1.0 INTRODUCTION TO THE NOAA KLM SYSTEM

The National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) jointly administer the civilian polar orbiting spacecraft system for the United States. Upon successful achievement of orbit, NASA conducts an engineering evaluation and checkout of each satellite. During the instrument turn-on checkout period, the NASA team directs the satellite, and obtains and analyzes engineering data necessary to the evaluation. Upon completion of testing, the satellite is turned over to NOAA for routine operational control.

In the Spring of 1998, a new series of NOAA Polar Operational Environmental Satellites (POES) commenced with the launch of NOAA-K (NOAA-15) and ended with NOAA-N Prime (NOAA-19). This series, represented an improvement over the previous series of NOAA polar-orbiting satellites which began with TIROS-N (launched in October 1978), and continued with NOAA-6 through NOAA-14 (launched in December 1994).

In order to eliminate redundancy for NOAA's POES satellite data users, the documents *NOAA Polar Orbiter Data User's Guide*, the *NOAA Technical Memorandum NESS 95* (*The TIROS-N, NOAA A-G Satellite Series*), the *NOAA Technical Memorandum NESS 107* (*Data Extraction and Calibration of TIROS-N/NOAA Radiometers*) and the *TIROS-N Series Direct Readout Services Users Guide* were combined into one document. The contents of this document, originally titled *NOAA KLM User's Guide* include information to the NOAA-K, -L, -M system with additions made as newer satellites were launched, namely, NOAA-N and NOAA-N Prime and the European Metop satellites, Metop-1 and Metop-2. These also carry the AVHRR and ATOVS instruments. The information within this document include descriptions of the spacecraft characteristics, orbital considerations, sensor package, calibration, and formats for Level 1b data and selected operational products. Due to limited resources in maintaining this large document over the years some of the information that is deemed not contingent to the understanding of the data and products themselves remains in its original form. This includes tracking procedures to acquire data from real-time transmission, systems sensors, ingest and preprocessing. Questions related to any information within this document should be directed to NCDC.satorder@noaa.gov.

1.1 THE NOAA KLM CONCEPT

The NOAA KLM POES satellites began a new era of improved environmental monitoring in support of NOAA missions. The instrument payload has significant improvements and additions/deletions. The instrument changes have affected the spacecraft subsystems and data formats.

The NOAA KLM satellites include improvements to instruments that are evolutionary and significant. The initial concept was to add more passive microwave instruments and channels in place of the four channel Microwave Sounding Unit (MSU) and the three channel Stratospheric Sounding Unit (SSU). During the satellite system design process, it became evident that the increased size, fields of view, and power requirements for the new instruments would have significant impacts on the spacecraft power, data handling, and attitude control systems. The NOAA KLM spacecraft were significantly heavier than previous spacecraft (2231.7 kg versus 1712.3) and required a more powerful Apogee Kick Motor (AKM) solid rocket booster and expendable launch vehicle, TITAN-II, to obtain orbit. Combined with command system security and frequency changes, NOAA KLM satellites look very much like previous satellites to the casual observer, but have significant changes to essentially every subsystem. To meet the increased power requirements, two additional solar panels have been added and the solar array has about 45% more output. The batteries, propulsion tank capacity, the size of the reaction wheels and magnetic coils used for momentum unloading and attitude control have also increased in capacity. The spacecraft structure has been stiffened primarily to support the heavier AMSU instruments and improve launch vehicle load margins. Several antennas have been relocated and/or built with new materials and processes to improve performance. Flight computer memory has been doubled and the flight software modified to meet new requirements.

The Advanced Microwave Sounding Units (AMSU-A1, AMSU-A2, and AMSU-B) are state-of-the- art passive microwave sounders that will significantly enhance NOAA's atmospheric sounding and non-sounding products suite. AMSU is expected to improve global sounding (especially in the presence of clouds), water vapor profiles and information on precipitation and ice. The AMSU instruments have better spatial resolution and upper atmospheric sounding capabilities than the previous MSU instrument flown on the TIROS-N series.

The Advanced Very High Resolution Radiometer (AVHRR/3) provides spectral and gain changes to the visible channels that will allow improved low energy/light detection and adds a sixth channel, called 3A, at 1.6 microns for improved snow and ice discrimination. Scan mechanism lifetime and jitter performance have been improved with changes to lubricants, motors and bearings. A fairly large external sun shield has been added to the AVHRR/3 scan motor housing to reduce sunlight impingement and associated calibration problems that have been briefly observed during some prior missions. Channel 3A will be time shared with the previous 3.7 micron channel, now called channel 3B.

The first half of the dynamic range for AVHRR/3 channels 1 and 2 represents 0 to 25% albedo while channel 3A has the first half of its dynamic range used for detection of albedo level changes from 0 to 12.5% albedo. These are referred to as dual slope or split gains. Previous AVHRR instruments used one linear calibration equation for each visible channel and now two are required for each visible channel. NOAA will be monitoring the dual slopes of the ramp calibrations more closely to assure that the linearity of the electronics and inflection points for the dual slopes do not change as the instrument ages or with other factors such as temperature, orbital or seasonal effects. The new visible channel ramp calibrations do not use the full dynamic range as was done previously and have been observed to change slightly as the instrument temperature changes.

The Automatic Picture Transmission (APT) user sees channel 3B as channel 6 using the wedge six grey scale modulation index.
The AMSU instruments required the addition of a new spacecraft data processing box called the AMSU Information Processor (AIP) and changes to the High Resolution Picture Transmission (HRPT), Local Area Coverage (LAC), and Global Area Coverage (GAC) formats to accommodate the new AMSU data. The AIP receives data from AMSU-A1, AMSU-A2, and AMSU-B at a combined data rate of 7.2 kbps and from the TIROS Information Processor (TIP) at 8.32 kbps. The AIP generates three data streams: (1) AMSU data only which is sent to the MIRP for merging into HRPT, Local Area Coverage (LAC) or recorded HRPT, and Global Area Coverage (GAC); (2) combined AMSU/TIP sent to the spacecraft Cross-Strap Unit (XSU) for tape recording if needed; (3) AMSU/TIP for direct transmission from the XSU. The HRPT is still broadcast at the old data rate of 665.5 kbps with the new AMSU data replacing what were previously spare words. Note that if the non-redundant MIRP was to fail, it would still be possible for NOAA to obtain global sounding data. Also note that Direct Sounder Broadcast (DSB) of TIP data does not include AMSU data. DSB users will have access to HIRS/3, DCS-2, SEM-2, and SBUV/2 data as defined in the new TIP format. Most of the previously used or spare TIP words now contain DCS-2 data to satisfy the growing needs of Data Collection System (DCS) users.

The High Resolution Infrared Radiation Sounder (HIRS/3) has spectral channel changes that were made primarily to improve soundings and to be congruent with the specifications developed for the GOES-I through -M Sounders. The HIRS/3 cooler set point was decreased to approximately 100K which will improve the two infrared detectors' performance. The HIRS/3 scan profile was also changed to eliminate the viewing of the second/cold blackbody internal calibration target from the automatic calibration sequence and to use the additional time to perform another scan (38 total scans per calibration sequence) of the earth. It was cost effective to leave the second calibration target in the instrument and leave its viewing as a commandable option. The HIRS/3 instrument has been improved for longer lifetime and produces lower noise levels (better NEDN performance).

The Space Environment Monitor (SEM-2) has improved calibration and particle detection capabilities. The Total Energy Detector (TED) measures to a lower energy of 0.05 KeV and the TED integral F (ALPHA) has two ranges of 0.05 to 1 and 1 to 20 KeV. The Medium Energy Proton and Electron Detector (MEPED) has a fourth Omni directional proton measure at 140 MEV. The MEPED has a new fixed mounting on the spacecraft and the TED has also been relocated to maximize particle detection abilities.

The Solar Backscatter Ultra Violet Spectral Radiometer (SBUV/2) has undergone relatively modest improvements. Its Programmable Read Only Memory (PROM) will be changed to a Random Access Memory (RAM) due to parts obsolescence and to provide more operational flexibility. The grating drive system has been improved to provide more torque margin. The diffuser angle was changed 9 degrees to improve the accuracy of radiometric data in the Irradiance mode. Range 3 data is provided from the PMT anode. The SBUV/2 is planned for afternoon missions only and is not presently planned for flight on NOAA-K although NOAA-K was tested with it and can be launched into either orbit.

The Data Collection System (DCS) data rate increased from 1200 to 2560 bps and the number of Data Recovery Units (DRUs) doubled from 4 to 8. DCS-2 bandwidth increased from 24 KHz to 80 KHz.

