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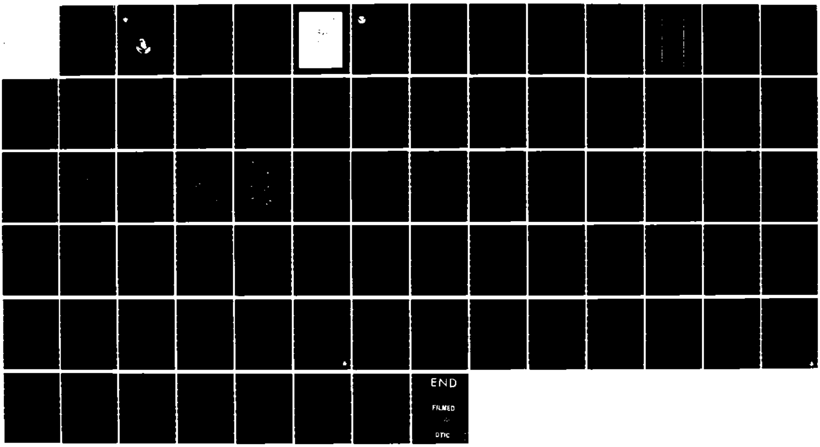

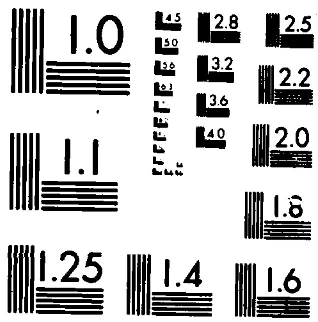

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ENVIROSAT–2000 Report

GOES–Next Overview

September 1985

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data and Information Service

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This report describes, in summary form, the current National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES) system and the scientific rationale used to develop specifications for the next generation of satellites of this series. The payload instruments of the current satellites are reviewed in conjunction with the products prepared from their data outputs. The rationale used by the National Weather Service (NWS) in developing top-level requirements for GOES-Next stresses the projected use of data within the restructured NWS organization expected in the 1990's. NOAA-certified requirements used by

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ENVIROSAT–2000 Report

GOES–Next Overview

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Washington, D.C.
September 1985

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GOES-NEXT OVERVIEW

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Frontispiece: Artist's rendering of the spacecraft of the GOES I, J, K series. The conical solar sail points north. (Art courtesy of Ford Aerospace and Communications Corporation.)

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I. INTRODUCTION

The Geostationary Operational Environmental Satellite (GOES) system provides coverage of dynamic weather events not only over the contiguous 48 states but also over a major portion of the central and eastern Pacific Ocean, and the central and western Atlantic Ocean. The Pacific coverage includes both Hawaii and the Gulf of Alaska, known to weather forecasters as "the birthplace of North American weather systems." As may be seen in figure I-1, coverage of both the Atlantic and Pacific basins by GOES satellites is only practical when two satellites (separated by 60° of longitude) are actively producing data. Since both areas have a strong influence on the weather affecting the United States, it becomes obvious that this capability is necessary if the weather monitoring and forecast service for the United States is not to suffer degradation. The procurement of GOES satellites is planned around maintaining this capability.

The objectives of the GOES system program are to:

> Maintain reliable operational, environmental, and storm warning systems to protect life and property; monitor the Earth's surface and space environmental conditions; and introduce improved atmospheric and oceanic observations and data dissemination capabilities. Develop and provide new and improved applications and products for a wide range of Federal agencies, State and local governments, and private users ...

In defining the goals for the GOES program, the National Oceanic and Atmospheric Administration (NOAA) strives to attain three objectives. These are:

- Continuity of service
- Low cost
- Technological superiority

Evolutionary improvements are indispensable to users and have been accommodated as the program has progressed from the 1974 Synchronous Meteorological Satellite (SMS-A) through the projected GOES I (GOES-Next) satellite planned for launch in the early 1990's. The principal focus of these improvements has been the provision of data that are useful for short-term forecasting of local severe weather and related events. GOES data are used both subjectively and, in recent years, objectively at National Weather Service (NWS) offices and are vital to the generation of tornado and severe thunderstorm forecasts and warnings. These data also play an important role in flood

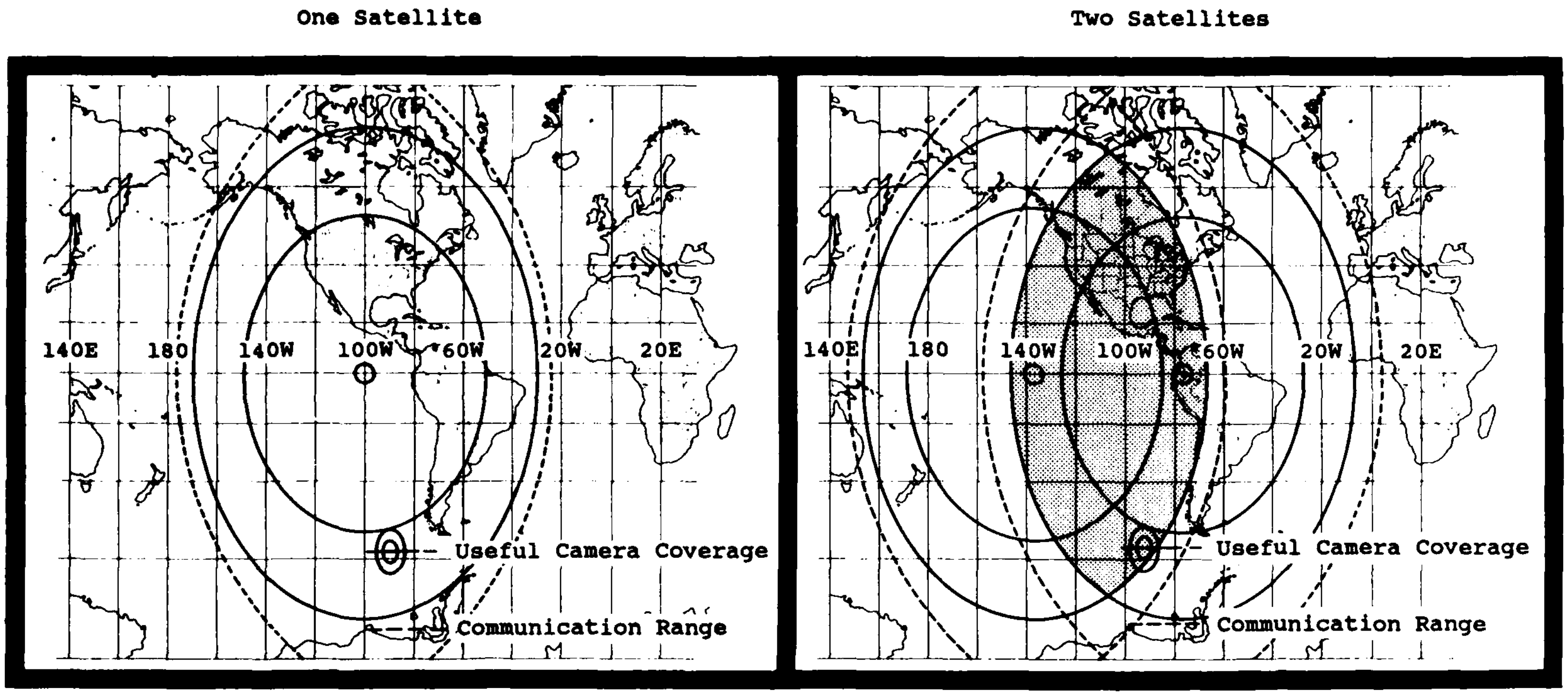


Figure I-1
GOES Geographic Coverage

and flash flood forecasting where quantitative precipitation estimates are significant inputs. The use of imagery and data obtained from in situ platforms by the GOES Data Collection System (DCS) are important to this process.

On order today are two satellites of the current generation of GOES satellites, called GOES G and GOES H. These satellites, which are planned for launch in 1986, are expected to maintain a continuity of data services from geostationary orbit into the early 1990's. The satellites that are to replace GOES G and GOES H have been called GOES-Next. These satellites are planned to provide evolutionary improvements in the quality and quantity of data available to the users. This paper first discusses the current generation of satellites and their capabilities, then describes the types of improvements planned for the future. Finally, a description of the satellite system (including instruments) projected for launch in 1990 is provided as a view of what the future holds in store.

