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National Aeronautics and
Space Administration

Washington, D.C. 20546
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For Release IMMEDIATE

Press Kit

Project Heat Capacity Mapping Mission

RELEASE NO: 78-60

(NASA-News-Release-78-60) HCMM SATELLITE TO TAKE EARTH'S TEMPERATURE (National Aeronautics and Space Administration) 42 p CSCL 22A

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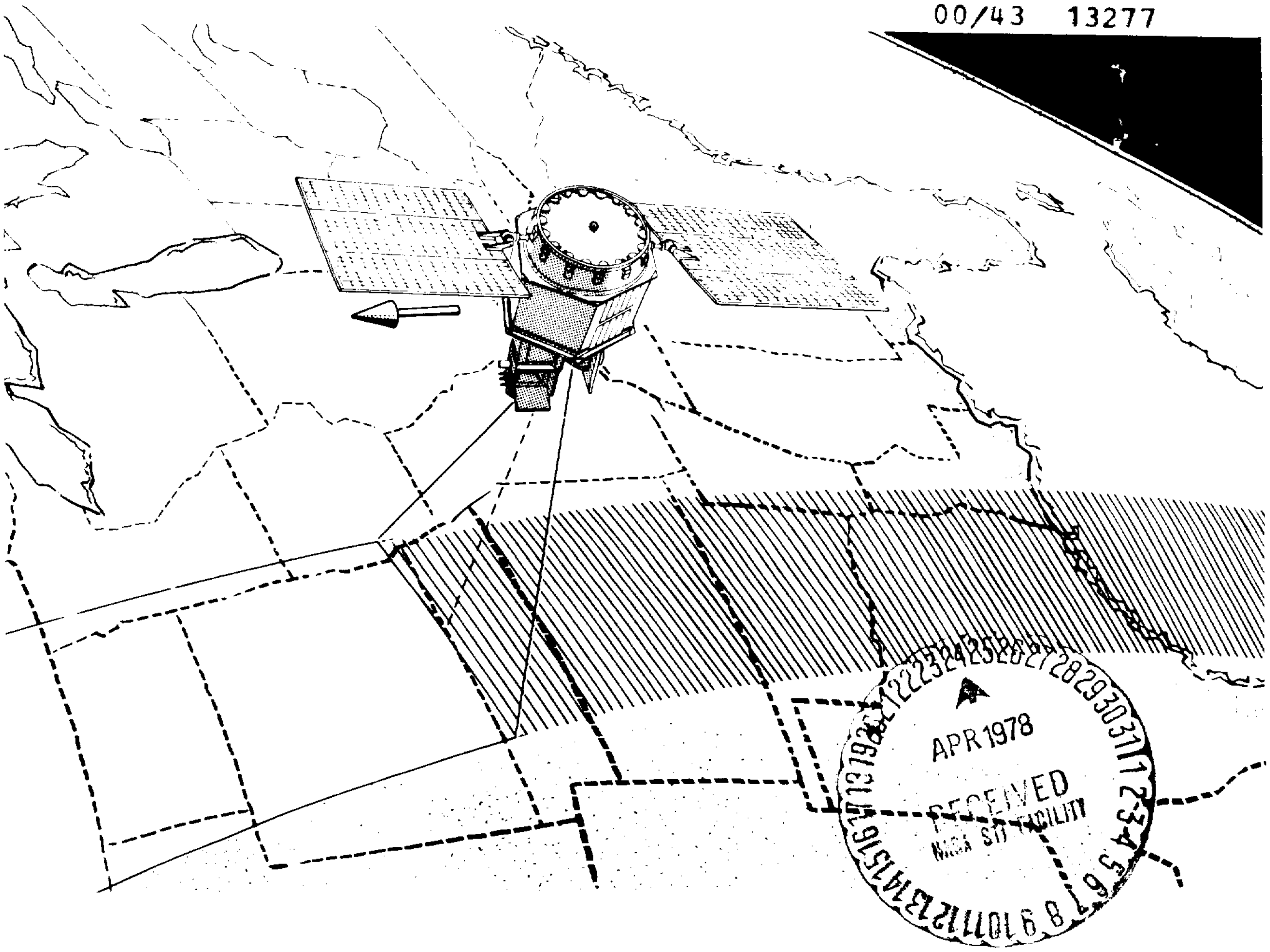

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April 20, 1978

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RELEASE NO: 78-60

HCMM SATELLITE TO TAKE EARTH'S TEMPERATURE

The first spacecraft built to test the feasibility of measuring variations in the Earth's temperature is scheduled to be launched from the Western Test Range, Vandenberg Air Force Base, Lompoc, Calif., aboard a Scout launch vehicle no earlier than April 25, 1978.

Called the Heat Capacity Mapping Mission (HCMM), this experimental satellite will travel in circular, sun-synchronous 620-kilometer (385-mile) orbit that allows for measuring mid-latitude test areas of the Earth's surface for their minimum temperatures and then measuring those same areas' maximum temperatures about 11 hours later.

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A two-channel scanning radiometer will acquire images in the visible and near infrared spectrum during the day and in the thermal infrared spectrum both day and night. Resolution of the two channels will be about 0.5 by 0.5 km (1,800 feet) as the spacecraft acquires data along a 700-km (435-mi.) wide swath.

HCMM is the first of a series of low-cost, modular-design spacecraft built for the Applications Explorer Missions (AEM) -- small experimental spacecraft in special orbits to satisfy mission-unique experimental data acquisition requirements. This mission was designed to allow scientists to determine the feasibility of using day-night thermal infrared remote sensor-derived data for:

- Discrimination of various rock types and possibly locating mineral resources.
- Measuring and monitoring surface soil moisture changes.
- Measuring plant canopy temperatures at frequent intervals to determine transpiration of water and plant stress.
- Measuring urban heat islands.

- Mapping surface temperature changes on land and water bodies.

- Deriving information from snow fields for water runoff prediction.

HCMM data will be correlated with that received from other satellites, especially from Landsat, the Earth resources spacecraft, and with ground observations, to provide a better insight into detecting temporal temperature variations of the Earth's surface.

The spacecraft is unique in that its day-night heat measurement sequence permits readings of temperature changes associated with solar heating during the daytime and radiative cooling at night. This temperature difference is related to the properties of the surface layer approximately 5-10 centimeters (2-4 inches) deep being measured. For instance, some types of rocks such as shale have a wide day-night temperature difference, while other types of rock such as quartz have a smaller day-night temperature difference.

Test sites for HCMM measurements are located in various parts of the Continental United States, Western Europe and Australia. Twelve American and 12 foreign investigators are participating in the program.

Some of the planned experiments are to:

- Discriminate among rock types and identify such features as subsurface faults or fracture not seen in the visible spectrum. For instance, some types of rock formations may emit similar radiation characteristics in the visible spectrum due to weathering erosion, or silt cover, whereas the thermal spectral band, by measuring temperature differences, may indicate structural and compositional differences.

- Survey soil moisture of cultivated areas including some with extensive irrigation. For example, wet soils have a very low temperature variation during the day-night period, while dry soils and sand reach very high temperatures during the day and become quite cold at night.

- Determine whether plants are "running temperatures" by observing the changes in temperature readings of the vegetated areas. When a plant has adequate water, its use of that water -- transpiration -- keeps it cooler than the surrounding air. A dehydrated plant exhibits a higher temperature, thus indicating plant stress.

- Map flood runoff and thermal effluents into coastal zones and the Great Lakes by measuring water temperature differences. Such data are expected to improve the monitoring from space of environmental and ecological disturbances to fresh and tidal water resources, i.e., animal, fish and plant life.

- Study "heat islands" -- concentrations of heat rising from large metropolitan areas. It is known that the higher temperatures associated with heat from cities can affect their local weather, but it is not known whether these higher temperatures can cause long-lasting changes in regional climate.

- Measure snow fields. Many areas of the country depend on melted snow for their water supplies. Other areas are threatened by floods caused by melting snow. Although snow field areas have been monitored for a number of years by Landsat and other satellites, HCMM should add improved temperature measurements to these snowmelt data and assist scientists in calculating the time and rate of snowmelt.

The HCMM is made up of two parts: (1) the instrument, the Heat Capacity Mapping Radiometer (HCMR) and its unique supporting gear; and (2) the spacecraft base module, or bus, containing the necessary data handling, power supply, communications and command and attitude control subsystems to support the instrument module.

The spacecraft bus is based on a state-of-the-art modular concept that keeps its cost relatively low, about $5 million. Its single hydrazine motor provides the spacecraft with the capability to alter its orbit altitude for experiments requiring special orbits or early engineering evaluation of mission sensors. The bus weighs about 100 kilograms (220 pounds). Its solar panels provide an orbital average power of 50 watts. A three-axis control of 1 to 2 degrees enables the satellite to keep pointed toward the Earth.

NASA's Goddard Space Flight Center, Greenbelt, Md., is responsible for the design, integration and testing of the satellite and data processing. HCMM data will be collected in real time when the satellite is within reception of the following NASA receiving stations -- Merritt Island, Fla.; Goldstone, Calif.; Fairbanks, Alaska; Orroral, Australia; Madrid, Spain; and the Goddard Center Engineering Test Center at Greenbelt.

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The base module was built by the Boeing Aerospace Co., Seattle, Wash., and the instrument by the International Telephone and Telegraph Co., Ft. Wayne, Ind.

NASA's Langley Research Center, Hampton, Va., manages the four-stage, solid fuel rocket which will place the spacecraft in orbit. Scout is built by the Vought Co., Dallas, Texas.

The launch window is 5:20 a.m. to 5:30 a.m. EST.

(END OF GENERAL RELEASE. BACKGROUND INFORMATION FOLLOWS.)

