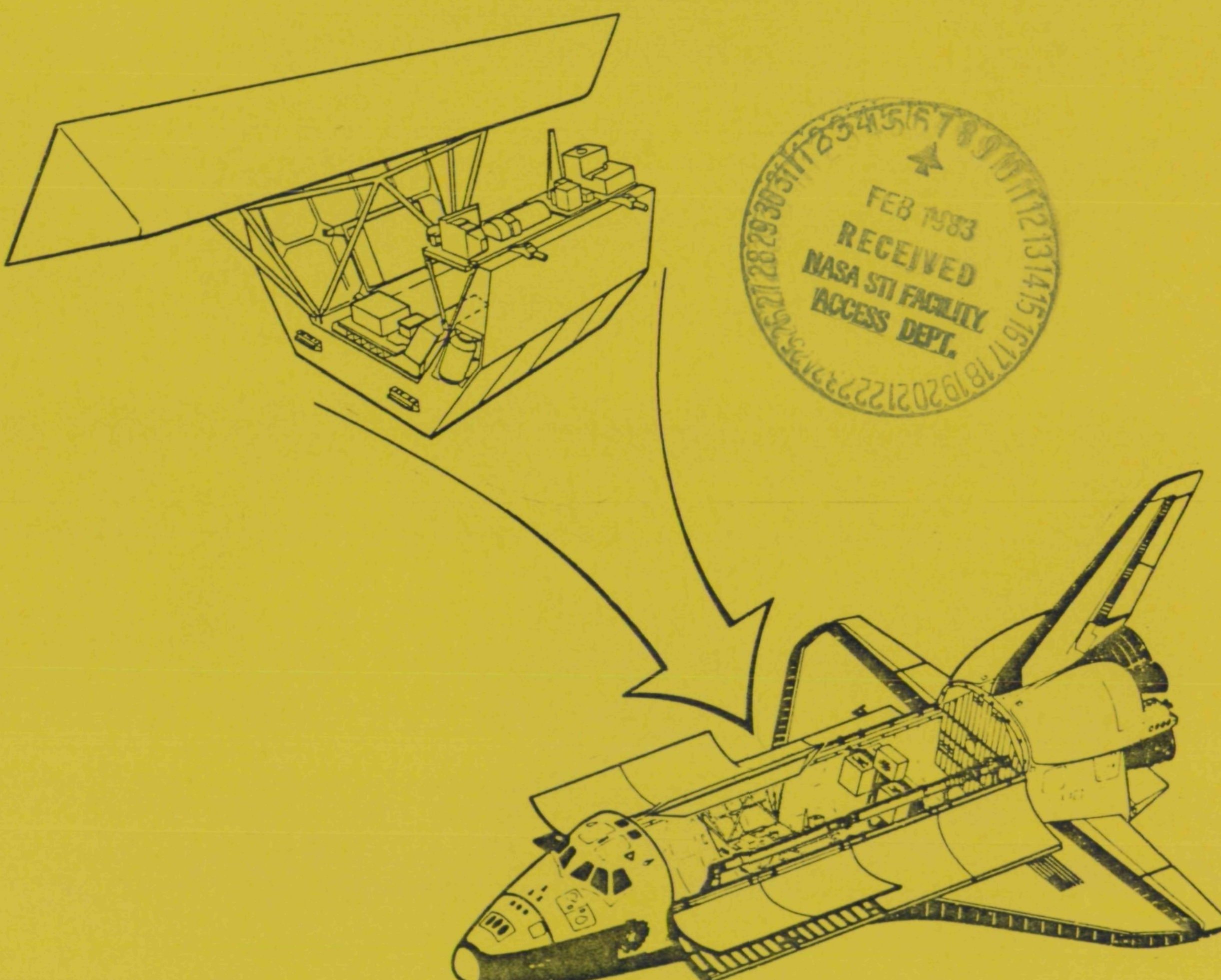
SPACE TRANSPORTATION SYSTEM FLIGHT 2

OSTA-1 SCIENTIFIC PAYLOAD DATA MANAGEMENT PLAN ADDENDUM



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SPACE TRANSPORTATION SYSTEM FLIGHT 2
OSTA-1 SCIENTIFIC PAYLOAD
DATA MANAGEMENT PLAN
ADDENDUM

April 1982

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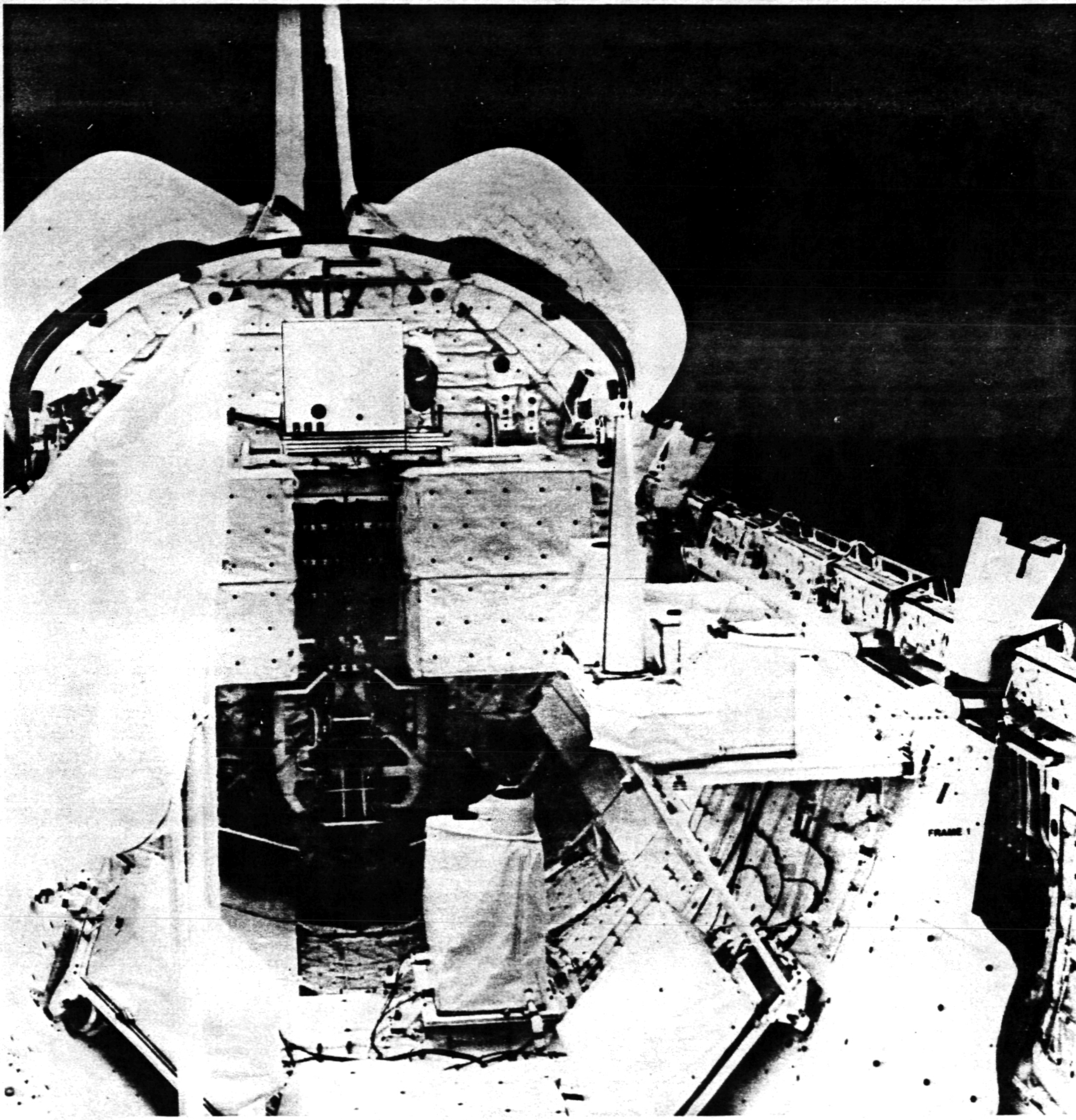

OSTA-1 PAYLOAD IN THE SHUTTLE CARGO BAY IN ORBIT
NOVEMBER 13, 1981

PREFACE

The OSTA-1 Data Management Plan was released by the National Aeronautics and Space Administration Office of Space and Terrestial Applications on September 25, 1981. The Data Management Plan included a data acquisition plan for the OSTA-1 scientific payload on the second flight of the Space Shuttle, STS-2.

This Data Management Plan Addendum provides a description of the actual flight events including a summary of the actual data acquisition. Furthermore, a discussion of problems encountered and a preliminary evaluation of data quality is also provided. This Addendum constitutes Appendix C of the original Data Management Plan, which was to be provided post-mission.

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ILLUSTRATIONS

TABLES

SECTION 1. BACKGROUND

STS-2, the second flight of the Space Shuttle, was launched with a two-man crew from Pad 39A of the Kennedy Space Center (KSC), on November 12, 1981, at 10:10 a.m. EST. The orbit achieved was 139 by 144 nautical miles, with an inclination of 38 degrees. One hour and 40 minutes after launch, the payload bay doors were opened and the radiators deployed and activated. The OSTA-1 payload was activated approximately 4-1/2 hours after launch.

The OSTA-1 mission operations were conducted from the Payload Operations Control Center (POCC) in the Johnson Space Center (JSC) Mission Control Center. The nominal pre-mission timeline was followed for the first 28 hours of the mission, at which time the "minimum" mission timeline was implemented. This decision reduced the mission duration from the planned 124 hours to 54 hours. Table I-1 depicts the major events timeline for the OSTA-1 mission.

The flight of STS-2 ended at Dryden Flight Research Center (DFRC) on November 14, 1981, after 54.25 hours of flight. The data retrieval team went to DFRC, and recovered the OSTA-1 data products as planned. The acquired data was turned over to the principal investigators, and the film and tape data were delivered as appropriate to JSC and KSC for processing.

Table 1-1
STS-2/OSTA-1 Major Events Timeline

Event	Mission Elapsed Time (Hours:Minutes	
	Actual*	Planned
Lift-Off	00:00	00:00
Circularization	00:43	00:45
Open Bay Doors	01:40	01:30
Begin ZLV Attitude Hold	04:05	03:15
OSTA-1 Pallet Activation	04:25	04:00
SMIRR Initial Data Take	04:37	04:30
MAPS Activation	05:17	04:10
NOSL Unstow	09:15	09:00
FILE Activation	09:18	26:20
SIR-A Initial Data Take	09:20	13:00
OCE Initial Data Take	10:33	09:30
Deactivation (Pallet)	46:45	116:45
End ZLV Attitude Hold	47:20	116:45
Begin Deorbit Preparations	47:20	116:45
Close Bay Doors	49:25	121:05
Deorbit (Ignition)	53:15	123:11
Landing	54:15	124:11

*Approximate

SECTION 2. MISSION ACTIVITIES SUMMARY

SECTION 2. MISSION ACTIVITIES SUMMARY

2.1 PRELAUNCH ACTIVITIES

Prior to launch, payload activities were affected by the delay in launch time from November 4 to November 12. For the FILE experiment, it was necessary to make a mechanical adjustment in accordance with the sun beta angle which depends on time of launch. The HBT experiment required freshly planted specimens. As the additional, shorter delay from 7:30 AM to 10:10 AM occurred, there were no opportunities for experimenter access to the payload. This subsequently caused a serious limitation on the ability of the FILE experiment to take data.

