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SECTION 34

MICHIGAN EXPERIMENTAL MULTISPECTRAL SCANNER SYSTEM

by

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The research laboratories of The University of Michigan pioneered the application of multispectral mapping techniques to earth resources problems with experimental hardware developments beginning in the mid sixties. During FY71 under NASA/MSC support, Michigan modified its original multipath multispectral airborne scanner system to provide the same spectral bands along a single optical line of sight. Previous to this modification, the choice of spectral bands for machine processing was limited to those few grouped in one of four separate optical paths. After the modification, any of the multispectral bands selected from throughout the ultraviolet, visible and infrared regions could be processed together. The modified system became operational in late June 1971, only six months after contract go ahead and just in time for use in the Corn Blight Watch experiment.

The Michigan experimental system has supplied all of the multispectral scanner data processed and analyzed by Michigan, Purdue, NASA/MSC and others during the past five years. The system can generate up to eighteen different spectral bands over a wavelength range of from 0.33 to 14.0 microns. Twelve of these bands can be selected for tape recording at any one time on a fourteen track analog tape machine. The scanner includes provisions for five separate radiation reference sources. These sources are viewed in sequence by each radiation detector as part of each line scan of the terrain beneath the aircraft.

For those not familiar with airborne scanners, a functional description of line scanning will be presented with reference to Figure 1, The Geometry of Airborne Scanning. As shown in the optical schematic at the top of the figure, the airborne scanner consists of an optical telescope with its narrow field of view directed by a rotating flat mirror to scan in a plane perpendicular to the longitudinal axis of the aircraft. In place of the usual eyeball at the eyepiece of the telescope, there is a radiation detector, or detectors, which converts the radiation to electrical signals. Again referring to Figure 1, the telescope field of view or ground resolution element scans laterally across the aircraft ground track through an opening in the bottom of the aircraft. Then it scans radiation references internal to the scanner before making the next ground scan. By the time the next ground scan begins, the aircraft has moved forward so that subsequent line scans form a continuous strip image of the terrain beneath the aircraft. The electrical voltage representation of a single line scan is shown in Figure 2, Scanner Voltage Output vs Time. Note that while the detectors for all wavelength bands view in phase each of the radiation references as well as the terrain, not all references apply to each wavelength band. Although the thermal ambient and dark level references may be a common radiation source, the other sources are associated with either thermal or non thermal bands as shown. A synchronization reference is generated by the scanner for recording with the video signals for indexing purposes. The marker pulse refers to the scan position relative to internally mounted radiation references and the roll stabilized pulse refers to ground scan nadir with aircraft roll motion removed.

The complete airborne scanner system is shown in schematic block diagram form in Figure 3, Michigan Experimental Multispectral Scanner System. The terrain radiation enters the scanner at the bottom left and is registered by the radiation detectors in the scanner assembly along with operator controlled reference sources. The output of the radiation detectors are electrical signals which are amplified in preamplifiers before being transmitted to an operator console for further amplification in postamplifiers. The operator monitors the video signals and adjusts them to the proper level for tape recording. During recording he monitors the signals reproduced from the tape record to confirm satisfactory recording. The system makes a linear transformation of input radiation to voltage recorded on the analog magnetic tape. The boresight camera which is part of the system records visible radiation on film for use in the analysis of the scanner data.

The system modification completed in June 1971 amounted to the substitution of the single scanner assembly shown on the left of the figure for two double ended military surplus scanners originally used in the system. The radiation references, detector assemblies, electronics, operator displays and the tape machine remained the same. However, the system configuration is a dynamic one which is continually changing to accept new detector assemblies and electronic components with improved performance. Figure 4, M7 Scanner Performance Characteristics, shows the gross parameters of the current system which is formed around the Michigan designated M7 scanner.

Figure 5, Optical Schematic of Michigan Experimental Multispectral Scanner, shows the optical configuration of the M7 scanner. Figure 6, Michigan Experimental Multispectral Scanner, shows a similar view of the actual scanner with inspection panels removed. The key feature to note in the design is the flexibility to easily accept different radiation reference sources and new detector assemblies. Weight and space savings were sacrificed to provide this flexibility which allowed the immediate use of references and detector assemblies from the original system with the understanding that they would eventually be replaced as time and funds permitted. Also, the scan motor drive shaft was extended beyond the aft end of the motor housing in order that illumination sources (such as lasers) might later be added to the system in time phase with the scan mirror.

The radiation intercepted by the five inch diameter collecting aperture is directed into the Dall-Kirkham telescope which has a three inch diameter secondary mirror. The incoming radiation blocked from the telescope by this secondary is directed upward to detector position number one. This nominal three inch diameter collecting aperture is broadband (0.3 to 14.0 microns). Currently a focusing lens designed for 8.0 to 14.0 microns is used at this position with a HgCdTe detector to provide thermal data. In work is a modification to use a dichroic mirror in this position to divert UV radiation onto a photomultiplier detector while maintaining the thermal detector in the same position. A wide variety of detector assemblies can be used in this position.