MISSION DESCRIPTION

HCMM, or the Applications Explorer Mission-A (AEM-A), spacecraft is scheduled to be launched on April 25, 1978, by a four-stage Scout-D solid fuel launch vehicle from the Western Test Range (WTR) at Vandenberg Air Force Base in California. It will be injected into near-Earth 620 kilometer, circular Sun-synchronous orbit, with a nominal 2:00 p.m. local Sun time at the ascending mode and a 97.86 degree inclination. An orbit adjust motor is provided for proper circularization of the orbit. The spacecraft is stabilized in three axes so that the instrument is Earth pointing. The expected useful lifetime of the spacecraft is one year from launch.

The orbit for the HCMM will permit the measurement of near maximum and minimum surface temperatures occurring during the diurnal cycle which is about 1:30 p.m. and 2:30 a.m. in the middle northern latitudes. This orbit will also allow for reflectence measurements during daytime passes. From the nominal orbit altitude of 620 km (385 mi.) the spatial resolution of the visible and thermal infrared radiometer channels will be approximately 500 by 500 meters (1,840 by 1,840 feet). The ground swath of data coverage along the track will be 700 km (435 mi.) wide as shown in Figure 1.

The nearly polar Sun synchronous HCMM orbit will cover every area of the Earth's surface between 85 degrees north latitude and 85 degrees south at least once during the day and once during the night within a 16-day interval. Both day and night passes over selected areas within 12 hours will repeat at 5- or 16-day intervals, depending on the latitudes of the areas. The areas between 20 degrees and 32 degrees latitude (north and south) will receive only 36-hour day/night coverage (Figure 2).

The objective of the AEM-A (HCMM) mission is the acquisition of visible and infrared (IR) images at a scale of 1:4,000,000 (approximately 23 cm^2 for 700 km^2 frame) for investigations in geology, plant stress, soil moisture and hydrology. Heat capacity, or the ability to retain heat (technically "thermal inertia"), will be estimated from the satellite measurements. It is known that low-heat capacities (high day/night temperature difference) are characteristic of certain rock types such as shale and dry soils, while high-heat capacities (low day/night temperature difference) are characteristic of other rock types such as quartz and wet soils.

Figure 1

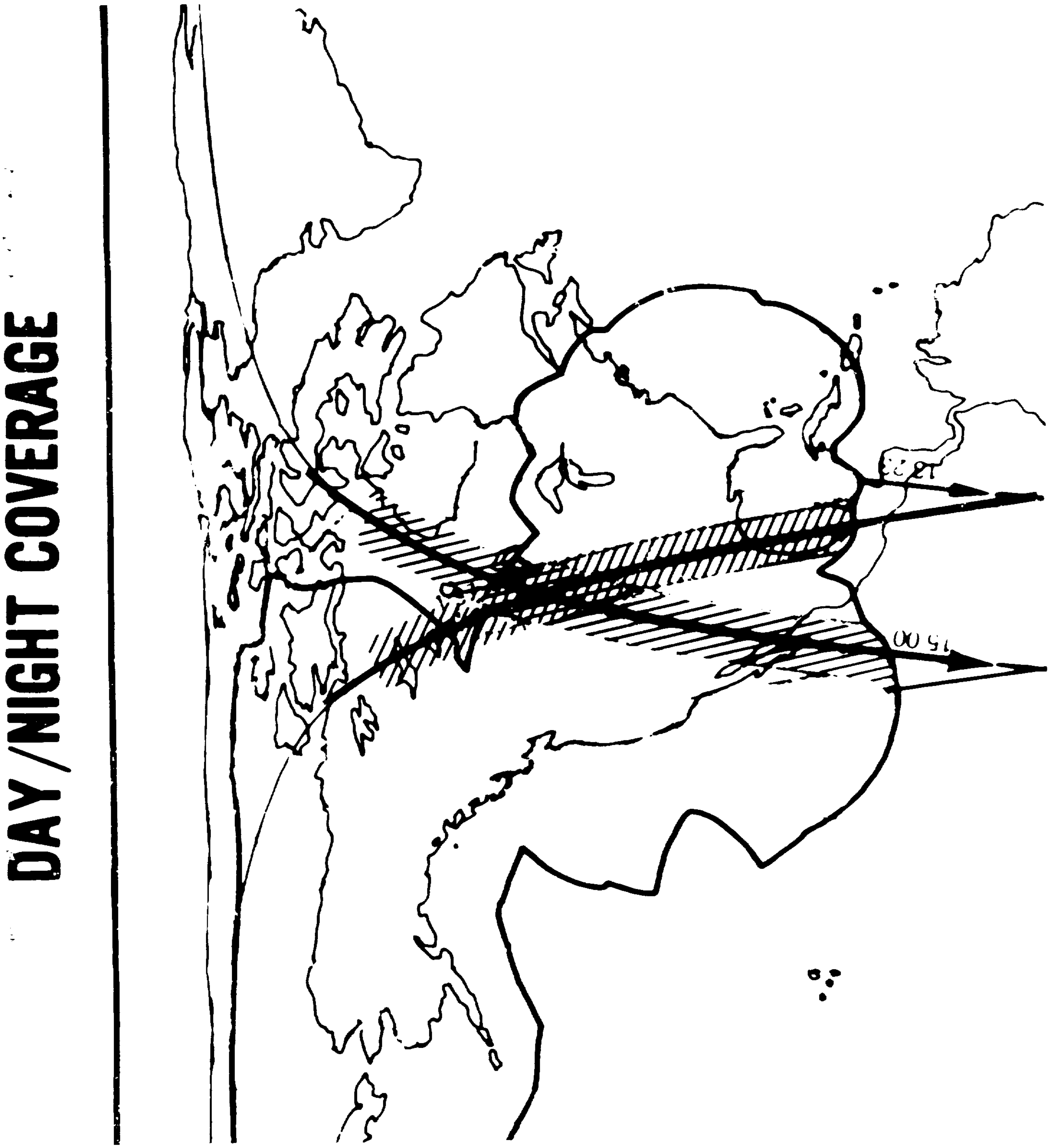
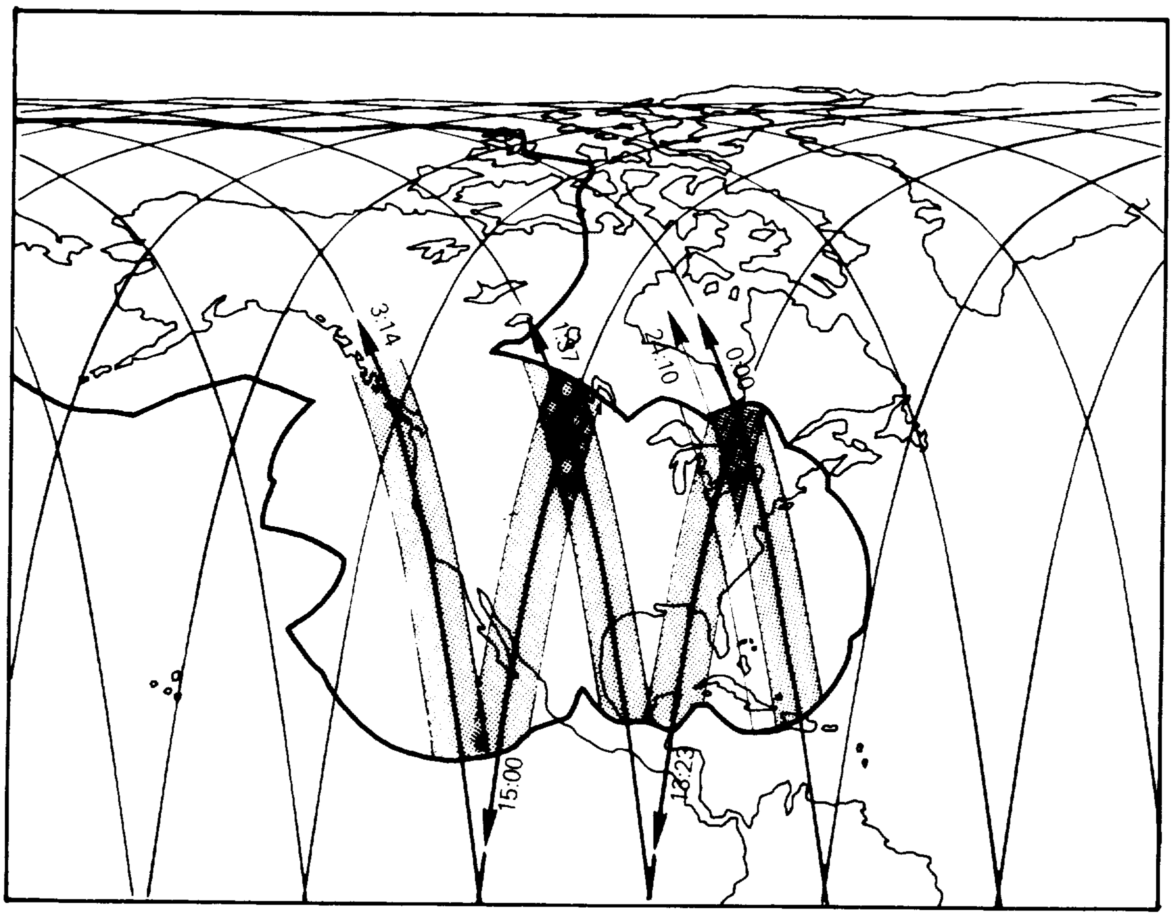