2.2 MISSION OPERATIONS

2.2.1 STS TIMELINE

The STS-2 mission, originally planned for 5 days, was to provide about 88 hours of Earth viewing in the -ZLV attitude for the OSTA-1 payload. However, the minimum mission flight plan reduced this Earth viewing time to about 36 hours. Table 2-1 gives the STS-2 as flown attitude timelines. Table 2-2 gives the STS-2 as flown activities timeline, including crew activities, instrument data-taking intervals and attitude description versus mission elasped time and central standard time. Summaries of data acquisition and data products status are given in Tables 2-3 and 2-4. More detailed discussion is provided in Section 3.

2.2.2 POCC ACTIVITIES

During the first 28 hours of the mission, experiment data collection was impacted by the loss of fuel cell no. 1 and the activities associated with understanding the Orbiter power situation.

The POCC activities centered around real-time replanning of the mission for several reasons. The change in final altitude to 139 nmi from planned 137 nmi caused a change in the orbital period. Implementation of the

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TABLE 2-1. STS-2 as Flown Attitude Timeline

Comment	Time		Attitude		
	MET (D:H:M:S)*	-ZLV (H:M)**	Roll	Pitch	Yaw
Prelaunch			180.00	0.00	0.00
NOM OMS 1 ATT	0:00:10:00		322.10	340.40	356.10
NOM OMS 2 ATT	0:00:32:00		27.10	113.00	332.20
-ZLV YPOP ATT	0:01:15:00		180.00	0.00	0.00
COAS CAL ATT	0:02:30:00	1:15	79.40	95.70	307.30
IMU ALN ATT	0:02:40:00		73.30	88.19	307.00
-ZLV YPOP ATT	0:04:15:00		180.00	0.00	0.00
OMS 3A BURN ATT	0:07:35:00	3:20	336.00	17.00	319.00
OMS 3B BURN ATT	0:07:47:00		336.00	16.50	319.00
OMS 4 BURN ATT	0:08:20:00		29.50	184.10	35.20
-ZLV YPOP ATT	0:09:10:00		180.00	0.00	0.00
IMU ALN ATT	0:11:00:00	1:50	268.40	194.90	24.60
ATTITUDE HOLD	0:11:37:00		310.00	195.00	24.60
-ZLV YPOP ATT	0:12:35:00		180.00	0.00	0.00
IMU ALN-THLD ATT	0:21:55:00	9:20	268.40	194.90	24.60
-ZLV YPOP ATT	0:22:18:00		180.00	0.00	0.00
-ZLV ATT BIAS	1:08:05:00	9:47	180.00	0.00	25.00
-ZLV YPOP ATT	1:09:30:00	1:25	180.00	0.00	0.00
RCS JET TEST	1:11:15:00		38.00	143.00	358.00
IMU ALN ATT	1:12:00:00		79.00	149.00	357.80
2ND THLD ALN ATT	1:12:25:00		28.10	252.70	9.90
-ZLV YPOP ATT	1:12:55:00		180.00	0.00	0.00
IMU ALN ATT	1:21:51:00	8:56	268.40	194.90	24.60
-ZLV YPOP ATT	1:22:07:00		180.00	0.00	0.00
TAIL SUN ATT	1:23:21:00	1:14	15.50	49.60	10.30
FREE DRIFT	2:00:00:00		356.40	60.30	2.00
FREE DRIFT	2:00:21:00		18.20	51.70	16.70
TAIL SUN ATT	2:00:25:00		96.50	49.50	16.20
TOP SUN ATT	2:02:28:00		318.30	101.20	298.00
IMU AL	2:03:20:00		243.00	86.00	13.70
IMU VERIF ATT	2:03:35:00		236.30	93.40	331.00

TABLE 2-1. STS-2 as Flown Attitude Timeline (cont.)

Comment	Time		Attitude		
	MET (D:H:M:S)*	-ZLV (H:M)**	Roll	Pitch	Yaw
TOP SUN ATT	2:03:50:00		198.80	351.70	4.00
FREE DRIFT	2:04:10:00		220.50	72.50	328.20
TOP SUN	2:04:42:00		198.80	351.70	4.00
DEORB ATT	2:04:59:00		138.30	355.30	13.00
MM 303 ENTRY	2:05:18:12		202.24	194.72	34.72
MM 304 ENTRY	2:05:35:38		1.41	38.85	358.25
TOTALS		37.07			

*Days:hours:minutes:seconds

**Hours:minutes

Table 2-2. STS-2 As Flown Activities Timeline

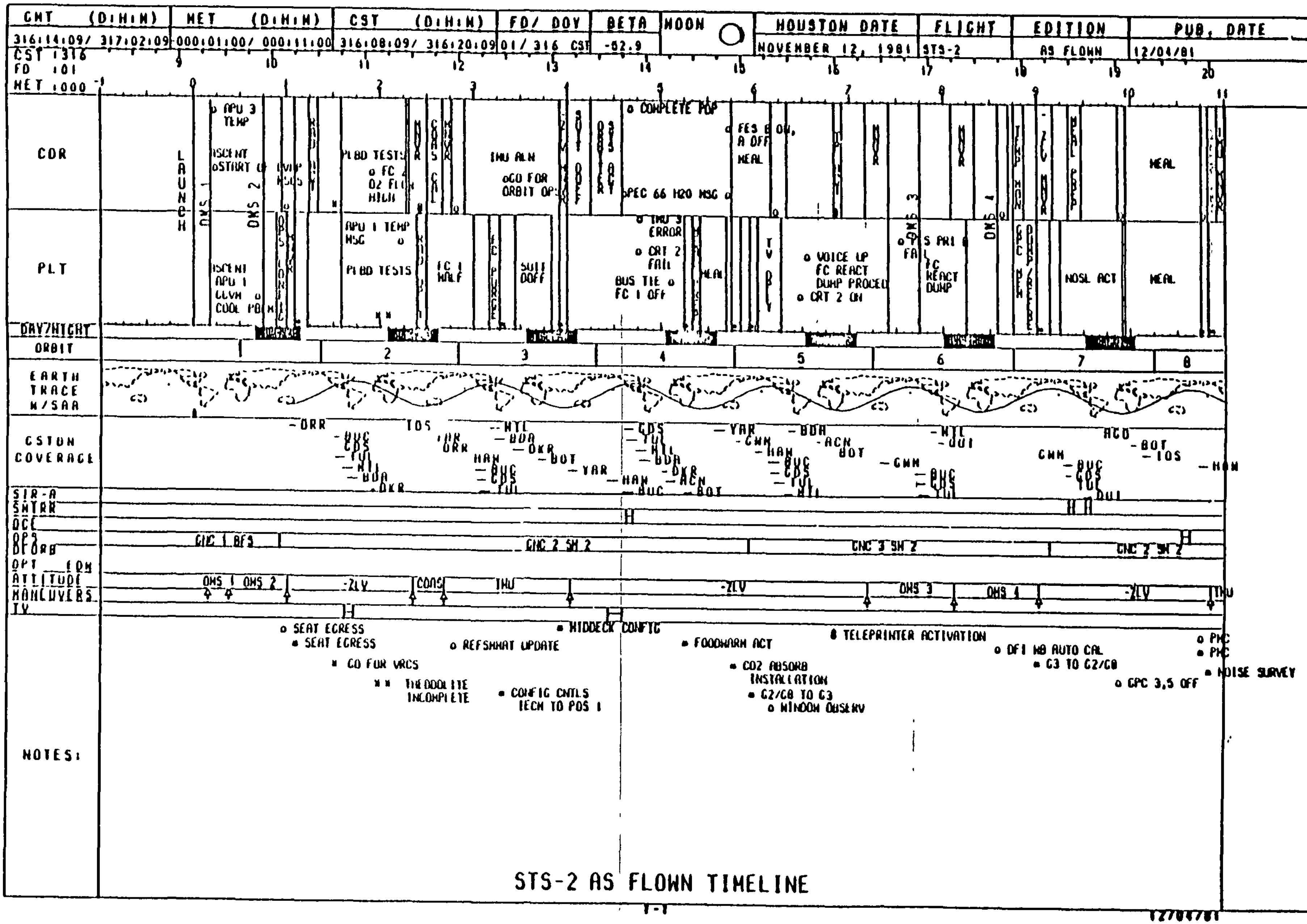

Table 2-2. STS-2 As Flown Activities Timeline (cont.)

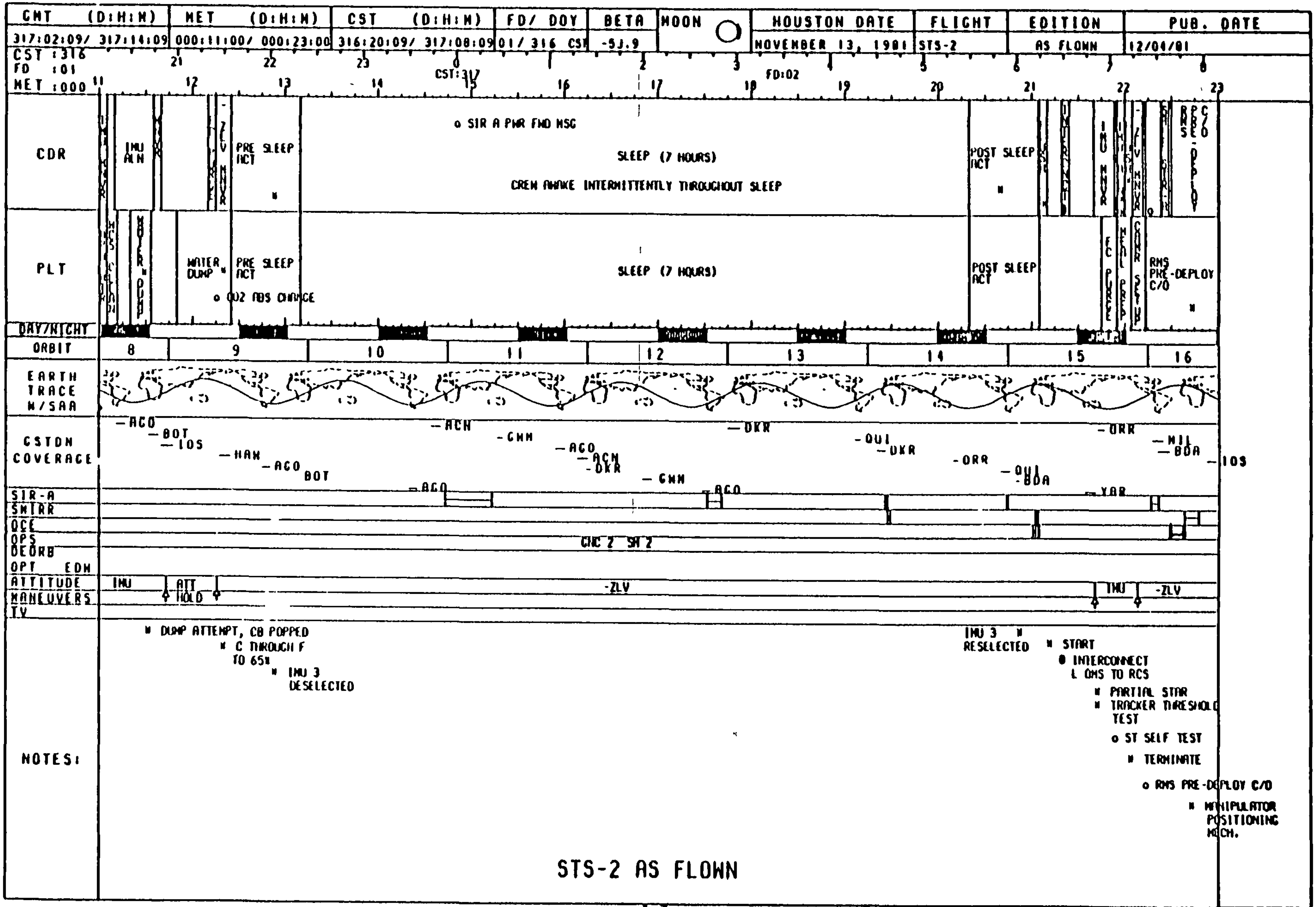

Table 2-2. STS-2 Flown Activities Timeline (cont.)