II. CURRENT GOES SATELLITES AND CAPABILITIES

The current generation of GOES satellites contains instrumentation used to make measurements of the Earth's atmosphere, surface, cloud cover, and electromagnetic environment. Other equipment supports data collection and distribution systems that form the basis for ongoing operational systems. These systems are logical follow-ons to those flown on the National Aeronautics and Space Administration (NASA) Applications Technology Satellites (ATS) and the early satellites of the SMS/GOES series. The following discusses the payload instrumentation and supporting subsystems; it also highlights some of the valuable products derived from the current GOES satellites, which are discussed more fully in appendix A.

A. VISSR ATMOSPHERIC SOUNDER

The Visible and Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS) is an advanced version of the VISSR developed for worldwide geostationary satellite systems. It is the principal meteorological instrument carried on the GOES satellite. The VISSR is a dual-band (visible and infrared) spin-scan imaging device that is used for day and night two-dimensional cloud cover images. The VAS retains the VISSR dual-band imaging function, but adds 12 infrared channels in a complex detector array that can provide data from which it is possible to infer the three-dimensional structure of atmospheric temperature and water vapor distribution. The VAS, with both imaging and sounding capabilities, provides near-continuous cloud cover data with resolutions of 1, 2, 4, and 8 km in the visible wavelengths and 8 to 14 km in the infrared wavelengths. The VAS also has 12 infrared channels whose data are used to derive vertical temperature and moisture profiles (soundings) over selected areas. Specific modes of operation for this instrument include:

- Two-channel imaging of the full Earth disk or a limited area on a repetitive basis.

- Multispectral imaging that adds a low-resolution output of an additional infrared channel to the two primary outputs. This mode is generally used to obtain water vapor images.

- The dwell sounding mode, which provides sequential data from 12 infrared channels as they scan a common geographic area on the Earth. When used in this mode, normal imaging is precluded.

VAS products include full Earth disk images of cloud patterns in the visible and infrared every 30 minutes throughout the day and night. As an alternative, the VAS may provide partial disk images (sectors) at more frequent intervals (up to every 3 minutes) as required to view the development and movement of severe storms. Full disk images in the water vapor portion of the spectrum are now provided four times a day. The VAS can also provide data to be used for atmospheric soundings. Imaging and sounding are not possible simultaneously, since soundings now require repeated scans of the same surface area to reduce signal-to-noise levels adequately to provide meaningful soundings.

The following are examples of some of the quantitative products derived from data acquired by the VAS instrument:

- Cloud top heights. The infrared band may be used to estimate the temperatures of cloud tops. These cloud top temperatures are combined with radiosonde data and conventional temperature analyses, using an interactive computer process, to determine the height of the tops of clouds.

- Sea surface thermal patterns. By saving the warmest values of infrared brightness temperatures for a period of time, the effect of clouds in the field of view is reduced, and the thermal patterns of the sea surface are preserved. The major ocean thermal features revealed include the Gulf Stream and its major meanders and eddies, the Gulf of Mexico Loop Current, and the changing flow patterns in equatorial ocean currents.

- Quantitative precipitation estimates. A combination of manual interpretation and interactive computer enhancement of both the visible and the infrared imagery is used to provide estimates of the amount of precipitation coming from convective storm systems and hurricanes.

- Weather warnings. Imagery data from geostationary satellites are used by the National Weather Service to provide a wide range of weather warnings and forecasts to public, aviation, and marine interests. Offices with hurricane warning responsibility, including the National Hurricane Center (NHC) and local forecast offices, use sequential GOES images to identify, track, and estimate the intensity of developing tropical storms and hurricanes for an area that stretches across the Atlantic Ocean to west of the Hawaiian Islands in the Pacific. Satellite imagery is often the only source of real-time information across this vast oceanic area.

- Sea fogs. Sequential ocean image analyses are used to detect fog at sea.

- Calculation of Earth's energy balance. The Earth's energy balance is calculated, by regions, with solar input reduced by infrared (heat radiation) losses to space to determine net regional energy gains. The results are useful in climate studies and to assess the impact on short-term weather of such events as volcano explosions.

- Ice paths. Paths through ice, for Alaskan waters and the Great Lakes, are plotted for oil tankers and other shipping vessels using GOES images and an ice analysis program.

B. SPACE ENVIRONMENT MONITOR

The Space Environment Monitor (SEM) sensors are designed to provide direct measurement of important effects of solar activity in such a manner that data are available continuously in real time to generate advisory or warning messages. The data also are available for other uses, such as forecasting and operational research. The SEM consists of three basic components:

- Energetic Partical Sensor (EPS). Three particle detector groups for measuring the flux of energetic electrons, protons, and alpha particles in the vicinity of the satellite

- Solar X-ray Sensor (XRS). An ion chamber instrument sensitive to x-ray quantum energies in two bands

- Magnetometer. A biaxial flux gate instrument with associated signal processing

These components were developed in direct response to a range of requirements for space environment information. The following discusses these requirements and how the SEM works to provide needed data.

1. Solar Energetic Particles Subsystem

Solar particle radiation constitutes the major radiation hazard to manned space flight activities. It also presents an operational problem to flights at high altitudes and is responsible for major high latitude communications blackouts.

The operational need exists to provide a warning at the onset of a solar event and a sufficient quantitative description of the flux to enable the actual radiation hazards and communications effects to be calculated. The second need cannot be met by ground-based measurements except in a very limited fashion. GOES has great advantages for operational monitoring because of the continuous transmission of real-time data.

The data required for radiation hazard calculations in the Manned Space Flight Program have been defined as at least four points in the spectrum between 15 and 100 MeV for protons and four points in the 60 to 400 MeV range for alpha particles.

Calculations of hazards to high altitude aircraft flights demand a knowledge of energies from 100 MeV up to the giga-electronvolt range because of the shielding effects of the atmosphere. The requirements for prediction of communications effects are primarily for information on proton fluxes below 50 MeV, where the high latitude fluxes and ionospheric effects are large.

2. Solar X-ray Data

X-ray emission is the direct cause of immediate ionospheric effects associated with solar flares (that is, changes in the heights of reflective layers and changes in absorption of very low frequency, low frequency, and high frequency radio paths). These effects can be calculated from quantitative x-ray measurements.

There is a continuous need for monitoring solar x-ray data. The background level of x-ray radiation from the quiet sun is an excellent general indicator of solar activity. There is also a good deal of evidence to suggest that most flares are preceded by a gradual buildup in background level over the preceding 10 to 30 minutes.

3. Magnetometer

The magnetosphere is a dynamic region whose magnetic field variations define, in many ways, the motions of the plasma of charged particles contained within its boundaries or guided to the Earth's surface. These are the particles responsible for auroral radio wave absorption, polar communications blackouts, radiation hazards for space flight, and so on.

These fields have been studied at ground observatories. However, the surface field is a complex mixture of solid Earth sources, magnetospheric perturbations, ionospheric currents, induced surface effects, and miscellaneous other contributions. Satellite field determination allows the separation of the space effects from the surface and ionospheric effects.

The magnetometer is used to measure the field direction and magnitudes in the range of 10 to 500 gamma. This can be used immediately to warn of magnetospheric boundary compressions past the satellite position. The data also are used to assist in predicting trajectories of observed energetic particles and developing techniques for projecting Earth observatory data into the space environment. In addition, the data enable investigation of currents within the magnetosphere and the magnetic field micropulsations in the region of the spacecraft.

C. DATA COLLECTION SYSTEM

A Data Collection System is used to obtain data from in situ platforms, on schedule or on command. Repeated environmental measurements are needed from locations that are difficult, hazardous, or expensive to access frequently. Measurements also are needed from locations not served by existing ground communications networks. The DCS service solves many of these problems by enabling rapid user access to measurements made by remotely located data collection platforms (DCPs).