Figure 2



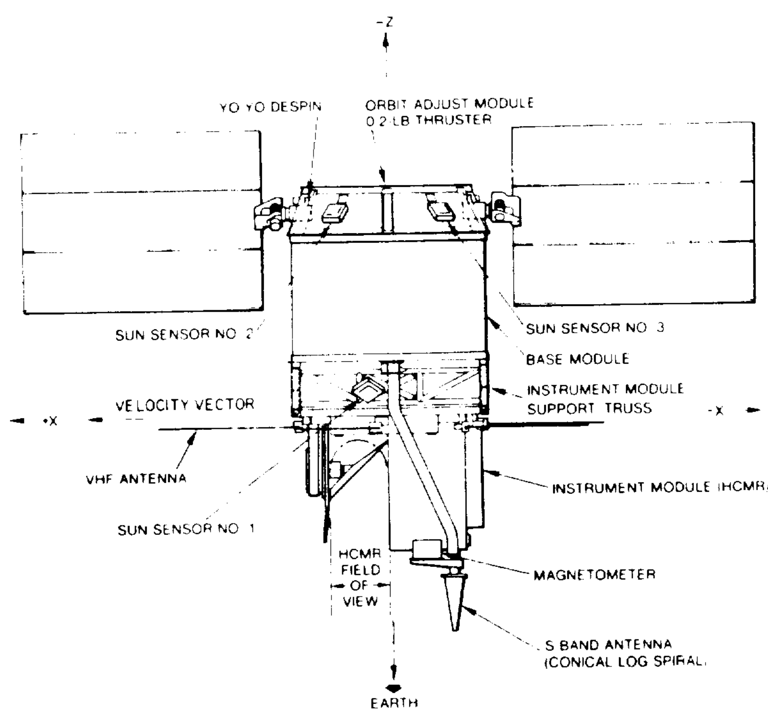
ELAPSED TIME SHOWN IN HOURS AND MINUTES FOR 35°N. LAT. CROSSING

HCMM Typical Coverage

THE SPACECRAFT

General

The HCMM (AEM-A) is a small, versatile, low-cost type spacecraft which uses three-axis stabilization for the Earth-viewing instruments carried by it. The spacecraft structure primarily consists of two major components: a base module which contains the necessary attitude control, data handling, communications, command and power subsystems for the instrument module, and an instrument module containing the HCMR and its supporting equipment. Two solar paddles are mounted on the spacecraft structure along the velocity vector. A yo-yo despin system is located on the base module cone section and below the solar array. Despin is accomplished by the transfer of some or all of the spacecraft's angular momentum into increased momentum of the yo-yo weights and cables (shown on Figure 3). Weight release will be initiated by the spacecraft timer soon after the fourth-stage burnout. Listed below are the weights, physical description and pertinent parameters of the spacecraft.



ORBITAL CONFIGURATION

Figure 3

Shape	Six-sided prism
Height	
Base module	63.5 cm (25 in.)
Overall height including antenna	161.85 cm (63.7 in.)
Weight	
Base module and adapter	97.8 kg (215.6 lb.)
Instrument module	36.5 kg (80.5 lb.)
Spacecraft total	134.3 kg (296.1 lb.)

<u>Power Dissipation</u>

Base module operating	50 W Operates about 20 min/orbit
Instrument module operating	22 W
Base module standby	25 W
Instrument module standby	25 W
<u>Orbit Adjust System</u>	Hydrazine, ΔV 259 ft/sec

<u>Attitude Control</u>

Despin	Yo-yo system
Three-axis stabilization	Active reaction wheel magnetic torquing system

<u>Command and Data Handling</u>

Telemetry	
PCM 136 MHz, 100 percent duty	1024 or 8192 bits/sec
S-band 2248 MHz, 25 per cent duty	480 ± 80 kHz subcarrier 800 ± 80 kHz subcarrier 70 ± 7.5 kHz subcarrier
Command	149 MHz, 600 bits/sec

A picture of the flight spacecraft with the solar panels folded in the launch configuration is shown in Figure 4.

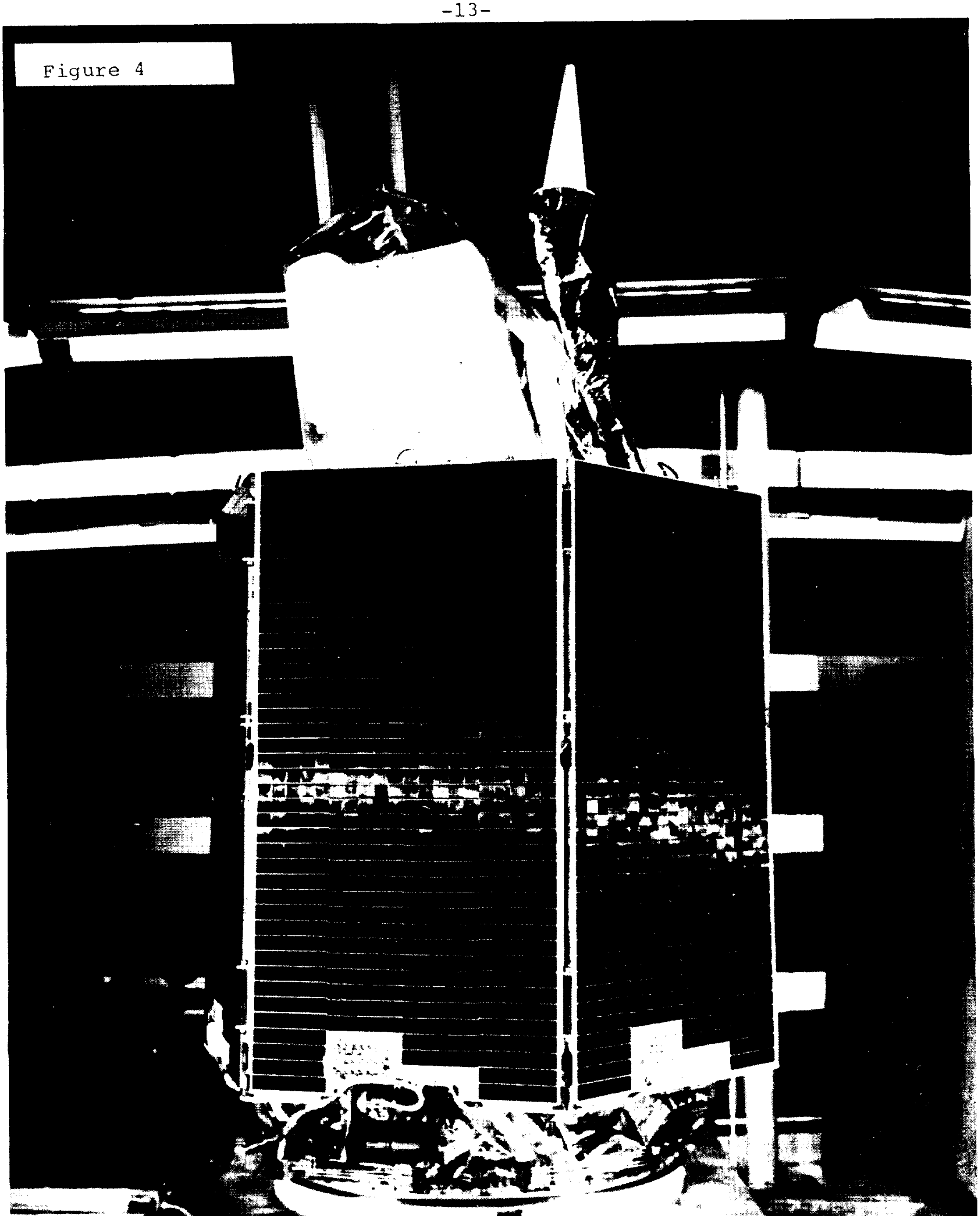


Figure 4

PAYLOAD

The instrument module is located on the spacecraft so that the Heat Capacity Mapping Radiometer (HCMR) is Earth pointing. An optical diagram for the HCMR is shown in Figure 5.

The basic radiometer instrument is a modified spare Surface Composition Mapping Radiometer similar to that flown on Nimbus 5. The HCMR will have a small geometric field of view (less than 1 by 1 milliradians), high radiometric accuracy and a wide enough swath coverage on the ground so that selected areas are covered within the 12-hour period corresponding to the maximum and minimum of temperature observed.

The instrument will operate in two channels, at approximately 0.5 to 1.1 micrometers (visible and near IR) and 10.5 and 12.5 micrometers (IR), providing measurements of reflected solar energy and equivalent black-body temperature.

It is planned that the spatial resolution of both channels will be 500 by 500 m (1,840 by 1,840 ft.) at nadir with registration between channels to 0.2 resolution elements. A summary of the principal parameters are listed below:

Heat Capacity Mapping Radiometer Summary

Orbital Altitude	620 km (nominal)
Angular Resolution	0.83 milliradians
Resolution	500 by 500 m at nadir
Scan Angle	60 degrees (full angle)
Scan Rate	14 revolutions/second
Scan Period	0.07 seconds/revolution
Sample Rate	One sample/resolution element
Sampling Interval	9.2 microseconds
Swath Width	700 km