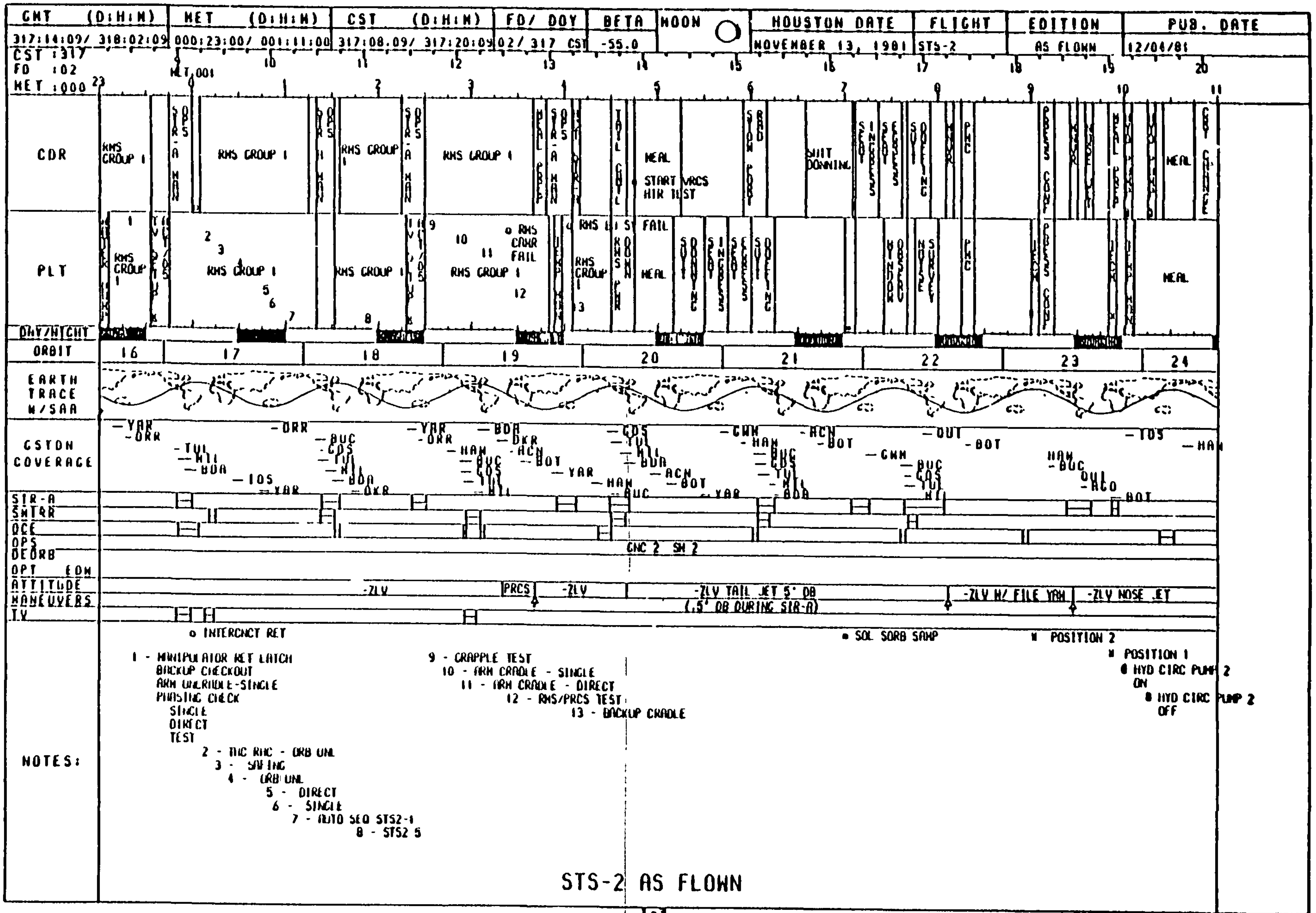

Table 2-2. STS-2 Flown Activities Timeline (cont.)

GMT (D:H:M)	MET (D:H:M)	CST (D:H:M)	FD/ DOY	BETA	MOON	HOUSTON DATE	FLIGHT	EDITION	PUB. DATE
318:02:09/ 318:14:09	001:11:00/ 001:23:00	317:20:09/ 318:08:09	02/ 317 CST	-55.7		NOVEMBER 14, 1981	STS-2	AS FLOWN	12/04/81

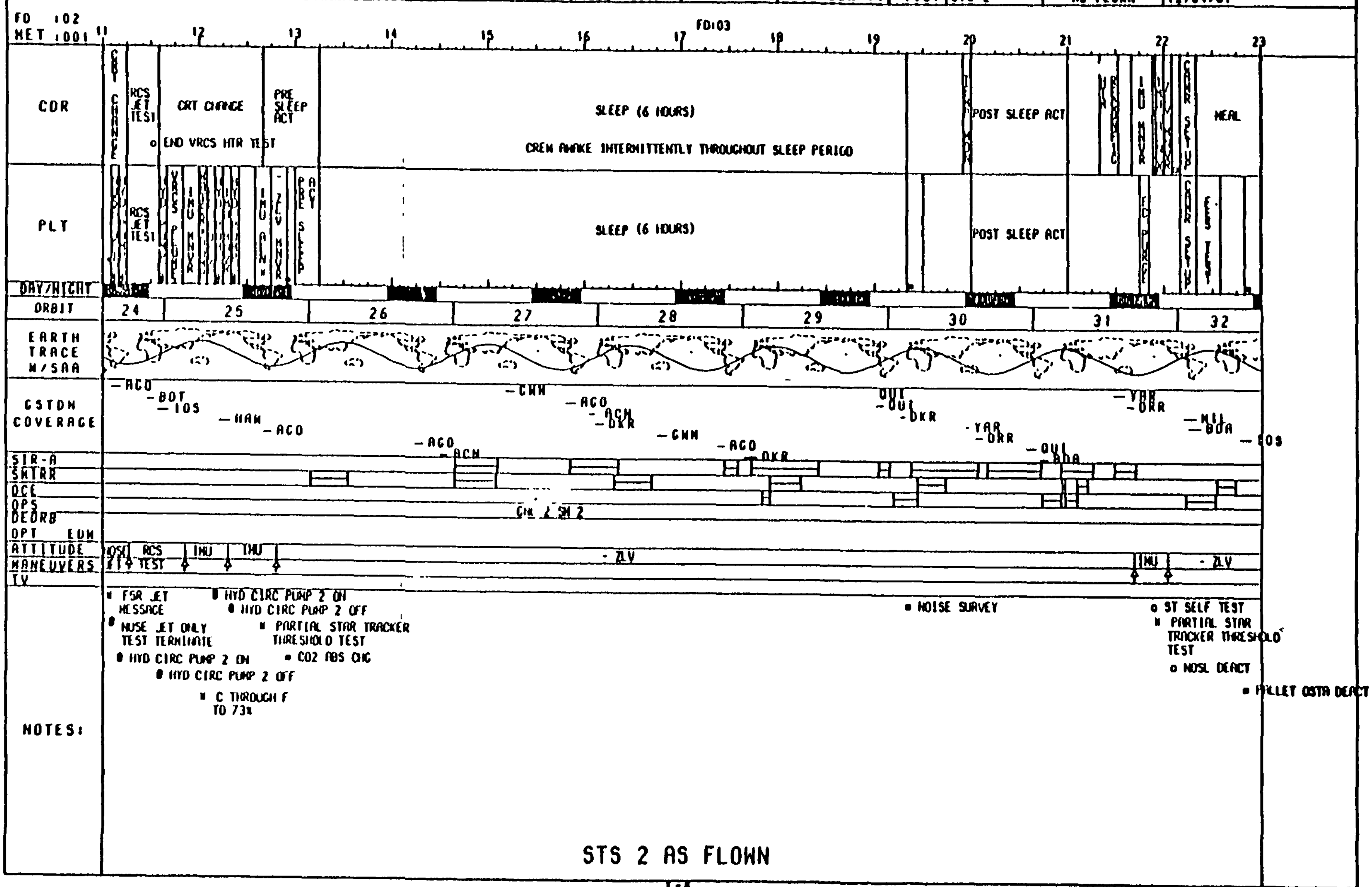

Table 2-2. STS-2 Flown Activities Timeline (cont.)