The Search and Rescue Processor (SARP-2) Data Recovery Units increased from 2 to 3 to handle more global distress messages and to better detect interfering signals. SARP output message formats are significantly different and commandable capability exists to issue pseudo messages for improved isolation of interfering signals from the ground.

Efforts have been made to improve reliability and performance while minimizing cost and impacts to users of POES satellite data. While the POES satellites may superficially appear to be production line copies, they have all been uniquely different. NOAA KLM era marked significant evolutionary and revolutionary improvements to NOAA's abilities to satisfy its multifaceted environmental monitoring and prediction missions.

1.2 NOAA KLM SPACECRAFT CHARACTERISTICS

The primary mission was to design, fabricate, integrate, test and launch five operational NOAA polar-orbiting satellites into Sun-synchronous orbits. These satellites are designated NOAA-K, L, M, N, N'. NOAA KLM mission characteristics are shown in Table 1.2-1.

Table 1.2-1. Mission Characteristics.

Item	**NOAA KLM Specifications**
Launch Date	NOAA-K (NOAA-15): May 13, 1998 NOAA-L (NOAA-16): September 21, 2000 NOAA-M (NOAA-17): June 24, 2002 (mid morning orbit) NOAA-N (NOAA-18): May 20, 2005 NOAA-N'(NOAA-19): Feb 6, 2009
Mission Life	2 years minimum required
Orbit	Sun-synchronous, 833 ± 19 km or 870 ± 19 km
Launch Vehicles	U.S. Air Force (USAF) Titan II
Spacecraft – Operational	
Mass	1478.9 kg on orbit/2231.7 kg at launch
Length/Diameter	4.18 m / 1.88 m
Propulsion	Mono propellant hydrazine, GN_2 and AKM
Attitude Control	3-axis stabilized
Power	Direct energy transfer
Thermal	Passive and active controls
Data Rates -Real Time	
TIROS Information Processor (TIP)	8.32 kilobits per second (kbps) includes low rate instrument (except AMSU) and spacecraft housekeeping and can be recorded
High Resolution Picture Transmission (HRPT)	665.4 kbps includes all instrument data and spacecraft housekeeping and can be recorded.
Automatic Picture Transmission (APT)	Approximately 2 kHz medium resolution imagery from two selected AVHRR sensor channels.
Data Rates – Recorded	
Global Area Coverage (GAC)	665.4 kbps include low-rate instrument, spacecraft housekeeping and medium resolution imagery.

Local Area Coverage (LAC)	665.4 kbps HRPT except the data field is randomized to record.
Playback	2.66 Megabits per second (mbps) during normal operations.
Ground System*	
Operation Control	NOAA/SOCC CDA stations at Wallops and Fairbanks. DSN 26-m and AFSCN for contingency support.
Forward Data Link	S-band command uplink encrypted.
Return Data Link	Housekeeping telemetry from HRPT and GAC downlinks.
Science Data Capture	Tape playback direct to CDA (typically eleven 12-minute contacts per day), relayed to the NOAA/DDS in Suitland, MD.
Science Data Processing	NOAA/DDS, Air Force Global Weather Central (AFGWC), International Weather Services and ARGOS

*at time of NOAA-K launch

The spacecrafts were all launched from the Vandenberg Air Force Base in California using modified, standardized Titan and Delta II launch vehicles and each spacecraft mission was required to be compatible with the existing NOAA ground system.

Reliability and continuous high performance were of utmost importance during the design process for the NOAA KLM satellites, and, just as importantly, the KLM satellites were required to provide continuity to the NOAA polar-orbiting observing system to ensure continuity in the extending the essential climate records for long term climate change studies.

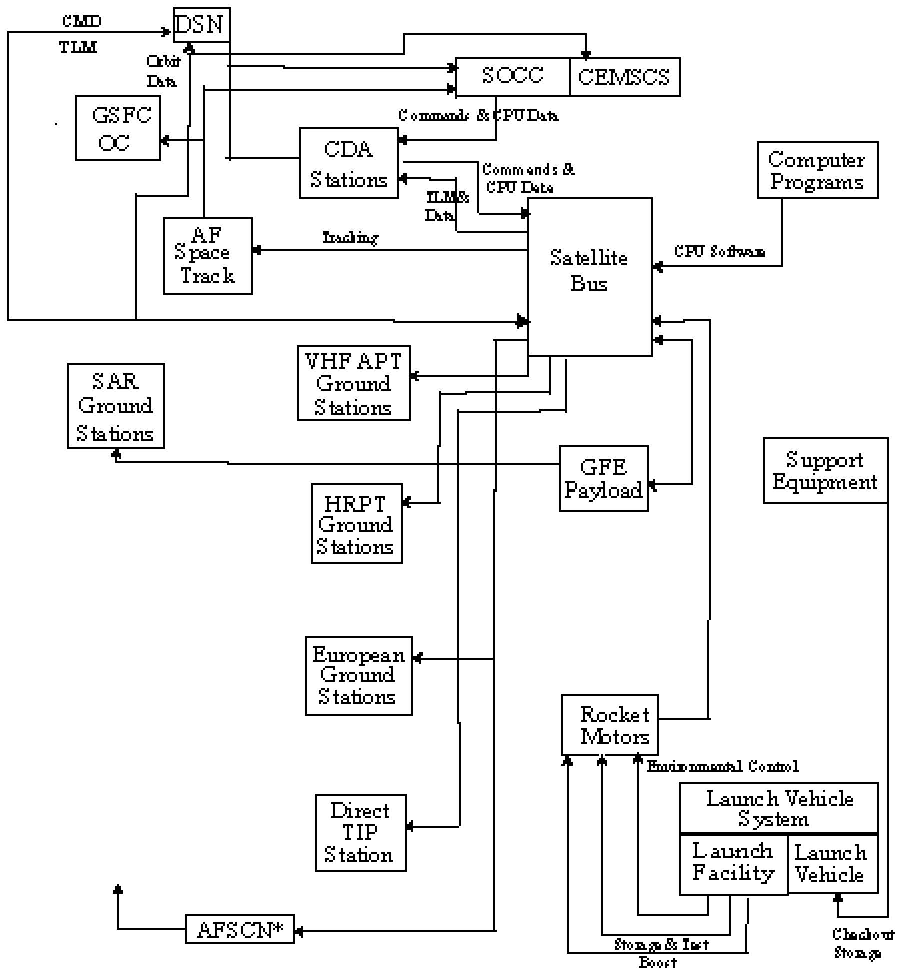
Each spacecraft was designed to meet all on-orbit performance requirements for a minimum period of two years.

NASA played an important role in the design and build out of each satellite. Upon successful achievement of orbit, NASA conducted engineering evaluation and checkout of each satellite. Upon completion of testing, each satellite was turned over to NOAA for routine operational control. During the NOAA operational period, the POES Project's responsibility was limited to investigation of spacecraft on-orbit anomalies upon NOAA's request. Figure 1.2-1 provides a NOAA KLM System Functional Diagram.

1.2.1 SPACECRAFT STRUCTURE

The NOAA KLM spacecraft structure, based on the NOAA-H, I, J integrated structure, is designed to support a complete meteorological payload plus the necessary support subsystems to meet all interface and system requirements. The structure comprises four major assemblies: the Instrument Mounting Platform (IMP), the Equipment Support Module (ESM), the Reaction Control Equipment (RCE), Reaction Support Structure (RSS), and the Solar Array (SA) assembly. Figure 1.2.1-1 provides a line drawing of the NOAA KLM spacecraft and Table 1.2.1-1 summarizes the primary physical characteristics.

Figure 1.2-1. NOAA KLM System Functional Design



*Early orbit and contingency support.

Figure 1.2.1-1 NOAA KLM Spacecraft Configuration.