The DCS can access data from a DCP. Data transmission from user-owned sensor platforms can be initiated in response to one of three signals: interrogation from the DCS, an internal timer, or sensor threshold conditions requiring immediate attention, such as seismic activity. GOES relays the platform signals to the Command and Data Acquisition (CDA) station, which performs error checks and relays them to NOAA offices at the World Weather Building in Camp Springs, Maryland. The data are then distributed to the users.

D. WEATHER DATA DISTRIBUTION

The weather facsimile (WEFAX) system is a communications service provided through GOES. Broadcasts are scheduled in the 10-minute interval between successive VISSR/VAS mode readouts, using the wide band VISSR mode communications channel. WEFAX transmissions include meteorological charts and imagery from GOES and NOAA polar-orbiting satellites. GOES VISSR images presented in the WEFAX format have a resolution of about 8 km. Images are transmitted in segments that are compatible with WEFAX ground equipment, which was developed from the early Automatic Picture Transmission (APT) image displays. Since each segment requires 4 minutes to transmit, two segments may be contained in each 10-minute broadcast interval. (A summary listing of current GOES products and some of their applications are included as table A-1 in appendix A.)

III. GOES-NEXT REQUIREMENTS

Requirements for the GOES-Next series of satellites were developed during a two-phase process. In phase one, NOAA and NASA looked at potential configurations for a comprehensive GOES system. After a careful review of the conceptual designs and their proposed cost [A Geostationary Operational Environmental Satellite (GOES)-Next Concept Study (Oct. 19, 1981)], it was decided that the GOES-Next should be Shuttle compatible, but should deviate from the current GOES satellites only in a manner that could be considered as evolutionary. NASA was then asked to procure satellites that met the requirements.

A. NATIONAL WEATHER SERVICE REQUIREMENTS

The National Weather Service reviewed the proposed system specifications and determined that they did not go far enough toward meeting their requirements for the 1990's. After a thorough analysis of imaging and sounding requirements, NWS requested that changes of a more innovative nature be implemented. The GOES-Next imaging and sounding requirements that formed the basis for the Request for Proposal (RFP) that was released to industry were inherently those of the NWS, modified slightly to meet technological constraints and to allow the Government to maintain a competitive procurement posture. The following material is extracted directly from NWS GOES-Next Requirements (April 1983).

Full-disk and sector displays are useful as a real-time source for the location of actual or potential severe weather and for issuing advisories in data-sparse areas, for following cloud motion and deducing wind speed and direction from successive pictures, numerical modeling, and for use (in sequence) in producing movie loops. As a research tool, or in alerting forecasters to potential areas of concern, the images may be altered by enhancing the data displayed. An enhancement can emphasize areas of interest such as cloud tops, stratus decks, fog areas, etc., by alteration of the gray scale used. During severe or potentially severe weather periods, a VISSR instrument can be operated to provide visible and infrared (IR) imagery every 15 minutes.

These images are routinely disseminated to NWS Forecast Offices in facsimile format and displayed as hard copy (paper). At present, selected Weather Service Forecast Offices (WSFOs), mainly those that are colocated with Satellite Field Service Stations (SFSS), and the National Centers, including the National Severe Storms Forecast Center (NSSFC), NHC, and the National Meteorological Center (NMC), receive and display satellite data on electronic animation devices. By 1987, field offices are also expected to have electronic displays.

There will be a continuing requirement for two operational geostationary meteorological satellites stationed around 75° and 135° W. longitude.

The pressures generated by severe weather and population growth on an increasingly complex society will have grown, not lessened, and the need for spaceborne Earth and atmosphere observing systems will grow as a result. It is assumed that there will be a complementary system of operational polar-orbiting satellites so that requirements for backup from GOES-Next over oceanic areas will not constitute a major use of the GOES sounder. If not, it will be necessary to adjust the user requirements for geostationary soundings from those defined in this document.

Forecasting techniques will gradually improve, over all scales and time periods, from local area short-period forecasts, through 1-day regional forecasts, up to global medium range forecasts extending over 3 to 10 days, and even beyond that into seasonal and climate forecasts. GOES data will be especially valuable for short time periods and 24-hour regional forecasts.

NWS expects to develop a new generation of interactive processing and display systems that will accommodate high-resolution digital satellite data. These systems will be deployed at the National Centers and regional and local forecast offices under a modified field structure. The principal focus will be on the short-term forecasting of local severe weather and related events.

The requirement to provide information at the local and regional level is the most critical since it requires:

- Higher horizontal resolution
- Flexibility to select the area of meteorological interest
- More spectral channels than those now in use
- Rapid and more frequent delivery to many users
- High reliability

Finally, with the emphasis on short-term forecasting over local areas, the delay between observations, receipt of the data at NWS offices, and the delivery of the forecast to the users must be significantly reduced.

In summary, the future use of geostationary satellites will be characterized by:

- Expanded operational use
- Increased demand for improved reliability and immediate availability
- Emphasis on short-period forecasts and warnings over local areas
- Increased use of numerical data
- Flexibility for growth, development, and research
- Accompanying developments in dissemination, meteorological interpretation, and display systems

1. GOES Imaging Requirements

The GOES imaging mission has been an outstanding success and emphasizes the need for improved services. Several aspects of the current GOES/VAS system have been identified as candidates ... improvements.

a. Spectral Selection. The current GOES imaging mission ha... been successful in detecting the existence and growth o... severe storms and the existence and movement of water vapor in the middle troposphere, during both daylight and nighttime. This success has led to a requirement for the acquisition and dissemination of at least five spectral channels, including the 0.55 to 0.75 μm visible channel required for daytime detection and monitoring of severe thunderstorms and tropical storms. Split window IR imagery in the ranges 10.2 to 11.2 μm and 11.5 to 12.5 μm is necessary to monitor low-level moisture and to estimate surface temperature. The 10.2 to 11.2 μm channel is also needed for the day and night surveillance of convective storms.

The 6.5 to 7.0 μm or "water vapor" imagery is used to depict jet stream location and midtropospheric circulations. The 3.8 to 4.0 μm IR channel is useful for cloud detection at night, and, when used in conjunction with other channels, it is useful for estimating water vapor in the lower troposphere.

b. Temporal Resolution. The current GOES can image the full disk in less than 20 minutes. This basic capability is used in three ways:

- The full disk is imaged once every half-hour for routine weather monitoring. Every 6 hours, a sequence of three of these images is used to produce cloud motion winds within a 50° great circle arc of the satellite subpoint.

- A less-than-full disk (North America) image is acquired every 15 minutes when severe storms are anticipated or in progress.

- Imagery over the conterminous states is obtained at 3-minute intervals in support of severe storms research activities.

These uses will continue, with the expectation that by 1990 operational severe storm forecasting will require imagery at 5-minute intervals. Therefore, the design for the GOES-Next system must minimize the conflict between large- and small-scale applications of the GOES imagery, i.e., the acquisition of full disk and U.S. image sectors. This conflict will be minimal if the instrument is capable of imaging the area within a 50° great circle arc of the subpoint in 15 minutes or less.

c. <u>Spatial Resolution</u>. The following is a summary of requirements by channel. The visible (0.55 to 0.75 μm) imagery must have a nadir resolution of at least 1 km. This will provide continued, accurate location of storm phenomena, and, when used with rapid scanning and cloud growth analysis techniques, it will provide for improved cloud motion and cloud growth analysis.

- The current resolution (field of view) of the IR window channel (10.2 to 12.5 μm) is 6.9 km square at the satellite subpoint. At 50° N., this square deteriorates to about 14 by 7 km. This limits the effectiveness of the GOES data over much of North America and the meteorologically active zones of the Atlantic and Pacific Oceans. Since many operational facilities in the United States are already in a position to use higher resolution data, the design objective for U.S. sectors should be 4 km at nadir for the 10.2 to 11.2 μm channel. The longest edge of any field of view within a 50° great circle area would be no more than 7 km, i.e., twice the present resolution. The resulting analyses of storm location, cloud motion, cloud top temperature, and surface temperature will all be significantly improved. For U.S. sectors, a 4 km resolution is also required for the companion split window channel (11.5 to 12.5 μm).

