NASA CR-
WRL 2599-11-P

MAINTENANCE AND OPERATION OF THE MULTISPECTRAL DATA COLLECTION AND REPRODUCTION FACILITIES OF THE UNIVERSITY OF MICHIGAN

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Willow Run Laboratories
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Manned Spacecraft Center
Contract NAS 9-9304
John F. Mitchell/TF3, Project Manager

cf-108717

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INTERIM REPORT

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CONTRACT NAS 9-9304

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ABSTRACT

This report summarizes the accomplishments in multispectral mapping during 1969; the mapping was done using the instrumented C-47 aircraft leased from the Air Force and operated by Willow Run Laboratories (WRL) of The University of Michigan. Specific information for flight operations sponsored by NASA/MSC (Manned Spacecraft Center) in 1969 is presented, and a total listing of flights for 1968 and 1969 is included in the appendixes. A brief description of The University of Michigan's multispectral data collection and reproduction facilities is also included.

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SUMMARY

The University of Michigan airborne multispectral data collection system was maintained in a state of operational readiness and accomplished twenty of the twenty-one NASA assigned missions during 1969. Unsuitable weather at the site caused the cancellation of one mission. Over 100,000 ground track miles of scanner imagery in ultraviolet, visible and infrared wavelengths were recorded on magnetic tape with about one third reproduced on film for visual analysis. All tape-recorded scanner data is available on duplicate magnetic tapes in analog form suitable for machine processing. Scanner boresight aerial photography was obtained simultaneously in various film/filter combinations at all sites.

The instrumentation and procedures used to obtain these data are described briefly and recommendations are made for continued use and improvement of the system.

1 INTRODUCTION

The primary purposes of this contract were to maintain The University of Michigan's airborne instrumentation and ground-based data reproduction facilities in a state of readiness for multispectral data collection missions and to accomplish missions when requested. Six specific data collection missions were authorized under the original contract: four in the vicinity of Lafayette, Indiana; one at Weslaco, Texas; and one at San Diego, California. Contractual authorization was received on 27 June 1969 for additional missions titled Oregon Coast, Wind River, Bucks Lake, Black Hills, Missouri River, and Ann Arbor. Further authorization was obtained on 31 July 1969 for additional local missions titled Lake Michigan, Ann Arbor, and Wastenaw County. In August, contractual authorization was received for 16 additional missions in the period from September 1969 through January 1970. This last authorization was revised in September to bring the total list of authorized missions to the 21 listed in Table 1.

2 ACCOMPLISHMENTS

The contract accomplishments during the period of 1 February 1969 through 31 January 1960 are discussed in this section.

2.1. FACILITY MAINTENANCE

The facility was maintained in a state of operational readiness throughout the contract period. The mission schedule was disrupted only twice as a result of equipment malfunction, and both of these were due to unavoidable failures in an aircraft engine. On both occasions, repairs were accomplished in the field with the data collection mission resumed after a delay, one day to replace an engine cylinder and three weeks to replace an entire engine. Without schedule disruption, periodic maintenance was accomplished on the aircraft and instrumentation equipment throughout the year. For the operations which required more than 50 flight hours before returning to WRL, periodic maintenance tasks were rescheduled to allow completion of the maintenance at the field sites. The aircraft periodic maintenance is normally accomplished on a programmed 50-flight-hour basis. Each of the two West Coast field operations exceeded 50 flight hours. A total of 245 aircraft flight hours was accumulated in support of NASA-sponsored missions during the contract period.

TABLE 1. SUMMARY OF NASA-SPONSORED MISSIONS IN 1969

Mission No.	Site	Data User	Application	Flight-Line Miles Planned	Flight-Line Miles Actual	Mission Date Planned	Mission Date Actual
1	Imperial Valley	Univ. of Michigan	Agriculture	170	250	3/8-10	3/8-12
	Anza Borrego	USGS	Geology			3/8-10	3/8-12
	LaJolla	Navy	Oceanography			3/8-10	3/12
2	Lafayette	Purdue Univ.	Agriculture	330	336	5/12-16	5/13-27
3	Lafayette	Purdue Univ.	Agriculture	330	336	6/23-27	6/25-26
4	Oregon Coast	Oregon State Univ.	Oceanography	3000	2840	6/30-7/11	7/3-13
5	Wind River	Forestry Service	Forestry	64	84	7/14-16	7/14-15
6	Bucks Lake	Univ. of California	Forestry	20	40	7/17-18	7/16
7	Black Hills	Forestry Service	Forestry	144	164	7/21-22	7/21-22
8	Missouri River	USGS	Geology	60	160	7/23	7/23
9	Ann Arbor	Univ. of Michigan	Forestry	40	40	7/24-25	8/4
10	Lafayette	Purdue Univ.	Agriculture	330	360	8/4-8	8/5-6
11	Lake Michigan	Univ. of Michigan	Oceanography	50	50	8/8	8/11
12	Ann Arbor	Univ. of Michigan	Forestry	40	72	8/11-15	8/13
13	Washtenaw	Univ. of Michigan	Agriculture	100	80	8/11-15	9/3
14	Oregon Coast	Oregon State Univ.	Oceanography	3000	1760	9/8-19	9/14-24
15	Wind River	Forestry Service	Forestry	64	32	9/22-23	9/26
16	Moses Lake	Dept. of Interior	Water Resources	40	40	9/24	9/25
17	Bucks Lake	Univ. of California	Forestry	20	24	9/25	10/24
18	Mill Creek	USGS	Geology	225	0	9/29-30	10/29*
19	Ann Arbor	Univ. of Michigan	Forestry	40	48	10/2-3	11/26
20	Lafayette	Purdue Univ.	Agriculture	330	312	10/6-10	11/5-6
21	Lafayette	Purdue Univ.	Agriculture	330	240	12/8-12	12/17

*Postponed because of weather

The instrumentation in the aircraft and in the laboratory was repaired, maintained, and calibrated between scheduled missions as time permitted. The priority in maintenance was assigned to equipment associated with the multispectral scanners. This equipment was maintained in good working order throughout the year. The aerial cameras, which provide boresight photography for the scanners, were not well maintained because their data is of secondary importance in multispectral analysis and because time and funds were limited. These cameras, supplied to The University of Michigan as surplus government equipment, were not in good repair when received, and they performed poorly during the year. Since an attempt was made to operate all available cameras as requested, maintenance was limited to obvious malfunctions; spares were not available to replace cameras of questionable performance. In addition, the cameras were often operated, as requested, outside their performance limitations with regard to adequate exposure with a specific film/filter combination. As a result, the aerial photography was of poor quality for those who expected multiple film/filter combination coverage of their sites, but it was adequate to document the boresight view of the multispectral scanners.

