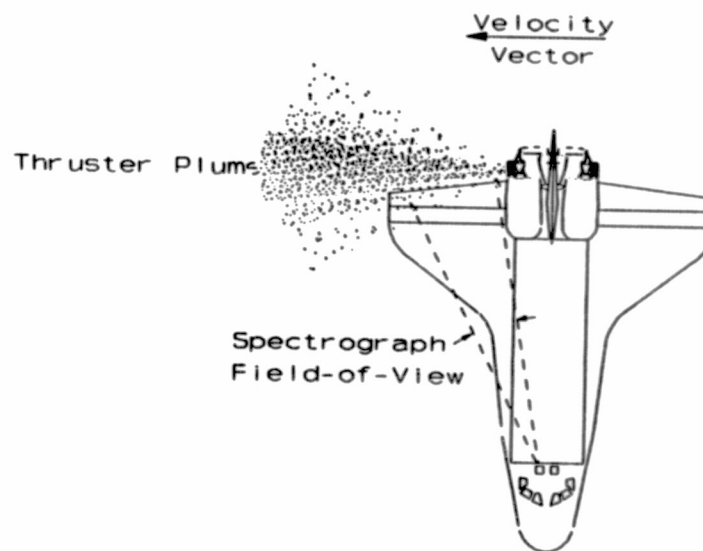


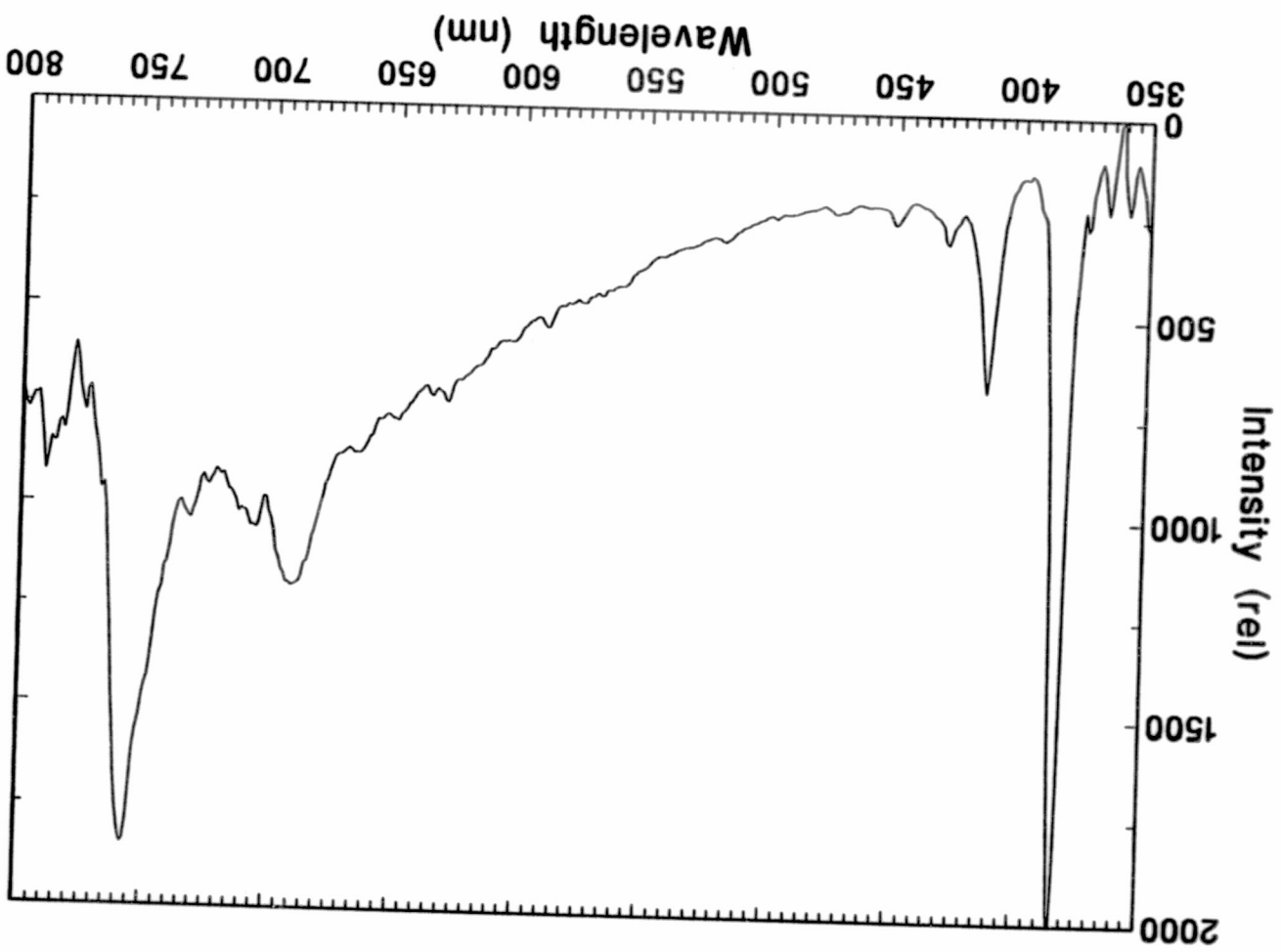
Procedures:

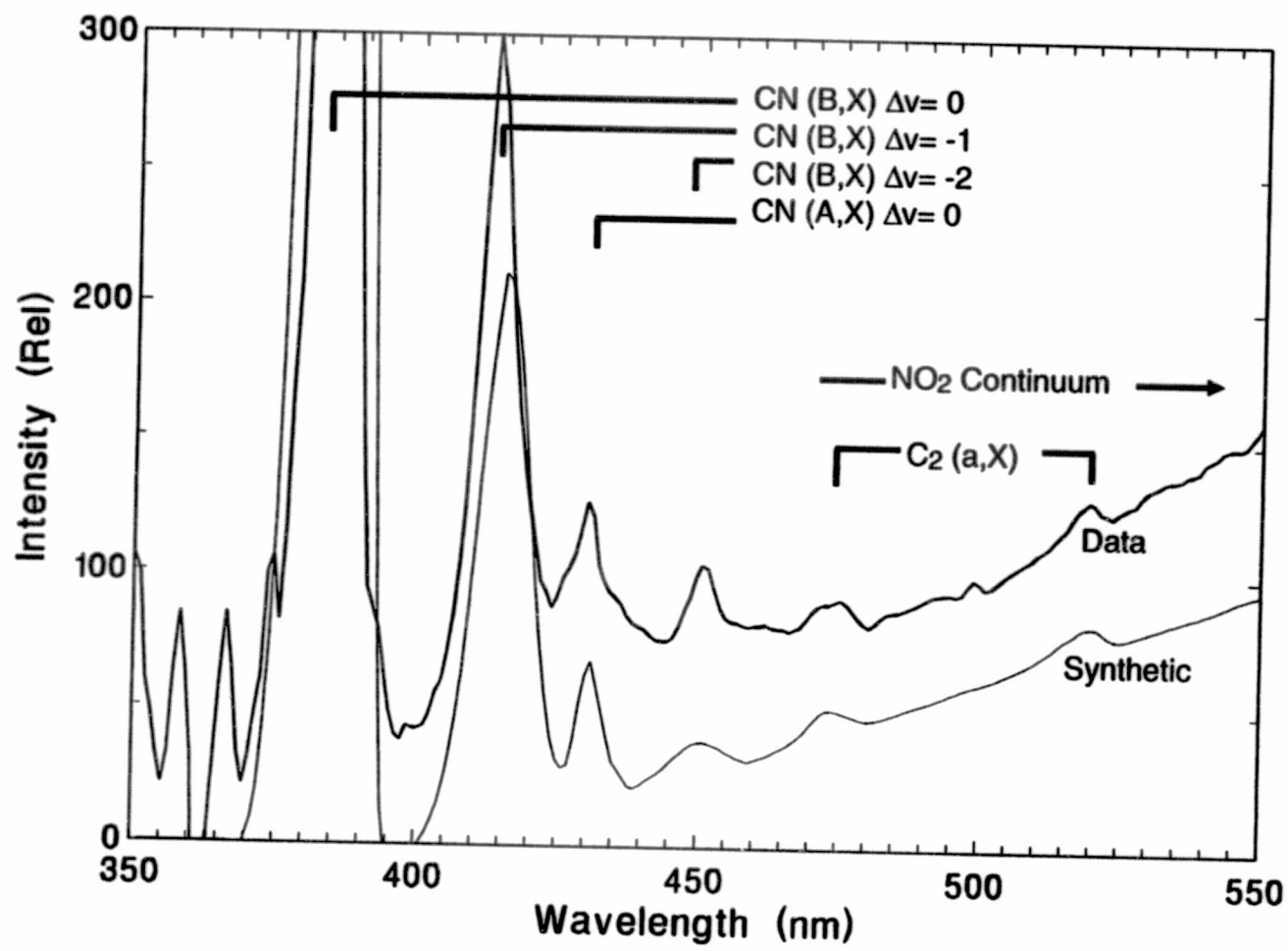
Spectrograph mounted in aft-flight-deck.
Aimed towards tail of orbiter
Slit parallel to centerline of plume
Series of 4 sec exposures