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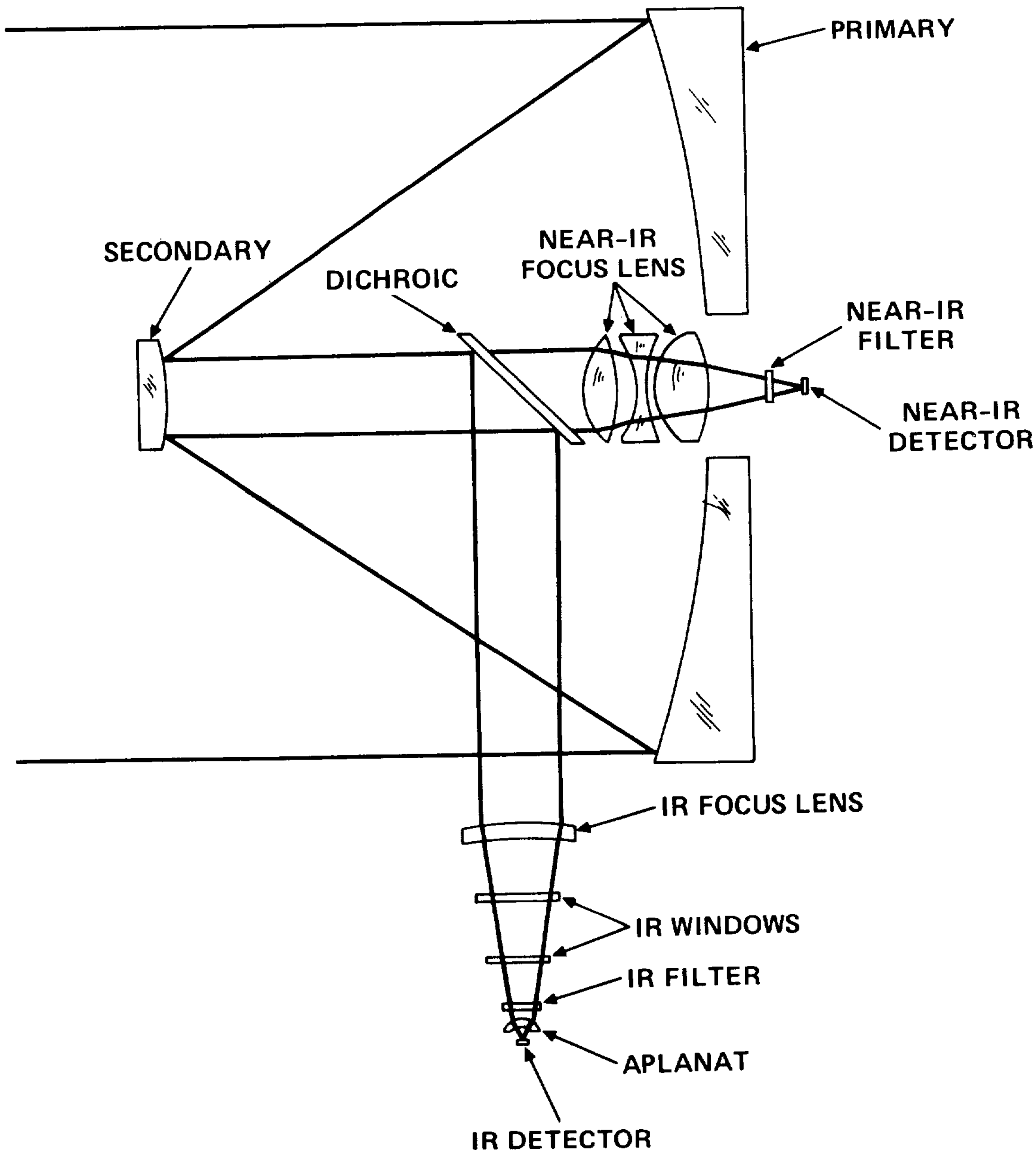
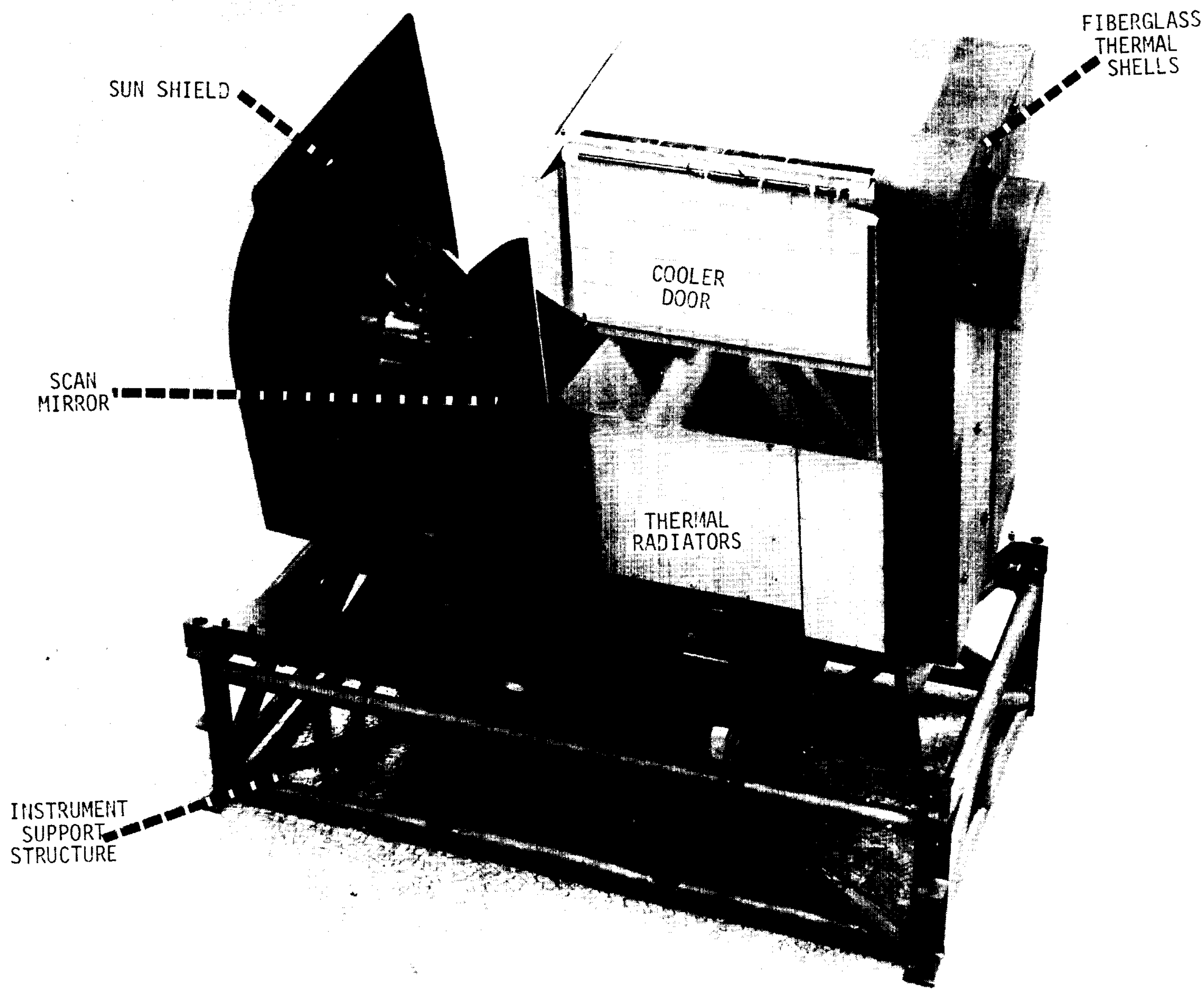
Figure 5



Optical Diagram for HCMR

Data Rate	105 kHz
Thermal IR Channel	10.5 to 12.5 micrometers
Visible and Near IR Channel	0.5 to 1.1 micrometers
Scan Mirror	45 degree elliptical flat
Nominal Telescope Optics Diameter	20 cm
View Ports	Clear view downward to one side
Calibration	View of dark space and seven-step staircase electronic calibration plus blackbody calibration once each scan

The HCMR is composed of four major subassemblies mounted in a common housing (Figure 6). These subassemblies are scan mirror and drive, optics, electronics and radiant cooler. The scan mirror drive assembly provides a cross-course scanning of the instantaneous field of view with reference to the subsatellite ground track. The optical subassembly provides increased ground resolution and spectral definition of the three channels. The electronics subassembly contains the data amplifiers and housekeeping telemetry; it formats the analog sensor data such that it is compatible with the HCMR data system. The radiant cooler subassembly provides detector operating temperatures of approximately 115 degrees K.



HEAT CAPACITY MAPPING MISSION
INSTRUMENT MODULE

Figure 6

SPACECRAFT ACTIVATION

The HCMM (AEM-A) spacecraft will be launched with only the power supplies, command and telemetry subsystem operating. When spacecraft separation has occurred about 10.5 minutes after launch, it is despun by a yo-yo system consisting of a pair of weights, cables and release mechanisms located at diametrically opposed facets, to maintain balance torques during despin. Weight release is initiated by a separation switch activated timer on board the spacecraft. Despin is accomplished by the transfer of some of the spacecraft angular momentum into the yo-yo system weights and wires. Despin is to 1 rev/min.

Approximately 10 seconds after despin is initiated, the solar arrays are deployed to a pre-fixed angle. The spacecraft begins stabilization operations, and up to five orbits may be required to enable it to stabilize in three-axes with the original spin axis aligned along the local vertical. Depending on the initial orbit achieved, orbit injection errors will be removed through a series of maneuvers, beginning, at the earliest, 12 hours after injection. This will be accomplished by firing the orbit adjust subsystem to change the perigee and/or apogee. Orbit injection error removal may require a series of orbit adjusts for a period of approximately two weeks.

The orbit parameters for the HCMM mission are as follows:

Circular orbit	620 km (385 mi.)
Orbit period	97.2 minutes
Sunsynchronous	2 PM ascending mode
Inclination	98.87 degrees

LAUNCH VEHICLE

The Scout launch vehicle is the smallest of the launch vehicles and was designed to provide a reliable and relatively inexpensive launch vehicle for small payloads. The launch vehicle has four stages, is 22.86 m (75 ft.) in length (less the spacecraft) and has a maximum diameter of 1.01 m (3.3 ft.) at its widest cross section. The Scout is the only U.S. launch vehicle which uses solid propellants exclusively. The Scout launch vehicle characteristics are listed in Table 1 and an outline drawing is shown in Figure 7.

Table 1
Characteristics of the Scout Launch Vehicle

Item	First Stage	Second Stage	Third Stage	Fourth Stage
Name	Algol IIIA	Castor IIA	Antares IIA	FW-4S Altair IIIA
Impulse (newtons/sec)	32,142,784	10,304,114	3,257,937	762,972
Fuel type	Solid	Solid	Solid	Solid
Fuel weight (kg)	12,684	3762	1161	275
Gross weight (kg)	14,175	4433	1272	301
Guidance	Aerodynamic tip and jet vane control surfaces	H_2C_2 reaction jets	H_2O_2 reaction jets	Unguided, spin stabilized
Tracking aids	Radar beacon*	Radar beacon*	Radar beacon*	—
Telemetry	S-band IRIG**	S-band IRIG**	S-band IRIG**	Spacecraft system***

Notes:

*Tracking is available up to ignition of fourth stage using a 500-watt, single-telemetry pulse radar beacon on the launch vehicle third stage.