The radiation collected by the effective four inch aperture of the telescope is folded into a dichroic mirror which reflects the radiation below a nominal 0.9 micron and transmits the energy beyond. The radiation beyond 0.9 microns is focused onto three separately filtered InAs detector elements by a lens optimized for transmission in the 1.0 to 2.6 micron region. This dichroic and lens can be changed relatively easily for different detector configurations at this detector position number two.

The radiation at wavelengths shorter than 0.9 microns is focused onto the entrance slit of a prism spectrometer at detector position number three. This spectrometer disperses visible and near infrared radiation through fiber optic bundles onto as many as twelve photomultiplier tubes. The sixteen fibers are directed onto nine separate photomultiplier detectors in the current configuration.

The radiation reference sources currently in use with the system are: (1) an NBS lamp packaged to simulate a point source, (2) two temperature controlled greybody thermal references which fill the collecting aperture, and (3) a sky illumination reference consisting of an opal glass diffusing plate mounted in the top of the aircraft. The operator has control of the radiation from all reference sources through electronic control of the lamp and greybodies and attenuating optical filters for the sky illumination. The calibrated output of these sources are monitored and recorded manually by the operator during data collection. These internal references are calibrated periodically against external standards in the laboratory.

Figure 7, Detector Configurations for M7 Scanner, shows the detector assemblies currently available for use in the system and those planned for the near future. All data collected during the last half of 1971 used the specific detectors listed in the top row of the chart.

A 9.3 micron long wavelength pass filter was used with the HgCdTe detector in position one to provide thermal coverage. Some of the future detectors will be available for use by the spring of 1972 and all should be operational by the summer of 1972. It is interesting to note that the most useful wavelength bands of those available for processing the corn blight data were the thermal IR (9.3 to 11.5 microns), two in the mid IR (1.0 to 2.6 microns) and three in visible and near IR (0.4 to 0.9 microns). The specific bands in the non thermal wavelengths varied with the changing crop conditions. It was fortunate that the system was modified in time to make these bands available for multispectral processing of corn blight.

Figures 8 and 9 show an external view of the Michigan C47 aircraft which normally transports the multispectral mapping system and an internal view of the instrumentation installed in the aircraft. The internal view looks forward in the aircraft from the rear. The M7 scanner with reference sources and radiation detectors removed is in the lower right hand corner of the figure. The scanner rests in an instrument well through the floor of the aircraft. The supporting electronics and operator positions for the system are forward of the scanner position. At the time of this photograph most of the original multispectral system was still installed in the aircraft including one of the double ended military surplus scanners. The modified multispectral system weighs about 1200 pounds which is about half the instrumentation payload of the C47 aircraft. Therefore other systems may be installed and operated in conjunction with the multispectral mapping functions.

The M7 multispectral system can also be installed in the Michigan C46 aircraft which contains a high resolution, side looking airborne radar (SLAR) system. This SLAR system is also used for earth resource applications. However, the two systems cannot be operated simultaneously and the aircraft data collection time is reduced from four to two hours because of reduced fuel capacity with both systems installed. This combined system installation in the C46 is usually a temporary one which provides for IR and radar mapping with one aircraft on the same field trip.

Aside from continued development of new detector assemblies and electronic components to improve scanner performance, several other items are scheduled for investigation in the near future. One is to make provision for scanning in an oblique instead of a vertical plane across the aircraft track. The oblique view of vegetation should show more vegetation and less ground in a resolution element. This mix of soil and crop in a common resolution element has been a problem in remotely identifying farm crops in the past and the technique may benefit other applications. The other new technique of potential benefit is to actively scan in selected wavelength bands which will be recorded along with passive bands. Laser radiation sources can be coupled with line scanners to provide this capability.