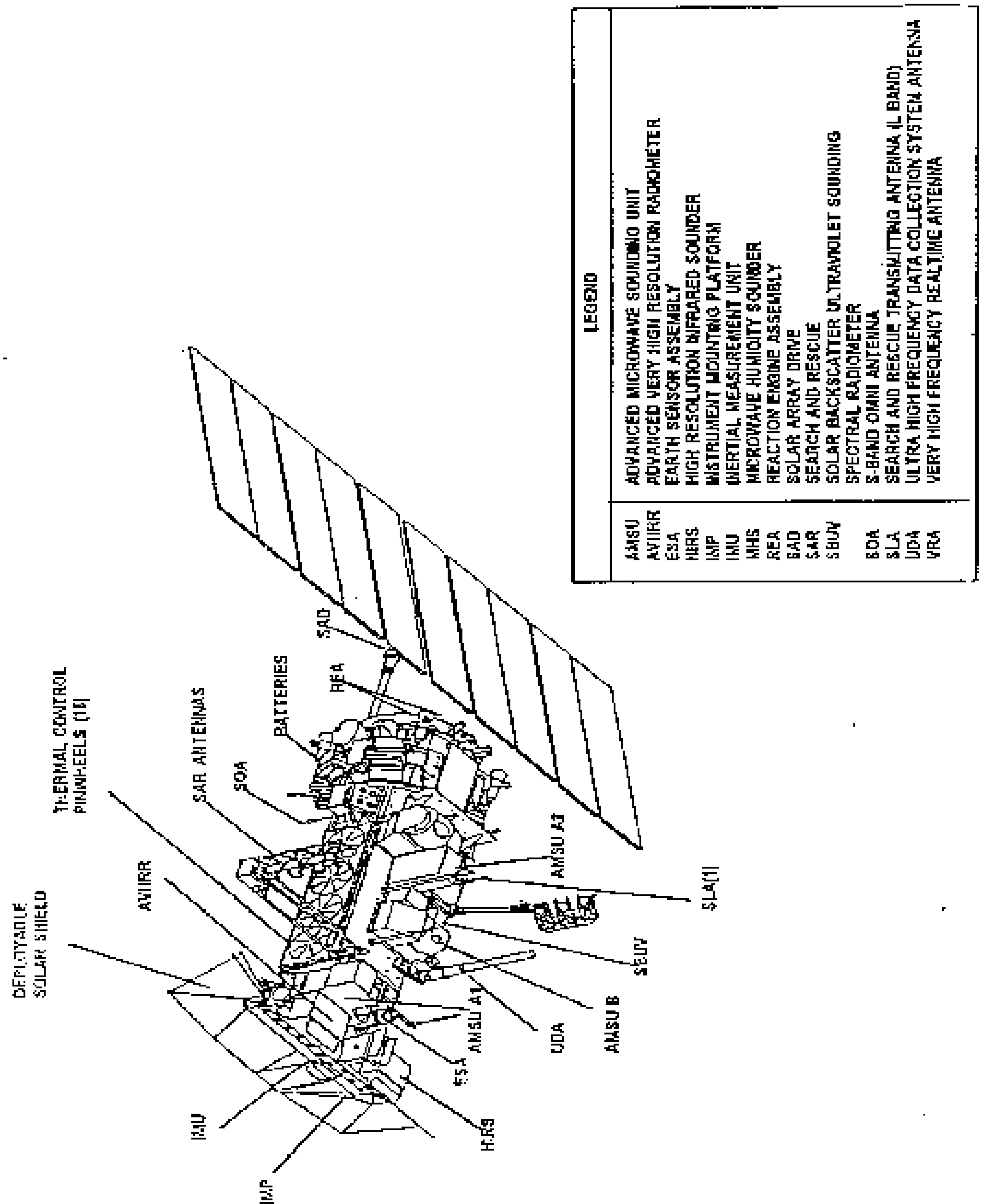


Table 1.2.1-1. NOAA KLM Physical Characteristics.	
Parameter	**NOAA KLM Characteristics**
General	
Configuration	3-axis body stabilized
Mission	2-years
Launch Vehicle	Titan II
Spacecraft Size	
Launch Configuration Envelope Expendable Launch Vehicle Static Envelope	2540 mm (100 in)
Fairing Diameter	3048 mm (120 in)
On-Orbit Configuration	
Main Body Length	4.2 m (13.75 ft)
Main Body Diameter	1.88 m (6.2 ft)
Array to Body	3.2 m (10.5 ft)
Overall Length	7.4 m (24.2 ft)
Spacecraft Mass (Titan II)	
Dry Satellite	1478.9 kg (3260.3 lb)
Propellant and pressurant	752.8 kg (1659.7 lb)
Total Deployment Weight	2231.7 kg (4920 lb)

1.2.1.1 Instrument Mounting Platform

The HIRS and AVHRR instruments are mounted on the Instrument Mounting Platform (IMP) because of stringent pointing requirements and/or the need for an uninterrupted view of space for detector-cooling purposes. The IMP also supports the primary attitude-sensing equipment: namely, an Earth horizon sensor, an inertial measurement unit and a Sun sensor. Overall, the approach achieves an instrument optical-axis pointing accuracy of better than 0.2 degrees relative to the local vertical. The surface of the IMP is the primary thermal control surface for the instruments. It houses an array of thermal control louvers, protected from solar illumination in mission orbit by a sunshade.

1.2.1.2 Equipment Support Module

The ESM contains the majority of the satellite electronic support equipment. It is pentagonal in cross section but asymmetric to provide a large Earth-viewing face upon which lower pointing accuracy instruments and antennas are mounted. Internal of the ESM are mounted most of the components contained in the data handling, attitude determination and control, communications, and command and control subsystems, as well as the SARR, SARP, and DCS instruments. External to the ESM, on the Earth facing surface, are mounted the AMSU-A1, AMSU-A2, AMSU-B, SBUV, as well as the communication system antennas. One segment of the mounting area, at the lower end of the module, is primarily dedicated to SAR equipment. Thermal control of the ESM itself is provided by thermal blankets and pinwheel louver assemblies integral to the side panels.

1.2.1.3 Reaction Control Equipment Support Structure

The RSS is a circular cylinder, which primarily supports a solid rocket AKM plus the Reaction Control Equipment (RCE) components consisting of two nitrogen tanks, two hydrazine tanks, four hydrazine thrusters, and eight nitrogen thrusters along with the valves and manifolding required to inter-connect the system. In addition to the propulsion equipment, the RSS supports the satellite batteries, battery charge controllers (for thermal reasons these items are outside the

Table 1.2.1.3-1. Government-furnished Satellite Equipment List.

Item	NOAA-K	NOAA-L	NOAA-M
AVHRR/3	X	X	X
HIRS/3	X	X	X
DCS/2	X	X	X

ESM) and certain antennas. It also furnishes support for the solar array assembly. Table 1.2.1.3-1 lists the satellite equipment furnished by the government.

SEM/2	X	X	X
SARP/2	X	X	X
SARR	X	X	X
SBUV/2		X	
AMSU-A1	X	X	X
AMSU-A2	X	X	X
AMSU-B	X	X	X

1.2.1.4 Solar Array

The SA consists of ten reinforced honeycomb panels, which are hinged to each other along their long edges. When deployed, the array is approximately 6.15 m (242 in) long by 2.73 m (107.5 in) wide. During launch, solar array panels are stowed on the ESM back apex panels. During mission mode, the array is supported from the RSS through the long boom, the solar array drive, the short boom and the mast. The array is canted 22 or 36 degrees from the short boom via the cant-deployment mechanism, located between the short boom and the mast.

1.2.1.5 Spacecraft/Launch Vehicle Interface

The NOAA KLM spacecraft used modified, standardized Titan II launch vehicles. A two-piece conical ring (the payload adapter), furnished by the spacecraft contractor, provided the mechanical interface between the spacecraft and the launch vehicle.

1.2.2 INSTRUMENT PAYLOAD (GENERAL DESCRIPTIONS)

1.2.2.1 Earth Imaging

The AVHRR/3, a six-channel scanning radiometer, views the same Earth area with each channel. The data acquired during each scan allows, after ground processing, multispectral analysis of hydrologic, oceanographic, land use and meteorological parameters. Data from channels l, 2, and 3A are used to monitor reflected energy in the visible and near-IR portions of the electromagnetic spectrum. These data provide means to observe vegetation, clouds, lakes, shorelines, snow, aerosols and ice. Data from channels 3B, 4 and 5 are used to determine the radiative energy from the temperature of the land, water, and sea surface as well as the clouds above them. Only five channels can be transmitted simultaneously, channels 3A and 3B being respectively switched for day/night operation and as determined by operational requirements for the afternoon satellite, while 3B will be on continuously for the morning satellite mission. For the first time, Channels 1, 2 and 3A on these spacecraft have incorporated the low light split-gain provision, providing better resolution in a portion of the radiance range. The Automatic Picture Transmission (APT) mode, using two selected channels, produces a more geometrically linear scan line but at the reduced resolution of 4 km. Table 1.2.2.1-1 lists the six channels and their required spectral, spatial and thermal resolution (where appropriate). For more information on the AVHRR/3 instrument, see

Section 3.1.