**Launch vehicle telemetry system is standard IRIG PAM/FM/FM at frequency of 2200 to 2300 MHz.

***Fourth-stage parameters telemetered through spacecraft VHF telemetry link.

The propulsion motors are arranged in tandem with transition sections between the stages to tie the structure together and to provide space for instrumentation.

The launch vehicle is guided from launch through third-stage burnout by a three-axis gyro reference system. Yaw and roll orientation are maintained about an initial reference established at launch. Pitch orientation is changed during flight by a series of commands timed from launch to follow the zero lift or gravity turn trajectory.

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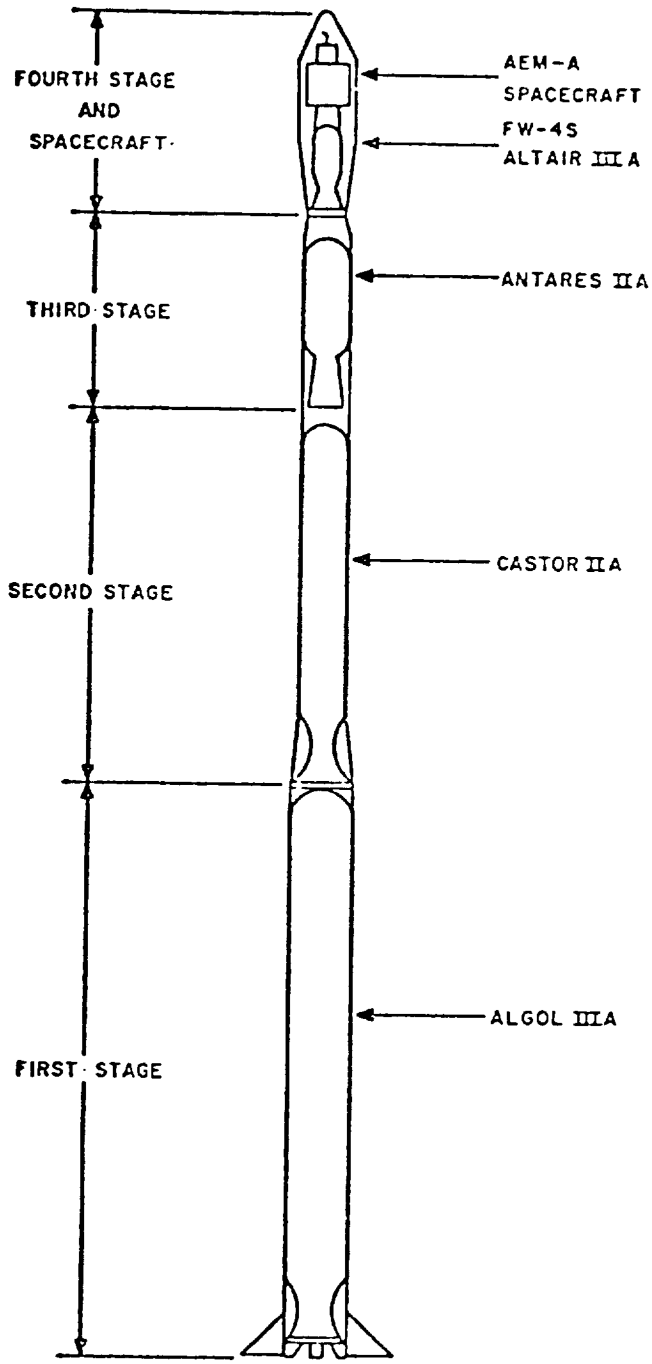

Figure 7 Scout-D Launch Vehicle

Yaw orientation can be changed during flight to obtain correct orbit inclination. Control during the first-stage boost is provided by jet vanes and aerodynamic fin tips.

Following burnout of the third-stage motor, the third stage spins up the fourth stage/spacecraft combination to 170 $\pm$ 20 rev/min prior to the third stage separation.

The third stage separation actuates two switches located in the fourth stage for the timing of burns, and the fourth stage ignition occurs shortly after third stage separation. The fourth stage is retained for a period of time after primary burnout to allow for small, residual burning (approximately 300 $\pm$ 20 seconds after third stage separation.) The spacecraft base module then provides the timing and electrical impulses needed to actuate the pyrotechnic separation bolt cutters. The planned sequence of launch events that will occur from liftoff through vehicle/spacecraft separation is listed in Table 2. The mission ground track is shown in Figure 8.

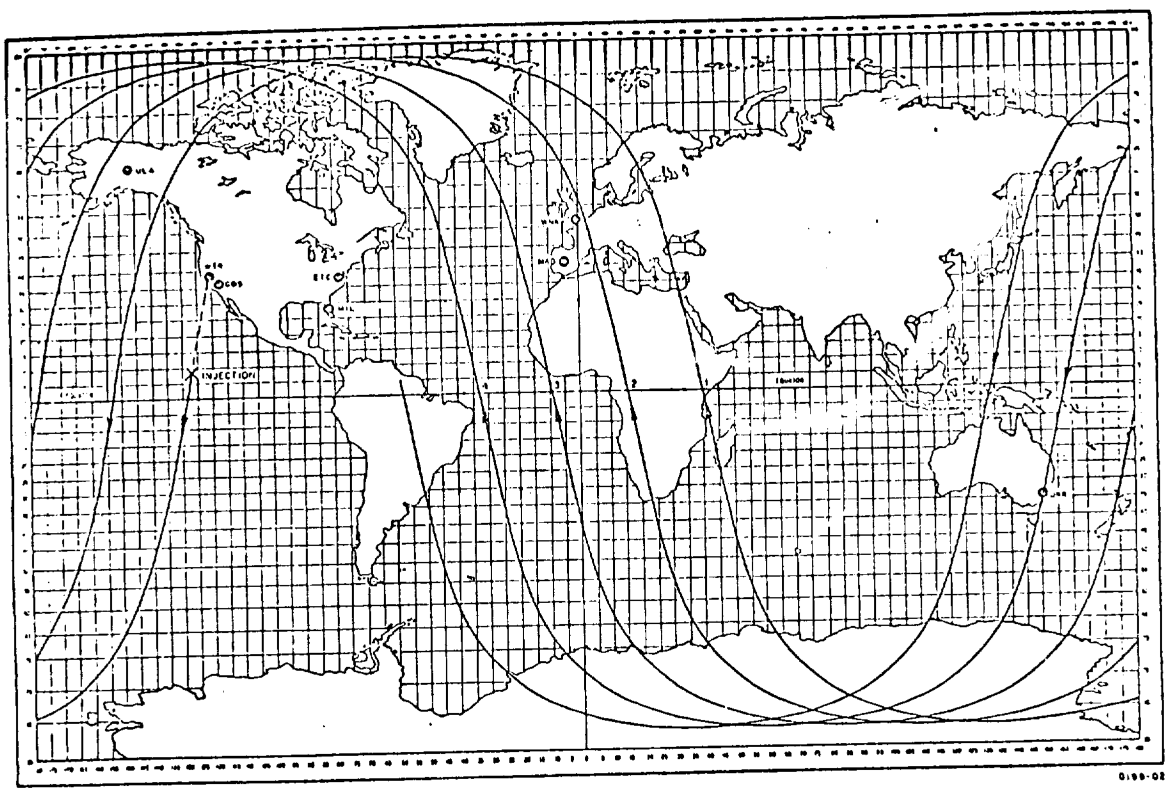

Figure 8 HCMM Ground Track

LAUNCH SEQUENCE FOR SCOUT/HCMM

Event	Time		Altitude		Range		Velocity	
	Min.	Sec.	Miles	KM	Miles	KM	MPH	KM/HR
Liftoff	00	00	0.05	0.08	0.00	0	0	0
First engine cutoff	01	23	25.11	40.41	23.58	37.95	2983	4800
First stage separation	01	28	27.44	44.16	26.73	43.02	2920	4699
Second stage ignition								
Second stage cutoff	02	06	53.32	85.81	70.61	113.63	7337	11806
Heat shield ejection	02	31	75.80	121.99	115.23	185.44	7098	11423
Third stage ignition	02	33	77.22	124.27	118.27	190.34	7082	11397
Third stage cutoff	03	06	113.07	181.97	201.10	323.64	12406	19966
Fourth stage spinup	09	49						
Third stage separation	09	51						
Fourth stage ignition	09	55	385.93	621.09	1383.03	2225.77	10748	17297
Fourth stage cutoff	10	29	386.14	621.43	1504.90	2421.90	16883	27170

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DATA COLLECTION AND PROCESSING

After spacecraft stabilization -- about two weeks -- HCMM data will be collected in real time when the satellete is within reception range (figure 9) of the NASA receiving station located at Fairbanks, Alaska; Goldstone, Calif.; engineering Test Center at Goddard Space Flight Center, Greenbelt, Md; Merritt Island, Fla.; Madrid, Spain; and Orroral, Australia. These stations will receive, record, discriminate, decode, and decommutate telemetry data and transmit these data in real time to GSFC for spacecraft health and performance evaluation. The real-time HCMR S-band (analog) data will be recorded on tape and shipped to GSFC (usually by air) for data processing.

Minitrack tracking support will be provided by Orroral, Australia, and Winkfield, England, and the data transmitted to GSFC for orbit computations. Command of the spacecraft can be either by real time or from the stored command memory from the GSFC control center.