- Since water vapor in the atmosphere changes more slowly than cloud shape, an 8 km nadir resolution is sufficient for its observation at 6.5 to 7.0 μm.

- The 3.8 to 4.0 μm IR channel is used in support of cloud detection and should have a 4 km nadir resolution.

d. <u>IR Temperature Sensitivity</u>. The tops of large thunderstorms with cloud top temperatures colder than 230 K should be monitored closely, since temperature fluctuations in clouds at the top of the thunderstorm are often related to severe rainfall, hail, tornadoes, and high wind events. High sensitivity for temperatures near 273 K is also necessary to detect Earth surface temperatures and to monitor the development of cumulus clouds. The 10.2 to 11.2 μm channel must provide temperature sensitivity of 1.45 K at scene temperatures of 200 K. The 6.5 to 7.0 μm channel should have a temperature sensitivity of 1.0 K at 200 K.

e. <u>Data Delivery Times</u>. The emphasis will be on short-range forecasts over geographically limited areas. High-resolution imagery is perishable, especially when it is required for the short-term forecast and warning function. Onboard processing of imagery data should introduce no more than a 30-second delay.

f. <u>Earth Location Requirements</u>. Equally important to the specific instrument requirements for GOES-Next observations is the need to determine accurately and quickly the location of those observations in true Earth coordinates. Navigation accuracy of the GOES-Next imagery information should, in an absolute sense, be no worse than 2 km. Picture-to-picture relative accuracy of one-half of a field of view over four consecutive images is required.

g. <u>Channel-to-Channel Registration</u>. Channel-to-channel misregistration should not exceed one-tenth of a field of view.

h. <u>Simultaneity</u>. A 40 m/sec wind moves across a 4 km space in 100 seconds. Therefore, information from all five imaging channels for a given 4 by 4 km area must be acquired within a small fraction of 100 seconds, say, 2 seconds.

i. <u>Advanced Options</u>. There are a number of research and potential operational improvements that should be considered. The first is temporal resolutions less than 5 minutes for smaller than 3,000 by 3,000 km areas. This would be expected to improve the quantity and quality of winds derived from cloud motions, and the analysis of thunderstorm cloud tops that can help discern and possibly predict storm severity. The highest useful temporal resolution should be about 0.5 minutes over an area of 1,000 by 1,000 km for the storm top analyses. The second improvement would be an increase of the thermal sensitivity of the three infrared channels (3.8 to 4.0 μm, 10.2 to 11.2 μm, and 11.5 to 12.5 μm) to improve the quantitative derivation of low-level moisture, surface temperature, and cloud parameters (amount, type, and height). The better thermal sensitivities (NEΔT) from these channels to achieve this are: 1) 3.8 to 4.0 μm, 0.2 K at 300 K; 2) 10.2 to 11.2 μm, 0.1 K at 300 K; 3) 11.5 to 12.5 μm, 0.1 K at 300 K. If they are inexpensive, either of these capabilities is worthwhile.

2. <u>GOES Sounding Requirements</u>

The current GOES satellite includes a combined imaging and sounding instrument known as VAS. The instrument can operate in two imaging modes--one identical to, and completely compatible with, earlier GOES imaging instruments, and the second a multispectral imaging mode. The mode of operation used to derive temperature soundings, however, is mutually exclusive with the two imaging modes. Hence, the single VAS instrument of the current GOES series must be time shared to acquire both sounding and imagery. The sounding requirements stated in this section must be met without compromising the imaging requirements stated in the previous section. The sounding data are needed to provide two types of products in clear and partly cloudy areas.

a. <u>Measurement</u>. Hourly measurements of temperatures and humidity in the troposphere, with a spatial resolution of 25 to 30 km, are required for the derivation of stability indices and temperature-moisture trends for short-period local area forecasting over the United States. The area covered should be selectable (on command) to be as large as 3,000 km latitude (e.g., 25° to 50° N.) and 3,000 km longitude (e.g., 60° to 100° or 120° to 160° W.). An area of this size should be observed in a time period no longer than 30 minutes. When the satellite sounding data are combined with conventional surface observations, the error of a computed "lifted index" in clear areas should be no larger than 25 K. [The lifted index is a stability parameter that is the difference between an air parcel lifted from the boundary layer (i.e., 850 mbar) to the 500 mbar level and compared with the ambient 500 mbar temperature.]

b. <u>Profiles</u>. Computation of profiles of temperature and moisture from ground to tropopause height should be available routinely or on demand, as follows:

- For possible use in mesoscale numerical weather prediction, data are needed every 12 hours over a continental U.S. area (25° latitude by 40° longitude). No restriction should prevent increasing the frequency of receipt of these data, in the event that more frequent numerical weather prediction is worthwhile. When these data are required they could replace the hourly soundings described previously. The measurements should take no longer than 30 minutes.

- As a backup to the polar-orbiting satellite system, soundings over oceanic areas adjacent to the United States (e.g., the eastern Pacific), extending from 25^{o} to 50^{o} N. and covering a longitude belt of 40^{o}, may be required on demand. This mode may also be useful in the numerical prediction of hurricane movement.

A simple statement of the desired accuracy of temperature and moisture soundings from GOES might be to request no more than about a +0.5^{o} error in temperature, and good reproduction of the vertical detail that is often present in the lower troposphere and considered to be important in forecasting convective outbreaks. Existing remote soundings, such as the VAS or High Resolution Infrared Radiation Sounder (HIRS), fall far short of this, having typical root mean square errors of about 2^{o} for 100-mbar-thick layers, with considerable smoothing of temperature inversions and the tops of moist surface layers. (Similar difficulties occur at sharp tropopauses.)

It is not known whether remote sensing can ever reproduce this requirement to capture vertical detail. It would be meaningless, therefore, to apply such criteria to soundings from GOES-Next at this time. It is important, nonetheless, to record this goal, since its attainment would allow considerable economies from a drastically reduced need for radiosonde temperatures and moistures.

There are several proposed IR instruments such as the Advanced Meteorological Temperature Sounder (AMTS) and the High Resolution Interferometric Sounder (HIS) that promise to reduce the present large satellite retrieval errors and capture more vertical detail. These conceptions are not advanced enough, however, to be reliably available for launch on GOES-Next by 1990. As a practical matter then, we are forced to list accuracy goals for soundings that seem to be attainable with present proven technology, i.e., goals that are close to the best results from VAS or HIRS in clear conditions. These data will be useful for the hourly measurement products listed earlier. At 0000 and 1200 G.m.t. these radiances, in combination with U.S. radiosondes, can provide temperature data of finer horizontal resolution (in clear air) than the 400 km or so distance between the radiosondes. This would be useful to predict regional numerical weather over the United States.

This method of making and using VAS retrievals is being studied by the NASA/Goddard Laboratory for Atmospheric Sciences (NASA/GLAS). The radiances would also be accurate enough to be used by themselves over the ocean areas described.

Experience with the finer resolution of visual images by the National Environmental Satellite, Data, and Information Service (NESDIS) (W. Smith) has shown that a smaller instantaneous field of view (IFOV) than the present 15 by 15 km IFOV of VAS would significantly improve the ability to find clear spots in partly cloudy regions. In the absence of microwave sensors, this consideration is very important. We recommend, therefore, a spatial resolution for sounding measurements (at nadir) of IFOV 10 by 10 km.

The meteorological uses described above can exploit retrievals as close together as 60 km. We consider it desirable, therefore, to be able to attain a retrieval from any 60 by 60 km area (i.e., an array of 36 contiguous IFOVs) that has at least nine clear IFOVs. Thus, the clear area radiances available for a retrieval can come from an area of at least 900 km^2.

Given these constraints, the currently practical and expedient retrieval root mean square errors are as follows:

Temperature (100-mbar layer means)

1,000 to 700 mbar: $\pm 2.0^{\circ}$

700 to 300 mbar: $\pm 1.5^{\circ}$

300 to 100 mbar: $\pm 2.5^{\circ}$

Relative humidity (200-mbar layer means)

1,000 to 600 mbar: $\pm 20\%$ (absolute)

600 to 200 mbar: $\pm 15\%$

It is understood that standard surface temperature and dew points (or sea surface temperature) may be combined with GOES radiances to obtain these accuracies, but that the retrieval process should attain this accuracy without the help of contemporaneous radiosondes. The radiances needed for a 3,000 by 3,000 km area (e.g., 90,000 IFOVs) should be obtained within 30 minutes, and the area should be relocatable at successive sounding runs (hourly).