In addition to periodic performance checks, the multispectral scanner equipment underwent a complete calibration check during late August. The calibration established the response of the system over the entire scan field of view in terms of absolute radiant energy at the scanner aperture for each of the scanner data channels. This was the third calibration check performed on the system since its assembly in early 1966.

Another maintenance function accomplished during the year was to assist NASA/MSC in the planning and scheduling of data collection missions using the C-47 aircraft. Mission requirements were discussed, and plans were made for over 30 different missions during the year, although only 21 missions were finally authorized under the contract. University of Michigan personnel participated in all of the mission planning meetings held at NASA/MSC during 1969.

2.2. DATA COLLECTION MISSIONS

The 21 missions authorized in the contract were all undertaken and accomplished successfully with the exception of the Mill Creek mission, which was cancelled because of unsuitable weather after system arrival at the site. The mission sites were located throughout the continental United States, as shown in Fig. 1. Some sites were mapped several times on separate missions. Over 100,000 ground-track miles of scanner imagery were obtained in 55 separate flight operations during the year. The data recorded and reproduced from these flights are tabulated in Table 2. The listing of each flight by date and time during 1969 is included in Appendix II. The listing shows the scanner wavelength bands collected during the 80 flights made in 1969. For comparison, Appendix I shows the 19 flights made during 1968; two of these were sponsored by NASA. Appendix III presents the tentative flight schedule for 1970.

