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Research and Development

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prepared for
EPA Region 5

APPENDIX A
THERMAL ANALYSIS
ISLAND, STURGEON, RUSH, AND PASSENGER LAKES

THERMAL ANALYSIS

The multispectral scanner data was collected over the study area October 21, 1980, between 10:00 a.m. and 10:30 a.m. central daylight time at an approximate altitude of 1,200 meters (4,000 feet) above ground level (see Figure A-1). Aircraft flight lines were orientated such that several hundred meters of land adjacent to lake shorelines was included in the data. The inclusion of a significant portion of terrestrial areas provided for accurate land-water separation during computer processing of data, and allowed for adequate visibility of land use-land cover activities adjacent to the lakes. The visibility and subsequent analysis of land use activities and land cover types oftentimes provides an indication to why some thermal variations in water bodies are evident.

Data collected over Island Lake and the north shore of Sturgeon Lake were partially obscured by storm clouds. The cloud cover was not considered sufficient to degrade the final data product. Data collected at an altitude of 1,200 meters above the terrain provided a minimum resolution area size of 3 square meters (10 square feet). All data was processed without a geometric correction factor so slight distortions in scale and projection will be encountered when comparisons are made with a topographic map. Relative temperatures were assigned to the thermal data, with 0° Celsius (deep blue) assigned to the coolest water counts and 1.5° Celsius (deep red) to the warmest. Refer to Appendix B for a discussion of the multispectral scanner system.

The following is a discussion of Island, Sturgeon, Rush, and Passenger Lakes thermal patterns.

ISLAND LAKE

Island Lake (see Figure A-2) appears to have numerous underground springs located adjacent to Doeblers subdivision and east of North Island Lake subdivision shorelines. The large mass of red (1.5° C) and pink (1.0° C) thermal patterns concentrated in the center of Island Lake suggest an absence of surface water circulation. An unidentified intermittant stream source, not visible on the image, located east of North Island Lake subdivision, appears to have no effect on lake thermal patterns. The outflow of Island Lake, located at Sunrise Bay, is also not visible on the imagery, and apparently not affecting surface thermal patterns. This suggests the possibility that no water was present in either stream course at the time of data collection. Thermal patterns in the vicinity of Doeblers subdivision reveal two distinct areas where warm water discharges appear to be entering Island Lake. The origin of these point source discharges are not known. The discharge points have been annotated of Figure A-2 to aid field inspection and additional water testing.