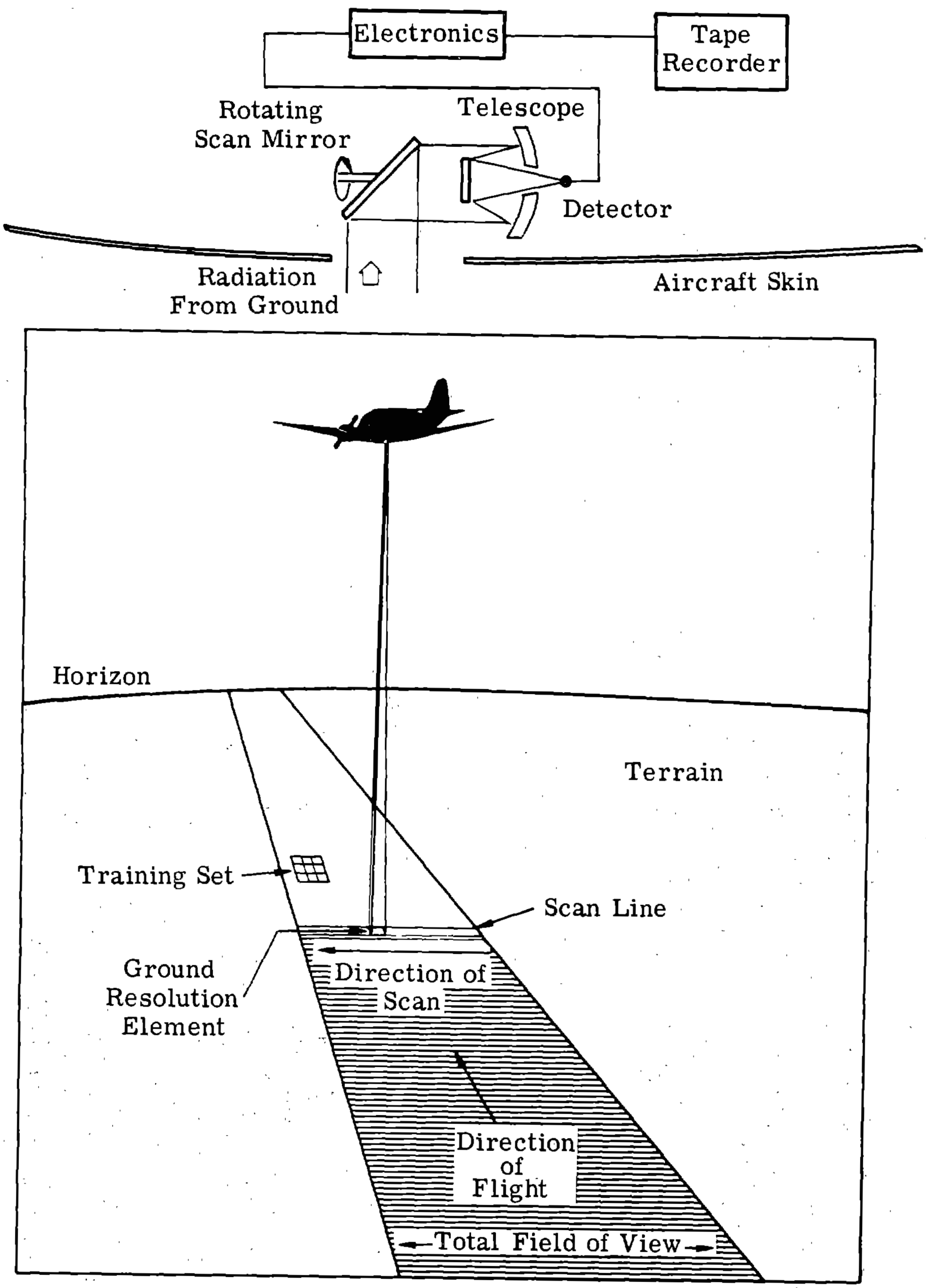

FIGURE 1. THE GEOMETRY OF AIRBORNE SCANNING

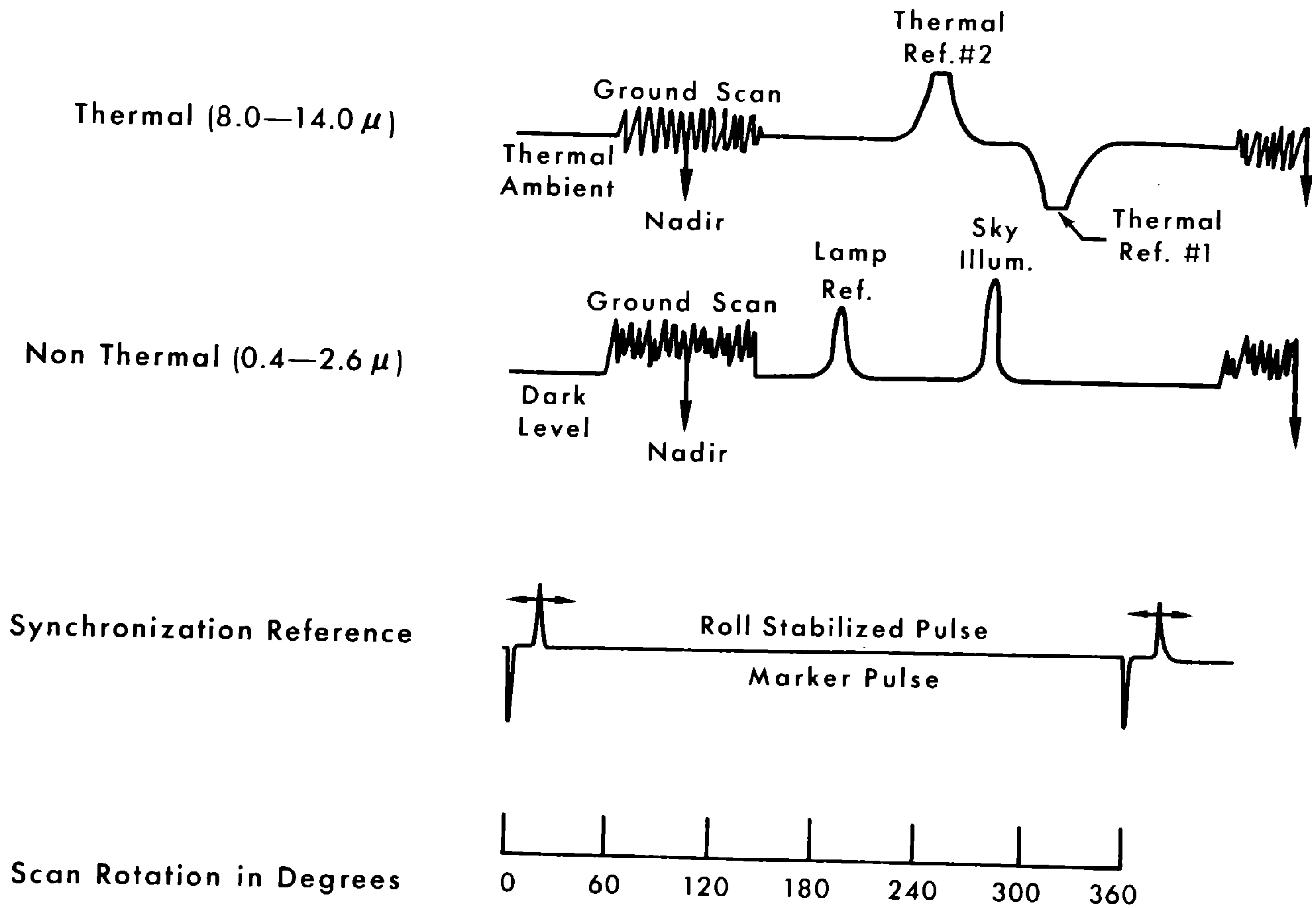

FIGURE 2. SCANNER VOLTAGE OUTPUT VERSUS TIME

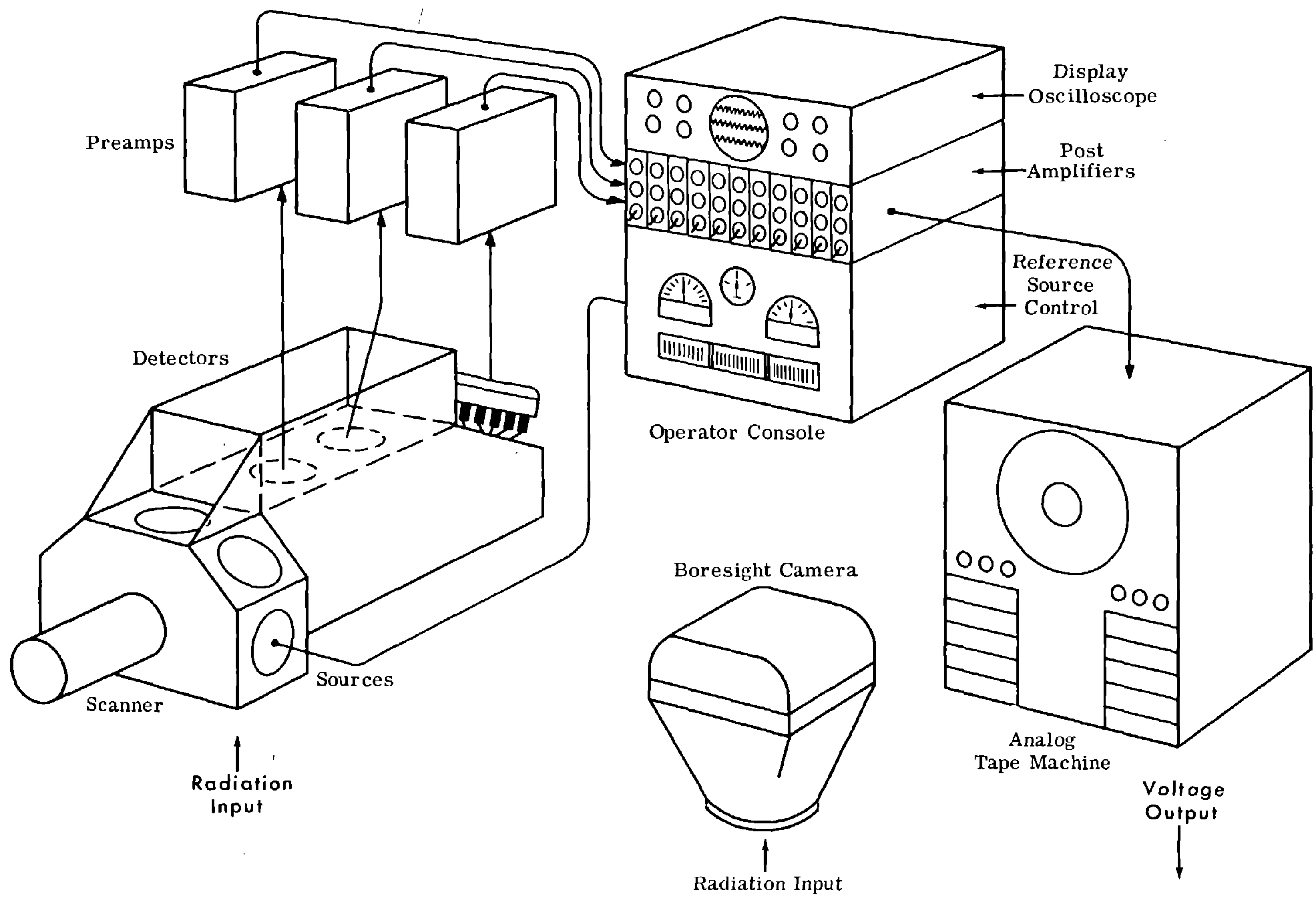

FIGURE 3. MICHIGAN EXPERIMENTAL MULTISPECTRAL SCANNER SYSTEM

- 12 Spectral Bands in UV, Vis, IR
- 90° External FOV ($\pm 45^{\circ}$ from nadir)
- 2 mr. Max. Spatial Resolution
- $0.3^{\circ}C$ Nominal Thermal Resolution
- 1% Nominal Reflectance Resolution
- 5 Radiation Reference Ports
- 5 in. Diameter Collector Optics
- 60 or 100 scans/sec. Scan Rate
- DC to 90 KHz Electronic Bandwidth
- Roll Stabilized Imagery