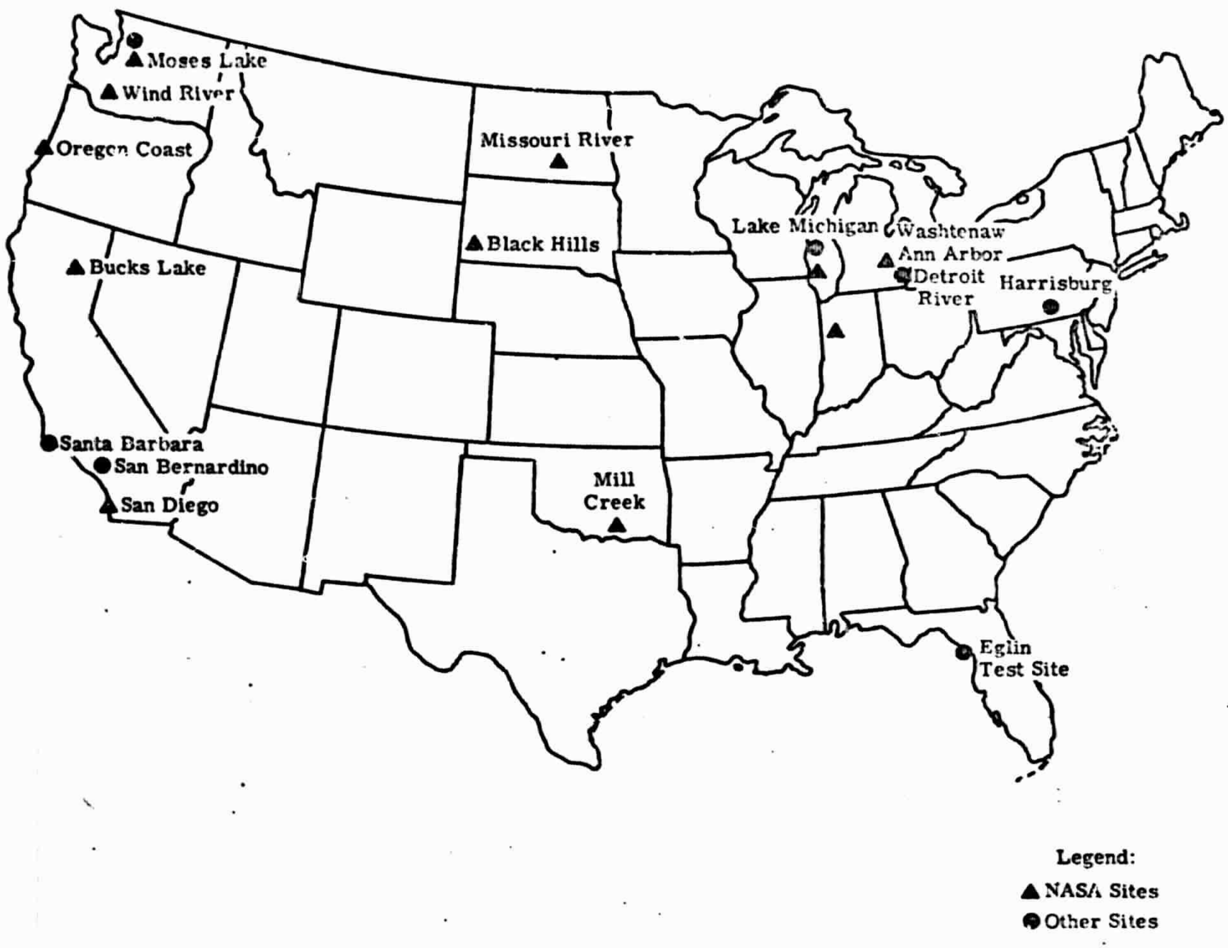


FIGURE 1. SITES OF MULTISPECTRAL DATA COLLECTION FLIGHTS IN 1969

TABLE 2. SUMMARY OF DATA OBTAINED AND DISTRIBUTED IN 1969 FOR NASA-SPONSORED MISSIONS

Missions Flown**			Tape-Recorded Scanner Data†			Scanner Data Reproduced‡		Rolls of Aerial-Camera Data††		
No.	and Date	Site	Original 1-in. Tapes	Original 1/2-in. Tapes	Duplicate 1-in. Tapes	No. of Film Rolls	Data Miles	70-mm Color	70-mm B&W	9.5-in. B&W
1	3/8-12	San Diego	7	7	11	8	21,000	11	7	2
2	5/13-27	Lafayette	14	14	21*	3	1344	14	12	3
3	6/25-26	Lafayette	14	14	21*	1	1344	18	6	3
4	7/3-13	Oregon Coast	108	0	4*	2	2840	9	7	0
5	7/14-15	Wind River	2	2	3	1	336	3	2	0
6	7/16	Bucks Lake	2	2	3	1	160	3	2	0
7	7/21-22	Black Hills	6	6	9	1	656	7	11	0
8	7/23	Missouri River	0	7	4	1	640	0	0	0
9	8/4	Ann Arbor	2	2	3	1	160	4	2	1
10	8/5-6	Lafayette	15	15	23*	3	1440	15	9	1
11	8/11	Lake Michigan	2	0	2	1	200	3	2	1
12	8/13	Ann Arbor	2	4	4	2	288	4	2	1
13	9/3	Washtenaw	4	4	6	2	320	12	0	0
14	9/14-24	Oregon Coast	66	0	8*	7	1760	6	6	0
15	9/26	Wind River	2	2	3	1	128	2	2	0
16	9/25	Moses Lake	2	2	3	1	160	2	1	0
17	10/24	Bucks Lake	1	1	2	1	96	0	3	0
18	10/29	Mill Creek	0	0	0	0	0	0	0	0
19	11/26	Ann Arbor	2	2	3	1	192	2	2	1
20	11/5-6	Lafayette	13	13	20*	1	1248	14	0	2
21	12/17	Lafayette	10	10	15*	1	960	8	0	2
			274	107	168	40	35,272	137	76	17

**Original flight data records retained at The University of Michigan; copies of records sent to NASA/MSC and Principal Investigators.

†All original tapes retained at The University of Michigan; duplicate analog tapes sent to NASA/MSC except for those noted with an asterisk (*), which were sent directly to the Principal Investigator.

‡All original scanner imagery reproduced on film sent to NASA/MSC.

††All original aerial-camera film sent to NASA/MSC.

Our operating procedure is as follows. We plan and conduct a particular mission in accordance with a mission request prepared by the principal investigator and approved by NASA/MSC. We satisfy the mission requirements to the extent possible within the limitations of allotted time at the site, weather conditions, allotted expendable materials, and allotted aircraft flight hours. The degree to which past missions were successful can be determined by a comparison of the planned and actual flight-line miles listed in Table 1. Most of the missions were considered successful. Unsuitable weather during the allotted time period restricted the amount of data collected on some, but none were restricted by allotted expendable material or aircraft flight hours.

The procedure for handling the large quantity of data collected on these missions is as follows:

(1) The raw tape and film data are scheduled for processing and reproduction according to the order in which they arrive at WRL (usually with the aircraft) after a mission.

(2) All aerial camera film is stamped with identifying perforations by the camera operator and sent to The University of Michigan photo lab at WRL, where the black and white film is processed. The color film is sent by the photo lab to Data Corporation for processing. A paper file print of the black and white aerial photography is made at the time of processing. Black and white film is usually processed within one week and color film within two weeks.

(3) The original magnetic tapes are duplicated in analog form and sent either to NASA/MSC or to the principal investigator with a rough copy of the flight data records within a week after the raw data are received at WRL. The 1-in. tapes are duplicated one for one on 1-in. tapes; the 1/2-in. tapes are duplicated two for one on 1-in. tapes.

(4) Four selected channels of tape-recorded scanner data are reproduced on [illegible]-mm film during the three weeks following the duplication of the data tapes. These scanne[illegible] imagery reproductions are made in the printing facility at WRL, and the film is processed by the photo lab. A paper file print of the imagery is made at the time of processing.

(5) The flight data records prepared by the flight crew are completed and typed in final form during the three weeks following a mission. These flight records, which include maps, a narrative report, and instrument settings, constitute the mission documentation.

(6) The original aerial-camera film transparencies, the original scanner imagery on film transparencies, and the flight data records are labeled by a data clerk and reviewed by the flight crew and test conductor before being packaged and shipped to NASA/MSC within a month after the mission. A paper print of all black and white imagery shipped is retained on file at The University of Michigan. In special cases, a second print of selected black and white imagery is also shipped directly to the principal investigator for the particular mission.

(7) The original analog magnetic tapes and original flight data records for each mission are retained on file at The University of Michigan.

The above procedure was followed as planned during the year except that the typing of the flight data records in final form lagged behind schedule. However, the flight information was distributed in rough form with the data so the use of the data was not delayed.

3
BRIEF DESCRIPTION OF FACILITIES

The multispectral data collection and reproduction facilities developed by The University of Michigan under government sponsorship are described briefly. The airborne system was first used operationally in early 1966 and has been in use without significant change since that time.

3.1. AIRBORNE MULTISPECTRAL DATA COLLECTION SYSTEM

WRL has been active for many years in a program to develop signal-processing techniques for discrimination of selected targets by remote observation of their optical radiation characteristics. In the course of this program, it was necessary to develop an airborne imaging sensor which could register the spectral properties of a terrain scene in absolute measure and in the form of an electrical signal.

Because of budget limitations, the resulting airborne data collection system is configured around readily available airborne scanners originally developed for military reconnaissance. The 19 multispectral data channels were obtained by using four detector assemblies, one installed in each end of two dual-channel scanners. A choice of detector configurations is available, but the basic grouping for data collection has been:

(1) Scanner 1

End A: GeHg detector filtered for 8.0 to 13.5 μm

End B: InSb detector with 3 elements filtered for 1.0 to 1.4 μm, 2.0 to 2.6 μm, and 4.5 to 5.5 μm

(2) Scanner 2

End A: Spectrometer with 12 photomultiplier detectors over a range of 0.4 to 1.0 μm

End B: InAs detector with 3 elements filtered for 1.0 to 1.4 μm, 1.5 to 1.8 μm, and 2.0 to 2.6 μm

An assortment of detector/filter combinations is available for substitution in End B of each scanner. These include a photomultiplier filtered for 0.32 to 0.38 μm, single element InAs or InSb detectors with filters for any of the wavelength bands shown for the 3-element detectors, and a single element HgCdTe detector with a selected wavelength band between 1.0 and 12.5 μm.

Analog processing of the multispectral signals is limited to the output of any selected detector assembly because the data must have a common aperture to be time synchronous. The multi-element detectors scan a ground target sequentially. The electrical signal from the lead elements is delayed to make their outputs approximately time synchronous.