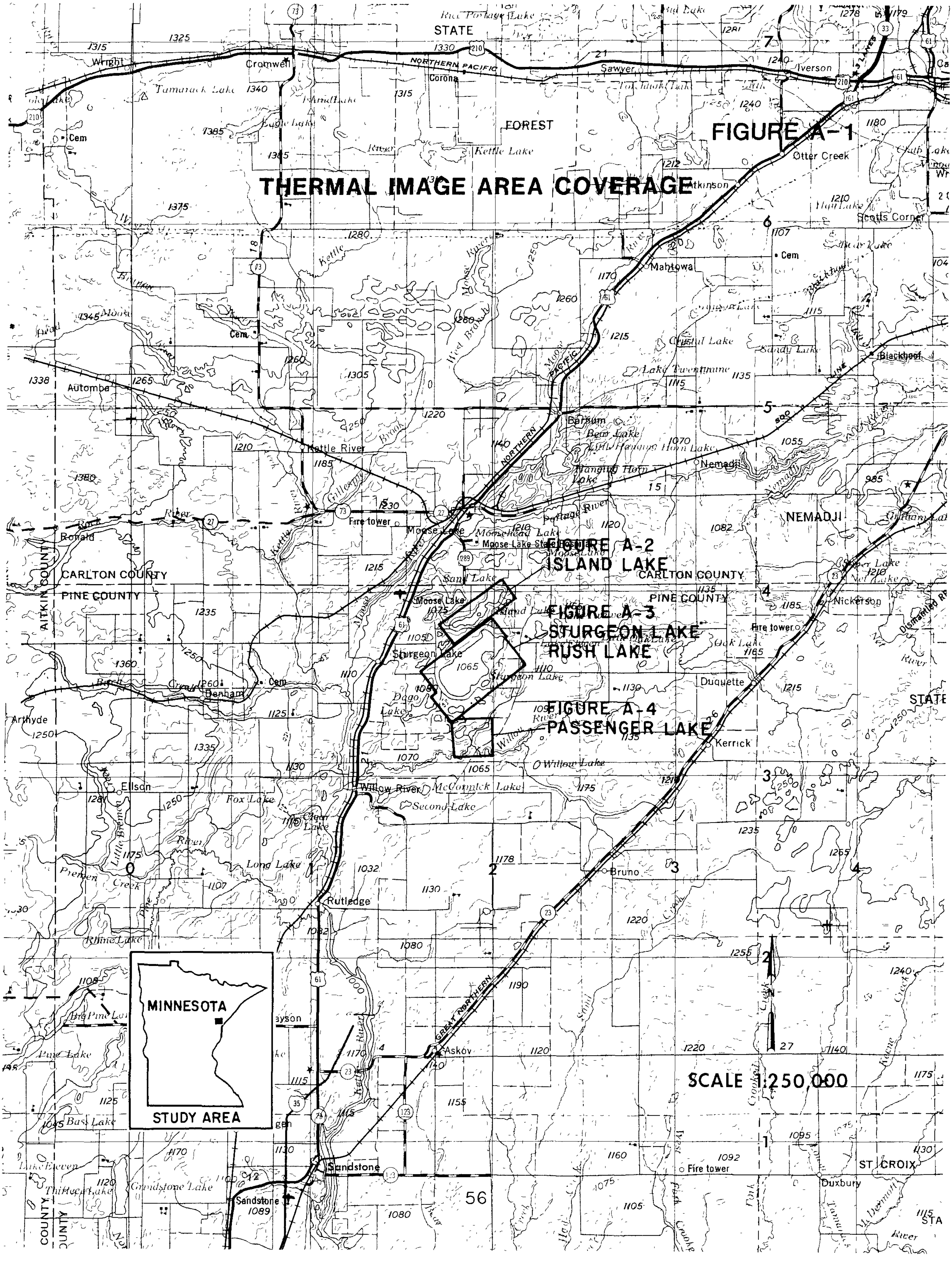