A more rapid sounding mode, in which a 1,000 by 1,000 km area can be scanned repeatedly within 10-minute intervals, could be an important way to sense the rapid changes in the vicinity of existing thunderstorm complexes. This mode should be easily achievable if the 3,000 by 3,000 km "standard" sounding area is made programmable to this more rapid mode.

These consolidated sets of requirements, which were provided by NWS, were summarized and sent to NASA to form the basis of the technical specification incorporated into the RFP for the GOES I, J, and K satellites. This summarized set of NOAA requirements is included as appendix B.

B. GOES-NEXT TOP-LEVEL REQUIREMENTS

The specification that was released requested industry to meet the stated performance characteristics without defining the technical implementation to be used. This offered the prospective contractors a wide range of options from which to choose a cost-effective approach for meeting the technical specifications. A summary of the top-level requirements includes:

- Space Transportation System (STS)-compatible satellite system
- Independent imaging and sounding functions--improved instrument characteristics (resolution, navigation, channelization, signal-to-noise, etc.)
- Full-time weather facsimile capability
- Data collection system
- Space environment monitor system
- Search and rescue (406 MHz) transponder

The FY86 budget request to Congress recommended procurement of the fourth and fifth GOES-Next satellites, to be called GOES L and GOES M. It was recommended that these satellites be procured to provide an operational configuration where failed satellites could immediately be replaced, thereby maintaining continuity of data. An option for these satellites has been obtained and may be exercised by December 1985 if approved by Congress.

IV. THE GOES-NEXT SYSTEM

The winning proposal for the GOES-Next system was submitted by the Ford Aerospace and Communications Corporation (FACC). The FACC-proposed on-orbit configuration is based on its STS-launched, flight-proven Indian Insat satellite design. It will be STS-optimized to minimize launch costs and will contain integral propulsion to boost the satellite from the Shuttle altitude into the final geostationary orbit. The three-axis, body-stabilized satellite will provide a space platform for the imager and sounder to be built by the ITT/Aerospace and Optical Division. The SEM instruments, to be built by Panametrics Corporation and Ball Aerospace Systems Division, will be technically improved models of the current series. A single solar array "wing" opposite the imager and sounder coolers will power the system. An artist's conception of the FACC GOES-Next design is shown in the frontispiece.

The satellite's configuration is essentially a compact, six-sided (main) body that carries the operational instrument payload, a continuous-drive solar array attached to the south panel through a yoke assembly, a solar sail mounted off the north panel to offset solar pressure torque, a telemetry and command (T&C) antenna boom-mounted on the east end for full omnidirectional coverage, and the SEM magnetometer on a boom off the anti-Earth side of the satellite. The spacecraft design includes provisions to add on the x-ray imager, if desired.

The main body of the satellite accommodates the imager, the sounder, and SEM instruments. It also carries all of the supporting subsystems. All of the communications antennas, except those for telemetry and command, are fixed to the Earth-facing panel for unobstructed Earth coverage with maximum alignment stability.

The sounder is mounted next to the imager, with the coolers for both instruments looking toward the north. Each instrument has a flight cooler cover to protect the sensitive surfaces from sunlight and particle contamination during the launch phase. After a period of on-orbit spacecraft outgassing, each of the cooler covers will be opened to allow the system to reach the appropriate operating temperature.

A flight-proven solar sail and boom, to be used to balance the solar array, have the exact dimensions and are deployed to the identical positions as on Insat. The solar array is a lightweight two-panel assembly, attached to a continuously rotating solar array drive assembly by a graphite yoke that also functions as a sun-tracking platform for the x-ray sensor.

thermal control of the spacecraft will be achieved primarily by passive techniques augmented by heaters and louvers. Ground-commanded heaters will be used on the propulsion tanks, lines, and valves.

A Payload Assist Module, Delta class (PAM-D; STAR 48) solid motor will be used as the perigee stage; a bipropellant system will be used as the apogee stage and for in-orbit manuevering.

The satellite configuration, as it will appear in orbit, is shown in figure IV-1.

A. THE SPACECRAFT BUS

The spacecraft will be designed in a modular configuration to provide maximum assembly and test accessibility to expedite assembly and testing. The bus will consist of two major components, the Propulsion Module (PM) and the Electronics Module (EM).

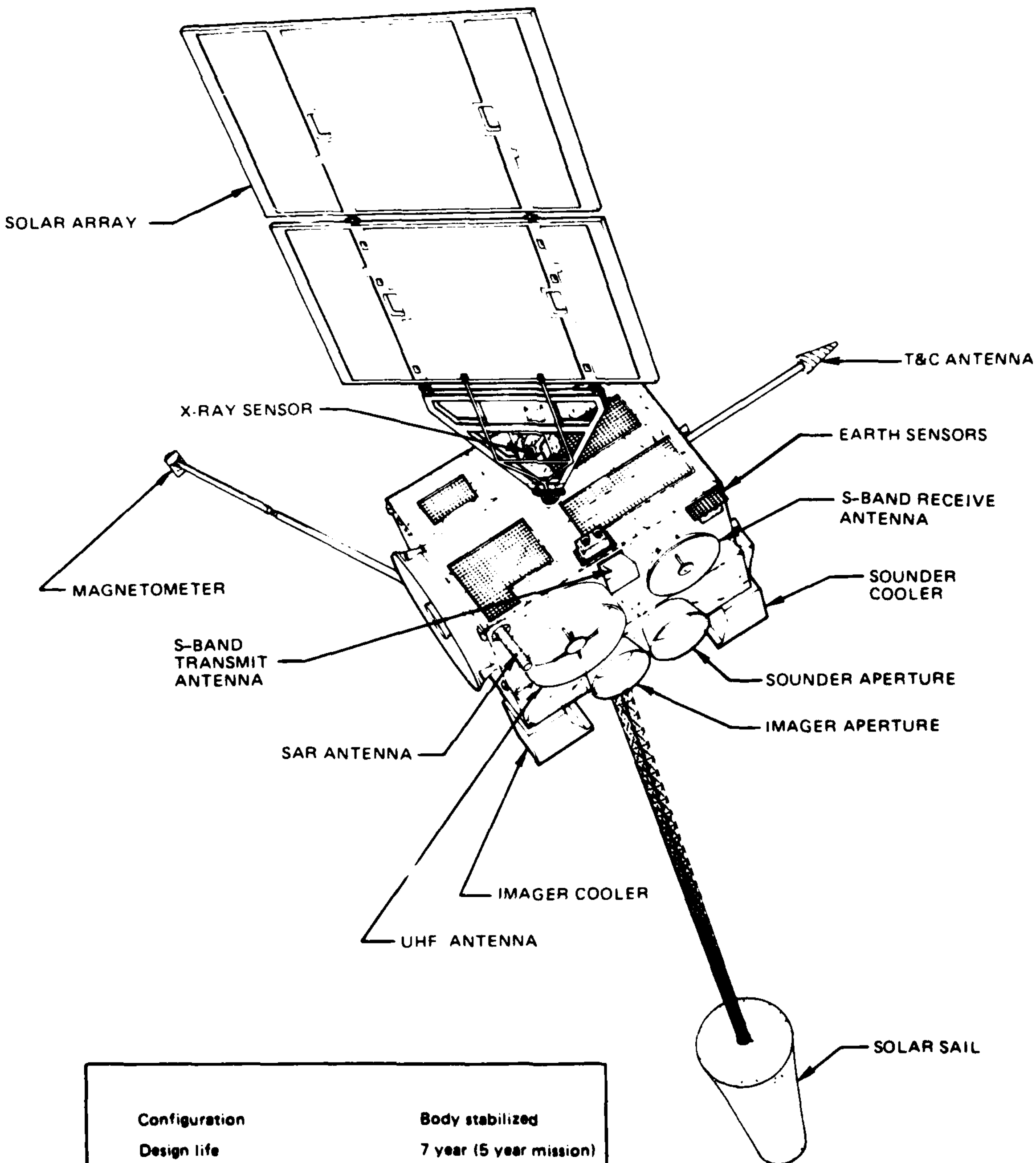
1. Propulsion Module

The Propulsion Module will be built around a central (structural) thrust tube with the fuel and oxidizer tanks for the bipropellant propulsion system mounted inside the tube. The apogee thruster will be mounted in the cone of the structure. The perigee solid motor is not considered to be a part of the spacecraft bus. There will be 12 control thrusters mounted to the central structure through brackets and panels for alignment stability. Four redundant pitch and yaw thrusters will be mounted on the east end and the other four on the west end. The four redundant roll thrusters will be mounted off the south panel to prevent plume impingement on the operational instrument's optical and cooler apertures.