Table 1.2.2.1-1. AVHRR/3 Channels .			
Channel	**Spectral Bandpass (micrometers)**	**Spatial Resolution at nadir (km)**	**Signal to Noise (S/N) or Noise Equivalent Delta Temperatures (NEΔT)**
1 (Visible)	0.580 - 0.68	1.1	9:1 at 0.5% Albedo
2 (Near IR)	0.725 - 1.00	1.1	9:1 at 0.5% Albedo
3A (Near IR)	1.580 - 1.64	1.1	20:1 at 0.5% Albedo
3B (IR-Window)	3.550 - 3.93	1.1	0.12 K at 300 K
4 (IR-Window)	10.300 - 11.3	1.1	0.12 K at 300 K
5 (IR-Window)	11.500 - 12.5	1.1	0.12 K at 300 K

1.2.2.2 Atmospheric Sounding Instruments

Three instruments are used to determine radiance needed to calculate the atmospheric temperature and humidity profiles form the earth's surface to the stratosphere. These instruments are the High-Resolution Infrared Sounder/3 (HIRS/3), the Advanced Microwave Sounding Unit-A (AMSU-A) and the Advanced Microwave Sounding Unit-B (AMSU-B) for NOAA KLM.

The HIRS/3 has twenty spectral bands, nineteen in the IR band and one in the visible band. This instrument is basically the same as the instrument flown on earlier spacecraft, except for five spectral band changes to improve sounding parameter accuracy. The instrument measures scene radiance in nineteen channels to permit calculation of the vertical temperature profile from the Earth's surface to about 40 km. The instrument scans ±49.5 degrees, having a ground resolution (nadir) of 17.4 km, 56 instantaneous fields of view (IFOV) for each 2250-km scan line at 6.4 seconds per scan line and 42 km between IFOV's along-track (nadir). See Section 3.2 for the required wavelength, half-power bandwidth and noise power requirements for the HIRS/3.

The AMSU-A is a total power radiometer and a line scan instrument designed to permit the calculation of the vertical temperature profile from the Earth's surface to about a 2-millibar pressure height 45 km (28.0 mi). Vertical profiles are obtained through the measurements of scene radiance in fifteen channels, ranging from 23.8 to 89 GHz. The instrument has an instantaneous field-of-view of 3.3 degrees at the half-power points. The antenna provides a cross-track scan, scanning ±50 degrees from nadir with a total of 30 Earth fields of view per scan line. Each Earth field of view is separated from the adjacent cell along the scan direction by 3 1/3 degrees. Spatial resolution at nadir is nominally 50 km (31.0 mi). See Section 3.3 for more details on AMSU-A.

The AMSU-B is a line scan instrument designed to allow the calculation of the vertical water vapor profiles from the Earth's surface to about a 20-millibar pressure 12 km (7.5 mi). Vertical profiles are obtained through the measurements of scene radiance in five channels, ranging from 89 to 183 GHz. AMSU-B, like the AMSU-A, is a total power radiometer and uses two target temperatures to provide for accurate radiance calibration with each scan. The instrument has an instantaneous field-of-view of 1.1 degrees at the half-power points. The antenna provides a cross-track scan, scanning of ±49.5 degrees from nadir with a total of 90 Earth fields of view per scan line. Each Earth field of view is separated from the adjacent cell along the scan direction by 1.1 degrees. Spatial resolution at nadir is nominally 16.7 km (10.4 mi). AMSU-B contains four water vapor channels (channels 17 through 20 inclusive) and one window channel (channel 16). AMSU-A channel 15 and AMSU-B channel 16 share the same atmospheric window band. See Section 3.4 for more details on AMSU-B.

1.2.2.3 Solar Backscatter Ultraviolet Radiometer (SBUV)

The SBUV/2 is a non-spatially scanning, spectrally scanning sounding radiometer. It is designed to measure scene radiance and solar spectral irradiance in the spectral range from 160 to 406 nanometers (nm). In the discrete mode, measurements are made in 12 spectral bands from which the total ozone and vertical distribution of the ozone are deduced. The sweep mode provides a continuous spectral scan from 406 to 160 nm that is used primarily for solar spectral irradiance measurements. The half power FOV is 11.33 degrees or 172 km (106.9 mi). Spectral characteristics are described in Table 1.2.2.3-1.

Table 1.2.2.3-1. SBUV/2 Spectral Characteristics (Discrete Mode)

Step Number	Central Wavelength (nm)	Bandwidth (nm)
1	252.00 ±0.05	1 + 0.2, -0
2	273.61 ±0.05	1 + 0.2, -0
3	283.10 ±0.05	1 + 0.2, -0
4	287.70 ±0.05	1 + 0.2, -0
5	292.29 ±0.05	1 + 0.2, -0
6	297.59 ±0.05	1 + 0.2, -0
7	301.97 ±0.05	1 + 0.2, -0
8	305.87 ±0.05	1 + 0.2, -0
9	312.57 ±0.05	1 + 0.2, -0
10	317.56 ±0.05	1 + 0.2, -0
11	331.26 ±0.05	1 + 0.2, -0
12	339.89 ±0.05	1 + 0.2, -0

Cloud Cover Radiometrics	379.00 ±1	3 + 0.3

1.2.2.4 Space Environment Monitor (SEM)

The SEM-2 provides measurements to determine the intensity of the Earth's radiation belts and data on charged particle precipitation phenomena in the upper atmosphere resulting from solar activity. It provides warnings of solar occurrences that may impair long-range radio communication or high-altitude manned operations.

The SEM-2 consists of two separate sensor units and a common Dat**a** Processing Unit (DPU). The sensor units are the Total Energy Detector (TED) and the Medium Energy Proton and Electron Detector (MEPED). Performance characteristics are given in Table 1.2.2.4-1.

The TED uses eight programmed swept electrostatic curved-plate analyzers to select particle type and energy and Channeltron detectors to sense and quantify the intensity in the sequentially selected energy bands. The particles of interest have energies ranging from 50 electron volts (eV) to 20 KeV.
The MEPED senses protons, electrons and ions with energies from 30 KeV to several tens of MeV. The MEPED is a collection of four directional solid-state detector telescopes and four "generally omnidirectional" sensors.

Accumulators are located in the DPU to sort and count the events. The processed data are multiplexed and fed to the satellite telemetry system.

The SEM-2 data are separated from the other data by NOAA/NESDIS and, along with orbital element data, are sent to the Space Environment Center (SEC) in Boulder, Colorado for processing.

Table 1.2.2.4-1. SEM-2 Characteristics.

SEM-2 Units	Performance Requirements	Energy Levels	Field of View
TED	Determine heat energy input into upper atmosphere from absorption of electrons, protons and positive ions.	Electrons: 0.05 KeV to 20 KeV Protons: 0.05 KeV to 20 KeV	Two at 15 degrees full angle, -x, -x + 30 degrees

MPED	Same as TED	Electrons: 30 keV V to 700 keV V Protons: 30 keV V to 6900 keV V Above ?16, >35, >70, >140 MeV	15 degrees full angle –x, -x +90 degrees 15 degrees full angle –x, X + 90 degrees 120 degrees full angle, -x
DPU	Combine outputs into a 2-second, 40 word format. Provide command, calibrate and timing interfaces.		
Summary (Maxi-mums)	Mass: 5 kg Power: 10 watts Volume: 0.0186 m^3 Telemetry: Two (8-bit) words/TIP minor frame		