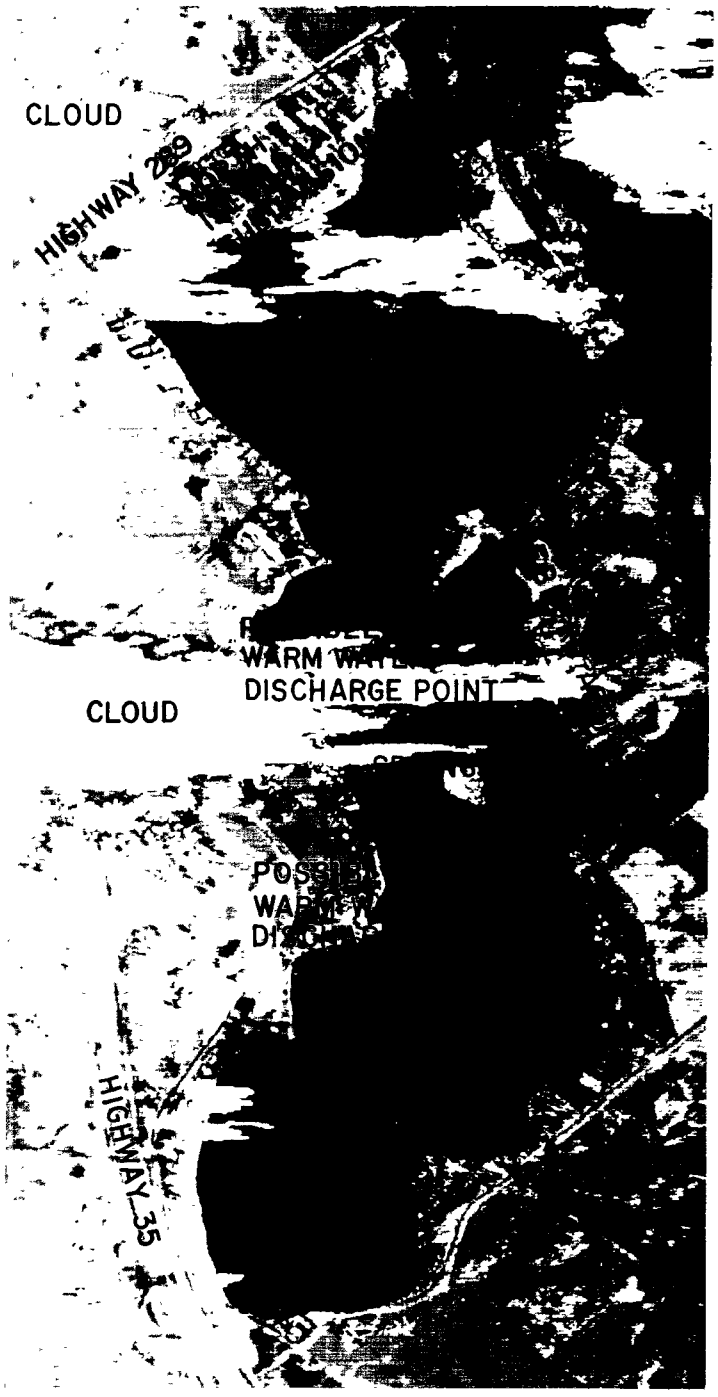