FIGURE 4. M7 SCANNER PERFORMANCE CHARACTERISTICS

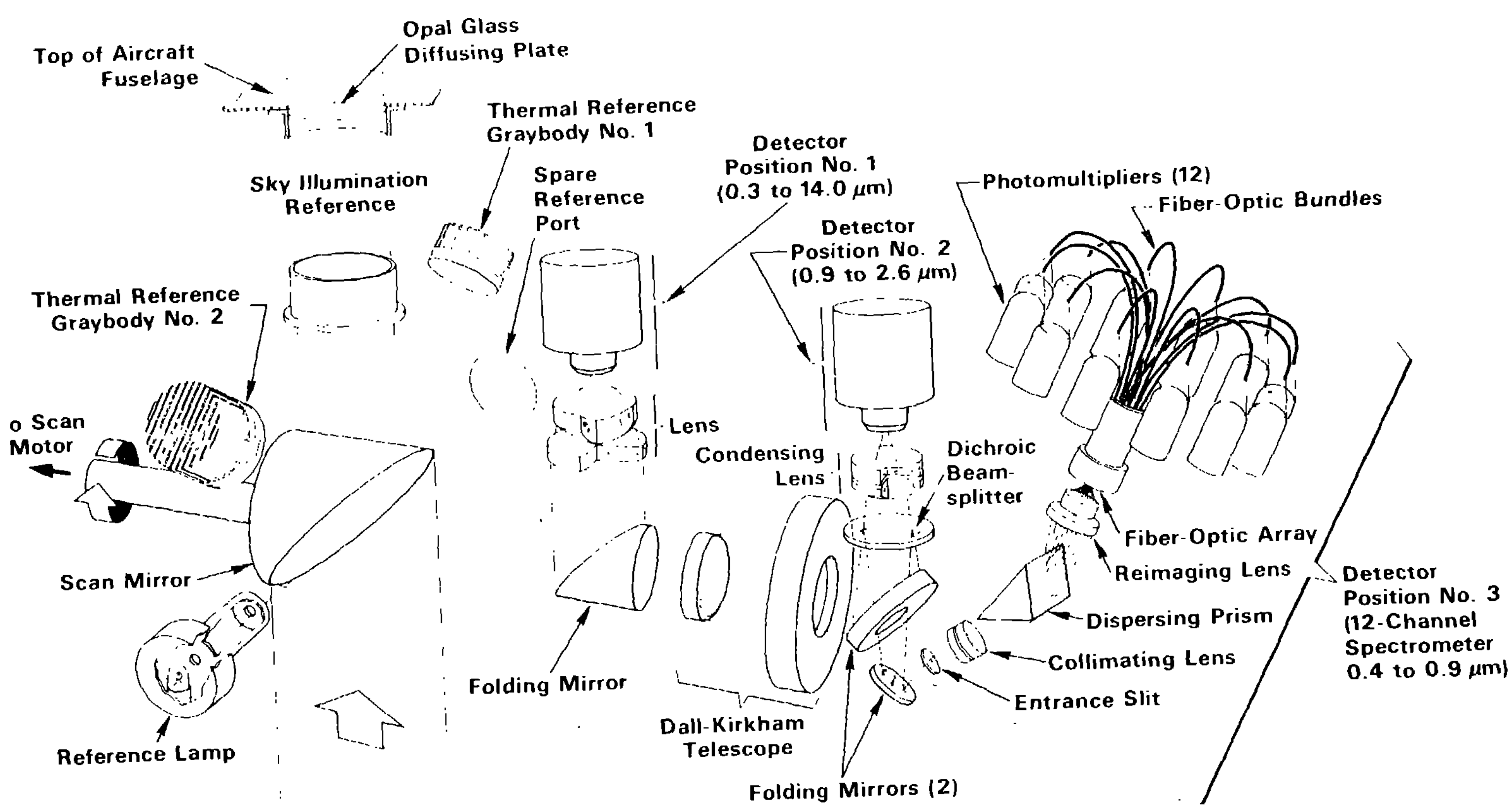

FIGURE 5. OPTICAL SCHEMATIC OF MICHIGAN EXPERIMENTAL MULTISPECTRAL SCANNER