1.2.2.5 Search and Rescue Satellite Aided Tracking System

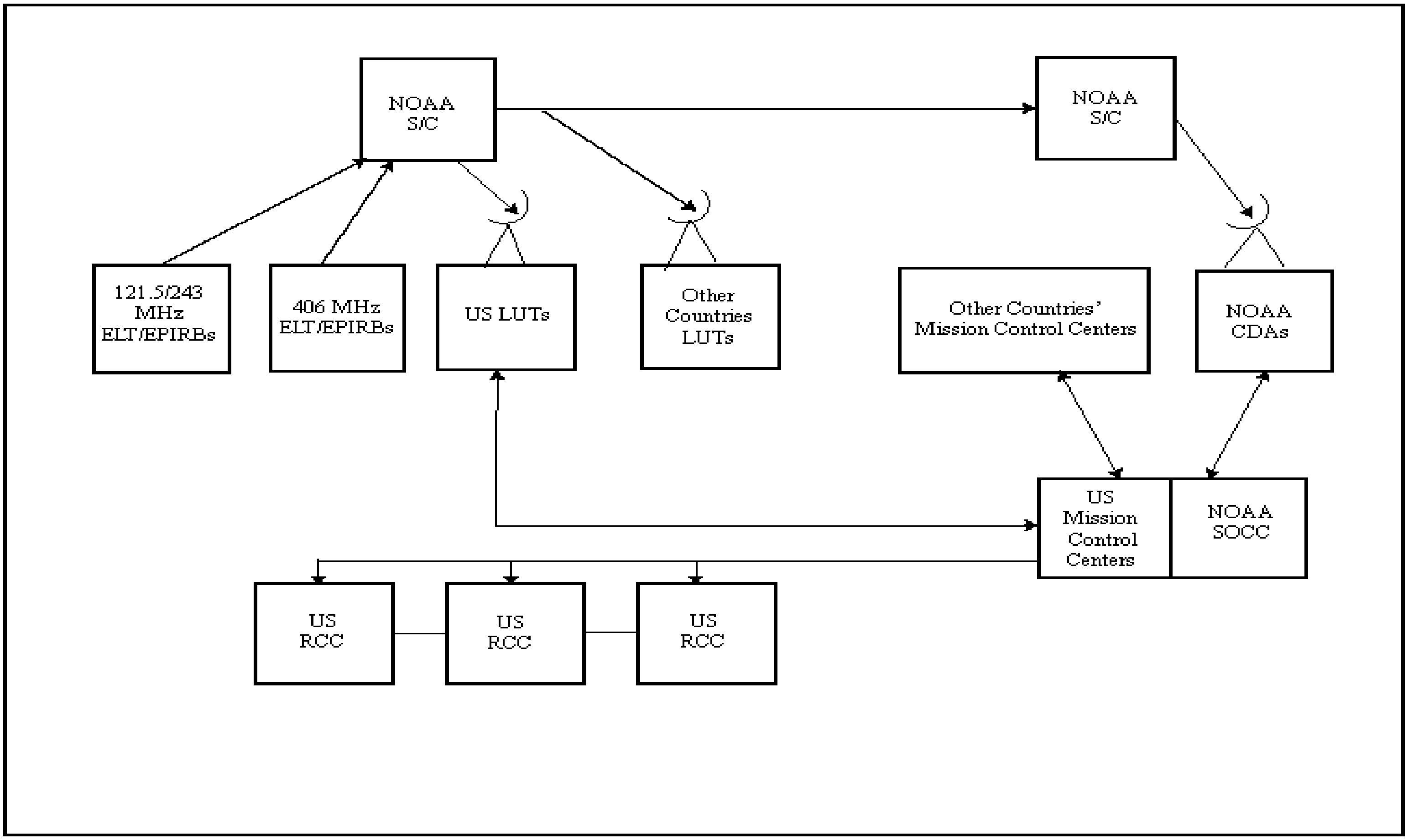
The SARSAT system is designed to detect and locate Emergency Locator Transmitters (ELTs) and Emergency Position-Indicating Radio Beacons (EPIRBs) operating at 121.5, 243, and 406.05 MHz. Figure 1.2.2.5-1 illustrates the SARSAT concept.

The SAR instrumentation on the NOAA KLM satellites comprises two elements, the SARR and the SARP-2. Table 1.2.2.5-1 summarizes the SARSAT instrumentation characteristics.

Table 1.2.2.5-1. SARSAT Subsystem Characteristics.	
Spacecraft Repeater (121.5, 243 and 406 MHz):	
Parameter	**Specification**
Bandwidths (Doppler shift + drift + tolerance + guard band)	
121.5 MHz	25 kHz
243 MHz	46 kHz
406.050 MHz	100 kHz
Transmitter Power (1,544 MHz)	8 W decibels referenced to a watt (dBW)
Physical Characteristics:	

Weight	24 kg
Size	0.034 m^3
Power	53 W
Spacecraft 406 MHz Processor:	
Maximum Bandwidth	80 kHz
Storage Capacity	324 kb
Output Data Rate (via Telemetry)	2.4 kbps
Physical Characteristics:	
Weight	27.5 kg
Size	0.034 m^3
Power	33 W

Figure 1.2.2.5-1. SARSAT Concept.



1.2.2.6 Data Collection System

The DCS-2 collects global telemetry data using a one-way radio frequency (RF) link 401.65 MHz from data collection platforms in the form of buoys, free-floating balloons, and remote weather stations and processes these inputs for on-board storage and subsequent transmission from the satellite. For free-floating telemetry transmitters, the system determines the location within 5 km to 8 km root mean square (rms) and velocity to an accuracy of 1 meter per second (mps) to 1.6 mps rms. Other characteristics are shown in Table 1.2.2.6-1. Measurements of environmental data are telemetered to the satellite for collection. The DCS-2 supplements the GOES data collection system in collecting both the information from the more-northern and more-southern latitudes and the location data on free-floating transmitters.

Table 1.2.2.6-1. DCS-2 System Characteristics.

Parameter	Characteristic
Minimum satellite elevation angle from platform	5 degrees
Number of platforms requiring location/velocity measurements visible in a 5 degree -visibility circle	Capacity: 230
Total number of such platforms over the globe	Capacity: 4100
Percentage of platforms with six good Doppler measurements per day	85%
Platform transmission repetition period	Approx. 60 sec
Message length	0.3 to 0.9 sec
Expected location accuracy	5 km to 8 km rms
Expected velocity accuracy	1 to 1.6 mps

For the incoming signals, the DCS-2 measures frequency and relative time. The formatted data are stored in the satellite for transmission to the CDA station. The DCS-2 data are stripped from the GAC data by NOAA/NESDIS and transmitted to the ARGOS center at the Centre National d'Etudes Spatiales (CNES) in Toulouse, France, for processing, distribution to users and storage for archival purposes. Alternatively, there is an operational feature that allows the stored data to be acquired directly by a European ground station.

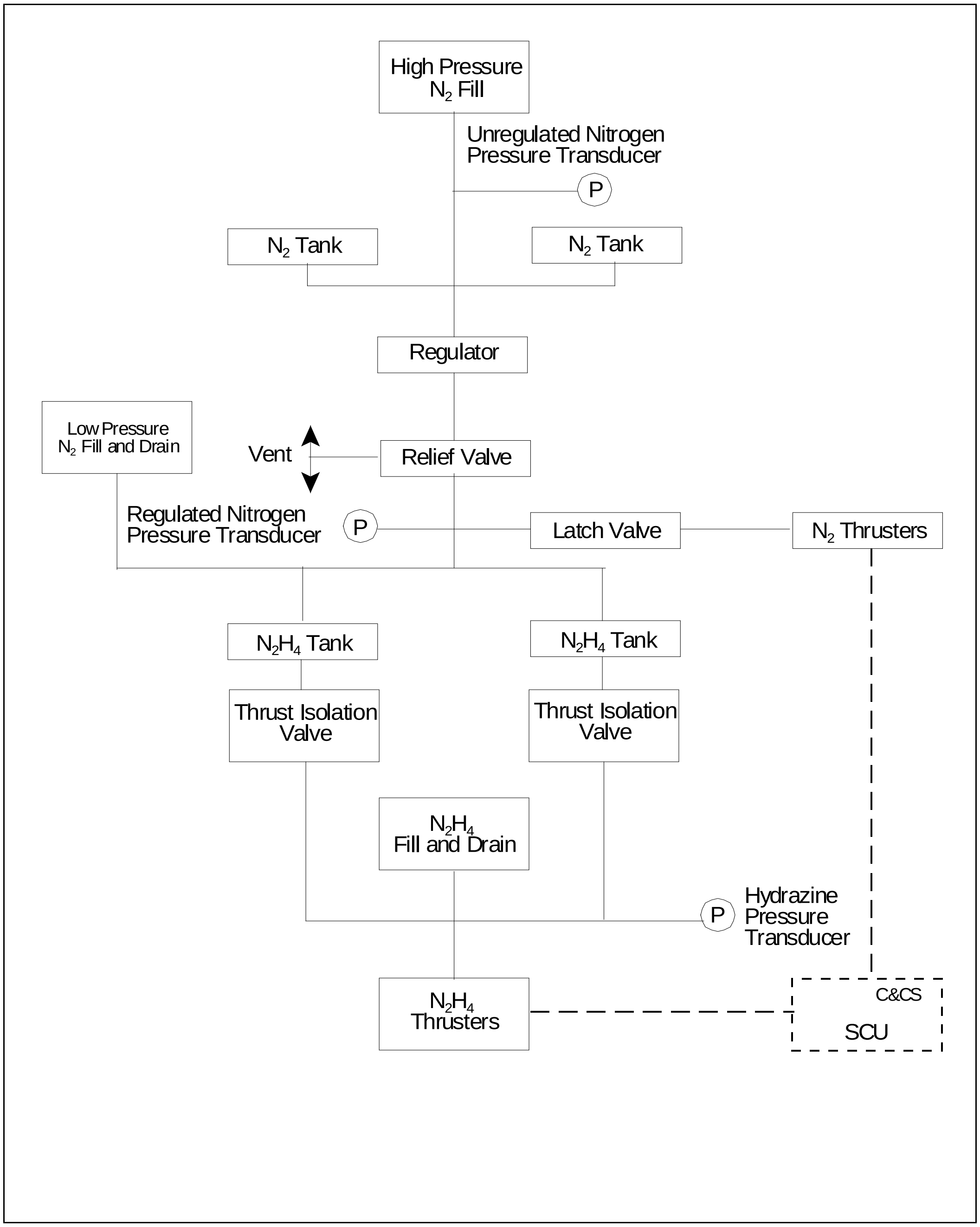
1.2.3 PROPULSION AND REACTION CONTROL SUBSYSTEM

The Propulsion and Reaction Control Subsystem is a hybrid solid/ liquid/cold-gas system consisting of a solid propellant for orbit (apogee) injection and a dual Reaction Control Equipment (RCE) system using both pressure-regulated cold-gas nitrogen thrusters and hydrazine monopropellant thrusters. This subsystem primarily provides separation from the Titan II booster, ascent-phase attitude control (three-axis stabilized) and orbital velocity trim for the satellite. Figure 1.2.3-1 provides a functional schematic of the RCE.