FIGURE A-1
THERMAL IMAGE AREA COVERAGE
FIGURE A-2
ISLAND LAKE
FIGURE A-3
STURGEON LAKE
RUSH LAKE
FIGURE A-4
PASSENGER LAKE
MINNESOTA
STUDY AREA
SCALE 1:250,000
CARLTON COUNTY
PINE COUNTY
STATE
FOREST
NEMADJI
Cromwell
Wright
Sawyer
Iverson
Otter Creek
Atkinson
Mahtowa
Barnum
Automba
Kettle River
Moose Lake
Nemadji
Blackhoof
Nickerson
Sturgeon Lake
Denham
Duquette
Kerrick
Arthyde
Ellson
Willow River
Bruno
Rutledge
Askov
Sandstone
Duxbury
ST CROIX

FIGURE A-2

ISLAND LAKE



NOMINAL SCALE 1:8,500

STURGEON LAKE

Sturgeon Lake is the most dynamic of four lakes studied. The presence of underground springs and their thermal influences around the entire periphery of Sturgeon Lake are evident on Figure A-3. The concentration of red (1.5° C) and pink (1.0° C) thermal patterns in the center and southern portions of the lake, suggests a general lack of circulation throughout the entire water body. Concentrations of the cooler blue (0° C) thermal pattern in the northeast corner of Sturgeon Lake indicates a combined effect of perhaps several underground springs emitting cool waters into the lake.

Four apparent warm water discharges, each of unknown origin, have been annotated on Figure A-3. Two discharges in the vicinity of Sturgeon Island, one, south of Sunset Shore subdivision, and one, adjacent to Section 9, Government Lot 2, are all clearly discernible on the imagery. Numerous similar discharge returns are visible along the northwestern shoreline between the developments of Sunrise View and Section 17, Government Lots 1, 2, and 3. Analysis of color infrared aerial photography simultaneously acquired with the thermal imagery, revealed that the red (1.5° C) thermal returns do not appear to be warm water discharges but channels or paths home owners have cleared through dense subsurface vegetation to provide access from lakefront property to Sturgeon Lake. These very shallow areas are more susceptible to the warming effect of solar heating. The lake shoreline adjacent to the YMCA camp, south of the aforementioned area (see annotation, Figure A-3), also has a very shallow beach area. The red thermal pattern in this area is probably due to the effects of solar heating.