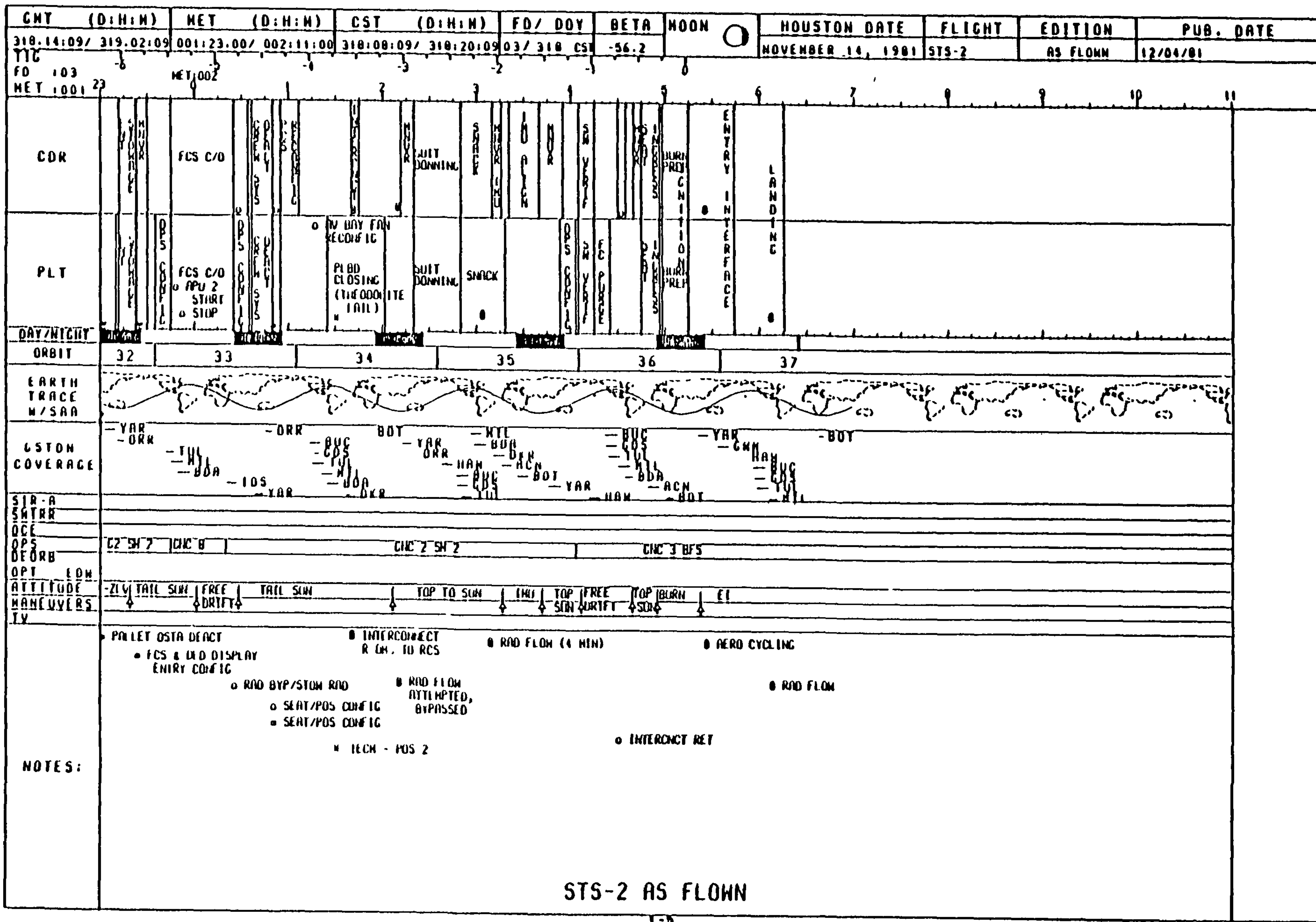

Table 2-3. Summary of OSTA-1 Data Acquisition

Instrument	Area	No. of passes	Time	Comments
SIR-A	U.S. N. and S. America Africa Europe Australia Asia	5 20	50 minutes 400 minutes	
SMIRR	China E. Mediterranean Mexico Eastern and Western U.S.	18	186 minutes 107 minutes (PRI)* 79 minutes (SEC)**	At least 60 minutes cloud-free
OCE	E. Mediterranean E. China S. Japan Mid-Pacific Spain Portugal Western U.S.	18	118 minutes	At least 35 minutes cloud-free Some data drop out
MAPS	Southern U.S. Australia Pacific Africa Other	Auto	37 hours	In -ZLV out of 42.5 hrs maximum
FILE	Japan Saudi Arabia Other	4	45 frames	120 frames maximum
NOSL	S. Africa Eight to 10 large storm systems		1 minute 3 minutes	Nighttime Stereo pairs of large storm systems

*Primary priority
**Secondary priority

Table 2-4. Summary of Data Products Status

Instrument	Data type	Quantity Max. available	Quantity Acquired	Calibration data	Comments
SIR-A	70 mm film	3600 ft	3600 ft	Calibration site data	Data acquired over most prime areas
SMIRR	Payload rec. tape* 16 mm film	9600 ft 1200 ft	5580 ft To be determined	Pre- and post-data acquisition	Cloud cover over western U.S.
OCE	Payload rec. tape*	22 800 ft	22 420 ft	Ground truth obtained	Data from all prime areas not acquired
MAPS	35 mm film Tape	580 ft 900 ft	4100 half-frame images 415 ft**	Yes-calibrate every 12 hours	20 percent of data with cloud cover
FILE	Tape 70 mm film	900 ft 120 frames	*** 45 frames	Film supplies ground truth	High beta angle limited data acquisition
NOSL	16 mm film Tape	2800 ft Two-60-min cassettes	One mag One cassette	Not applicable	Limited opportunities available because of minimum mission
HBT	Specimens	N/A	N/A	N/A	Seeds did germinate

*14-track tape
**Based on total operate time
***Less than one frame of data was recorded on tape

minimum mission reduced the number of data take opportunities (secondary targets replaced primary targets). The delay in launch of 2 hours and 40 minutes changed solar illumination conditions along the ground track and sun elevation angle. Cloud cover impacted the Ocean Color Experiment and Shuttle Multispectral Infrared Radiometer targets. The flight plan was modified to include a yaw maneuver which would allow the FILE sun sensor to be illuminated.

This replanning activity was effectively accomplished and the OSTA-1 experiments were able to collect a significant portion of the data that was to have been collected during the planned 5-day mission.

2.2.3 GROUND TRUTH ACTIVITIES

Three Shuttle underflights were made by aircraft carrying airborne CO sensors over Virginia, Florida, and California for calibration of the MAPS. Good ground truth data were obtained over Virginia and California; however, the data from over Florida is questionable because of clouds. An additional underflight was made over Australia.

2.2.4 PROBLEMS

The major problems encountered were the shortened (minimum) mission, cloud cover of several target areas, and late time-of-day launch (high beta angle), as discussed in the section on POCC activities. There were two additional minor problems. First, SIR-A alerts for forward and reflected power levels occurred during the mission. These may have been caused by sensor problems, since some of these cases had good instrument performance. Postmission analysis of hardware is needed to identify the cause. The second problem was fluctuation in inlet temperature of the pallet coolant loop which exceeded the limit for MAPS. Post-flight thermal-vacuum tests are planned to characterize the effects on data reduction.

2.3 POST-FLIGHT DATA RETRIEVAL AND DISTRIBUTION

The Shuttle landed at DFRC on November 14, 1981. The data materials were successfully removed and transferred to their proper destinations according to the following schedule:

a. The plant growth (HBT) locker was removed from the crew compartment and was given to the PI within 1 hour after landing.

b. The NOSL film magazines were removed and transported to JSC via the T-38 aircraft on November 15, 1981.

c. The Space Shuttle payload tape recorder with SMIRR and OCE data was dumped and duplicated and then turned over to the mission manager on November 16, 1981.

d. Computer compatible tapes (CCT's) were made from the tape payload recorder duplicates at KSC, and the CCT's were turned over to GSFC for OCE, and JPL for SMIRR on November 18, 1981.

e. Access ground support equipment (GSE) was installed in the payload bay, and the data was removed on November 16, 1981.

   1. The SIR-A optical recorder film was sent to Jet Propulsion Lab (JPL).

   2. The MAPS and FILE tape recorders were sent to Langley Research Center (LARC).

   3. The MAPS, FILE, and SMIRR film were sent to JSC for processing.

The Shuttle Orbiter, with the OSTA-1 payload was ferried to KSC, arriving on November 25, 1981. At KSC, the OSTA-1 payload was removed from the Orbiter in the Orbiter Processing Facility (OPF), placed in the canister, and transported to the Operations and Checkout (O&C) building for experiment removal, experiment laboratory testing, and OFT pallet refurbishment.

The experiments were completely deintegrated and were returned to the Principal Investigators. The pallet subsystems (the PCB, FMDM, etc.) were returned to the KSC hardware inventory.

SECTION 3. INSTRUMENT DATA SUMMARY

SECTION 3. INSTRUMENT DATA SUMMARY

This section discusses the extent to which each of the experiments met their objectives, the data acquisition ground tracks where appropriate, the quality of the data obtained, and any problems encountered.

3.1 SIR-A

3.1.1 SIR-A SUMMARY

The Shuttle Imaging Radar-A (SIR-A) experiment was extremely successful. The experiment will achieve its major objectives of evaluating the potential of spaceborne imaging radar in geologic mapping and determining the synergism of using radar imaging in conjunction with Landsat imagery for Earth resources observations. The quality of the SIR-A data is better than expected and will enable the objectives of geological mapping with an orbiting radar to be achieved.

Approximately 7.5 hours (8 hours maximum capacity, one half hour of which was for engineering test and leader) of excellent imaging radar data of major geologic environments in twenty-five data acquisitions over North and South America, Africa, Europe, Australia, Asia and several island areas were obtained. Approximately 10 million square-kilometers were covered by SIR-A. The longest data take was 16,000 kilometers long.

Some passes of ocean data were obtained, providing information on ocean surface features. In addition, an Orbiter Forward Reaction Control System thermal test was deleted on orbits 20, 21 and 22 which enabled SIR-A to obtain data from high priority U.S. targets.

3.1.2 SIR-A PROBLEMS

Three SIR-A systems maintenance (SM) alerts occurred during the STS-2 mission. All were related to forward and reflected power out-of-limit conditions experienced during three separate SIR-A data takes. These alerts were caused by reflected power (return signal) high, which occurred twice and forward power high, which occurred only once. The high reflected and forward power anomalies are believed to be caused by an instrumentation (power sensor) anomaly since the SIR-A was working properly and data quality is good. Post-mission analysis of the hardware must be completed before the cause can be positively identified.

- Alert No. 1 (At MET 0:12:21:18). The first alert occurred when the reflected power exceeded the upper limit of 75 watts for approximately 2 seconds during the data take initiated at MET 0:12:20:10. Strip chart recorder (SCR) data indicated that the reflected power reached approximately 240 watts for a two-sample duration and then dropped back within liimits. At first, the problem was thought to be caused by a water dump occurring at the same time as the data take. Later problems with forward and reflected power indicated a possible sensor problem. This particular problem was not repeated during subsequent data takes.

- Alert No. 2 (At MET 0:14:48:30). The second alert occurred when forward power dropped below 800 watts during a data take initiated at MET 0:14:43:00. Playback data showed that the power reached 750 watts before slowly increasing above the lower-limit value. SCR data showed that the echo sample gate (ESG) analog signal was good throughout the pass, indicating a possible sensor problem. This pattern for the forward power was observed in all subsequent data passes.

- Alert No. 3 (At MET 1:19:02:30). The third alert occurred upon initiation of a data take at MET 1:19:02:30 when the reflected power came up off-scale high. SCR data indicated a good data take. The reflected power telemetry was known to be in error, because at that time the reflected power reading was greater than the radiated power from the transmitter. The reflected power dropped, but it remained high (several hundred watts) for the duration of the data take. This anomaly did not occur in subsequent data takes. Again, the problem appeared to be with the sensor.

3.1.3 SIR-A DATA

JPL has processed all of the 3,600 feet of the data film and the images are in focus and very clear. A resolution of 38 meters (one-half line-pair) was obtained. The signal-to-noise ratio was as expected and there was no effect of the orbiter structure on the antenna pattern.

The shortened mission caused changes in the sites; however, all geologic types were covered.

Data were acquired over all prime areas. Twenty-five passes of SIR-A data were acquired. Five passes (50 minutes) are of the United States. The other twenty passes (400 minutes) include all of the continents except Antarctica. Figure 3-1 depicts the SIR-A data acquisition ground tracks. The swath width was 50 kilometers, the resolution 38 meters, the illumination angle 50^{o} and the operating wavelength 25 centimeters.

A brief summary of the preliminary analysis of the early data follows:

a. Arid regions: A number of arid and desert regions were observed in the Sahara, Arabian penninsula, southern Russia and China. Sand dunes seem to be clearly observed in the radar images as well as variations of the albedo over large sections of some desert regions. Images of a number of playas, salt beds of dry lakes and dry drainage channels, particularly in northern Africa, show considerably more detail than Landsat images. This is a result of the fact that the radar is mapping variations of the surface roughness on the scale of a few centimeters to a few tens of centimeters. Numerous geologic structures (folds, faults, fractures) were observed. In some remote areas, preliminary interpretation of the data shows appreciably more structural detail than the most recent available geologic maps.