The hydrazine RCE consists of four thrusters and two spherical storage tanks. The hydrazine thrusters are used for maneuvers requiring large control torques and for all velocity change maneuvers, i.e., spacecraft separation from the booster and orbit circulation trim, as well as pitch and yaw control during the AKM burn. After completion of the orbital velocity trim burn, pyrotechnic valves at the outlet of each hydrazine propellant tank may be fired to isolate the hydrazine thrusters from the propellant tanks and render the system inoperative.

The cold-gas nitrogen RCE consists of eight thrusters and two spherical storage tanks of usable nitrogen. The nitrogen thrusters are used for three-axis control during ascent (except during AKM burn), Earth acquisition after handover and as a backup for momentum unloading in normal orbit mode control. Four of the thrusters provide roll control through Ascent Guidance Software (AGS), and are operated, under software control, in coupled pairs. The remaining four thrusters are operated individually to provide AGS pitch and AGS yaw control.

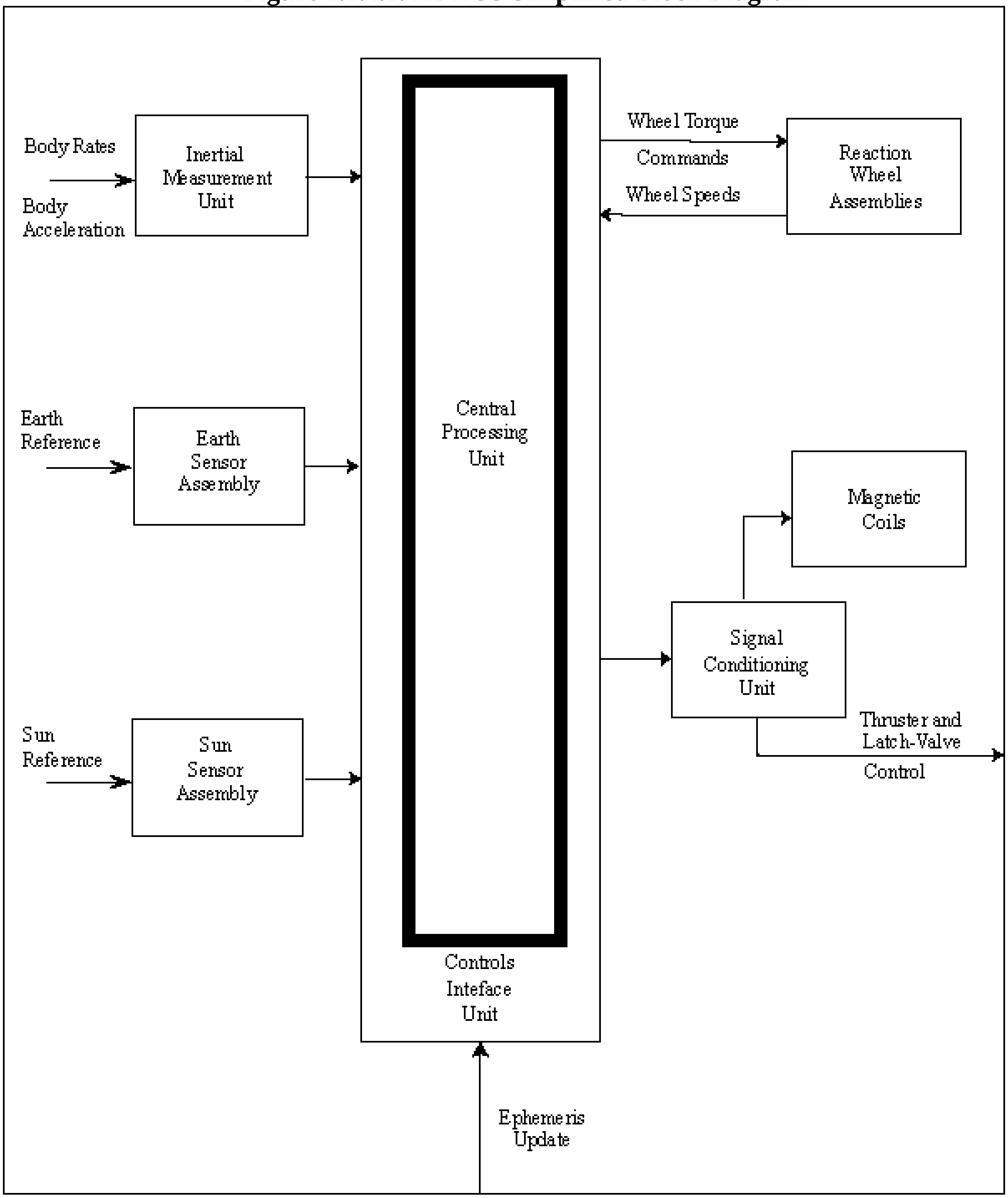
Figure 1.2.3-1. RCE Functional Schematic.



1.2.4 ATTITUDE DETERMINATION AND CONTROL SUBSYSTEM

The Attitude Determination and Control Subsystem (ADACS) provides, in conjunction with the RCS and Command and Control Subsystems (CCS), the functions of the on-orbit attitude control and ascent guidance. It is a zero-momentum system consisting of reaction wheels and Earth, Sun, and inertial reference sensors. Figure 1.2.4-1 provides a simplified block diagram of the subsystem.

Figure 1.2.4.1. ADACS Simplified Block Diagram



In the subsystem's attitude-control mode, the Earth Sensor Assembly (ESA) and the Sun sensor, together with rates derived from the Inertial Measurement Unit (IMU), furnish the primary attitude reference. Control torquing is accomplished by an orthogonal set of Reaction Wheel Assemblies (RWA's) backed up by a fourth skewed reaction wheel. The momentum accumulation in the wheels is unloaded by means of magnetic coils, which, in turn, are backed up by the RCS cold-gas thrusters. The subsystem requires ephemeris data for orbital operation, and this typically can be satisfied with a ground update once per week. In all other respects, the subsystem is autonomous, including the capability for Earth acquisition and reacquisition.

The IMU, which provides yaw, pitch, and roll rate information in orbital mode, is the key component in the ascent guidance phase. The same closed-loop guidance scheme previously used on TIROS-N and ATN missions will be retained. The IMU will furnish a navigation reference from liftoff until orbit insertion and closed-loop guidance for all satellite maneuvers following separation from the launch vehicle.

Satellite attitude-control accuracy in mission orbit is +0.2 degrees with respect to the local geodetic reference frame; knowledge of attitude is obtainable through on-ground processing to an accuracy of ± 0.10 degrees in all axes. Attitude rates do not exceed 0.035 degrees per sec in pitch and yaw and 0.015 degrees per sec in roll. Attitude determination with a maximum 3-sigma variation better than 0.14 degrees is provided onboard the satellite.

1.2.5 MISSION DATA ACQUISITION AND FORMATS

1.2.5.1 Environmental Data Formats

No significant changes were proposed in the method of mission data handling and acquisition from that developed for previous satellites in the TIROS-N/ATN series, but a sixth data format was added for AMSU data handling. These six basic data formats are generated onboard the satellite, each associated with one or more of the acquisition modes (stored or real-time, very high frequency (VHF) or S-band transmission). These formats are as follows:

- TIROS Information Processor (TIP) Data

  Under routine mission-orbit operations, the TIP output contains low-rate instrument data multiplexed with satellite housekeeping data. It contains all environmental instrument information except that from the AVHRR and the AMSU. It is available in real-time and as stored data.

  Low rate instrument data are included every minor frame. Real-time TIP data are normally available through the VHF beacon link. See Section 4 for more information.