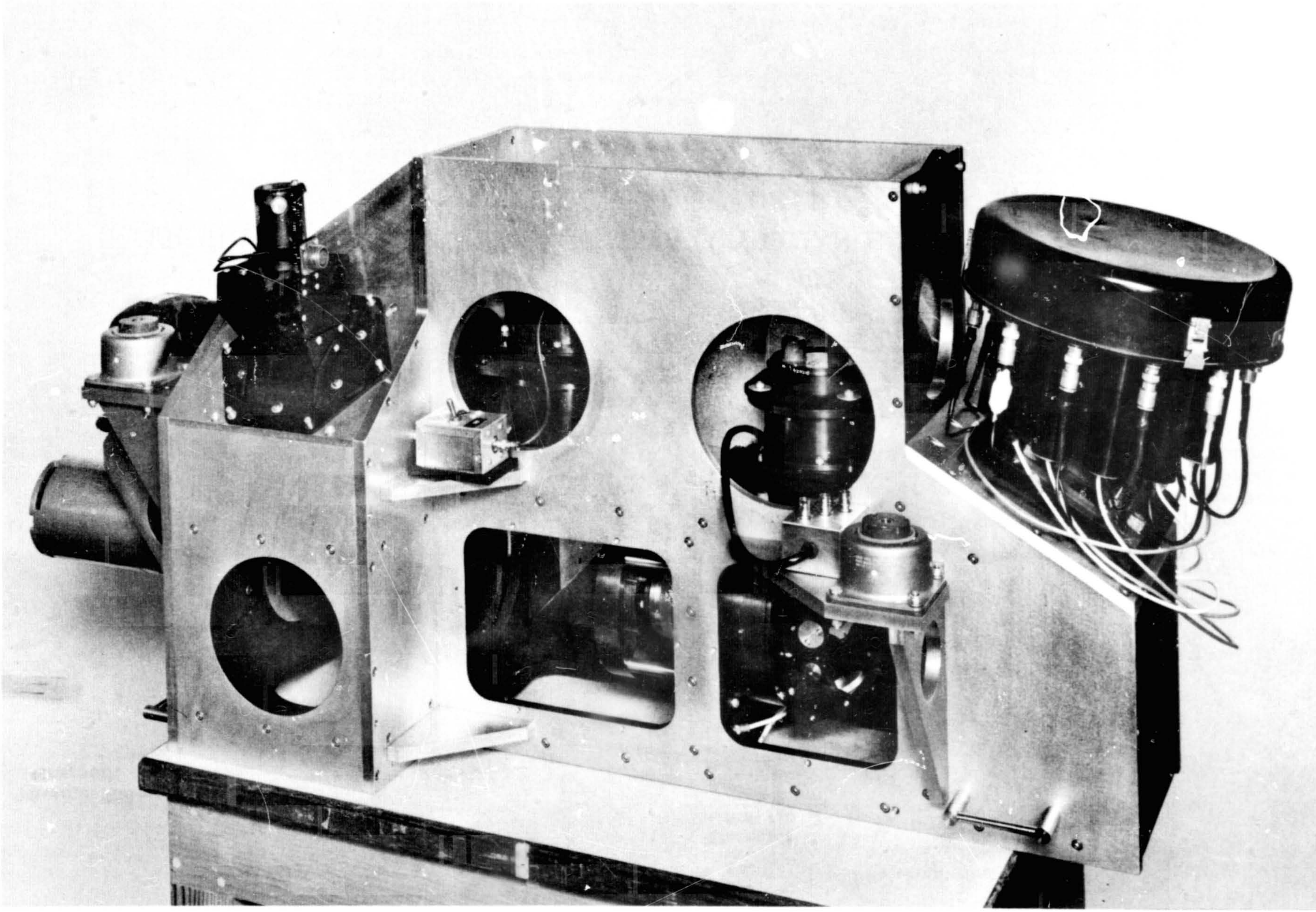

FIGURE 6. MICHIGAN EXPERIMENTAL MULTISPECTRAL SCANNER.
(View with inspection panels removed.)