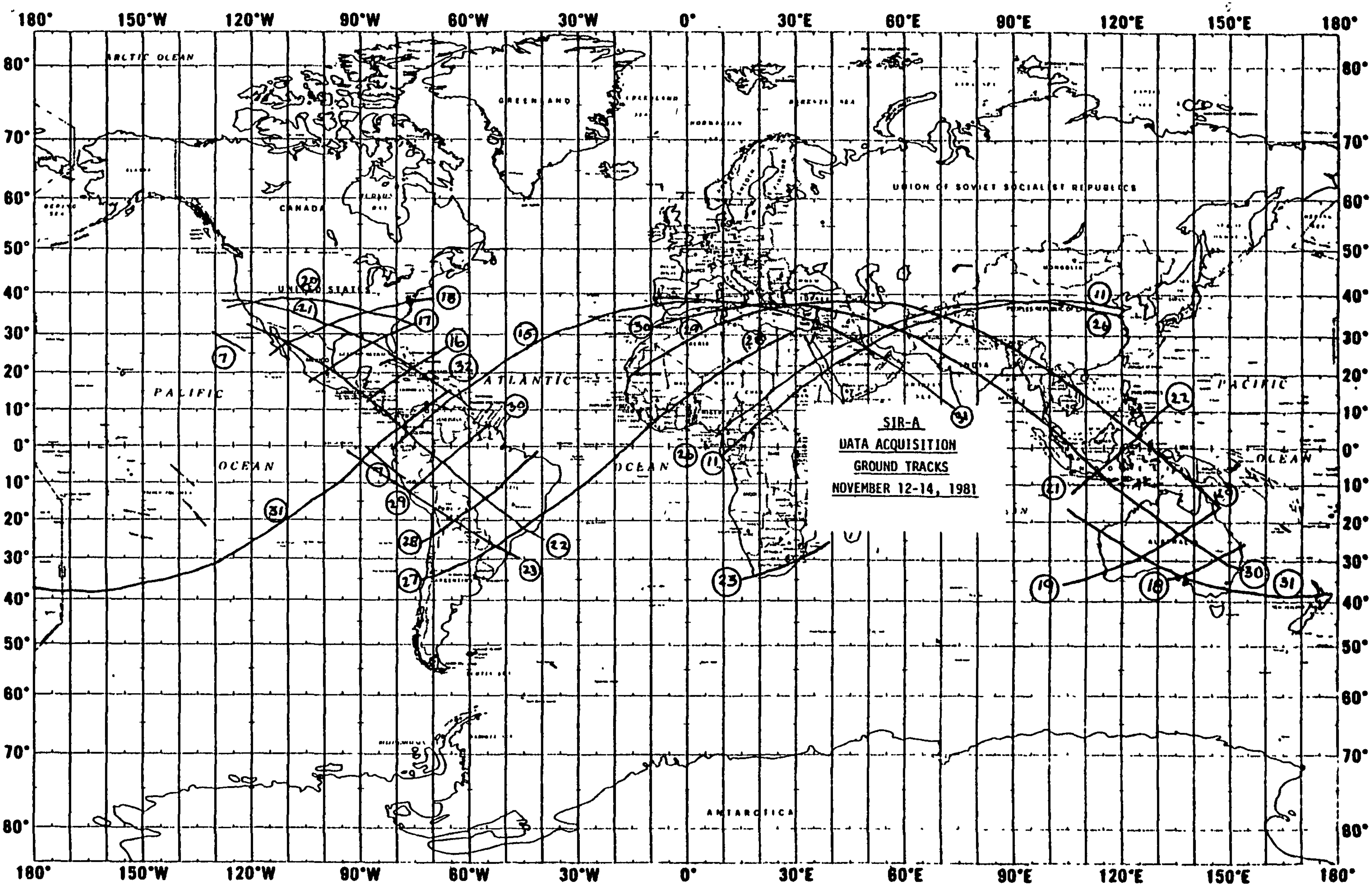

Figure 3-1. SIR-A Data Acquisition Ground Tracks

b. Tropical regions: Images were acquired over numerous tropical regions with cloud cover and dense forest regions in New Guinea and the Amazon. Karst regions were delineated because of the characteristic texture associated with this type of morphology.

c. In cultivated regions, brightness variations clearly delineate cultivation fields and forested regions.

d. Comparative analysis: The SIR-A data provides information with a very specific set of sensor characteristics: spectral band and illumination geometry. This data is being analyzed in conjunction with Seasat radar images (different illumination angle and geometry), airborne radar data (different frequency), HCMM data (thermal), Landsat data (visible and IR), and SMIRR data (IR radiometer) to provide a complete signature of the surface. These different types of sensors provide complementary information which when combined provides a great deal of information on the surface structure and composition.

3.2 SMIRR

3.2.1 SMIRR SUMMARY

The Shuttle Multispectral Infrared Radiometer (SMIRR) experiment was designed to identify different types of rocks and soil associated with hidden resources. The experiment operated successfully and will meet all science objectives:

a. Obtain radiometric reflectance measurements in 10 wavelength channels between 0.5μm and 2.5μm of selected portions of the Earth's surface.

b. Assess the value of very narrow spectral channels (0.02μm) for mineralogic and lithologic identification from orbit.

c. Assess the value of the 10 chosen wavelength channels for use in future imaging systems for geologic mapping.

d. Assess the variabilty of reflectance signatures of major rock types from portions of the earth as affected by environmental conditions.

e. Determine the correlation between ground-based reflectance measurements and SMIRR orbital measurements.

The SMIRR experiment began operating about four-and-a-half hours after launch, controlled throughout the flight by commands from the ground. SMIRR acquired 3 hours and 6 minutes of data over Africa, Asia and the Middle East, Europe, Mexico and the U.S. Two hours were found to have been taken over cloudy or partly cloudy areas, while over one hour of prime data was obtained over totally cloud-free land areas.

Data from the experiment will help determine which bands from the infrared portion of the spectrum should be used in future Earth-orbiting satellite imaging systems for finding and mapping rock types associated with mineral and petroleum deposits. Studies by scientists at JPL and the U.S. Geological Survey indicated that bands in the 1.0 to 2.5 micrometer region could perceive subtle differences between similar geological units. SMIRR tested ten bands within that region to determine their effectiveness in identifying surface materials from orbit, which will aid in building an orbital system that may produce a global map showing areas where mineral deposits are likely to be found.

Because the SMIRR is not an imaging device, photographs are necessary to geographically locate the instrument's readings. Two 16-millimeter cameras, one color and one black-and-white, were aligned with the SMIRR telescope to provide accompanying images to the SMIRR data. Analysis has shown that the cameras remained aligned after launch stresses.

Preliminary analyses of SMIRR data show that clay minerals can be identified, a result that has not been obtained with previous spaceborne instruments. SMIRR's global sample of different geological types in a variety of climatic environments may reveal unknown relationships that exist between surface and subsurface materials. The results will also show the effect of varying climatic environments on the reflectance signatures of similar rock types, as well as study the effect of variable atmospheric absorption on the quality of the data.

In all SMIRR sampled 80,000 kilometers of the Earth's surface. Figure 3-2 depicts the SIRR data acquisition ground tracks.

3.2.2 SMIRR PROBLEMS

The quantity of data is less than desired because of cloud cover and the shortened mission. The experiment was to have collected data primarily in the Western U.S., where the majority of ground-based field reflectance measurements were obtained, but clouds covered the area during most of the shortened flight. SMIRR team members will collect ground-based reflectance measurements in other areas where SMIRR obtained data. Planned coverage of Australia, southern Africa and South America was not possible because of unfavorable lighting resulting from the two hour launch delay.

3.2.3 SMIRR DATA

Eighteen data acquisitions were accomplished, resulting in 186 minutes of data with the surface visible. Approximately 70 minutes of data, equivalent to 400,000 spectra, were obtained under totally cloud-free conditions. Another 50 minutes of data were acquired in apparently cloud-free conditions but the presence of high thin clouds cannot be ruled out. Extremely good data were obtained over China, Mexico and Asia Minor. An extensive weather system limited the U.S. coverage, however, one minute of good data was taken over the Western U.S., and the quality of the data is excellent.

At this time, only data from orbit 18, extending from lower Baja California to southern Virginia, and a portion of orbit 16 over western Egypt have been analyzed. Atmospheric corrections were made using the Lowtran-V atmospheric model. Several ground control points such as a sand beach and a coniferous forest were used to establish preliminary normalization factors, to allow absolute spectral reflectances to be plotted. The preliminary results show the expected major influence of vegetation on the spectra as well as areas in which clay bands can be observed.

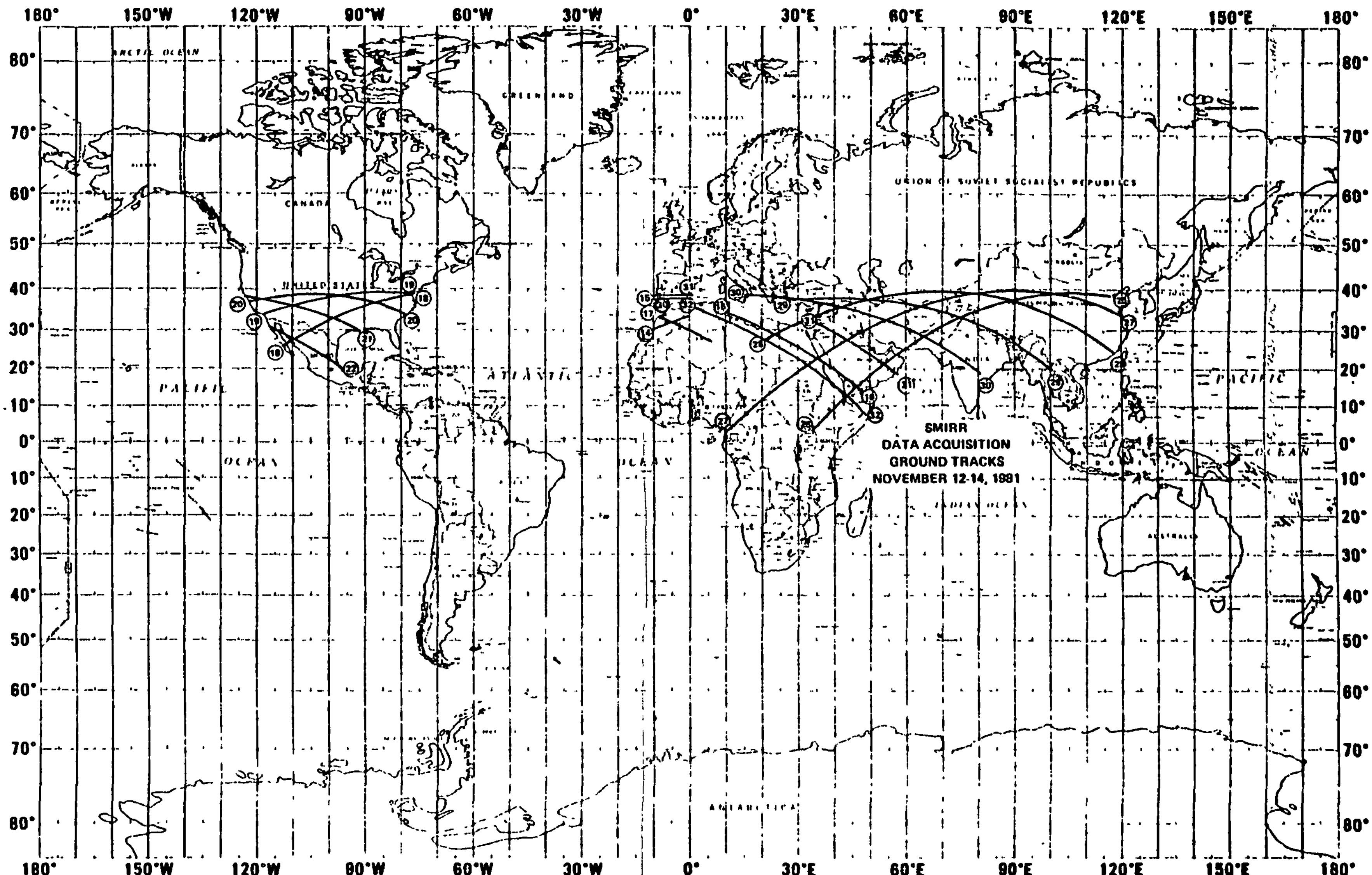

Figure 3-2. SMIRR Data Acquisition Ground Tracks

On orbit 16 in an area near Kharga in western Egypt an identification of carbonate was made in two outcrops. This is the first known direct identification of carbonate by remote measurement from orbit. In addition, an identification of clay-rich soil, probably kaolinite, was made in the same region. This area coincides with a playa containing kaolinite. The identification was made based on higher than average values for the ratio 1.6/2.1 and 2.17/2.20 in an area containing no vegetation. The verification of all results awaits ground spectral measurements and sample analysis.