  For early orbit support and maintenance operations, the TIP has three other operating modes: boost, dwell and satellite computer memory dump.

- High Resolution Picture Transmission (HRPT) Data

HRPT comprises full-resolution data from the AVHRR multiplexed with TIP and AMSU data. HRPT is dedicated to real-time transmissions and is available to local users in split-phase format via either of two S-band communications links with the option of transmission from a third with left circular polarization rather than right circular polarization, which the other two provide. An HRPT major frame comprises three minor frames. One minor frame will contain TIP data, one will contain AMSU data and one will contain backfill data. See Section 4 for more information.

- Local Area Coverage (LAC) Data

  The LAC data are essentially the stored version of HRPT, played back at either two or four times the real-time rate, and are made available for centralized processing. They are not intended for local users. LAC data storage is scheduled via the stored command table to provide up to 10 minutes of coverage per tape transport. See Section 4 for more information.

- Global Area Coverage (GAC) Data

  GAC data contains TIP, AMSU and reduced resolution AVHRR data. The overall data rate is one-tenth of the LAC data rate, allowing over 100 minutes of data to be stored on one tape transport. Record-to-playback ratio is either 20:1 or 40:1. The GAC stream is for stored data only and is used to develop global data sets for centralized processing and analysis. It is not intended for local users. The reduced resolution of this format allows 100% recovery of the data even under worst-case blind-orbit conditions. See Section 4 for more information.

- Automatic Picture Transmission (APT) Data

  APT data are specifically tailored for low-cost VHF local-user ground stations. Again, it is derived from AVHRR video data but at medium resolution. Any two of the five AVHRR channels provided to the MIRP can be selected and processed as "Video A" and "Video B."

  One APT line, consisting of one line of Video A and one line of Video B, is output every third AVHRR scan. Ancillary AVHRR data appear at one edge of each line and their 64-second repetition period defines the APT frame length. The resulting line rate is two per second.

  APT data are transmitted continuously over a dedicated VHF link as an analog signal consisting of an amplitude-modulated 2400 Hz subcarrier frequency modulating the RF carrier. Table 1.2.5-1 gives the APT line characteristics.

- AMSU Information Processor (AIP) Data

AMSU data is available as part of a low-rate data format. This format contains both standard TIP data and AMSU sensor data. The primary use of this 16 kbps format will be for global recording and playback to CDA stations. It is anticipated that AMSU AIP data will normally be extracted from HRPT, LAC and GAC data. See Section 4 for more information.

Table 1.2.5-1. APT Line Characteristics NOAA KLM Satellites.

Frequency Band	136 to 139 MHz band
Carrier Frequencies	137.50 to 137.62 MHz
Frequency Stability	±0.002%
Out-of-band Emissions	-60 dB at ± 170 KHz and greater from carrier frequency
Transmitted Bandwidth	-3 dB at ± 25 KHz from carrier frequency
Modulated Rate and Type	±17 KHz FM with a 2.4 KHz subcarrier
EIRP	±33.5 dBm

1.2.6 DATA HANDLING SUBSYSTEM

The functions of the Data Handling Subsystem (DHS) are to collect, format, average, and store baseband data from other satellite subsystems; to output baseband data to other satellite subsystems; and to provide synchronous signals and clocks to other satellite subsystems. Tables 1.2.6-1 and 1.2.6-2 list the subsystem data inputs and data outputs, respectively.

Table 1.2.6-1. NOAA KLM Data Handling Subsystem Data Inputs.

Name of Data	**Source of Data**	**First Component Receiving the data**	**Data Characteristics**
Analog Telemetry	All active electronic components on the satellite - 512 separate channels	TIP	Analog health-monitor voltage on a dedicated wire per quantity.
Digital-B Telemetry	Same as above, but 352 separate channels.	TIP	Bi-level status voltage on a dedicated wire per quantity.

Central Processing Unit (CPU) Telemetry-Boost Mode	Same as above, but 352 separate channels.	TIP	NRZ-L data per a specified hand-shake. 8000 bps.
CPU Telemetry - Orbit Mode	CIU	TIP	Same as above, but at 960 bps.
Command Verification Data	CIU	TIP	NRZ-L data per a specified hand-shake. One 16-word per 0.05 second (Boost Mode) or 0.1 second (Orbit Mode).
Digital-A Data	All Government-furnished instruments except AVHRR, SARR, SARP and AMSU. (16 channels, 4 used).	TIP	NRZ-L data per a specified hand-shake. In multiples of 8 bits per 0.1 second: not accepted in TIP Boost or Dwell Modes.
AVHRR Data	AVHRR	MIRP	NRZ-L data per a specified hand-shake. In bursts at 1.9968 Mbps, averaging to 0.6213 Mbps.
AMSU Data	AMSU-A1, A2, B and MHS	AIP	NRZ-L data per a specified hand-shake. 25 8-bit words from AMSU-A1, 13 8-bit words from AMSU-A2, and 50 8-bit words from AMSU-B per 0.1 second. Not intended for TIP Boost or Dwell Modes.

Table 1.2.6-2. NOAA KLM Data Handling Subsystem Data Outputs

Name of Data	**Real-Time or Playback**	**Destination**	**Conditions**	**Data Characteristics**
TIP Orbit	Real-Time	Both Beacon Transmitters (BTX's)	TIP in Orbit Mode	8320 bps split phase

TIP Orbit	Real-Time	STX-2 STX-4	TIP in Orbit Mode Command to XSU Command to AIP	8320 bps split phase
TIP Boost	Real-Time	STX-2 STX-4 (PRIMARY)	TIP in Boost Mode Command to XSU Command to AIP	16640 bps split phase
HRPT	Real-Time	STX-1, -2, or -3	MIRP On Command to XSU	665.4 kbps split phase
APT	Real-Time	Both VHF Real-time Transmitters (VTX's)	MIRP On	Amplitude-modulated 2400-Hz subcarrier
TIP Orbit	Playback	STX-1, -2, or -3	Command to XSU	332.7 kbps split phase
TIP Boost	Playback	STX-1, -2, or -3	Command to XSU	332.7 kbps split phase
GAC	Playback	STX-1, -2, or -3 and STX-4	MIRP on Command to XSU	2.6616 Mbps NRZ or 1.3308 Mbps split phase
LAC	Playback	STX-1, -2, or -3 and STX-4	MIRP on Command to XSU	2.6616 Mbps NRZ or 1.3308 Mbps split phase
TIP Subcom Data	Real-Time	CIU	CIU responds to handshake	64 bits per TIP minor frame-in bursts
AIP	Playback	STX-1, -2, or -3 and STX-4	AIP in Data Mode TIP in Orbit Mode Command to XSU	332.7 kbps split phase

AIP	Real-Time	STX-1, -2 or -3	AIP in Data Mode TIP in Orbit Mode Command to XSU	16640 bps split phase
		STX-4	Command to AIP	

The MIRP generates the four formats (GAC, LAC, HRPT and APT) described earlier. It incorporates algorithms for data processing and data compression and contains large multi-access buffer stores, which time-average the intermittent AVHRR Earth-scan input (thereby achieving a bandwidth reduction) and manipulates the AVHRR signals together with TIP and AIP data into the desired digital formats.

Data storage is provided by five identical DTRs. Each DTR consists of one Electronic Unit (EU) and two tape Transport Units (TU's) with the EU switchable to either of the TU's. Each TU has a record capacity of 225 min of TIP data, 113 min of GAC data or 11.3 min of LAC data. Normal operational playback time for GAC or LAC data is 3 min, but a one-half speed (6 min) GAC or LAC playback can also be commanded. The DTRs are identical to provide flexibility and redundancy at a minimum cost. The spacecraft XSU during record provides the selected record mode command (TIP, GAC, or LAC) clock, and record input data to any of the five DTRs. During playback, the XSU provides the selected playback mode command (TIP, GAC, or LAC) and clock to any of the five DTRs, as well as playback output data from any of the five DTRs to any of four S-band transmitters.

1.2.7 COMMUNICATIONS SUBSYSTEMS

The functional requirements of the Communications subsystem are separated into three distinct phases: prelaunch, liftoff to handover and the mission phase where the solar array and all antennas are deployed. During the mission phase, the subsystem provides the following function:

- <u>Mission Phase</u>

    - Reception and demodulation of S-band commands.
    - Continuous transmission of TIP data via the VHF Beacon.
    - Continuous transmission of APT data at VHF.
    - Continuous transmission of HRPT data at S-band.
    - Transmission of stored LAC, GAC, TIP, and AIP data upon command at S-band.
    - Reception and filtering of DCS signals.
    - Reception, processing and retransmission of SAR signals.