The scanners* were modified to provide a single scanning surface for each detector assembly at a fixed scan rate of approximately sixty scans per second. The single scanning surface was selected (by covering one of the two scan mirror surfaces) in order to restrict the detector to a single radiation input at any one time. The scan rate selected was the maximum available for the particular scanner and was fixed to simplify scanner controls. Most of our data were collected at low altitudes. This required the maximum scan rates, and the scan overlap at higher altitudes was acceptable. With this scan rate and a normal aircraft ground speed, a continuous registration of terrain without scan overlap is obtained at an altitude of about 1000 ft. The scanning geometry is illustrated in Fig. 2.

For calibration of the radiation input to each detector channel, scanner 1 contains two thermal-reference plates and a lamp radiation source, and scanner 2 contains two lamp sources and a solar-reference source; these are registered in the detector outputs during each line scan. The thermal plates provide two blackbodies as temperature references for the two thermal-IR channels (4.5-5.5 μm and 8-13.5 μm), and the lamps provide radiation-reference levels corresponding to the reflected energy (from solar illumination) of typical targets in the data channels from 0.32 to 2.6 μm. The dark interior of the scanner is registered as the zero-radiation input for the scanner channels in the 0.32 to 2.6 μm region.

The electrical outputs of the radiation detectors are amplified for recording on tape recorders with an electrical bandwidth of from near dc to at least 20 kHz. With appropriate selection of amplifier gains, dc restoration, and special electronic filtering in the tape playback, a bandwidth of dc to 50 kHz can be realized. The information bandwidth of the scanner itself is approximately 70 kc. The separate detector outputs are displayed on oscilloscopes to the airborne operators, who select the appropriate amplifier gains to match each signal level to the dynamic range of the tape recorder. A separate tape machine records the output of each scanner. A 7-channel recorder accepts one synchronization and up to six video signals from scanner 1, and a 14-channel recorder accepts one synchronization and 13 video signals from scanner 2.

*This report assumes the reader is familiar with line scanners. For information on them, see M. R. Holter and W. L. Wolfe, "Optical-Mechanical Scanning Techniques," Proc. IRE, Vol. 47, No. 9, 1959, pp. 1546-1550.

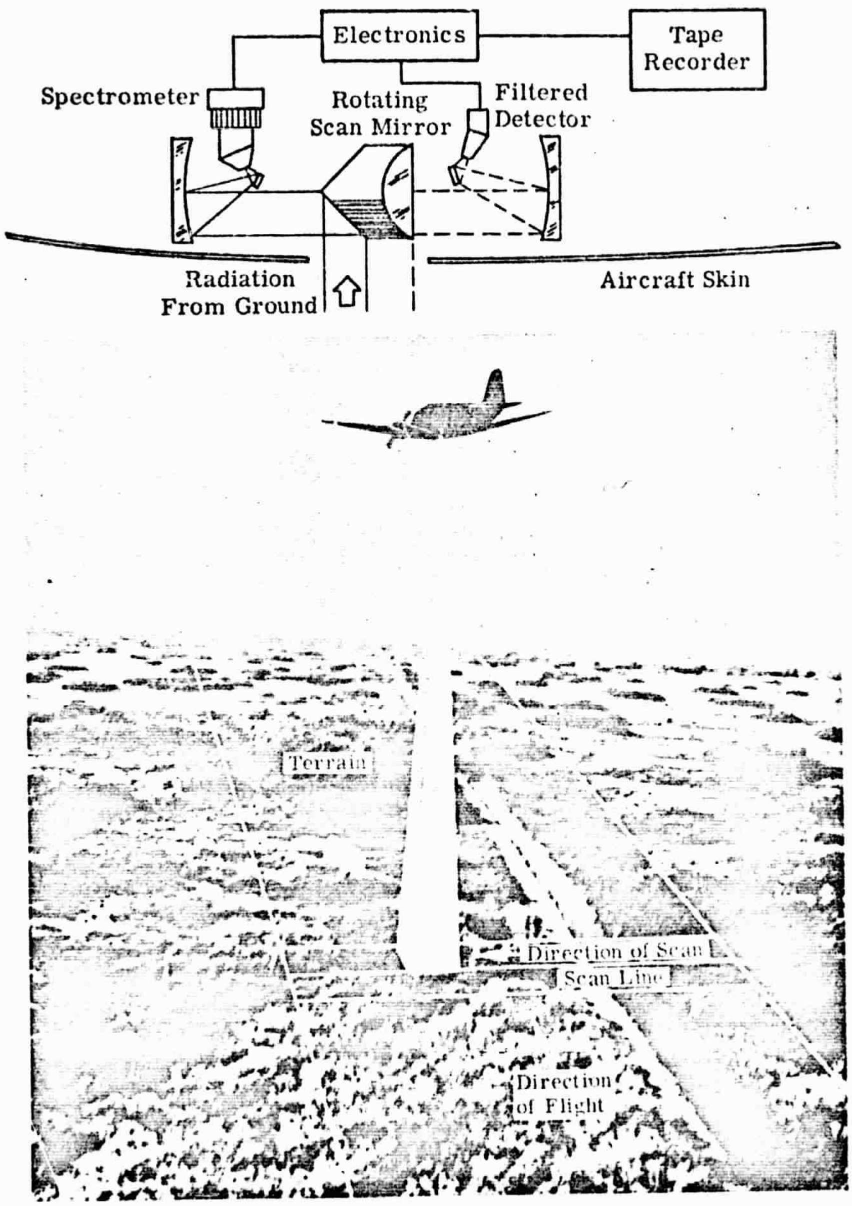


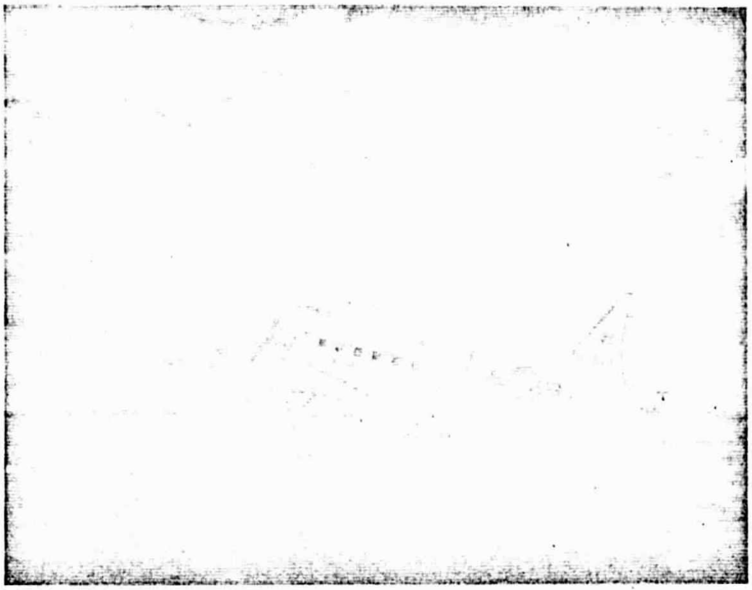
FIGURE 2. MULTISPECTRAL SCANNER OPERATION