As the SMIRR data is processed, computer-assemled maps will be produced, and each 100 meter- (328 foot-) diameter area will be tagged with a color according to its predominant rock type. The radiometer data occupy a total of 4 computer compatible tapes. These and two 400-ft rolls of 16-mm film along with a calibration report will be placed in NSSDC by June 1982.

3.3 OCE

3.3.1 OCE SUMMARY

The Ocean Color Experiment (OCE) was designed to map ocean features using an eight-channel scanning radiometer. The objective of the experiment was to demonstrate the ability to locate plankton or chlorophyll concentrations and identify circulation features by mapping color patterns in the ocean. The experiment operated successfully and the overall image quality and spectral information is excellent.

The OCE has met its basic objectives by demonstrating the ability to map chlorophyll concentrations and identify ocean circulation features. In addition, underwater topographic features have been delineated in areas of clear water. Analysis of the data is continuing and refinements in the results are expected. The experiment could have been much more fruitful, had the mission not been abbreviated. Otherwise, the instrument performed flawlessly and execution of the mission was successful. The OCE will contribute to the refining of ocean colorimetry thus boosting the oceanographers capability to more accurately observe the ocean.

3.3.2 OCE PROBLEMS

During the first two days of the mission two large storm systems covered both the east and west coasts of the United States. The east coast had been selected as a prime target area, however the cloud cover was so dense that the sea surface was invisible. No ground truth data could be obtained.

It was well known from previous airplane flights and other data that the coast is cloud free about 30 percent of the time. The full length mission would have allowed sufficient time to select cloudless sites. When it became known that the mission would be terminated early the scanner was left on in hope of obtaining something.

The instrument worked well throughout the mission with no dropout lines. When the instrument was returned for post-flight calibration the scanner surface mirror was coated with some type of degassed material. This material reduced reflectivity by about 4 percent. Post-flight calibration is currently in progress. The mirror is being cleaned up and the residue analyzed to determine its origin. The important question is did the contamination happen during or after the flight.

3.3.3 OCE DATA

Eighteen data acquisitions were accomplished, resulting in approximately 118 minutes of data acquired; maximum capability was 120 minutes. Approximately 20 to 30 minutes of cloud-free data were acquired. Cloud cover and a low Sun angle will reduce the quality of the remaining data. Excellent data were obtained of the following areas: off Portugal, the Mediterranean Sea, the China coast, and mid-Pacific and mid-Atlantic Oceans. Good ground truth was obtained off Portugal and in the Mediterranean Sea. Figure 3-3 depicts the OCE data acquisition ground tracks. Table 3-1 is a history log of the data taken. It provides the orbit number, GMT, length of data acquisition, latitude, longitude, solar zenith angle and comments.

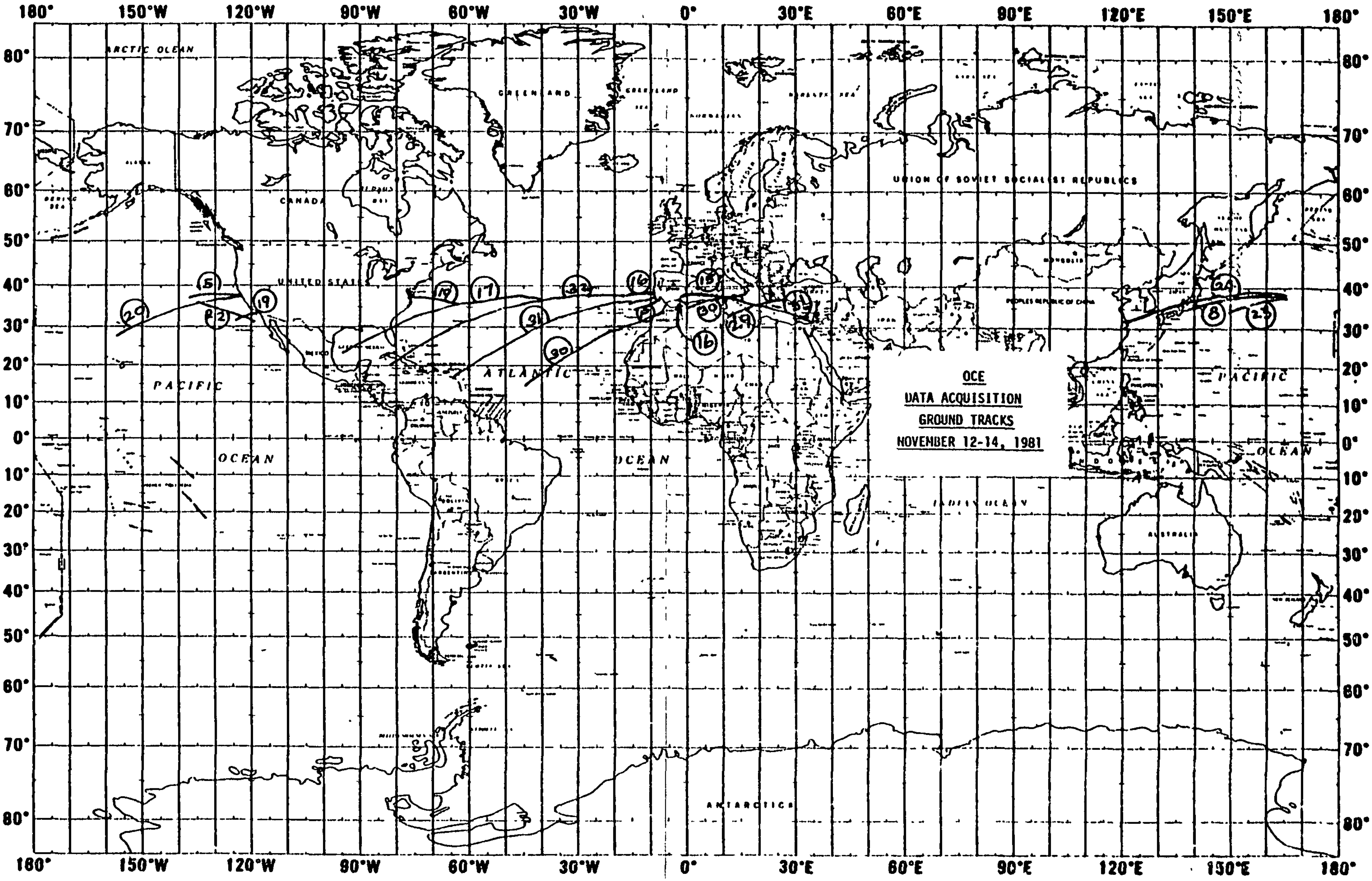

Figure 3-3. OCE Data Acquisition Ground Tracks

Table 3-1. Actual OCE Data Takes

Data Take	Orbit	GMT	ΔT	Latitude	Longitude	Solar Zenith Angle	Location	Notes
1	8	317:01:43:15		34.96 N	137.9 E	54	Mid Pacific Rise	Cloudy
		:01:48:00	4:45	38.19 N	162.5 E	57		
2	15	317:12:11:00		36.49 N	-15.04 W	54.9	Portugal -	Cloudy
		:12:12:35	1:35	37.50 N	-8.00 W	55.3	Atlantic	
3	15	317:12:14:16		38.09 N	0.40 E	56.2	Spain - Mediterrean	Cloudy
		:12:15:29	1:15	38.16 N	6.45 E	57.5		
4	16	317:13:45:00		38.1 N	-16.6 W	57.4	Gibraltar	Cloudy
		:13:48:45	3:45	36:25 N	1.16 E	62.1		
5	17	317:15:01:15		22.7 N	-96.5 N	61.5	Gulf of Mexico	Cloudy
		:15:14:30	13:15	38.17 N	-39.7 W	57.31	to Mid-Atlantic	SIR-A was on
6	18	317:16:41:15		37.6 N	-76.0 W	55.5	Chesapeake to	Cloudy
		:16:44:30	3:15	38.1 N	-60.38 W	57.6	Mid-Atlantic	Sea surface invisible
7	19	317:18:04:45		30.7 N	-125.7 W	57.0	Pacific to	Cloudy
		:18:06:30	1:45	33.5 N	-118.5 W	55.9	Western U.S.	
8	19	317:18:15:30		37.5 N	-76.2 W	59	North Carolina	Cloudy
		:18:17:45	2:15	35.9 N	-65.7 W	62	to Bermuda	Sea surface invisible
9	20	317:19:32:00		26.9 N	-157. W	59	Pacific	SIR-A on 17:39:20
		:19:40:00	8:00	37.4 N	-123.4 W	55.4	Hawaii	Clear ocean area

Table 3-1. Actual OCE Data Takes (cont.)

Data Take	Orbit	GMT	Δ T	Latitude	Longitude	Solar Zenith Angle	Location	Notes
10	21	317:21:12:00		38.2 N	-134.4 W	56.5	West US	Cloudy
		:21:14:15	2:15	37.74 N	-123.5 W	58.4	West Coast	
11	22	317:22:46:45		36.2 N	-136.0 W	60.56	San Diego	Cloudy
		:22:49:30	3:45	31.9 N	-120.0 W	66.31		SIR-A on
12	23	318:00:04:45		36.6 N	150 E	56.6		Cloudy
		:00:08:00	3:15	37.0 N	165 E	55.6	Mid Pacific	(20^0 Yaw Mid Pacific)
13	24	318:01:32:00		31.85 N	122.1 E	57.8	Yellow Sea/Sea	Very clear sky, good
		:01:42:15	9:15	37.9 N	164.8 E	57.5	of Japan/Pacific	data until E Japan
14	29	318:09:00:04		30.8 N	05.1 E	58.4	Eastern Mediterrean	Cloudy
		:09:05:00	4:56	36.9 N	26.9 E	56.3		
15	30	318:10:21:45		14.9 N	-45.2 W	73.0	Atlantic/Sicily	Became clear 318:10:33 before
		:10:36:30	14:45	37.9 N	13.4 E	56.1		Portugal coast clear to end next orbit
16	31	318:11:52:30		17.8 N	17.8 E	70.1	Atlantic	Partially clear
		:12:06:15	13:45	38.0 N	38.0 E	56.2	Portugal	Gulf of Libya to Greece
17	31	318:12:08:00		38.2 N	0.1 E	56.5	Spain to Israel	Clear coast of Spain until
		:12:15:30	7.30	31.7 N	4.7 E	64.0		end
18	32	318:13:23:30		21.0 N	-82.2 W	68.6	Gulf of Mexico	Clear area S Cuba
		:13:42:15	18:45	35.3 N	-0.5 W	60.1	Atlantic	Nassau, Bahamas