	Position 1 (14.0 to 0.3 μ)			Position 2 (2.6 to 0.9[1] μ)			Position 3 (0.9[1] to 0.4 μ)		
	Det.SN	Spec. Band (μ)	Spat. Res. (mr)	Det. SN	Spec. Band (μ)	Spat. Res. (mr)	Det. SN	Spec. Band (μ)	Spat. Res. (mr)
CURRENT	HgCdTe1-3	1.0-11.5[2]	3.3×3.3	InAs3-5	2.0-2.6	2.0×4.0	PM12-1	.67-.94	2.0×2.0
					1.5-1.8	2.0×4.0		.62-.70	2.0×2.0
	HgCdTe1-2	1.0-14.0[2]	6.6×6.6		1.0-1.4	2.0×4.0		.58-.64	2.0×2.0
								.55-.60	2.0×2.0
				InSb3-6	2.0-2.6	2.0×4.0		.52-.57	2.0×2.0
					1.0-1.4	2.0×4.0		.50-.54	2.0×2.0
								.48-.52	2.0×2.0
								.46-.49	2.0×2.0
								.41-.48	2.0×2.0
FUTURE	HgCdTe3-1	8.2-9.3	6.6×6.6	InAs3-6	2.0-2.6	2.0×4.0	PM10-1	.90-1.1	3.0×3.0
		10.2-11.3	6.6×6.6		1.5-1.8	2.0×4.0		.67-.94	3.0×3.0
		11.7-13.8	6.6×6.6		1.0-1.4	2.0×4.0		.62-.70	3.0×3.0
								.58-.64	3.0×3.0
	HgCdTe1-4	1.0-14.0[2]	3.0×3.0	HgCdTe2-3	2.0-2.6	3.0-3.0		.55-.60	3.0×3.0
	UVPM1-3	0.3-0.7[2]	3.0×3.0		1.5-1.8	3.0×3.0		.52-.57	3.0×3.0
								.50-.54	3.0×3.0
	UVPM1-3	0.3-0.7[2]	3.0×3.0	InAs1-2	1.0-2.6[2]	3.0×3.0		.48-.52	3.0×3.0
								.46-.49	3.0×3.0
								.41-.48	3.0×3.0

Note: 1. Cutoff established by replaceable dichroic mirror.
2. Bandpass established by external optical filter.