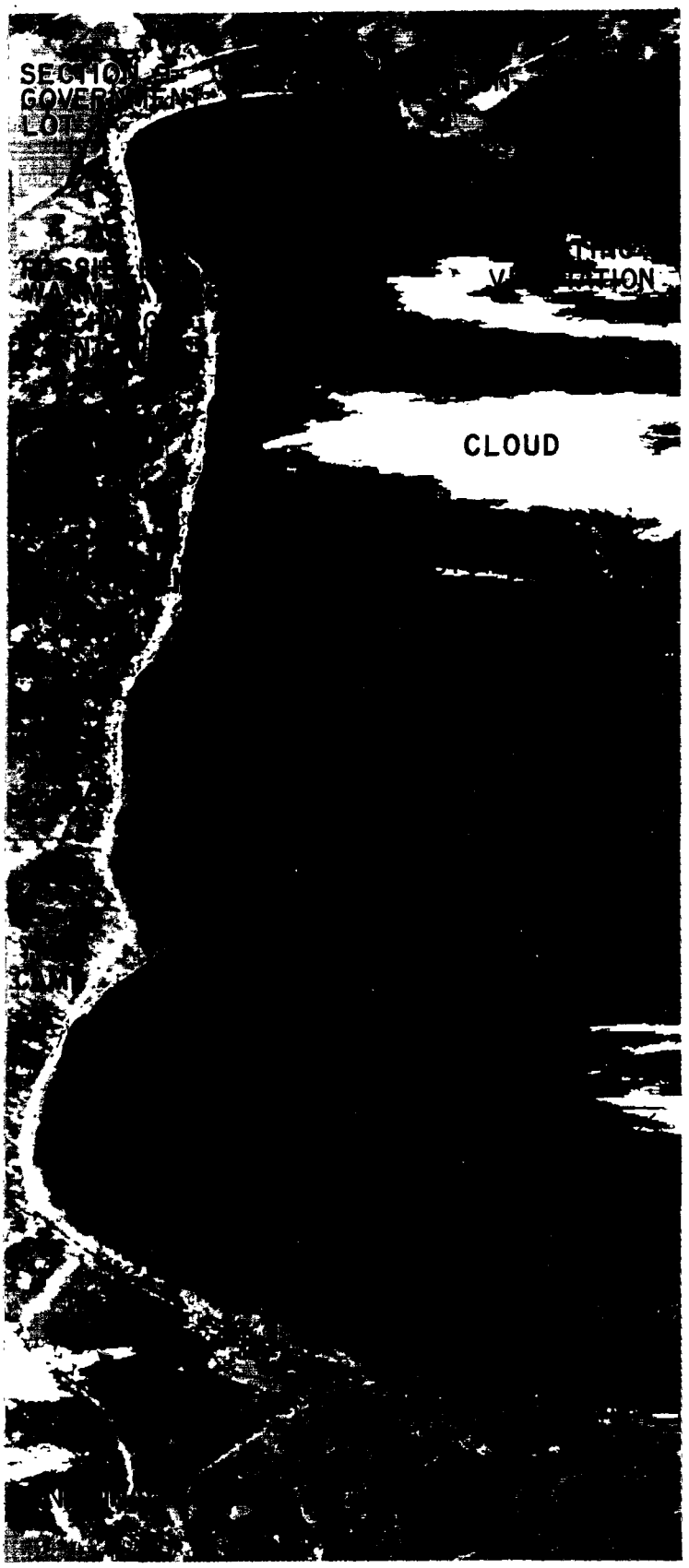
RUSH LAKE

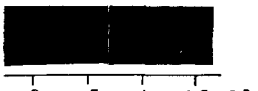
The thermal patterns of Rush Lake, located in the lower

right portion of the Figure A-3, exhibit a general lack of water circulation. This is evident by the even 0.5° C temperature gradients distributed from the northern to southern end of this shallow water body. The source of cool water (0° C) in the northern end of the lake, appears to be eminating from under the extensive mat of vegetation adjacent to the shoreline. This cool water phenomenon is common to bog ecosystems. The thick floating vegetative mat, acts as a shield and insulating blanket against the warming effect of solar radiation.