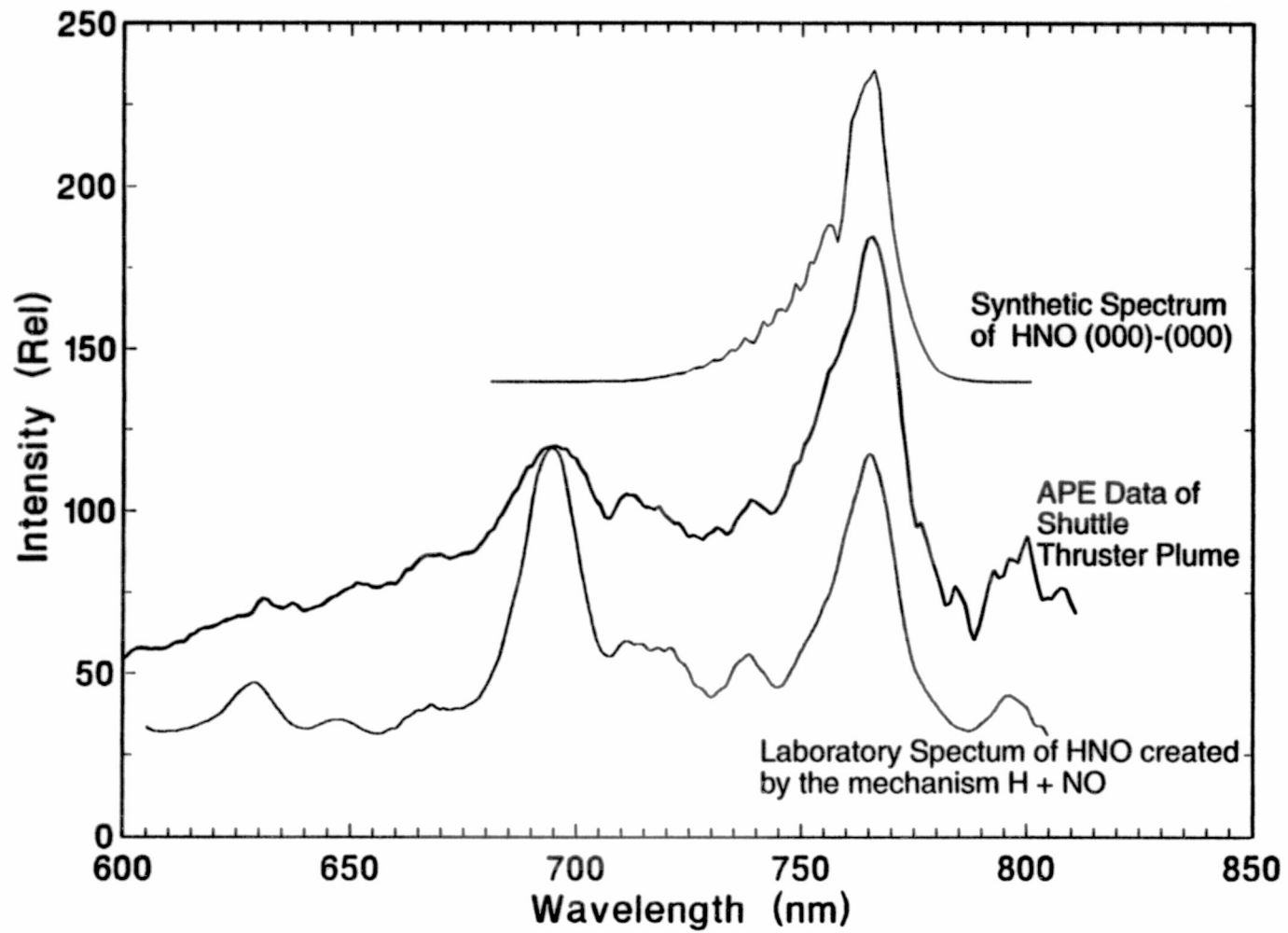
Condition:

Orbiter Altitude	240 km (night)
Orbiter Attitude	Bay to Earth
	Right wing to ram
Thruster	From OMS pod into ram
	820 lb Thruster
	Fired for 4 seconds
	MMH and H ₂ O ₄ film cooled











Flight Experiments Technical Interchange Meeting



Results:

Thruster Plumes

Spectral Features Identified: CN (B→X) $\Delta v=0,-1,-2$
CH (B→X) $\Delta v=0$
C₂ (A→X) Swan Bands
NO₂ continuum
HNO^{*}
Na
O¹D and O¹S^{*}

Spatial Features:

CN, CH, C ₂ , Na	- Decrease Rapidly from nozzle, Down to zero within 1 meter
NO ₂ and HNO	- Rise and peak at 1 meter, then fall to 20% at 3 meters
O ¹ D and O ¹ S	- Seem to get stronger with increasing distance. O ¹ S more evident in ram burns than in wake burns.

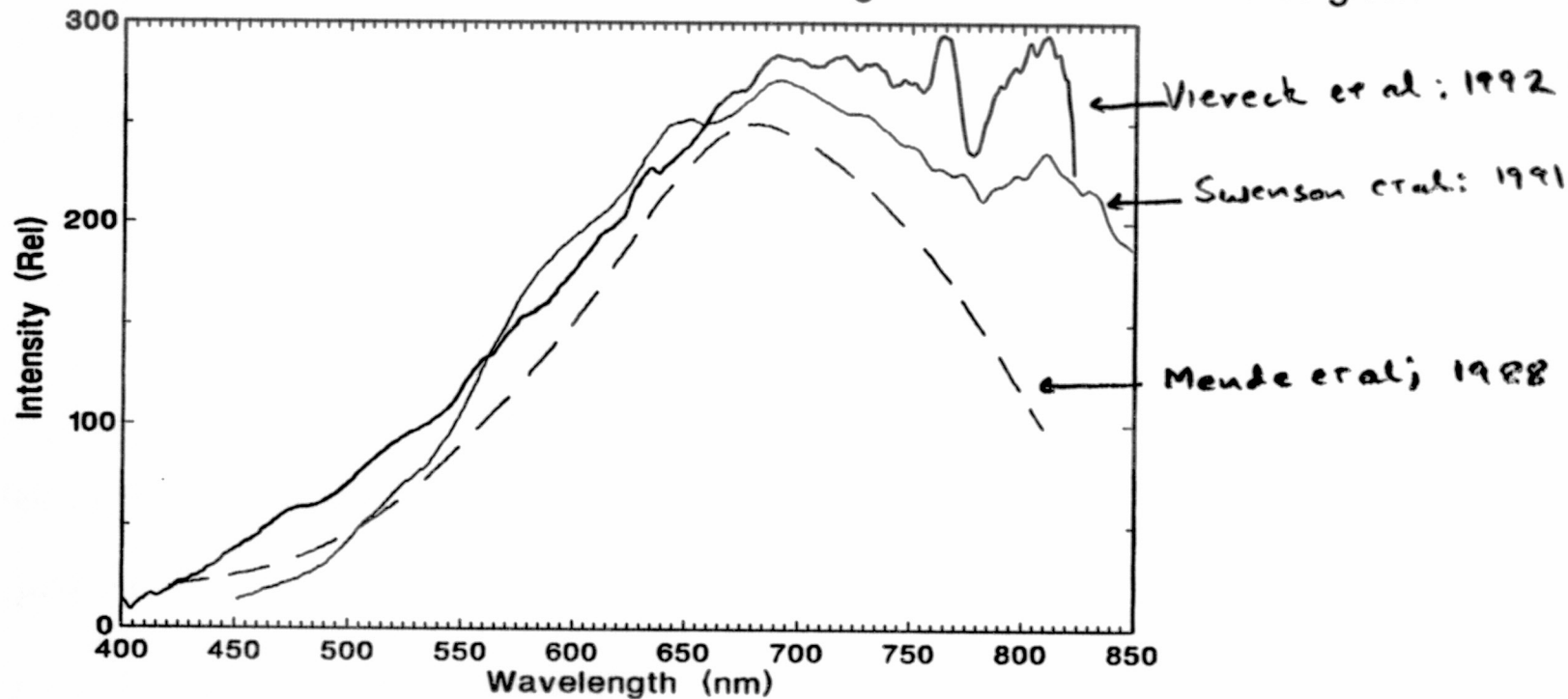


Flight Experiments Technical Interchange Meeting



Shuttle Glow

Confirmation of NO_2 as the primary emitting species in the visible
Proper calculation of window transmission resulting in red-shift in the shuttle glow.