The subsystem comprises 14 antennas, 9 transmitters, and redundant receivers, together with associated filters and other RF feed components. Three 7-watt STX's (STX-1, -2, and -3) and three directional S-band antennas (SBA's) (SBA-1, -2, and -3) mounted on the satellite Earth-facing (+X) surface provide the three principal S-band data links. VHF Omni coverage for real-time TIP telemetry is provided by two 1-watt beacon transmitters (BTX-1 and -2) operating through an omni antenna also mounted on the +X side of the spacecraft. Launch and emergency coverage is provided by a fourth 7-watt (STX-4) and a set of omni antennas mounted on the +X and -X sides of the spacecraft. The two APT 5-watt VTX's (VTX-1 and -2) use a separate dedicated helical antenna; this, like the instrument dedicated antennas, is also directional, Earth-face mounted, and used only in mission mode. The SAR Receiver Antenna (SRA) developed on the ATN program is a unique design incorporating two nested helices: the outer element serving the 121.5 MHz and 243 MHz link, the inner one the 406.05 MHz link.

The fourth SAR uplink (406.025 MHz) is combined with the DCS uplink and is received via the UDA.

The subsystem has two sets of communications links (ascent and operational), which are summarized in Tables 1.2.7-1 and 1.2.7-2. The following summary describes the relationship of subsystem equipment to the communications links:

- S-Band Transmitting Equipment - Three directional SBA's (SBA-1, -2, and -3), and three STX's (STX-1, -2, and -3) provide the routine S-Band downlink services in operational orbit. These downlink services consist of HRPT, GAC playback, TIP playback and LAC playback data. SBA-1 and STX-1 transmit the lowest of the three frequencies, while SBA-3 and STX-3 transmit the highest.

  The S-Band omni antennas (SOA's) (SOA-3, -4) and STX-4 provide launch real-time telemetry to the NASA tracking station at VAFB/WR and to the Advanced Range Instrumented Aircraft (ARIA) aircraft.

- Command Receiving Equipment - The command signal is Phase Modulated (PM) on a carrier at 2026.0 MHz. The modulating signal is a 16 kHz subcarrier modulated by 2 kbps split-phase-level data.

  The Command Antennas, RF Filters, and Dual Command Receiver recover the signal. Both command receivers operate simultaneously and continuously. The outputs of both receivers are cross-strapped externally to the two Command Demodulators. The Command Receiver-Demodulator provides two isolated sets of outputs. Each set of separate output lines are provided to the Control Interface Unit (CIU) and Decryption/Authentication Unit (DAU) for uplink processing.
  The receivers are permanently connected to a set of S-band omni-directional antennas via a hybrid network.

- VHF Telemetry Equipment - The beacon antenna, RF filter, RF switch and BTX (BTX-1 or BTX-2) provide the TIP real-time data listed in Tables 1.2.7-1 and 1.2.7-2.

The directional VHF real-time antenna (VRA), RF filter, and VHF real-time transmitter (VTX-1 or -2) provide the APT data in Table 1.2.7-1.

- Antennas and RF Filters for Payload Instruments - The directional UDA, Data Collection System/Search and Rescue Processor Diplexer (DPD), and RF filter provide the antenna and electromagnetic interference isolation for the DCS listed in Table 1.2.7-1.

The UDA, DPD and RF filter provide the corresponding service for the SARP.

The directional SRA, the directional Search and Rescue L-Band Antenna (SLA) and RF filters provide the corresponding services for the SARR.

Table 1.2.7-1. Ascent, Early-Orbit and Contingency RF Communications Link Characteristics Summary.

Link	Ground Facility	Frequency	Modulation	Bit Rate
S-Band Command	NAGE (pre-launch), CDA, GN	2026 MHz	BPSK/NRZ-M	2 kbps
S-Band TIP Real-Time	WSMC, ARIA Aircraft, AFSCN, DSN, CDA	2247.5 MHz and 1702.5 MHz	Split-Phase Level Data	8,320 bps or 16,640 bps
S-Band TIP Playback	WTR, CDA, Lannion	1702.5 MHz 1707.0 MHz	Same as above	332.7 kbps
VHF TIP Real-Time	CDA, Lannion	137.35 or 137.77 MHz	Same as above	8,320 bps

Table 1.2.7-2. NOAA KLM Operational Link Summary			
Link	**Data Contents**	**Ground Facility**	**Frequency**
S-Band Command	Satellite commands (clear mode or encrypted)	CDA	2026 MHz
VHF TIP Real-Time	Housekeeping telemetry and payload data from all meteorological instruments except AVHRR and AMSU	CDA, TIP Stations	137.35 or 137.77 MHz
HRPT	Full-resolution AVHRR data plus concurrent TIP AMSU and TIP data	CDA, HRPT Stations	1698 or 1707 MHz
GAC Playback	Global reduced-resolution AVHRR data plus TIP data stored on satellite tape recorders	CDA	1702.5 MHz and either 1698 or 1707 MHz
LAC Playback	Tape-recorded-replica of HRPT data		Same as above.
TIP/AIP Playback	Tape-recorded-replica of TIP/AIP real-time data	Lannion TIP Playback Station	1698 or 1702.5 or 1707 MHz
APT	Reduced resolution, geometrically-corrected analog video from two of the five AVHRR channels, selected by command	CDA, APT Stations	137.50 or 137.62 MHz
DCS Uplink Messages	Environmental measurements, identification, and a frequency reference for Doppler navigation; from unattended platforms	DCS Platforms	401.65 MHz
SAR 121.5 MHz Uplink Signals, 243 MHz Uplink Signals	Emergency transmissions from downed aircraft and ships. Aircraft transmitters are ELT's; ship transmitters are EPIRB's	121.5/243-MHz ELT's EPIRB's	121.5 MHz 243 MHz

SAR 406 MHz Uplink Messages Received Separately by SARR 406 MHz Channel and by SARP	Same as above, but with improved frequency stability and modulation containing identification of the aircraft or ship	406-MHz ELT's and EPIRB's	406.05 MHz
SARR Downlink	Transponder frequency-multiplexed SAR uplink signals and messages from all three uplink frequencies, preserving uplink phase for Doppler tracking by ground stations; also 406-MHz messages reformatted and tagged with time and Doppler measurements by the SARP; the SARP data transmitted in near-real-time and also cyclically from SARM.	SAR LUT's	1544.5 MHz

1.2.8 THERMAL CONTROL SYSTEMS (TCS)

The TCS consist of active and passive thermal control equipment. The TCS maintains unit temperatures within the specified operating range, generally within limits of 0 to 35 degrees Centigrade (C). A combination of onboard and nonflight thermal control is required during test or prelaunch phase.

Passive thermal control is affected by the appropriate use of multilayer insulation blankets, aluminized Teflon thermal shielding, special finishes, and thermal-conduction-control materials. The major active elements of the TCS are heaters and louver-controlled cooling radiators. There are two types of louvers: vane louvers and pinwheel louvers, both controlled by Thermal Control Electronics (TCE) units. The satellite incorporates a safe-state mode of operation where, in the event of a major anomaly such as loss of proper attitude, a powered-down state is automatically entered. Under this condition, TCS heaters maintain critical equipment, including instruments, at a safe temperature until mission operations can be re-established.

The thermal control system is designed to achieve satellite thermal control for all Sun angles between 0 degrees to 80 degrees. The TCS functions include the following:

- Maintain spacecraft subsystem and instrument temperatures within spacecraft allowable limits;
- Minimize temperature excursions within the specified limits (T<5 degrees C/hour);

- Minimize thermal impact of AKM burn during mission ascent phase;
- Prevent on-orbit low temperatures within the RCE hydrazine system;
- Maintain instrument interface temperatures, operational mode only, between 0 and 30 degrees C and internal satellite/equipment between 5 and 35 degrees C;
- Prelaunch thermal conditioning of equipment before and during mission ascent phase.

1.2.9 POWER SYSTEM

Electrical power is provided by a direct energy transfer regulated bus power system. The primary energy converter is a single-axis-sun tracking solar array, and the energy storage system consists of a set of three nickel-cadmium batteries. The major components are the Solar Array (SA), batteries, Power Supply Electronics (PSE), Battery Charge Assembly (BCA), Solar Array Drive (SAD), Array Drive Electronics (ADE), Battery Reconditioning Unit (BRU) and the Controls Power Converter (CPC).

In the mission mode, the SAD rotates the SA once per orbit so that it continually faces the Sun. The SA is canted to either 22 or 36 degrees to the orbit normal, depending on whether the spacecraft is in a morning or afternoon orbit. The three batteries supply power through the boost regulator during the dark portions of each orbit and augment the solar array for peak-load conditions during orbital daylight.