FIGURE A-3

STURGEON AND RUSH LAKES



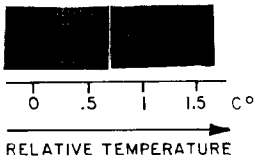


PASSENGER LAKE

Passenger Lake (see Figure A-4) appears to be similar to Island, Sturgeon, and Rush Lakes in that an apparent lack of water circulation is very pronounced. This is evident by the uniform temperature gradients that range from 1.5° C along the north shore to 0° C at the lakes outlet. Passenger Lake drains into Big Slough Lake via a narrow stream that is not completely visible on the image. The cool water (0° C) moving out of Passenger Lake has noticeably increased in relative temperature to 1.5° C, at the point of discharge into Big Slough Lake (see outlet annotation, Figure A-4). The discharge appears as a significant warm water entry point due to the overall lower general temperature of Big Slough Lake.

FIGURE A-4

PASSENGER LAKE



NOMINAL SCALE 1:18,300

APPENDIX B
THE EMSL-LV MULTISPECTRAL SCANNER SYSTEM

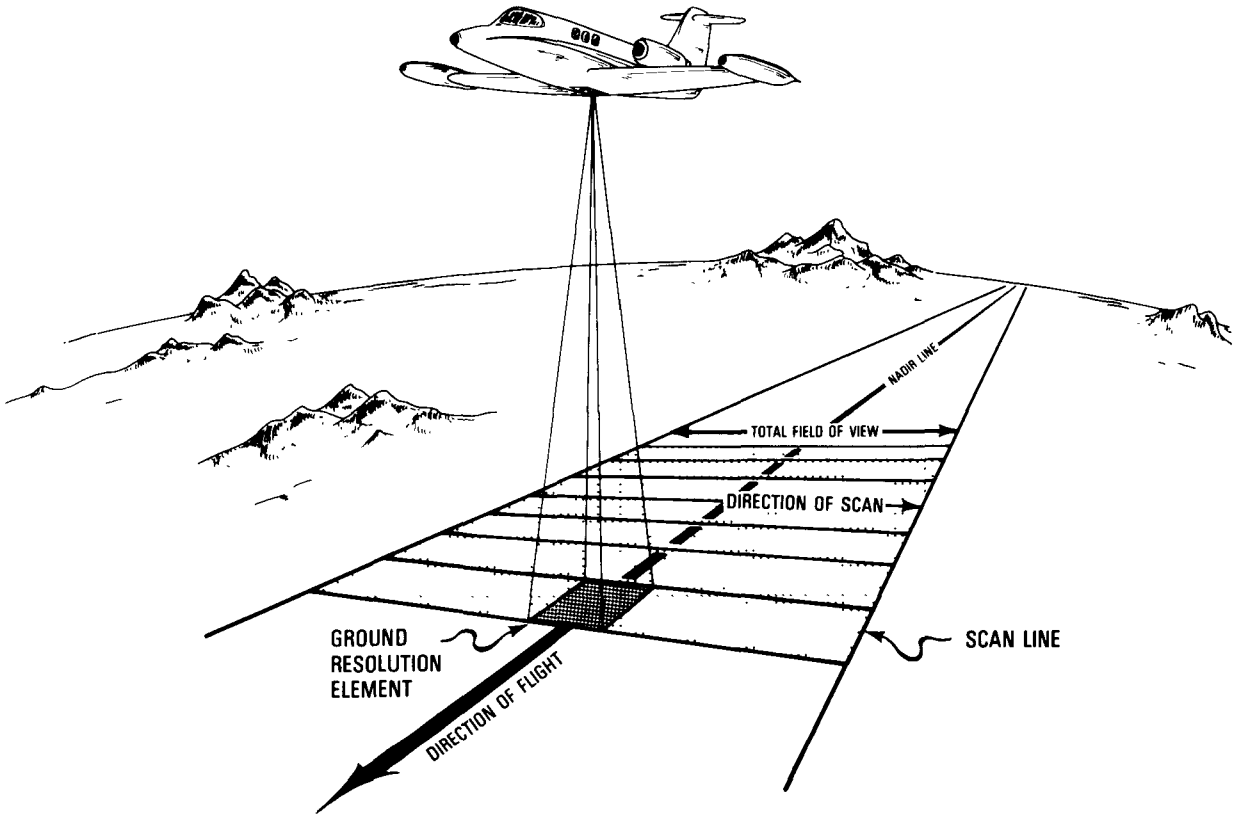
AIRBORNE MULTISPECTRAL SCANNER

The airborne multispectral scanner (MSS) acquires data at altitudes ranging from 370 to 6,100 meters (1,200 to 20,000 feet) above ground level. This is an 11-band system designed to collect and record radiant energy data in the near-ultraviolet through the thermal infrared portions of the electromagnetic spectrum (see Table on MSS Wavelength Bands). The scanner has a rotating mirror that scans across the ground scene, perpendicular to the line of flight. Radiant energy from the ground surface is reflected through focusing optics to a beam splitter which diverts the visible radiation (Channels 1-10) to a 10 channel spectrometer and the thermal infrared radiation (Channel 11) to a solid state detector. Electronic signals from the 11 detectors are digitized and recorded on magnetic tape in a high density format. During operation, the MSS scan rate is controlled and synchronized to the aircraft ground speed and altitude, resulting in scan line contiguity at nadir (see Figure on MSS Imaging Characteristics). The scanner is equipped with internal visible and thermal reference sources, which provide information for calibration of the data. The aircraft sensor tape is processed on a ground based Data Analysis System (DAS) to display, analyze, and create images of the surveyed scene.

MSS WAVELENGTH BANDS

Channel	Wavelength Band	Color/Spectrum
1	0.38-0.42μm	Near Ultraviolet
2	0.42-0.45μm	Blue
3	0.45-0.50μm	Blue
4	0.50-0.55μm	Green
5	0.55-0.60μm	Green
6	0.60-0.65μm	Red
7	0.65-0.70μm	Red
8	0.70-0.79μm	Near Infrared
9	0.80-0.89μm	Near Infrared
10	0.92-1.10μm	Near Infrared
11	8.00-14.00μm	Thermal Infrared

MULTISPECTRAL SCANNER
IMAGING CHARACTERISTICS (SIMPLIFIED)