The aircraft in which the airborne sensor equipment is installed is shown in Fig. 3. The layout of equipment in the aircraft is shown in Fig. 4. Two instrumentation wells in the bottom rear section of the aircraft house the ground-scanning equipment. Aerial cameras are mounted in the left well to register photographically what the scanner maps; these aid in data interpretation. The two scanners are located in the right well. Full operation of the airborne system requires a crew of seven: a pilot, a copilot, and a flight engineer for the aircraft, and a test conductor and three equipment operators for the instrumentation. One equipment operator controls the aerial cameras and the direct printing of two data channels from scanner 2, which is done during flight. The same video printing equipment can be operated on the ground to reproduce on film any selected channel from the tape-recorded data. The other two equipment operators monitor and control the signals and record general data associated with each pair of scanners and tape recorders.

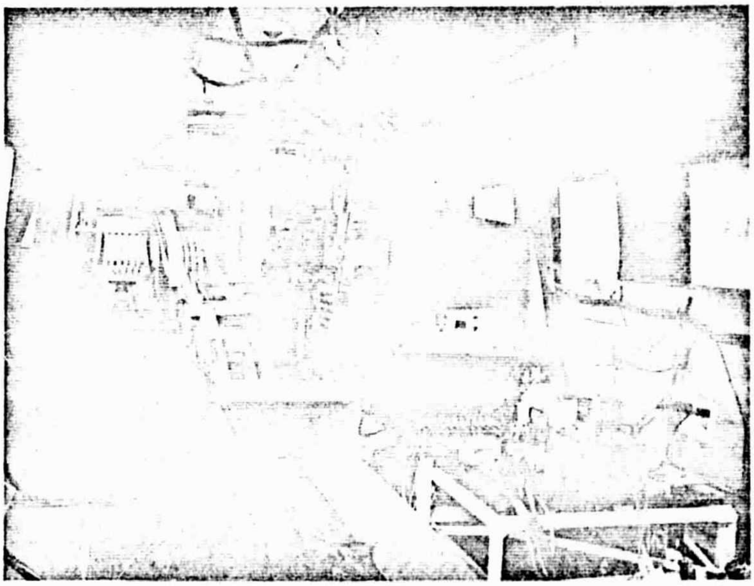
System performance is adequate for registration of terrain in all scanner data channels during daylight hours under all weather conditions suitable for VFR aircraft operation; however, there can be no clouds between the aircraft and the terrain. Only the two thermal channels (4.5 to 5.5 μm and 8 to 13.5 μm) are operable at night or twilight. Data can be collected at flight altitudes from 500 ft above terrain to 15,000 ft above sea level. However, scans do not cover all the ground under the aircraft at 500 ft because of the limited maximum scan rate and the minimum airspeed of the aircraft. The best scan overlap (approximately 50%) occurs at a flight altitude of 2000 ft above terrain and at a ground speed of 120 knots. The fixed scan rate produces increasing scan overlap at higher altitudes.

The nominal unobscured field of view (FOV) of the scanners is 80° across the flight line and continuous in the flight direction. However, when the thermal reference plates are used with scanner 1, the unobscured external FOV is reduced to 37°. The lamp reference sources for scanner 2 are registered during the period of internal scan so that the external FOV for this scanner is unaffected by the calibration sources. The synchronization signal is stabilized about the roll axis to reduce significant pattern distortion in the imagery representing scanned terrain. No corrections are made for aircraft pitch and yaw during the scan.

The system will register quantitatively in 19 bands on magnetic tape the spectral signature of targets as small as several resolution elements (approximately 10-ft diameter at 1000-ft altitude). The quantitative measure of the signal level (radiance) in each band is established by interpolation between two known radiation inputs at the scanner aperture. The radiation inputs are common to data channels within a scanner and can be compared between scanners.