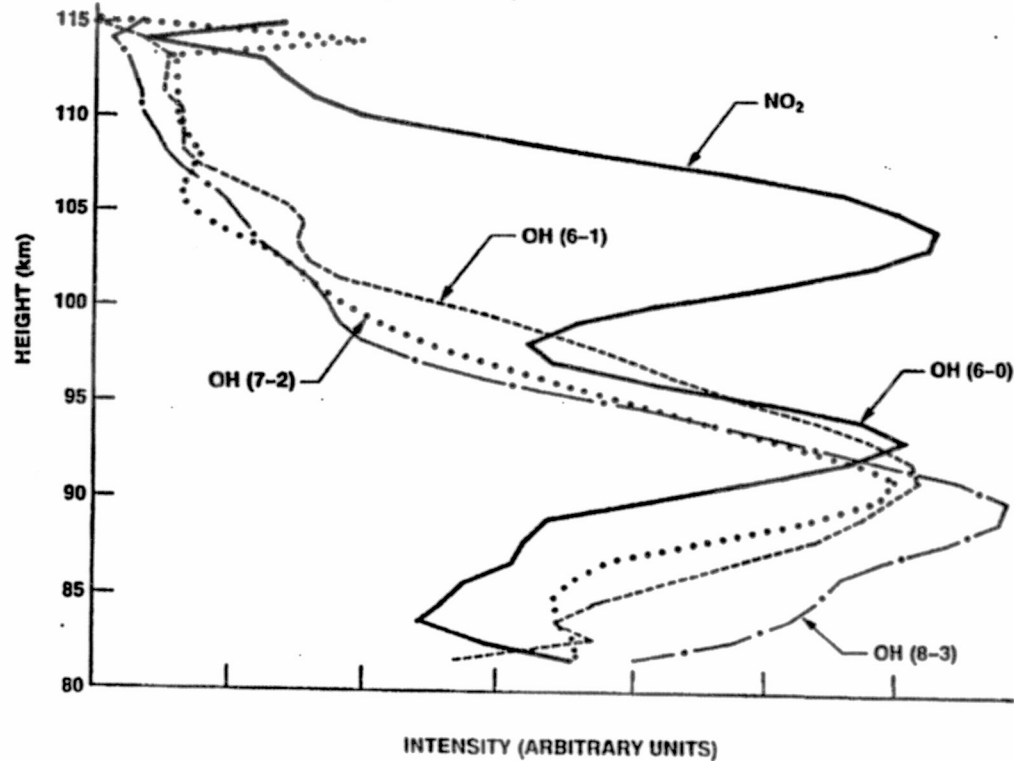


Flight Experiments Technical Interchange Meeting



Airglow

Identification of NO_2 in the atmosphere.
Observation of a Double airglow layer.





Flight Experiments Technical Interchange Meeting



Conclusions:

Lessons Learned

Small mid-deck locker experiments provide a short turn around and a very high return for the amount of effort.

Shuttle is a difficult platform from which to do science.

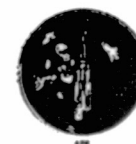
Safety requirements

Large attitude dead-band and uncertainty

Windows with poor optical quality for observations



Flight Experiments Technical Interchange Meeting



Future Experiments

Several experiments planned for the next 12 months.

Further map the spatial and temporal distribution of plumes

Extend the wavelength observations into the UV and IR (APE-C)

Speed up the data rate by using Video instead of Film.

Collaborate the observations with other experiments