2. Electronics Module

The Electronics Module will consist of aluminum honeycomb equipment panels upon which the subsystems' electronic boxes will be mounted. The location of each component has been optimized for functionality within a particular subsystem, maximum accessibility, static and dynamic mass properties balance, and minimum electrical and coaxial cable lengths. Upon completion of mechanical integration and electrical subsystem tests, the EM will be mated to the PM to form the GOES satellite main body.

The imager and sounder will be externally mounted to the main body structure, adjacent to each other on the Earth face, and with their coolers looking north. This will provide unobstructed views for their optical and cooler apertures, and will enable the instruments to be easily installed and removed



Configuration	Body stabilized
Design life	7 year (5 year mission)
Launch Vehicle	STS

Figure IV-1
In-Orbit Satellite Configuration

without disturbing the structural integrity of the main body or the functional integrity of the other electrical subsystems.

B. LAUNCH-TO-ORBIT CONFIGURATION

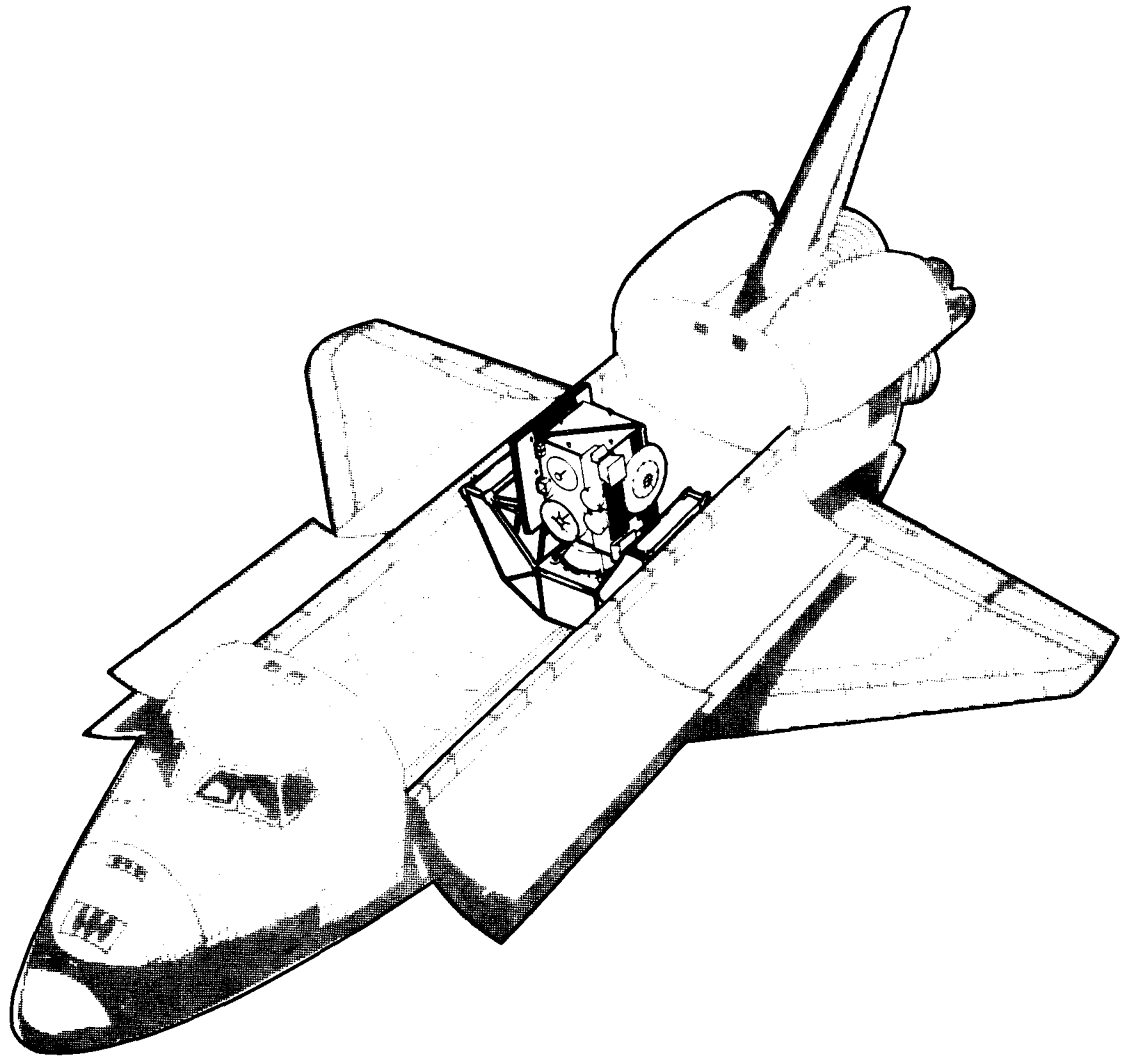
The GOES satellite will use the STS-compatible Insat design baseline and will meet all the requirements for launch by the STS. The satellite and its perigee injection system will be supported in the orbiter cargo bay by a reusable cradle structure. The spacecraft length and weight are balanced to provide economical use of the STS launch capacity and capability. The GOES cargo element is being designed to only use an economical 13.4 percent of the STS cargo bay capacity. The system is composed of the on-orbit satellite mated to the upper stage. The complete STS launch-to-orbit configuration sequence for the operational satellite is shown in figure IV-2.

Design simplicity will be achieved in the upper stage and flight support equipment by using the satellite to provide timing, electrical power, sequencing, and control functions to the upper stage, thus eliminating the PAM-D upper stage avionics. In addition, the nonspinning deployment of the satellite chosen for GOES-Next eliminates the need for a spin table and its control electronics. Thermal blankets and heaters provide adequate thermal control. Lateral load support is inherent in the cradle structure, so no complicated restraint mechanisms are required. Data and command requirements will be provided by the orbiter multiplexer/demultiplexer system, making much of the normal PAM-D avionics unnecessary.

Mass efficiency will be achieved by an upper stage/flight support equipment combination that will use low-weight, high-strength materials. Design simplicity will reduce the amount of equipment needed for flight. Although launch charges are not a part of the space segment contract cost, they are an important part of the overall system cost to NOAA. Accordingly, the space segment configuration has been designed to minimize these charges. STS launch charges are based on the greater of either the cargo's fraction of total cargo mass or the length fraction of the orbiter occupancy. Because the spacecraft is not spinning, only the length (rather than the diagonal dimensions) of the spacecraft needs to be considered in determining the STS tariff charges.