(a) External View



(b) Internal View

FIGURE 3. C-47 AIRCRAFT INSTRUMENTED AND OPERATED AT WILLOW RUN LABORATORIES

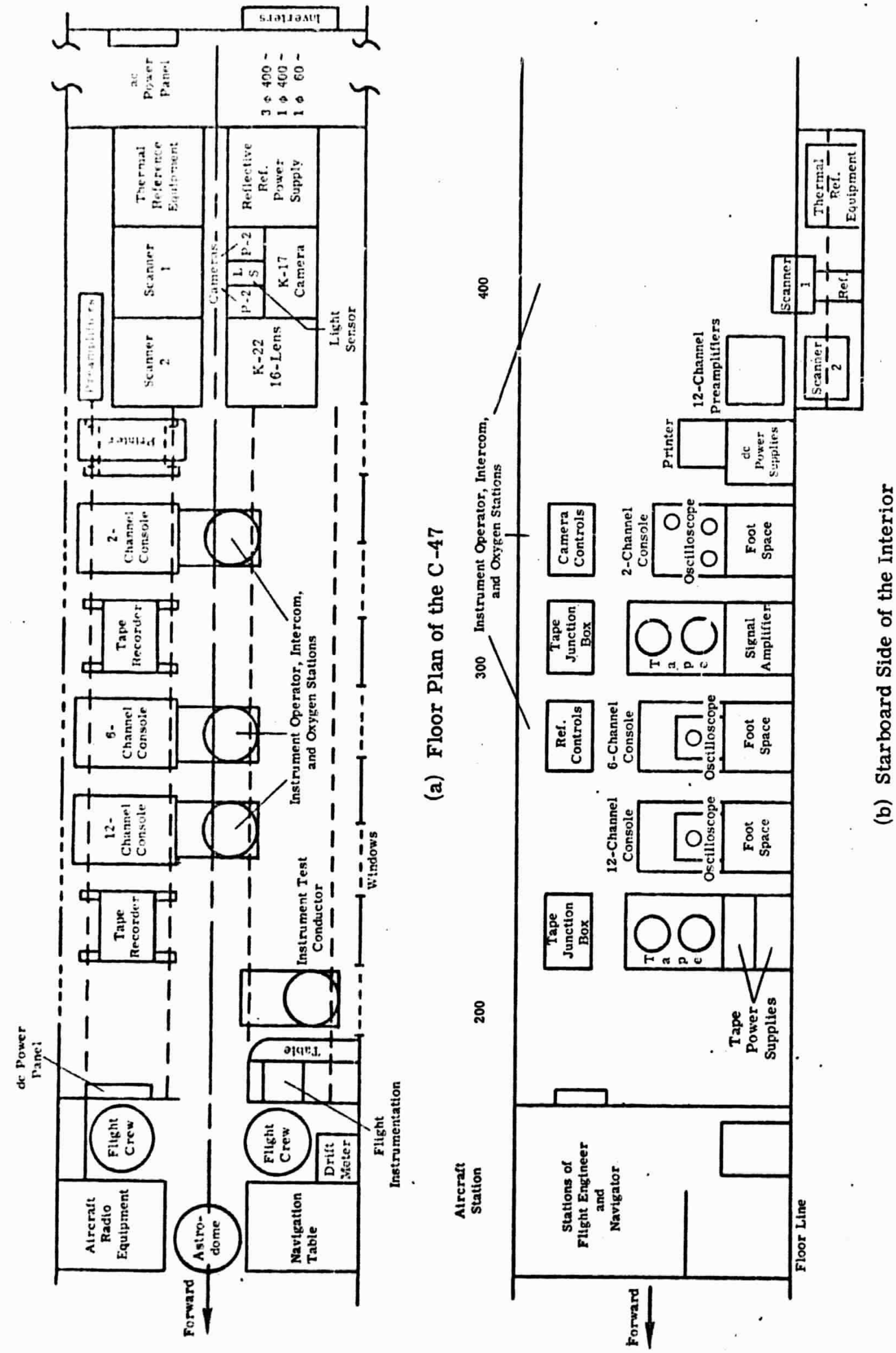


FIGURE 4. LAYOUT OF THE INSTRUMENTATION IN THE C-47 AIRCRAFT

3.2. DATA REPRODUCTION AND DATA HANDLING

Although some data reproduction can be done with the airborne equipment in the field to obtain preliminary results, the majority of the reproduction is accomplished at WRL. The scanner imagery is reproduced in two basic forms, analog magnetic tapes and film strips, for distribution to data users.

The duplication of the original analog tapes is accomplished by playing back the original tape on one tape machine and transferring the electrical signal to a second tape machine. The electronics of both machines were modified by The University of Michigan to transfer the electrical signal between tapes with minimum signal degradation. The scanner signals are FM recorded to preserve low-frequency information and must be demodulated for restoration to the original form. The tape duplications are made without going through the demodulation and remodulation of the signal. All tape duplications are made from the original analog tape which is retained on file.

The scanner imagery is reproduced on 70-mm film strips in the data-playback facility. This facility contains 1-in. and 1/2-in. tape machines, signal-handling equipment, operator displays and controls, and a CRT/film printer. The signal-handling equipment provides special video-bandwidth filtering, amplification, gating, clamping, sampling, and holding circuitry to allow maximum retention of information and reformatting of the data on film. In reformatting (see Fig. 5), the calibration reference sources are sampled, stored, and mixed with the gated video at the appropriate time so that maximum use is made of the 70-mm film area. This radiation reference information is printed beside the scene imagery in a continuous film strip. Periodically (usually between runs), the scene imagery is interrupted by the insertion of a 16-step, equal-voltage-increment grey scale across the film width. Thus, the film retains a quantitative correlation between film tone and signal voltage, regardless of the film processing variables. The film drive for the CRT/printer was adapted from a magnetic-tape-machine belt drive to provide smooth and accurate film motion for printing the line scan imagery. The printer camera originally contained a gear drive which did not operate smoothly. A unique feature of the facility is a flying-spot-scanner labeling device which introduces identifying nomenclature onto the film strip from a data card.

All reproduced data are reviewed and distributed by the same personnel who operated the instrumentation to collect the data. Thus, equipment performance degradations or malfunctions are noted promptly and are corrected immediately after their discovery.