After the S-band analog HCMR tapes arrive at the Goddard Space Flight Center, the first phase of data processing will involve the calibration of the data. The instrument will be calibrated before launch and monitored during its lifetime with an onboard black-body temperature reference. The visible channel data will be reduced to reflected energy and digitized.

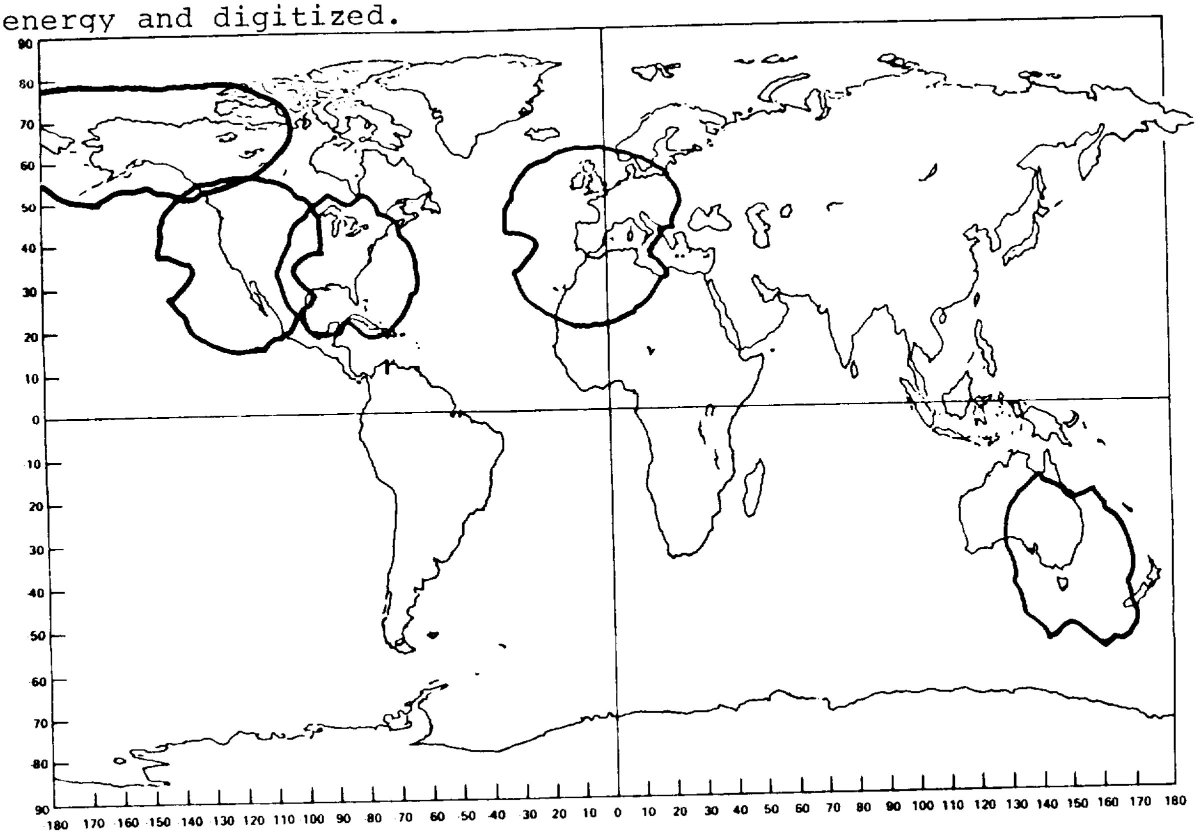

Figure 9. HCMM Tracking Station Data Acquisition Circles

The thermal infrared channel will be calibrated to radiance by using space viewing as a cold reference and an on-board black body at approximately 300°K as a hot reference. Data digitized in units of energy to eight bits equivalent to a temperature range to 260 degrees to 340 degrees K.

All data will be processed to maximum geometric fidelity by taking into account satellite orbit and attitude information. Geographic referencing of the data will be accomplished using information from the satellite ephemeris and attitude tapes. Because resampling of data to a standard grid tends to degrade slightly the accuracy of the radiance values, unresampled data will also be available in digital format.

During the initial phase of the mission, the preprocessed data will be fed directly to high resolution film recorders and an image data recording system for quick-look evaluation.

The second phase of data processing deals with the registration of day and night thermal infrared data. Data registration will be achieved by inspection of day and night thermal imagery of selected areas for identification of features such as shorelines, lakes, rivers, cities, and significant topography. Following identification of such features, a digital procedure will be used to define more precisely the offsets between corresponding day and night representations of these features. Following computation of a number of tiepoints, the night thermal images will be remapped to overlay day images. These remapped images will also be available in digital tape format.

The registered day and night thermal infrared data will be archived at the Goddard Space Flight Center and used to produced day/night temperature difference data in both image and digital computer tape format.

The production of thermal inertia image data is the last phase of data processing. This will be accomplished by applying an algorithm to the registered day-night thermal infrared data for the production of a simulated depiction of thermal inertia as an indicator of geologic features or soil moisture.

Processed data from the HCMM will be available in three formats.

- Black-and-white imagery as 241 mm prints or transparencies at a scale of 1:4,000,000.
- Computer compatible tapes (CCTs) of calibrated and geometrically corrected data.
- Computer compatible tapes of calibrated but geometrically uncorrected data.

Figure 10 provides a functional overview of the data collection and control center systems. A further expansion of the HCMR data processing in GSFC Image Processing Facility is shown in Figure 11.

HCMM FUNCTIONAL OVERVIEW

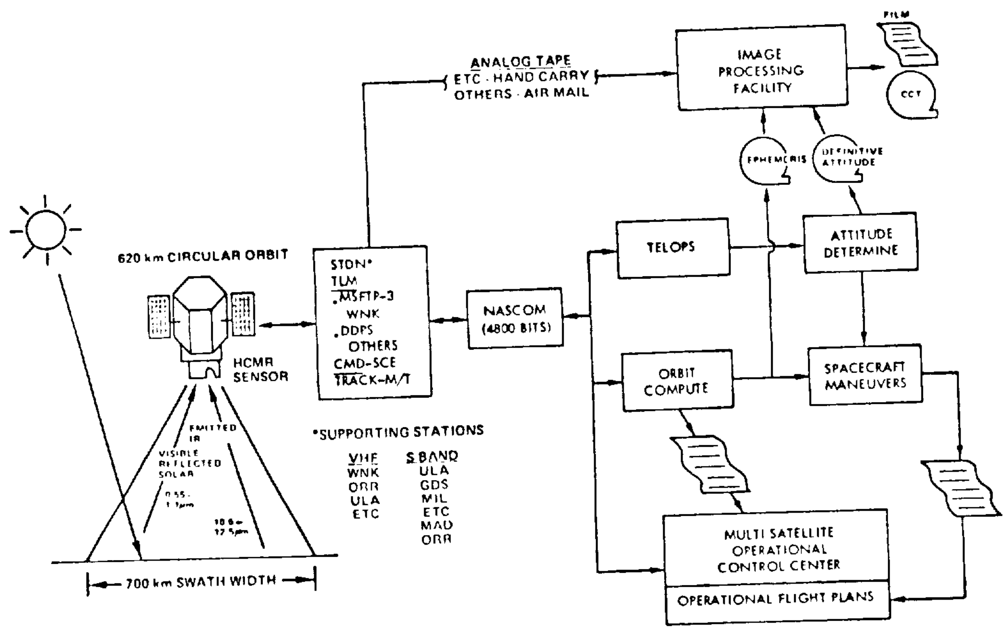

Figure 10.

HCMR DATA PROCESSING SYSTEM
IN THE IMAGE PROCESSING FACILITY

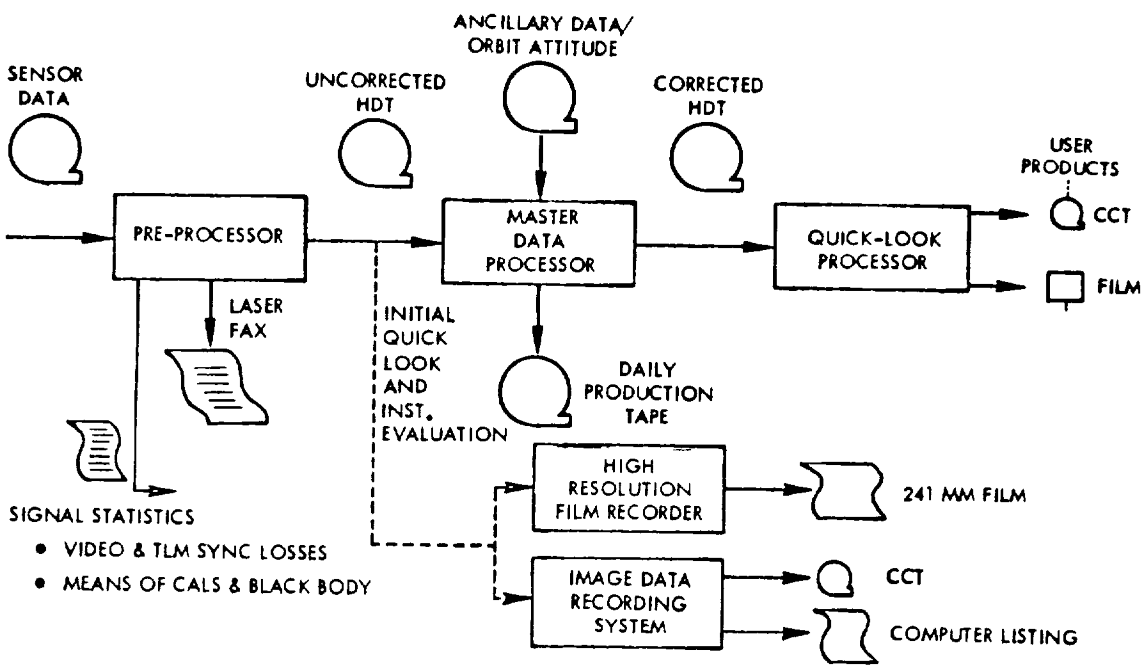

Figure 11.