C. IMAGER AND SOUNDER

The imager and sounder have been designed to use common hardware extensively, while retaining total operational independence and significant performance margins. The instruments



(1) GOES I/J/K Cargo in the STS Orbiter

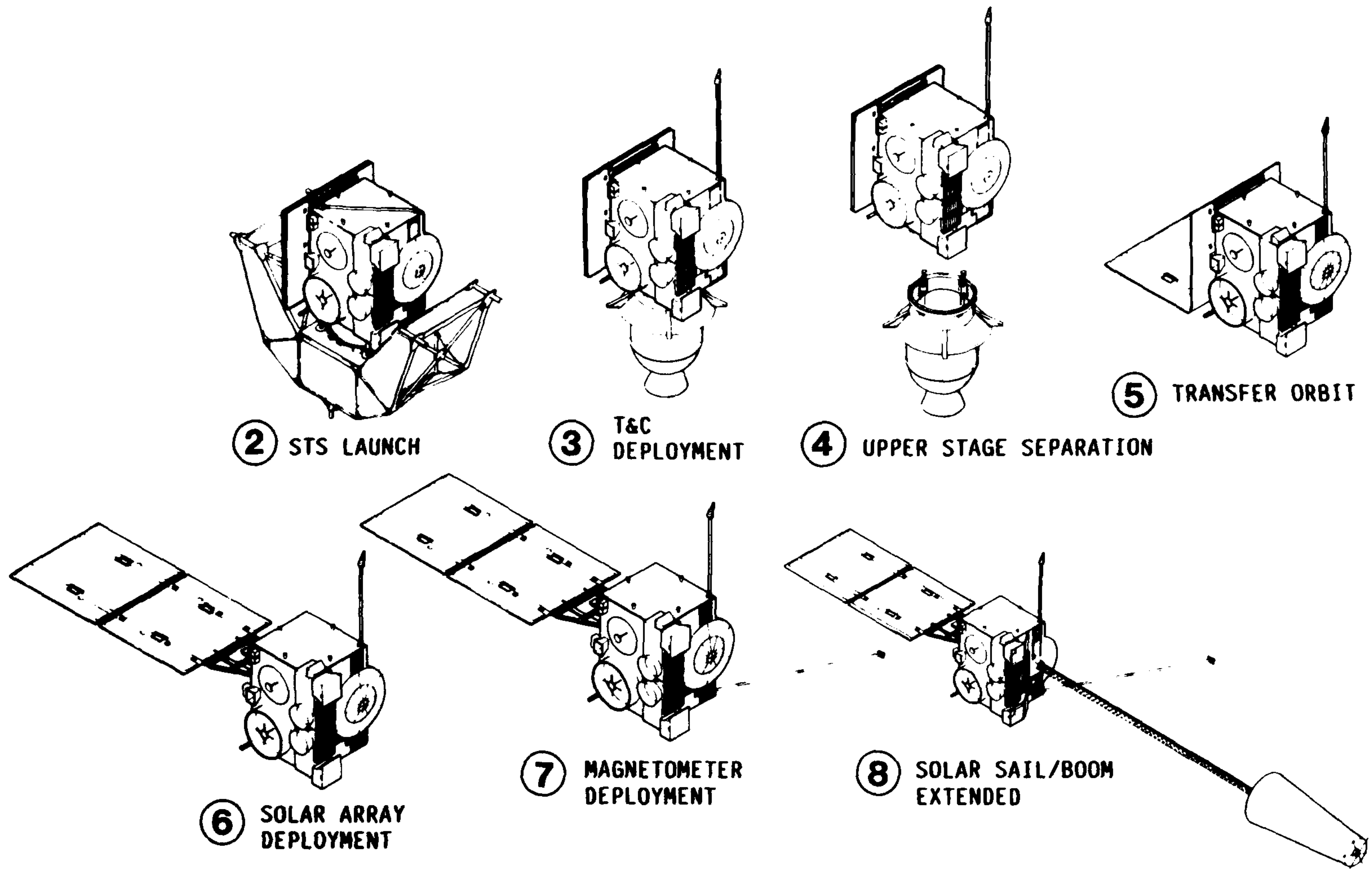


Figure IV-2
Launch to On-Orbit Configuration

will be designed, built, and tested by ITT Aerospace/Optical Divison.

The two independent instruments will exploit the full-time Earth viewing capability of the three-axis, body-stabilized spacecraft, providing radiometric imaging and sounding that are expected to equal or exceed the GOES specification. The imager sensitivity is equivalent to that of the operational Advanced Very High Resolution Radiometer (AVHRR) and will provide users with increased quantitative capability. The sounder's high quality, increased sounding rate, and flexibility of control is expected to increase the utility of data received from geostationary orbit.

Optical performance for each of the instruments will be extracted from a 30.5 cm optical system that is equal to the 40.6 cm VAS instrument because of the low (21 percent) central obscuration as compared to the VAS (40 percent). The signal-to-noise ratio is predicted to be better than that received from the VAS today.

The imager is derived from the Insat Very High Resolution Radiometer (VHRR) and the Television and Infrared Observation Satellite (TIROS)/NOAA AVHRR. The sounder will be a scaled-up version of the TIROS/NOAA series of HIRS/2 instruments. The imager and sounder instruments are being designed to use common components; their scanners, telescopes, and passive radiative coolers will be identical. Commonality of design will minimize programmatic risk and reduce instrument development and production costs. Advanced techniques, such as the cooling system anticontamination measures, motor bearing and lubrication developments applied to the Insat VHRR, and use of redundant electronics and space-proven components, are planned to ensure that the specified 5-year, in-orbit operational life is achieved.

The instruments will be designed to keep uncompensated momentum to a minimum and to reduce interaction of instrument and spacecraft motion. Mirrors and rotating parts will be specifically designed for low mass and inertia, minimizing the interaction of the instruments with the spacecraft.

The small residual effect on spacecraft motion will be determined analytically on the satellite, where real-time compensating signals will bias the scan systems, allowing all combinations of imager-sounder scan with no apparent interaction. These design concepts permit the full use of the high-accuracy scan drive systems on each instrument. The system will maintain the location of any element from the imager to within 7 μrad (0.25 km at nadir) or to 15 μrad (0.53 km at nadir) for the sounder.

Star sensing will be provided in each instrument. This capability will enable correction of the pixel locations to account for short-term or long-term deviations of the optic axes of the two instruments. It also will provide highly accurate attitude knowledge that will be used to Earth-locate the data.

To meet NOAA's operational needs for synoptic and mesoscale imaging and sounding, flexible scan methods will be used. Area coverage is at the user's complete discretion.

Each instrument is expected to generate the same high-quality sensed information, calibration data, and housekeeping information that are familiar to users of the AVHRR and HIRS/2. At the Command and Data Acquisition station, the imager data will be reformatted to appear similar to the VAS mode AAA format in terms of header information, synchronizing signals, and data blocks for each line of sensed data. The only differences will come from the improved performance and flexibility, such as the greater number of bit levels, increased number of channels, and expandable information content resulting from variable sampling area sizes and sampling frequencies. The users will be able to apply the satellite's output signal, broadcast at the same transmission rate, with minimal impact on equipment or techniques.

1. Imager

The imager will be a five-channel (four IR and one visible) radiometer containing a two-axis gimballed scanning mirror that will sweep an 8 km longitude swath along an east-west path. It will provide coregistered data of the viewed scene from all channels simultaneously. Instrument characteristics are shown in table IV-1.

To meet NOAA's operational needs for synoptic and mesoscale imaging, digitally controlled scan methods will be developed that enable the user to specify the coverage area needed to meet special requirements. A few of the large number of operating combinations are shown below:

- Full Earth disk overscan, 19° by 19°, in 30 minutes
- Minimum Earth scan, 60° N. to S. latitude, by 17.4° E. to W. Earth scan, in 22.5 minutes
- Sector scan, 19° E. to W. by 3,000 km N. to S., in 7.6 minutes
- Area scan, 3,000 by 3,000 km, in 3.1 minutes

Table IV-1
GOES-Next Instrument Characteristics

Major Characteristics	GOES Imager			
Visible Channel				
Spectral Interval	0.53 - 0.78 μm			
IGFOV* (km) - nadir	1.0			
Signal Levels	1,024 (10-bit accuracy) to CDA 256 (8-bit accuracy) to users			
IR Channels				
Spectral Intervals (micrometers)	3.9	6.75	10.7	12.0
IGFOV (km) - nadir	4	8	4	4
Signal Levels	1,024	1,024	1,024	1,024