It will require several months to process, analyze and correlate the observations with the ground truth data. However, the results of an initial assessment are summarized below:

a. Ocean Radiometry. The eight strategically placed spectral channels of the scanner produced valuable information on water color signatures. A variety of ocean and atmospheric conditions were observed. Atmospheric turbidity conditions ranged from a near Rayleigh sky at the Bahama site to the Yellow Sea where conditions of τ Mie = 0.3, as estimated from OCE data, were encountered. The contribution of the atmospheric aerosols to radiometric signatures has been determined for some of the images. A set of ocean color data was also collected from the Nimbus-7 Coastal Zone Color Scanner which covered the Gibraltar area at approximately the same time as the OCE overflight. This will provide an opportunity to compare data from two spaceborne ocean color sensors. Preliminary results indicate significant differences in the blue spectral channel radiances.

b. Chlorophyll Analysis. Relatively low sun angles in the northern Hemisphere at the time of the mission and loss of opportunity to take data over areas of the east and west coasts of the US due to cloud cover limited the amount of chlorophyll bearing water that could be observed. In addition, extensive cloud cover over frontal areas of the Kuroshio Current and the Gulf Stream during the STS-2 mission reduced the opportunity to observe mesoscale eddies. However, the 3-day mission produced chlorophyll images from the coastal waters of Portugal and the Yellow Sea.

c. Measurement of a Plankton Patch Drift Velocity. A patch of plankton extending several tens of kilometers was observed in OCE data taken during orbit 30 (November 14, 1981 at 10:40 a.m.) and orbit 32 (November 14, 1981 at 1:40 p.m.). Overlay of these successive images indicates a drift of the patch in the northward direction at a velocity of 1.5 km/hr. The process of inferring flow fields from point measurements from successive space sensor coverages seems feasible if land features are used as stationary anchor points.

d. Underwater Topography. In the absence of chlorophyll, the blue-green spectral components of the light penetrates deeper into the water and reflects from the bottom to yield underwater topographic information. An ocean scene obtained during orbit 32 over the Great Bahama Bank in a spectral channel centered at 518 nm reveals very clear water conditions. The derived attenuation coefficient was about 0.02 m^{-1}.

3.4 MAPS

3.4.1 MAPS SUMMARY

The Measurement of Air Pollution from Satellites (MAPS) experiment operated successfully throughout the mission.

After being powered up 4 hours, 25 minutes into the STS-2 mission, the instrument operated normally for about 42.5 hours, after which it was powered-down in preparation for de-orbit and landing. During operation, the instrument executed five self-calibration cycles, three automatically initiated and two on command from the ground. The instrument operated in the data collection mode for 42.5 hours and during approximately 32 hours of that time, the spacecraft was in the proper attitude for earth-viewing by the instrument. The instrument was rebalanced approximately every 12 hours.

The MAPS experiment was aimed at seasonal, global maps of carbon monoxide (CO) that are needed to substantiate and provide insight into theories and mathematical models required to increase our understanding of atmospheric physics.

The experiment objectives may be divided into two general categories:

Scientific Objectives:

Measure the latitudinal and longitudinal distribution of carbon monoxide in the middle troposphere.

Verify the transport of carbon monoxide from the northern hemisphere to the sourthern hemisphere.

From this and subsequent missions, to study the seasonal dependence of this transport.

Observe and define the extent of interhemispheric air mass transport in the troposhpere.

Technical Objectives:

Investigate and define the performance and operation characteristics of the sensor system.

Evaluate the operational difficulties involved in the accumulation, characterization, and evaluation of remote sensor data in a world-wide application.

Evaluate and refine the method of inversion used for obtaining carbon monoxide concentration from sensor output.

Begin to evaluate the use of multiple, short-term Shuttle flights to compile a data set useful in the investigation of long-term changes in atmospheric composition.

From preliminary examinations of the data, the MAPS experiment was highly successfully. It appears that sufficient data were obtained to achieve all of the technical objectives and 80-90% of the scientific objectives.

3.4.2 MAPS PROBLEMS

During the mission, the pallet coolant loop temperature fluctuated over a 10 degree C range due to the on and off cycling of the Orbiter flash evaporator system. This caused a concern that there would be a problem in analyzing the data due to changes in the MAPS instrument temperatures. It is anticipated that any impact on measurements can be taken into account during data reduction.

3.4.3 MAPS DATA

The MAPS operated continuously for 42.5 hours and obtained approximately 32 hours of excellent data on the global distribution of carbon monoxide (CO) in the atmosphere. Approximately 20% of the observations occurred in long stretches of apparently cloud-free fields of view, averaging 4000 km (2500 miles) along the Shuttle ground track; these segments are expected to provide excellent quality measurements. Long periods of continuous cloud-free data were collected from the northern to southern hemisphere. Coverage was obtained over 90% of the earth's surface between 37½ degrees north and south latitude.

In addition to the measurements made by the Shuttle instrument, several correlative aircraft underflights were carried out. Two of these flights occurred on the east coast of the United States where a jet aircraft supplied by Lewis Research Center and based at Langley Research Center carrying a prototype of the MAPS Shuttle instrument underflew orbits 18 and 21. Atmosphere samples were also collected during these flights at several altitudes between 41,000 feet and 1,000 feet to provide additional information about the distribution of pollutants. Similar atmospheric samples were obtained over the eastern Pacific by an aircraft based at Ames Research Center which underflew orbits 21 and 22. A number of air samples were also obtained in the southern hemisphere through a joint effort of the Australian Commonwealth Scientific and Industrial Research Organizations (CSIRO) and the Oregon Graduate Center. The results of these correlative measurements will be compared with those made from the Shuttle as part of the data validation process.

Current data reduction efforts are concentrated on verifying instrument calibrations and validating inferred CO concentrations of selected sites.

All the MAPS data have been processed into CO concentrations at attitudes of 7-8 km and 10-12 km. These data will enable the objective of global measurements of CO concentration to be achieved.

3.5 FILE

3.5.1 FILE SUMMARY

The objective of the Feature Identification and Location Experiment (FILE) was to test a techinque for autonomously classifying Earth's features into four categories: water, vegetation, bare land, and clouds/snow/ice. The FILE experiment operated successfully during several orbits.

The launch delay caused the FILE experiment to stop recording data after about the sixteenth earth orbit because of a 55^{0} beta angle constraint. It was hoped that the yaw maneuver in orbit 23 would position the FILE sun sensor to see the sun at an angle of less than 55^{0} and activate the experiment. Unfortunately the maneuver resulted in a pass over only water and no data were collected, because a previous pass had filled the water register.

Forty-four frames of film data were obtained out of a possible 120. Review of the film indicated that 25 frames of imagery were good, and that at least one frame of imagery was obtained in each of the four resource categories. The quantity of the data is less than desired. The color imagery is one-half stop overexposed, and because of a tape recorder malfunction, only seven-tenths of a frame was recorded on tape. Not all of the experiment objectives will be achieved.

3.5.2 FILE PROBLEMS

The FILE operations were severely hampered due to sun elevation angle problems caused by the time of day and season of launch. The FILE hardware worked properly, and discriminated appropriate scenes during orbits 8-11 when the sun elevation angle was within the instrument constraints. The FILE experiment used a sun sensor to operate the system and its predetermined value limited its operation to beta angles less then 55^o. If the capability to override the limit with a real-line command had existed the experiment could have been more successful.

Although sufficient raw digital imagery was recorded to demonstrate successful experimental operation, insufficient digital data was recorded to generate a desirable broad base statistical sample for further parametric studies. Only 5 seconds (approximately one scene) of classified data was recorded on the FILE digital tape recorder with good agreement with the photographic data. The recorder is a two channel recorder which first records data on channel 1 in the forward direction and then reverses automatically and records on channel 2. Post-flight data analysis indicates that at the time of initial data taking, the recorder was already switched to record on channel 2 instead of channel 1. Five seconds of tape was all that remained on the recorder when recording on channel 2 at the start of the mission. Because the tape recorder is a sealed unit with a captive tape, extensive post-flight testing of the experiment is necessary to duplicate the problem by way of simulations. Both Langley Research Center and Martin Marietta are committed to find the cause of this problem. A reflight of this experiment is proposed to gather the statistical data.

3.5.3 FILE DATA

Forty-five frames of instrument selected film data were obtained and at least one image was obtained in each of the four scene categories, bare earth, vegetation, water and clouds/snow.

There is evidence that the experiment worked properly and discriminated scenes correctly. The system was activated four times, producing 19 frames of data in orbit eight and six frames in orbit 11. Orbit nine resulted in 19 blank frames, and orbit 23 produced no data. It was suspected that the sun sensor, in orbit nine, was illuminated about 5 minutes before the terminator; this started the timing cycle and exposed the film for 19 frames on the dark side of the earth and catalogued the data as water.

Thus when the orbit 23 pass was over only water no data was taken because the water register was probably filled.

3.6 NOSL

3.6.1 NOSL SUMMARY

The Night/Day Observations of Storms and Lightning (NOSL) experiment, involving observation of lightning and thunderstorms from space, was in some respects quite different from the other six experiments that were flown on the second flight of the space shuttle. In contrast to the experiments in the payload bay, which could be operated by computers or from the ground, the camera and its photocell attachment riding on the flight deck, could function only when held, aimed and operated by an astronaut.

Furthermore, instead of involving exactly predictable data taking opportunities, the NOSL experiment data takes, because they involved thunderstorms, were very unpredictable in space and time. The plans for operation could be specified only to the extent that the astronauts would be expected to operate the apparatus when and if targets of opportunity presented themselves, providing that this did not interfere with any of the other detailed plans for crew activities.

Despite the curtailed duration of the flight and the greatly increased demands on the crew, they were able to obtain photographs of lightning at night and excellent motion picture sequences of six large thunderstorm systems during the day. Thus according to success criteria published before the flight, 80 percent of the experiment goals were achieved. Plans are to refly the NOSL on STS-4 and STS-5.

3.6.2 NOSL PROBLEMS

Because of the shortened mission and intense crew activity, limited opportunities were available for the crew to operate NOSL. Of the six targets voiced up to the crew, one was successfully completed. The rest of the data was collected near the end of the mission of storms observed by the crew. No lightning data was obtained on the NOSL tape recorder as audible clicks since the observed lightning flashes were outside the photo-optical sensor field of view.

The camera was not utilized during critical flight phases because there were higher priority functions, the crew was unfamiliar with the camera, i.e., film replacement, and the camera was not ready for use. The crew reported good targets of opportunity, but provided no camera data.

Because the astronauts did not follow the plan of recording the time and position of their NOSL observations either on the tape recorder or as notes, it is difficult to determine where and when the various photographs on the film were taken. On the basis of a preliminary analysis, it appears that the frames 0 through 1341, showing thunderstorms at night, were taken over South Africa and Australia. From photographic sequences made by other OSTA-1 experiments whose time and location are accurately known, it may be possible to obtain the times and locations of the various cloud scenes on the NOSL 16-mm film.

The tape recorder was operated for a total of approximately 31 minutes. The first recording made during sequence A up to frame 1341 has a synchronization signal indicating that the camera was running. After 55 seconds the synchronization signal ceases, and conversation of the astronauts can occasionally be heard in the background. Approximatley 31 minutes after the beginning of the tape, the synchronization signal can be heard for approximately 8 seconds, and then after an interval of approximately 24 seconds, for another 4 seconds until the end of the tape.