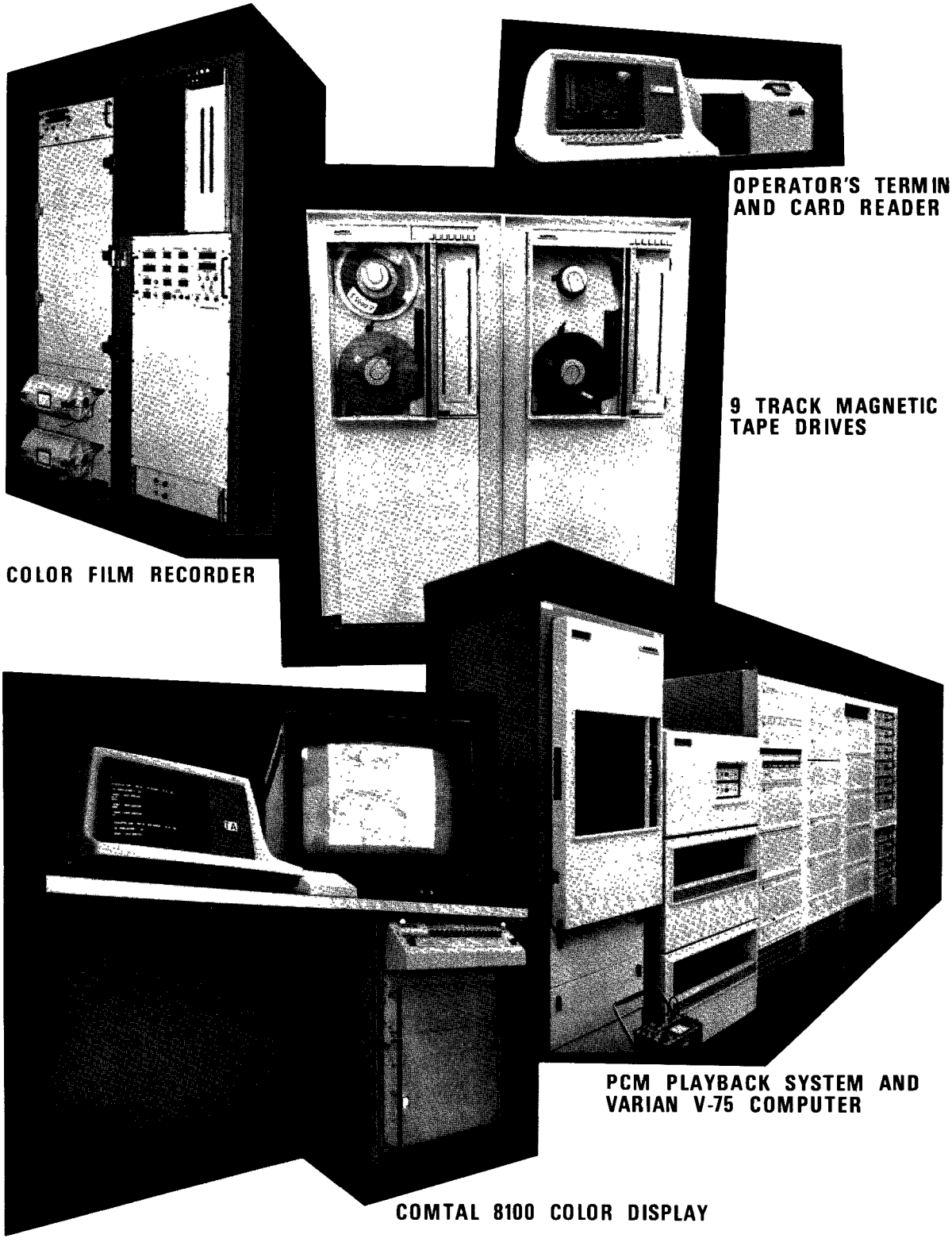
THERMAL DATA PROCESSING

For thermal mapping applications, the scanner's internal, temperature calibration reference sources (blackbodies) are used along with surface temperature measurements to develop an accurate surface temperature map. Data processing is accomplished with the Data Analysis System (DAS) (see attached figure) consisting of a sensor tape playback unit, a high speed digital computer, an interactive color display system, and an off-line color film recorder.

The Thermal Data Computer Processing diagram illustrates the steps involved in processing the scanner data. The sensor tape is reformatted to a 9-track computer compatible tape. Computations are then performed to calibrate the thermal image. Land and water areas in the imagery are separated. The water surface data are sliced into temperature levels and displayed in color. Land surfaces are displayed in shades of gray. A geometric correction is applied to the data to rectify scan line distortions. The data are output to magnetic tape and the desired film product is recorded on color film. Finally, an annotation print is generated on a printer/plotter. A color film print of the thermal image is then combined with a duplicate of the annotation print to complete the finished product.

The thermal image is essentially a temperature map. The temperature of the water surface is represented by distinct colors. The color bars establish relative temperatures in 1° C or 0.5° C increments. The ground truth reference, when provided, establishes absolute calibration. This defines the temperature within ±0.5° C tolerance for all points on the water. When ground truth is not provided, the thermal image indicates relative temperatures, with the coldest water surface in the image as 0° C.

DATA ANALYSIS SYSTEM



THERMAL DATA COMPUTER PROCESSING