HCMM INVESTIGATIONS

Following a NASA Announcement of Opportunity April 14, 1975, a number of investigators were selected to conduct experiments using the HCMR data. The selected investigators represent both U.S. and foreign government agencies, universities and industry.

The 12 U.S. investigations are as follows:

Applications of HCMM Satellite Data to the Study of Urban Heating Patterns

Principal investigator is Dr. Toby N. Carlson, Department of Meteorology, Pennsylvania State University, University Park, Pa.

The objective of the experiment is to utilize data from HCMR as input to mesoscale wind model to study urban heat islands. The approach used will be to develop a surface heat flux model suitable for use in atmospheric prediction schemes, acquire satellite and aircraft data to study the patterns of surface heating in urban areas and measure surface albedo, evaporative potential and thermal inertia as inputs for the model.

Anticipated results will be made available for further studies in urban meteorology. Test sites are located in Los Angeles, Calif.; St. Louis, Mo.; Houston, Texas; and Washington, D.C.

Freeze Damage Assessment, Planting Date Advisory and Evapotranspiration

Principal investigator is Dr. Craig L. Wiegand, U.S. Department of Agriculture-ARS, Weslaco, Texas.

The objectives of the experiment are to use optimum day and night HCMM data for freeze damage assessment, planting data advisory and evapotranspiration. Analysis will be made of HCMM data in relation to ground truth and aircraft-obtained data. Continuous measurements of solar radiation, total hemispherical radiation, wind movements, air temperature, vapor pressure and soil temperature in wet and dry plots will be obtained.

Anticipated results are to identify areas of least freeze hazard for growing temperature-sensitive crops, maximize harvestable yield from freeze-damaged crops, assess freeze damage to citrus relative to HCMM data, relate HCMM temperature versus soil water depletion and days since irrigation, determine whether canopy temperature differs characteristically among crops and relate nighttime soil temperature to major soil texture variations over the Rio Grande Valley. Test site is located in Texas.

Remote Detection of Soil Moisture Using Data From HCMM

Principal investigator is Dr. Ray D. Jackson* U.S. Department of Agriculture-ARS, Water Conservation Laboratory, Phoenix, Ariz.

Objectives are to demonstrate the usefulness of soil temperature and albedo data measured from a space platform in assessing soil moisture over large areas for the purpose of improving agricultural resources management practices.

The approach is to use multilevel sampling to evaluate the feasibility of transferring ground proven methods for measuring soil moisture to spacecraft use. Ground truth and airborne measurements of reflected sunlight and infrared radiances will provide the basis for interpreting the spacecraft data.

Anticipated results are to demonstrate the ability to detect and monitor soil moisture from space, and maps of soil moisture and soil temperature. Test site is located in California.

Data Use Investigations for Applications Explorer Mission-A

Principal investigator is John R. Schott, Calspan Corp., Buffalo, N.Y.

Objectives are to study the thermal properties of the Great Lakes as they relate to water quality, lake hydrology and energy exchange; study urban heat islands (Buffalo, Rochester and Syracuse).

Approach is to relate remotely sensed water quality data to the thermal properties of water by examining in spring and fall the thermal bars on the lakes which form between the warm, nutrient rich inshore waters and the cold mid-lake water, and to use day and night HCMM data to detect and map the extent and magnitude of the heat islands.

Anticipated results are to determine: if the quality of surface water is significantly affected by solar heating; to what extent quality has an effect on solar heating; and, whether inertia properties and the use of thermal properties assist in mapping hydrologic conditions and to study the effects of current and upwelling conditions on the lakes' trophic state; to map the physical structure of the city (heat island) and to use HCMM data to aid in studying the factors that lead to the formation of the heat islands and the factors that help to alleviate its effects. The test site is the Great Lakes.

Geological and Geothermal Data Use Investigations for Application Explorer Mission-A

Principal investigator is Prof. Ronald J. P. Lyon,* Department of Applied Earth Science, Stanford University, Stanford, Calif.

Objectives are to investigate the type and complexity of thermal models needed for remote sensing of rock and soil parameters and to develop the capability thereby to utilize airborne (U-2) and satellite (HCMM) thermal data for these purposes; to conduct field measurement programs at test sites to test the validity of those thermal models; and to relate the overflight data over test sites to localized calibration sites at these localities.

Approach: Landsat/U-2 and HCMM data will be used in conjunction with each other to use the thermal parameters related to rock density to devise a clear discrimination between terrain with altered, clay-bearing rocks stained with ferric oxides derived from sulfides and volcanics with ferric oxide coatings derived from magnetite.

Anticipated results are to better discriminate rock types for better mineral exploration searches. Test site is located in Nevada.

Geologic Applications of Thermal Inertia Mapping From Satellite

Principal investigator is Terry W. Offield,* U.S. Geological Survey, U.S. Department of the Interior.

Objectives are thermal mapping for discrimination of geologic units and energy or mineral resource areas and evaluation of thermal modeling and satellite mapping techniques.

Approach: The thermal model to be developed will consider the effects of topography using digital topographic information. Satellite and aircraft measurements will be compared to evaluate the effects of scale and resolution versus topography at different scales.

Anticipated results: a refined thermal model; establish techniques for producing thermal inertia maps, evaluation of thermal inertia data for detecting soil moisture variations, rock types and alteration areas, and geothermal energy areas. Test sites are located in eastern Wyoming and southwestern Arizona.

<u>Geologic Application of Thermal Inertia Imaging Using HCMM Data</u>

Principal investigator is Dr. Anne B. Kahle,* Jet Propulsion Laboratory, Pasadena, Calif.

Objective is the investigation of the feasibility of using thermal inertia inferred from remotely sensed temperature data to complement Landsat reflectivity data for reconnaissance geologic mapping and mineral exploration.

Approach will be day and nighttime thermal images, as well as daytime reflectance data from HCMM used in conjunction with surface meteorological information as applied to the JPL thermal model to construct thermal inertia images and maps of three test sites in the western United States.

Anticipated results are to demonstrate the utility of thermal data, thermal inertia data and the combination of thermal and reflective MSS data for lithologic mapping and mineral exploration. Test sites are located in Pisgah, Calif.; Walker Lane, Nev.; and Death Valley, Calif.

<u>HCMM Energy Budget Data as a Model Input for Assessing Regions of High Potential Groundwater Pollution</u>

Principal investigator is Dr. Donald G. Moore,* Remote Sensing Institute, South Dakota State University, Brookings, S.D.

Objective is the development of a remote sensing method for rapid and accurate detection and monitoring of regions with shallow water tables which are susceptable to groundwater contamination.

Approach: Ten "intensive" test sites will be selected on the basis of water table depth, aquifer thickness, groundwater flow rate and landuse. Soil temperatures will be measured with thermocouples and data related to HCMM, Landsat and aircraft information.

Anticipated results: Thermal inertia, temperature, albedo information will be used to predict water table depths and other aquifer properties which can be used to locate regions having a high potential for groundwater contamination. Test site is located in eastern South Dakota.

Investigation of Methods to Use HCMM Thermal Data in Snow

Hydrology Programs

Principal investigator is James C. Barnes,* Environmental Research and Technology, Inc.

Objectives are to determine the capability of HCMM thermal data to provide accurate measurements of the distribution and surface temperature of snow cover; determine how the HCMM measurement can be incorporated with visible data into a snow hydrology program related directly to snowmelt runoff prediction; and develop an approach toward an automated data processing for snow hydrology.

The approach is to correlate HCMM data to ground truth and other data using methods similar to those used by the ERT scientists in previous studies.

Anticipated results are development of improved techniques for mapping and analyzing snow cover using spacecraft acquired data. Test sites are located in the Sierra Nevada, Calif.; Salt Verde, Ariz.; Cascades, Wash.; Columbia Basin, Idaho; and upper Mississippi-Missouri River Basin.

Applications of HCMM Data to Soil Moisture, Snow and

Estuarine Current Studies

Principal investigator is Donald R. Wiesnet,*National Oceanic and Atmospheric Administration, National Environmental Satellite Service, Environmental Sciences Group.

Objectives are to chart tidal currents in estuaries, thermal inertia, soil moisture measurements/thermal emission of snow.

The approach will be comparison of HCMM data analyses with ground truth.

Anticipated results will be synoptic tidal current charts; evaluation of contamination of thermal signature of snow by forest cover in winter and by type of tree. Test sites are the Potomac River, Md.; Cooper River, S.C.; Cranberry Lake, N.Y.; and Luverne, Minn.

Plant Canopy Temperature and Soil Moisture Experiment

Principal investigator is Dr. J. C. Harlan, Remote Sensing Center, Texas A & M University, Prairie View, Texas.

Objective is to demonstrate the feasibility of utilizing HCMM derived plant canopy temperature and soil moisture data as a measure of cultivated crop condition in ungaged dryland farming areas where temperature and precipitation measurement do not exist.

The approach is to use HCMM data processing to determine mean and variance for large delineated areas followed by multiple regression analysis against ground truth to provide correlation information towards creation of inputs to crop production models.

Anticipated results: The reliability of HCMM derived parameters will be determined. Test sites are located in Oklahoma and Kansas.

Soil Moisture in Relation to Geologic Structure and Lithology in Northern California

Principal investigator is Dr. Ernest I. Rich, Stanford University, Stanford, Calif.

Objectives are to identify rock types via seasonal thermal changes, identify linear features buried under alluvial fill and to determine the optimum time of year to record geothermal heat. Approach: HCMM data will be compared to Landsat and aircraft data. Seasonal recognition criteria will be established and criteria will be translated to other regions in northern California.

Anticipated results: Aid to mineral exploration in deverse climate, topography and geologic settings, establish rock type recognition criteria. Test site is located in northern California.