During none of the tape's operation, either during the minute when the camera was running or during the time when the camera was not running, are there any signals that can be related to lightning or to modulated light. It is not to be expected that any of the lightning events filmed in the nocturnal sequences would provide any signal for the photocell, for, with the exception of a possible lightning discharge on frame 604, none of the lightning would have been in the field of view of the photocell.

No lightning signals are to be found during the approximately 12 seconds that the camera was in operation photographing clouds in bright sunlight.

In the absence of the exposures to modulated light, which were supposed to have been made before each scene, it is impossible to determine the calibration of the system and whether the apparatus would have produced usable signals had it been pointed at lightning.

It appears that additional science training is required by the crew in the operation of the NOSL camera. It is recommended that the NOSL system be reviewed for more practical operation, and that the crew have it assembled as soon as possible with full knowledge of its operation.

3.6.3 NOSL DATA

The data obtained were of two kinds. The first comprised photographs of lightning and clouds taken with a 16-mm motion picture camera. The second comprised signals from a photocell light sensor designed to pick up light transients from lightning, which were recorded on a stereo cassette recorder. Although the data analysis is presently incomplete and studies are still being made of the photographic film and the magnetic tape, the general features of the data obtained have been determined.

Only one of the 20 film cassettes carried on the mission was used. It consisted of a total of 5335 exposed frames. These are summarized in Table 3-2.

A detailed examination of the 1341 16-mm frames taken at night shows a total of 10 small luminous areas that very probably are the result of lightning, see Table 3-3.

When a single point of light is observed on the film, as in frames 433, 604, and 636, there is considerable uncertainty as to whether this is evidence of lightning, either a segment of a lightning channel or a cloud illuminated by lightning, or whether this may merely be a defect in the film emulsion.

Table 3-2. Scenes on NOSL 16-mm Film, OSTA-1, STS-2

Sequence	Frame Number*	
(A)	0 - 1341	Taken at night showing several lightning events. See detailed lightning sequence A.
(B)	1341	Fairly well covered with convective cloud elements. There is some clear area in upper left-hand quadrant and a smaller clear area in lower left-hand quadrant.
(C)	1547	A convective cloud system running from upper right-hand quadrant to lower left-hand quadrant. There seems to be a point of origin for the convection at about .6 and .7, and this extends to the lower left-hand quadrant. There are minor cloud formations on the edges.
(D)	1663	Bright convective area in the center of the frame, mostly in the upper half.
(E)	1836	Sun illuminated clouds approximately center of frame in the upper half. Clouds occupy only small part of area. Just to the right of the illuminated clouds there may be some bluish filamentary structures that conceiveably might be lightning. These should be looked at more closely.
(F)	1898	Two cumulus clouds running on an axis from upper left to lower right. These are apparently illuminated from one side by the sunlight and may be a part of the previous sequence.
(G)	2031	Stringy bunch of convective clouds most of which appear vertically about mid-frame in the lower half. A smaller region at the top of the frame a little to the right of middle.
(H)	2089	Small cloud systems mid-frame. On the left-hand side of the frame at about .6, .4 is a small bright bluish slanted region.

* Frame 0 arbitrarily chosen to be vertical one hundred pen-written on leader.

Table 3-2. Scenes on NOSL 16-mm Film, OSTA-1, STS-2 (cont.)

Sequence	Frame Number	
(I)	2166	Cloud system shows convective clouds going from the upper right to lower left. There is a large number of small cells of the order of maybe several miles in diameter. There appears to be a dark hole in the cloud system centered at about .85 and at about .45.
(J)	2496	Primarily a region of cumulus convection running from about .6, .3 to about .75, .4. There are more convective elements mostly in the upper right-hand quadrant.
(K)	2702	Convective cloud system running from upper left to lower right. Appears to have a hole in it at about .5, .4.
(L)	2969	Cloud system primarily in lower left quadrant has streamers coming out of it tapering and going to the right. This sequence has reflections from window that can be seen as the camera is panned.
(M)	3340	Big convective cloud system covering most of frame with pronounced penetrative turrets at .4, .3. At about one or two o'clock with respect to this turret there is another very large oval shaped convective region that appears to be spreading out. This is centered at about .5, .5 and its dimensions are around 30 miles wide and perhaps 60 miles long.
(N)	3808	Isolated cumulus systems running from upper left to lower right. In the lower right quadrant there appears to be a big rather solid system.
(O)	4120	Most of the screen covered with cumulus clouds and cirriform clouds. Appears to be a circle of clouds a little to the left of center of the frame probably of the order of 50 miles in diameter.
(P)	4588	Frame almost filled with clouds. Large convective region with penetrative towers in lower half of the frame extending from about .4, .3 to about .6, .2.

Table 3-2. Scenes on NOSL 16--mm Film, OSTA-1, STS-2 (cont.)

Sequence	Frame Number	
(Q)	4968	Frame practically covered with clouds showing a series of penetrative tops about 5 or 6 of them. They begin in lower left-hand corner and go up almost to the center.
(R)	5302-5335	Overexposed frame going to unexposed frame ending at 5335.

Table 3-3. NOSL Detailed Lightning Sequence A

Frame	Coordinates*	Description
58	50 75	Pinhole
116	99 70	Bright pinhole
214	60 80	Green pinhole
265		Exposed frame mostly on right half
433	15 15	Single flash?
461	20 30	Multiple lightning flash
464		
465		
549	50 60	Orange pinhole
604	60 40	Single flash?
636	85 93	Single flash?
1252	80 50	Multiple lightning flash
1253		
1254		
1255		

* X and Y coordinates given in percentage of width and height of frame

The diameters of the cloud images are of the order of 0.1 radians. From this we can estimate that if the storm was directly beneath the shuttle when the photograph was taken, at a distance of approximately 260 km, then the dimensions of the cloud would be of the order to 2 or 3 km. It is probable the lightning was photographed at a position some distance from the point beneath the spacecraft, so the probable dimensions of the luminous cloud may be several times greater. Such size is commensurate with photographs of ordinary lightning taken from the ground or from aircraft. Particularly in the absence of data from the photocell optical system, it is difficult to determine whether the lightning illuminating the cloud was of the intra-cloud or cloud-to-ground variety. That lightning was absent from frames 462 and 463 corresponds to an interval of the order of 100 msec. It seems possible, therefore, that the lightning in this sequence occurred as discrete strokes and was probably of the cloud-to-ground variety. In the sequence 1252-1255, in which the lightning was visible on each frame, it is possible that the lightning may have been of the intra-cloud variety. The intensity of the lightning induced images in the two sequences is high enough that one would expect to see spectra produced by the diffraction grating, which should have been in place during the nocturnal photography. Since no spectral images were observed, it appears probable that the grating may not have been in position over the lens at the time these pictures were taken.

Following the scenes photographed at night, the NOSL film contains 16 sequences photographed during the day and at dawn or dusk that show various cloud systems. Of these about half show what appear to be extensive, quite active thunderstorm cloud systems. These sequences clearly demonstrate that good quality photographs of convective storm systems are possible by the use of the 16-mm hand-held camera.

Detailed analysis of the cloud systems is complicated by several factors. Because the investigators have not been able to determine the time and location of the various sequences, it is not yet possible to determine what meteorological data are available concerning these clouds to permit their interpretation. It is possible data may be available concerning how these cloud systems are related to the surrounding synoptic situation and the probable height of the cloud tops. Radar information may be available concerning the cloud system. In the absence of data on lightning activity from the ground, it will not be possible to relate these figures to thunderstorm electrification processes because no simultaneous data were obtained with the photocell tape recorder system.

From preliminary observations of the film, it does not appear to be possible to detect convective motions of the clouds that were photographed.

Preliminary experimentation has begun to observe the three-dimensional structure of the cloud systems by viewing two frames as stereo pairs. This has been complicated by the lack of information on the relationship between the shuttle motion and the camera orientation. It appears possible, however, by trial and error to arrive at something approximating the proper orientation and to obtain impressive three-dimensional effects. Experiments are planned to determine by experimentation what appears to be the optimum time or distance separation between frames for observing stereo pairs.

Because no land features appear in the cloud photographs, it will not be possible to provide estimates of cloud-top height and the distance convective towers penetrate into the stratosphere.

The limited amount of data collected will not allow NOSL to achieve its objective to survey lightning and thunderstorms from space but the data collected have demonstrated the feasibility of collecting thunderstorm data with this equipment.

3.7 HBT

3.7.1 HBT SUMMARY

The Helfex Bioengineering Test (HBT) obtained some information that may be useful for planning operational procedures in future missions including Spacelab I. However, the chief objective of the test was not achieved because a minimum of 4 days is required to quantitatively assess the effect of soil moisture content on the rate of shoot development in Helianthus annuus seedlings grown in microgravity.

3.7.2 HBT PROBLEMS

In addition to the fact that the mission did not last long enough for the experiment to be completed, some temperature control problems were encountered.

A battery operated temperature recorder was included in the Plant Carry-on Container (PCOC) with the 85 planted Modules. The container temperature recorder recorded 23.2^{o}C (73.8^{o}F) when the PCOC was closed and locked. At the time of installation into the Orbiter mid-deck locker MF28K, it was 23.4^{o}C (74.1^{o}F). Thereafter the temperature rose gradually to 24.8^{o}C (76.6^{o}F) at time of launch. At L + 4 hours the temperature again began rising until at L + 16 hours it was 27.4^{o}C (81.3^{o}F).

During the remainder of the mission only minor fluctuations occurred. During reentry, landing, removal from the locker, and transport by van from the Orbiter to the temporary laboratory in Trailer TR-55, the PCOC temperature remained between 26.5^{o}C (79.7^{o}F) and 29.9^{o}C (80.5^{o}F).

There is as yet no explanation for the relatively high temperature recorded during the flight. It was expected that the locker temperature would be about the same as the ambient air in the mid-deck region, which could be controlled by the crew for their personal comfort. A temperature that stabilized above 81^{o}F seems incompatible with crew comfort. The higher than expected locker temperature, if it prevails on future missions, could have significant impact on several biological experiments that, according to current planning, will be located in mid-deck lockers. Engineering analyses should determine the factors which control mid-deck locker temperature during flight.

3.7.3 HBT RESULTS

The experiment confirmed that Helianthus annuus (sunflower) seeds can germinate in microgravity. The actual germination percentage was 98%.

Subsequent growth of root and shoot system was also confirmed with primary root development preceeding shoot development. These results have been expected from similar observations made on other plant species in earlier U.S. and USSR flight test.

It was expected on the basis of ground-based tests that germination and early stages of seedling growth would occur at all moisture contents tested: from 55% to 77%; this was confirmed. However, this result alone did not contribute materially to accomplishment of the main purpose of HBT which was a quantitative - not a merely qualitative - assessment of the effect of soil moisture content on the stage of shoot development of 4 to 5 days old H. annuus seedlings grown in microgravity.

The flight provided on-the-job training in carrying out and timing the preparatory sequence that must be accomplished as late as possible before handing over the flight package to NASA support personnel for loading into the Orbiter.

It demonstrated (twice) that temporary lab facilities assigned to HBT for prelaunch preparation of the flight package were adequate for the procedures that had to be accomplished.

It also provided opportunity for conducting all procedures relevant to acquiring test data after receipt of the HBT flight package after landing. This demonstrated that delivery of the flight package could be accomplished within 70 minutes of touchdown. It also demonstrated that quite primitive lab facilities (with a bit of ingenuity) could be at least marginally adequate for the data acquisition procedures.

It is recommended that when a reflight is to be undertaken, consideration should be given to improving lab facilities at the landing site.

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