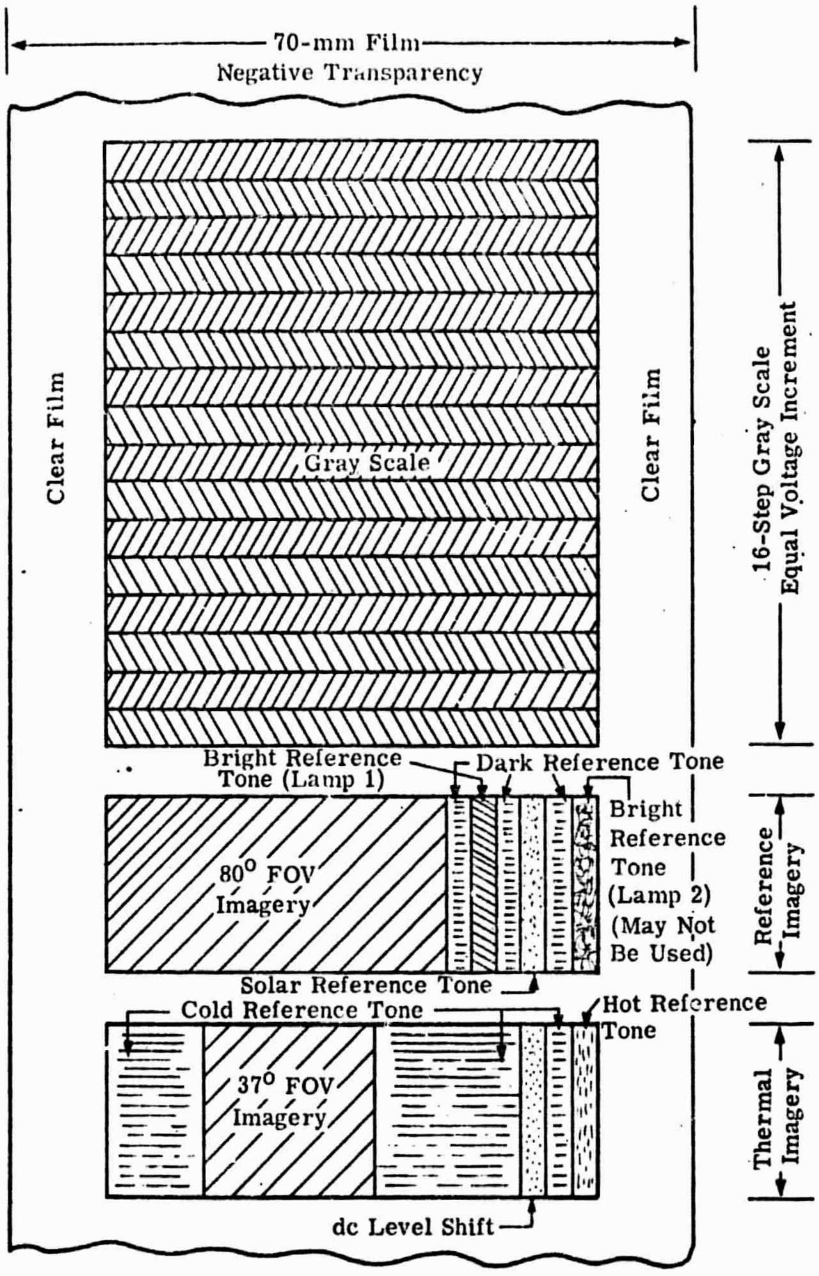


FIGURE 5. ILLUSTRATION OF SCANNER IMAGERY REPRODUCTION ON FILM

4
RECOMMENDATIONS

After completion of this year's data collection missions, it is apparent that insufficient resources are being allocated for equipment maintenance and equipment modification to meet changing requirements. By the final quarter, most of our supply of cooled infrared detectors and our stock of spare electronic components had been expended, and insufficient funds remained in the contract to replace them. Although our estimates of manpower requirements for maintenance and operation have been accurate, our estimates of equipment repair and replacement have not. Also during the year we have been urged by data users to provide common-aperture visible and infrared scanner data which would be suitable for automatic machine processing and would provide accurate area maps with identified scenery. In view of these conditions, I make the following recommendations:

(1) This facility maintenance and operation contract should be extended for at least another year to satisfy user requirements for multispectral terrain mapping during 1970.

(2) The contract resources should be sufficient for replacing or repairing equipment as well as supplying expendable material such as tape and film.

(3) Modifications should be made to the sensor equipment to provide for the registration of all reflected visible and infrared radiation in a common-aperture detector assembly so that data processing using a total reflectance signature can be accomplished.

(4) As an aid to multispectral processing, the feasibility of active scanning with laser sources should be investigated.

(5) Relatively inexpensive navigation aids such as Distance Measuring Equipment (DME) and a navigational computer should be added to the aircraft omni equipment to help in the mosaic mapping of terrain.

(6) Modifications should be incorporated in the film-strip reproduction facility to correct the spatial distortion of the imagery as a function of scan angle.

(7) Facility capabilities to supply radiation reference standards and navigational ground markers at test sites should be expanded.

Appendix I
SCANNER DATA COLLECTION FLIGHTS IN 1968
(Number in column indicates scanner data channels in that spectral region.)

Date	Time	Area	0.3-0.4 μm UV	0.4-0.7 μm Vis	0.7-3.0 μm NIR	3.0-6.0 μm MIR	8.0-14.0 μm FIR
5/22/68	1000	Local Agriculture		8	5	1	1
5/31/68	0730	Jamestown, N. Dakota		8	5	1	1
5/29/68	0830	Black Hills, S. Dakota		8	5	1	1
5/29/68	1130	Black Hills, S. Dakota		8	5	1	1
5/29/68	1400	Black Hills, S. Dakota		8	5	1	1
5/30/68	0730	Black Hills, S. Dakota		8	5	1	1
7/25/68	0900	Local Agriculture		8	5	1	1
7/30/68	0900	Lafayette, Indiana		8	5	1	1
8/22/68	1000	Local Agriculture		8	5	1	1
9/9/68	1330	Local Test		8	5	1	1
9/17/68	0800	Ft. Collins, Colorado		8	5	1	1
9/20/68	0900	Sacramento, California		8	5	1	1
9/23/68	0900	Mono Lake, California		8	4	2	2
9/26/68	0900	Lafayette, Indiana		8	5	1	1
9/26/68	1400	Lake Michigan		8	5	1	1
10/15/68	1000	Knoxville, Tennessee		8	5	1	1
10/21/68	1030	Local Forestry		8	5	1	1

Appendix II
SCANNER DATA COLLECTION FLIGHTS IN 1969
(Number in column indicates scanner data channels in that spectral region.)

Date	Time	Area	0.3-0.4 μm UV	0.4-0.7 μm Vis.	0.7-3.0 μm NIR	3.0-6.0 μm MIR	8.0-14.0 μm FIR
2/26/69	1100	Local Test		8	5	1	1
*3/6/69	1500	Santa Barbara		8	5	1	1
*3/7/69	0615	Santa Barbara	1	9	4	1	1
*3/7/69	1130	Santa Barbara		9	4	1	2
3/8/69	1100	San Diego		8	5	1	1
3/12/69	0900	San Diego		8	5	1	1
5/12/69	0945	Local Test		8	5	1	1
5/13/69	0800	Lafayette, Indiana		8	5	1	1
*5/15/69	1200	Harrisburg, Pennsylvania		9	4	1	1
*5/15/69	2100	Harrisburg, Pennsylvania			1	2	2
5/26/69	1100	Lafayette, Indiana		8	5	1	1
5/27/69	1100	Lafayette, Indiana		8	5	1	1
*5/27/69	1330	Lake Michigan		10	5	1	1
*6/9/69	1115	Eglin Test Site		8	4	2	2
*6/10/69	1115	Eglin Test Site		8	4	2	2
*6/10/69	2245	Eglin Test Site			2	2	2
*6/11/69	0315	Eglin Test Site			2	2	2
*6/12/69	2245	Eglin Test Site			2	2	2
*6/13/69	1115	Eglin Test Site		8	4	2	2
*6/13/69	1615	Eglin Test Site		8	4	2	2
*6/14/69	0315	Eglin Test Site			2	2	2
6/25/69	1100	Lafayette, Indiana		8	5	1	1
6/25/69	1700	Lafayette, Indiana		8	5	1	1
6/26/69	1030	Lafayette, Indiana		8	5	1	1
7/3/69	1400	Oregon Coast		7	1	1	2
7/5/69	0900	Oregon Coast		7	1	1	2
7/5/69	1430	Oregon Coast		7	1	1	2
7/6/69	1130	Oregon Coast		7	1	1	2
7/8/69	1130	Oregon Coast		7	1	1	2
7/12/69	0900	Oregon Coast		7	1	1	2

*Data collection flights for sponsors other than NASA.