The 12 foreign investigations are as follows:

Investigation Using Data From HCMM

Principal investigator is Dr. P. Y. Deschamps, Group De Recherches D'Oceanographie Spatiale, University de Lille, France.

Objectives are to map the various thermal gradients in the Coastal Zone of France in relation with natural phenomena (upwellings estuaries) and manmade thermal effluents; study the tidal gradients appearing in the English Channel using both HCMM and NOAA-VHRR; contribute in the modeling of diurnal heating of sea surface temperature and its influences on the thermal strafication of the oceanic surface layer.

Approach: VHRR data, A/C radiometer and surface measurements will be utilized to assess the improvements of HCMM data in terms of spatial resolution, temperature accuracy and calibration. HCMM data will be used to study the evaluation of thermal gradients in estuaries, mesoscale circulation in the Golfe du Lion, tidal gradients in the English Channel and diurnal heating of sea surface.

Anticipated results: maps of the evolution of thermal gradients generated by three main estuaries will be produced. The possible effect on ecosystems of a probable increase in temperature due to new power plants will be assessed. Maps of the mesoscale circulation in the Golfe du Lion in relation to upwellings generated by strong coastal winds will be produced to help in planning of future tidal power plants. Test sites are located in the Atlantic Coast of France and Golfe du Lion.

Investigation Using Data From HCMM

Principal investigator is Dr. Jean-Yves Scanvic, Bureau de Recherches Geologiques et Minieres, Orleans, France.

Objectives are to investigate the existence of regional thermal anomalies related to different magmatic areas; the ability of spatial thermal images to discriminate limestones from dolomites and to discriminate other rock types; to detect, under temperate climate conditions (soil, weathering, vegetation) an eventual thermal anomaly due to small temperature differences in vicinity of ore bodies (sulphide) and to use visible/IR bands to detect tectonic and geological map changes.

The approach will be an analytical study of thermal energy imagery acquired day and night and at different seasons of the year to detect anomalies.

Anticipated results are the detection of potential active volcanic zones and/or geothermal anomalies which cannot be detected from thermal IR images from aircraft; discrimination of limestone from dolomite as a guide for mineral exploration, geohydrology and petroleum exploration and improvement of geologic (rock-type) maps. Test site is Massif Central, Bretagne, France.

Topoclimatological and Snowhydrological Survey in Switzerland

Principal investigator is Dr. Matthias Winiger, Department of Geography, University of Bern, Switzerland.

Objectives are to delineate and map cold air masses, fog layers and dust layers; determine influence of built-up areas on the heat flux; map the areal extent of the snow cover and its changes, snow melting conditions and melting water runoff.

Appraoch: Project will rely upon already existing observation networks, test sites, organizations, instruments and techniques. Extensive field measurements, continuous automatic measurements of meteorological data, aircraft overflights and weather satellite data will be utilized. Visual interpretation of HCMM visible and thermal data will be used for the delineation and mapping of the selected elements. A determination will be made as to the accuracy of the different measuring processing and mapping methods, and to the correlation of HCMM data to ground truth and remotely sensed data.

Anticipated results are processing and interpretation techniques which may be used in operational topoclimatological surveys and water runoff predictions; an estimate of the influence of the topographic situation, seasons and weather situations on observed features; particular statements on the usefulness of HCMM data (spectral bands, spatial resolution, sequence of satellite passes); indications on possible reductions of the ground observation network; a set of thematic maps showing distribution and changes of cold air masses, fog layers, thermal distribution, snow and amount of melting water; correlation of the mapped elements to selected features such as phenological observations, vegetation time, frost damages, etc. Test sites are located in Switzerland and parts of France, Germany, Austria and Italy.

Monitoring Large Scale Pollution Effects in the North Sea

Principal investigator is Dr. Gilbert Fielder, Department of Environmental Sciences, University of Lancaster, England.

Objective is the investigation of the feasibility of monitoring marine pollutants, mainly oil.

The approach is to determine if it is possible to recognize an anomalous area of sea known to be polluted in a certain way. The pollutant will be tracked and its composition determined if possible.

Anticipated results: temperature and thermal inertia anomalies will be recognized and specific pollutants identified. Demonstration of the feasibility of using HCMM data for ocean pollutant monitoring. Test sites are located in various parts of Great Britain.

Soil Moisture and Heat Budget Evaluation in Selected European Zones of Agricultural and Environmental Interest (Tellus Project)

Principal investigator is Dr. S. G. Paratesi, Joint Research Center of the European Communities.

Objectives: A consortium of several European investigators (Tellus) will conduct studies of soil moisture, vegetation, evapotranspiration and the nature of the land surface to determine the features which can be successfully monitored by the HCMM's radiometer.

Approach: Laboratory and ground calibration of instruments; verification of existing thermal inertia models for bare soil; construction of an on-ground agrometeorological measuring network and aircraft and ground truth measurements.

Anticipated results: Seasonal mapping of soil moisture; monitoring of vegegation stress relationships between soil moisture, groundwater and erosion; frost tendency monitoring and effect of local effluents on heat budget. Test sites are located in southern Italy, Sardinia and central Europe.

Multidisciplinary Application of Thermal Data

Principal investigator is Dr. Rupert Haydn, Central Laboratory for Geophotogrammetry and Remote Sensing.

Objectives are to apply HCMM data to studies in the fields of geology, ecology, hydrology and climatology and to develop processing and analytical methods.

Approach: HCMM thermal and visible data will be used in conjunction with studies of urban heat islands, manmade thermal influences in alpine valleys, temperature conditions relative to angiosperms, interpretation of subsurface morphology and soil moisture variations, lithological mapping in southern Italy and detection of submarine fresh water springs.

Anticipated results are the determination of effectiveness of use of HCMM data in accomplishing investigation objectives. Test sites are located in West Germany, Italy and Morocco.

Investigation of User Applications of HCMM Data in the Australian Environment

Principal investigator is Dr. K. G. McCracken, CSIRO, Division of Mineral Physics.

Objective is to develop a thermal inertia model suitable for HCMM data; applicability of thermal inertia mapping to geology, vegetation and soil moisture characteristics of arid regions; classification of wetlands; and extrapolation of frost data.

Approach: Multidisciplinary evaluation of HCMM data analyses.

Anticipated results: Determination of the suitability of HCMM data in providing information for geology, vegetation and soil moisture. Test sites are located in various parts of Australia.

Use of Repetitive Thermal Imagery of Two Selected Areas in Italy for Geological and Hydrological Applications

Principal investigator is Prof. R. Cassinis, Instituto Per La Geofisica Della Litosfera.

Objectives are the determination of the thermal inertia of rock types, definition of discontinuities (faults), detection of thermal anomalies, investigation of coastal and legunar water circulation patterns.

The approach is to use temporal comparisons to enhance faults and study anomalous heat flows, especially in the coastal areas.

Anticipated results: Improved knowledge of the geology and structure of Sicily and of the water circulation patterns in two coastal areas. Test site is located in Italy.

<u>Use of the Resultant HCMM Data</u>

Principal investigator is Paul D. Scully-Power, Royal Australian Navy Research Laboratory.

Objectives are to study the life span, advection rate, formation, decay and aggregation of mesoscale ocean eddies.

The approach is to use the temperature gradient and spatial resolutions of the HCMR and the synopticity of the swath to resolve the ocean processes that control the life span, advection rate, formation, decay and aggregation of mesoscale ocean eddies.

Anticipated results: Determination of the life span, advection rate, formation, decay and aggregation of mesoscale ocean eddies. Test site: Tasman Sea, Australia.

<u>Mineral Exploration, Energy Resources, Range Resources</u>

Principal investigator is Dr. Monica M. Cole, Bedford College, London, England.

Objectives: Rock discrimination for mineral exploration, detection of geothermal heat sources, moisture content assessment for rangeland management.

Approach: HCMM data to be compared to known mineral deposits, aircraft, Landsat and Skylab data and checked in the field. Discrimination of rock types will be done with ground investigation of anomalous areas. Thermal inertia maps will be constructed.

Anticipated results: Discrimination and mapping of rock types with eventual value to geologic surveys and mining concerns; identification of geothermal hot spots and variations in soil moisture. Test site is located in Australia.

Soil Moisture Estimating in Agricultural Areas From Thermal Emission Measurements

Principal investigator is Dr. Joseph Cihlar, Canada Centre for Remote Sensing.

Objectives are to evaluate the usefulness of the thermal inertia concept to estimate soil moisture from remote sensing measurements.

Approach is to study soil moisture from remotely sensed data using the thermal inertia concept to prepare a model for spring wheat yield prediction. Soil type effects, atmospheric conditions, seasonal effect, crop cover, aircraft versus satellite measurements of same soil type will all be addressed.

Anticipated results: Answers will be obtained to questions regarding soil moisture measurement, soil type effects, environmental (atmospheric) effects, algorithm determination and thermal inertia applications. Test sites are located in various parts of Canada.

Mapping, Geothermal Source Location, Natural Effluents and Plant Stress in Mediterranean Coast of Spain

Principal investigator is Dr. Ing. Rodolfo Nunez de las Cuevas, Instituto Geografico y Catastral, Madrid, Spain.

Objectives are thermal mapping, geothermal source location, natural effluents detection and plant stress identification.

Approach is to form correlative analyses of HCMM data with multidisciplinary ground truth information to determine the utility of thermal infrared satellite data in Earth resources exploration.

Anticipated results will be a thermal map of test site showing rock type discrimination and plant stress and indicating the location of geothermal energy sources and natural effluents into the sea. Test site is located in eastern Spain.

*Investigators also members of HCMM Experiment Team (HET).

The HET advises NASA on the science related aspects of the mission such as data products output and format, development and testing of algorithms for apparent thermal inertia, assisting in post launch activities such as sensor evaluation, data processing software validation and future applications.

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