FIGURE 7. DETECTOR CONFIGURATIONS FOR M7 SCANNER

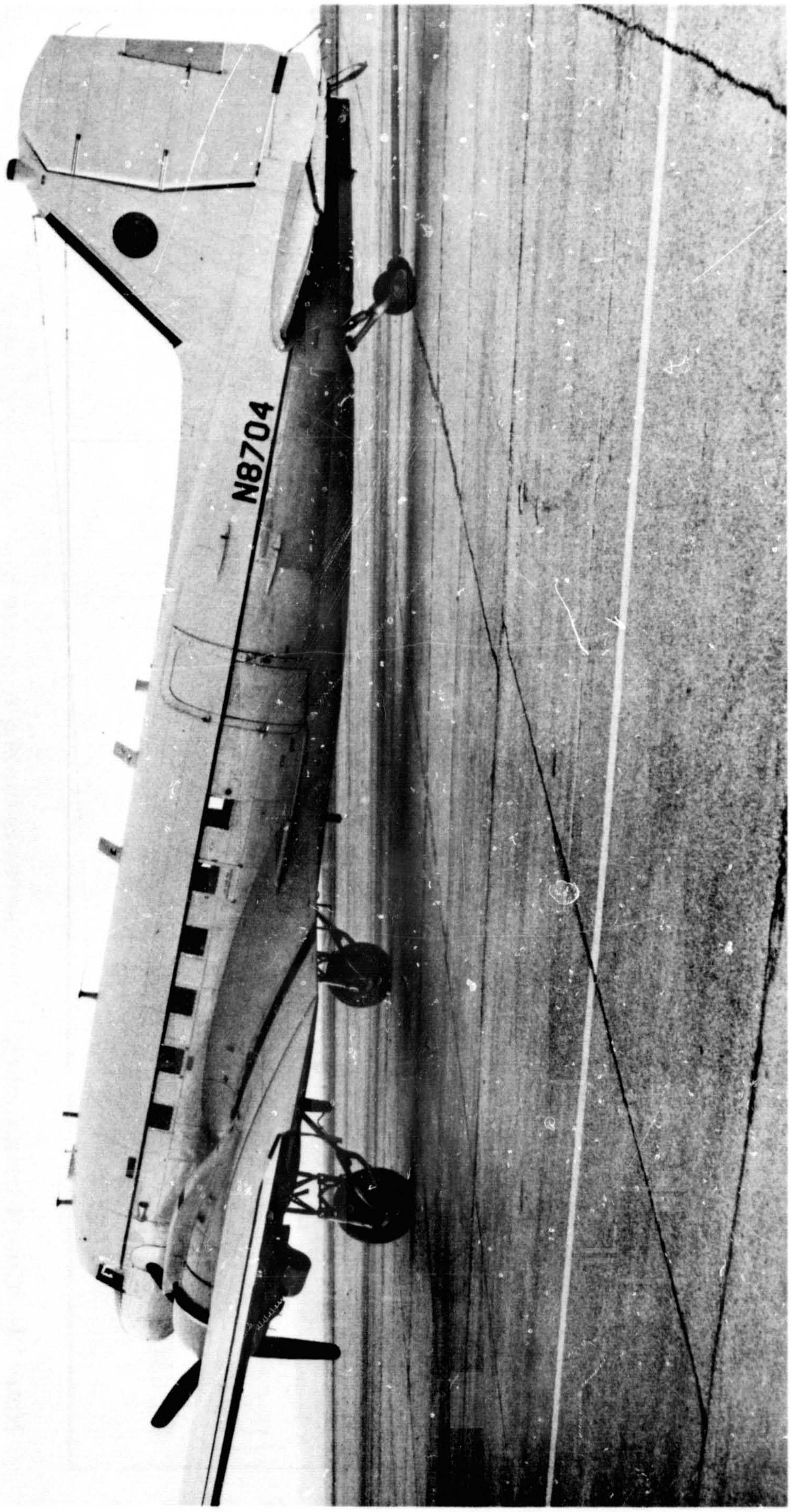

FIGURE 8. MICHIGAN C-47 REMOTE SENSING AIRCRAFT

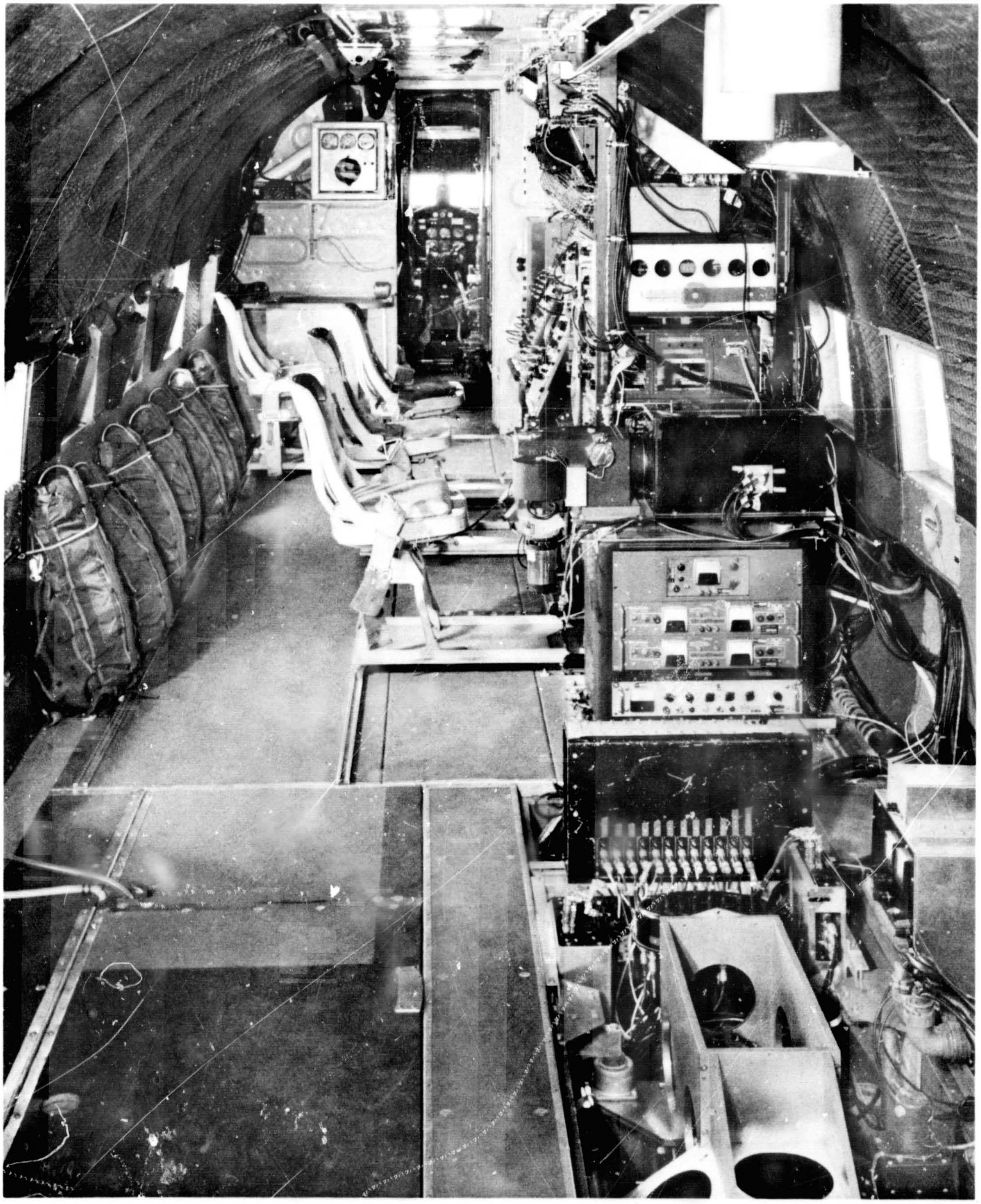

FIGURE 9. INTERIOR VIEW OF C-47 REMOTE SENSING AIRCRAFT SHOWING MULTISPECTRAL MAPPING SYSTEM