Appendix II (Continued)
SCANNER DATA COLLECTION FLIGHTS IN 1969
(Number in column indicates scanner data channels in that spectral region.)

Date	Time	Area	0.3-0.4 μm UV	0.4-0.7 μm Vis.	0.7-3.0 μm NIR	3.0-6.0 μm MIR	8.0-14.0 μm FIR
7/12/69	1500	Oregon Coast		7	1	1	2
7/13/69	0900	Oregon Coast		7	1	1	2
7/13/69	1400	Oregon Coast		7	1	1	2
7/14/69	0800	Wind River		8	5	1	1
7/14/69	1330	Wind River		8	5	1	1
7/15/69	0630	Wind River		8	5	1	1
7/15/69	1030	Wind River		8	5	1	1
7/16/69	1000	Bucks Lake		8	5	1	1
7/21/69	1030	Black Hills, S. Dakota		8	5	1	1
7/21/69	1430	Black Hills, S. Dakota		8	5	1	1
7/22/69	0830	Black Hills, S. Dakota		8	5	1	1
7/22/69	1230	Black Hills, S. Dakota		8	5	1	1
7/23/69	0245	Missouri River				1	2
8/4/69	0930	Ann Arbor		8	5	1	1
8/5/69	0700	Lafayette, Indiana		8	5	1	1
8/5/69	1030	Lafayette, Indiana		8	5	1	1
8/6/69	1030	Lafayette, Indiana		8	5	1	1
*8/11/69	0930	Lake Michigan	1	7	2	1	1
8/11/69	0930	Lake Michigan	1	7	2	1	1
8/13/69	0900	Ann Arbor		8	5	1	1
*8/13/69	0900	Detroit River		8	5	1	1
8/13/69	2100	Ann Arbor				2	1
*8/13/69	2100	Detroit River				2	1
9/3/69	0715	Washtenaw		8	5	1	1
9/3/69	1100	Washtenaw		8	5	1	1
9/14/69	0900	Oregon Coast	1	7	1	1	1
9/15/69	1045	Oregon Coast	1	8	1	1	1
9/15/69	1500	Oregon Coast	1	8	1	1	1
9/21/69	1000	Oregon Coast	1	8	1	1	1
9/23/69	0900	Oregon Coast	1	8	1	1	1

*Data collection flights for sponsors other than NASA.

Appendix II (Concluded)
SCANNER DATA COLLECTION FLIGHTS IN 1969
(Number in column indicates scanner data channels in that spectral region.)

Date	Time	Area	0.3-0.4 μm UV	0.4-0.7 μm Vis	0.7-3.0 μm NIR	3.0-6.0 μm MIR	8.0-14.0 μm FIR
9/23/69	1330	Oregon Coast	1	8	1	1	1
9/24/69	1300	Oregon Coast	1	8	1	1	1
9/25/69	1000	Moses Lake		8	5	1	1
9/26/69	0730	Wind River		8	5	1	1
9/26/69	1030	Wind River		8	5	1	1
*10/22/69	0930	Moses Lake		8	5	1	1
*10/22/69	1430	Moses Lake		8	5	1	1
*10/22/69	1900	Moses Lake			3	1	1
*10/23/69	0530	Moses Lake			3	1	1
10/24/69	1200	Bucks Lake		8	5	1	1
*10/25/69	1330	L. A. Forestry		8	5	1	1
*10/27/69	0800	L. A. Forestry		8	5	1	1
*10/27/69	1030	L. A. Forestry		8	5	1	1
11/5/69	1300	Lafayette, Indiana		8	5	1	1
11/6/69	0830	Lafayette, Indiana		8	5	1	1
11/6/69	1100	Lafayette, Indiana		8	5	1	1
*11/20/69	1000	Detroit River		10	5		1
11/26/69	1000	Ann Arbor		8	5	1	1
*11/26/69	1000	Detroit River		8	5	1	1
12/17/69	1200	Lafayette, Indiana		8	5	1	1

*Data collection flights for sponsors other than NASA.

Appendix III
TENTATIVE FLIGHT SCHEDULE FOR 1970

Date	Mission	Operations Base	No. of Flights	Data Miles	Flight Hours
January 5-9	Maintenance	Willow Run			
12-16	Maintenance	Willow Run			
19-23	Maintenance	Willow Run			
26-30	Maintenance	Willow Run			
February 2-6	Maintenance	Willow Run			
9-13	Performance Checks	Willow Run			
16-20	Calibration	Willow Run			
23-27	Test Flight	Willow Run	1	0	3
March 2-6	Field Trip Prep.	Willow Run			
9-13	*Alafia/Pease	Tampa	2	300	15
16-20	*Everglades/Florida Keys	Miami	2	300	17
23-27	Aircraft Periodic Maintenance	Willow Run			
30-3	Kansas Highway	Kansas City	2	100	12
April 6-10	Virginia Highway	Staunton	2	50	11
13-17	*Purdue	Lafayette	3	330	11
20-24	*Ann Arbor	Willow Run	2	160	7
27-1				100	3
May 4-8	Aircraft Periodic Maintenance	Willow Run			
11-15	*Mill Creek	Ardmore	5	225	15
18-22	*Black Hills	Rapid City	4	145	12
25-29	*North Dakota	Jamestown	1	90	10
June 1-5					
8-12	*Ann Arbor	Willow Run	2	160	7
15-19	*Washtenaw	Willow Run	2	110	4
22-26	Aircraft Periodic Maintenance	Willow Run			
29-3	*Purdue	Lafayette	3	330	11
July 6-10					
13-17					
20-24	*North Dakota	Jamestown	1	90	14
27-31					
August 3-7					
10-14	*Washtenaw	Willow Run	2	110	4
17-21					
24-28					
31-4					
September 7-11					
14-18					
21-25					
28-2					
October 5-9					
12-16					
19-23					
26-30	Virginia Highway	Staunton	2	50	11

*NASA-supported missions.

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