*Instantaneous geographic field of view

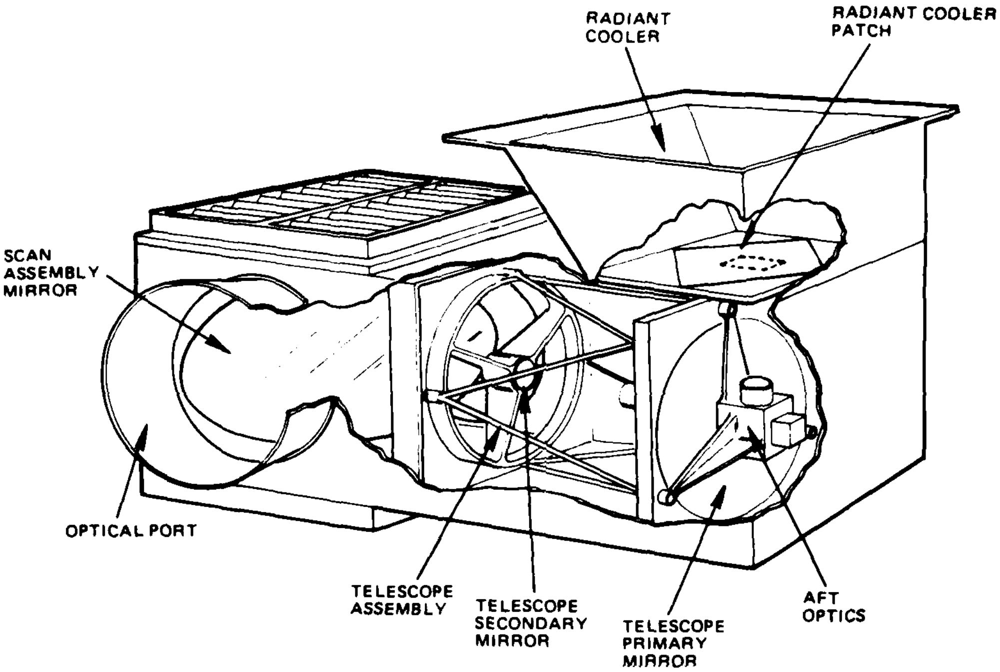
- Small area scan, 1,000 by 1,000 km, in 40 seconds
- Small area scan, 1,000 by 500 km, in 20 seconds

At the end of each frame, the scan mirror will slew to the IR blackbody for calibration. A star-sensing capability has been included in the imager to provide precise attitude determinations that will be used to Earth-locate the data to a very high degree of accuracy.

Instrument characteristics are shown in figure IV-3.

2. <u>Sounder</u>

Atmospheric sounding will be accomplished using a 19-channel (18 IR and 1 visible) discrete filter wheel radiometer. A two-axis gimballed scanning mirror will step a 40 km longitude swath across an east-west path in 10 km increments.



Optical FOV	Square		
Channels Detectors and IGFOV	Visible	Silicon	1 km
	Shortwave	InSb	4 km
	Moisture	HgCdTe	8 km
	Longwave 1	HgCdTe	4 km
	Longwave 2	HgCdTe	4 km
FOV defining element	Detector		
Channel-to-channel alignment	14 μr (0.5 km)		
Radiometric calibration	Space and 290K IR blackbody (varies with housing temperature)		
Signal quantizing	10 bits, all channels		
Scan capability	Full Earth, sector, area		

Figure IV-3
Imager Instrument Characteristics

All channels of the radiometer will be coregistered to a 215 μrad square column. Radiance will be sampled at each dwell location for all channels within one 75 ms rotation of the filter wheel. A passive radiation cooler will control the IR detector temperature, and a separate passive cooler will control the filter wheel assembly temperature. This approach will enable operation of the passive cooler at a low temperature, which will enhance its sensitivity. Radiometric calibration will be provided by periodic views of space and an internal blackbody target.

This instrument will contain features of the HIRS/2 from the low-orbit TIROS-N series of satellites and will provide the sensitivity, accuracy, and sounding rate required for the GOES. The design heritage includes such features as the filter wheel approach, the small number of detectors that promote registration, the stepping mirror system to ensure correlation of data to a single column of the atmosphere, and the scan-viewed blackbody reference that provides a calibration of the total optical and detection system. A star-sensing capability will provide precise attitude and optical axis correlation data that will be used to Earth-locate the data.

Instrument characteristics are shown in figure IV-4.

D. SPACE ENVIRONMENT MONITOR

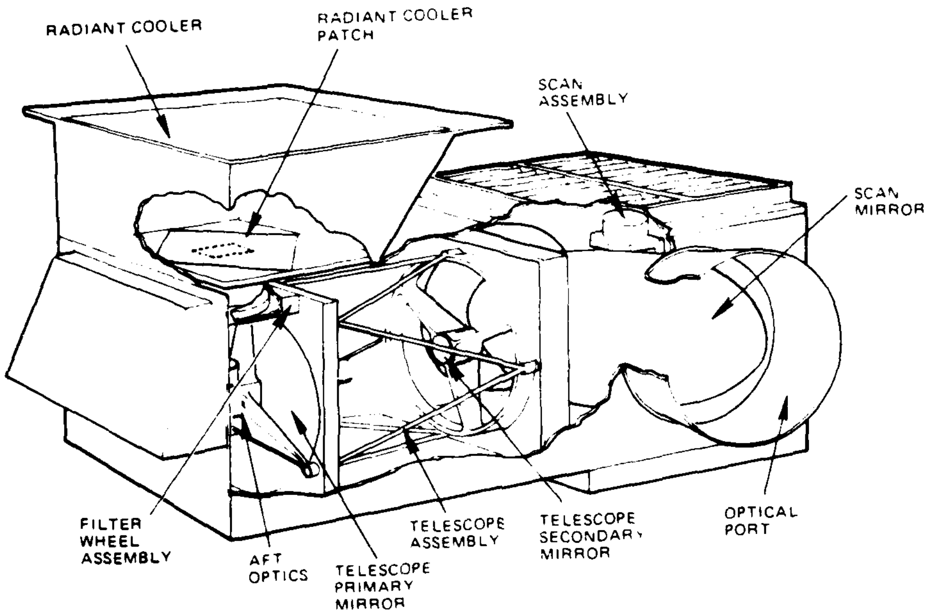
Panametrics Corporation and Ball Aerospace Systems Division will provide the Space Environment Monitor instruments for the GOES-Next series of satellites. The SEM consists of four basic instruments.

1. Magnetometer

The magnetometer is a simplified version of the original instrument flown on the current generation of GOES satellites. Three separate orthogonal probes positioned at the end of a boom will measure field components. The satellite magnetic torquer coil will provide an in-orbit commandable calibrating source.

2. Solar X-ray Sensor

The Solar X-ray Sensor uses a dual ion chamber with electromagnetic preamplifiers to sense solar x-rays. The GOES-Next system implementation takes advantage of the stabilized platform that enables the sensor to be continuously pointed at the sun. It will be mounted on the solar panel yoke. The solar array drive assembly will continuously track the sun diurnally, while a positioner will move the x-ray sensor line of sight in the north-south direction to track the sun.



FOV defining element	Field stop	Nominal IGFOV	215 μr (all channels)
Telescope aperture	30.5 cm (12 in) diameter	Scan step angle	280 μr (110 km nadir)
Channel definition	Interference filters	Step and dwell time	0.1 seconds
Radiometric calibration	Space and 290K-IR blackbody	Scan capability	Full earth and space
Field sampling	4 areas N-S on 10 km centers	Sounding areas	10 km X 40 km to 60° N-S and 60° E-W
		Signal quantizing	12 bits all channels
		Output data rate	29920 bits per second

Channels	Detector Type	Nominal Square IGFOV (μrad)
1 - 7 (Longwave IR)	HgCdTe	215
8 - 12 (Midwave IR)	HgCdTe	215
13 -18 (Shortwave IR)	InSb	215
19 (Visible)	Silicon	215

Figure IV-4
Sounder Instrument Characteristics

3. Energetic Particle Sensor

The Energetic Particle Sensor will consist of a dome assembly, a telescope assembly unchanged from the original design flown on current generation GOES satellites, and a signal analyzer data processing unit changed to conform to the high-bit-rate telemetry, and the command and power interfaces.

4. High-Energy Proton Alpha Particle Detector

The High-Energy Proton Alpha Particle Detector (HEPAD) will be functionally identical to the original instrument flown first on the NOAA polar-orbiting satellites and later on the GOES. Packaging will be changed to replace parts no longer available. The instrument will be designed to sense protons with energies greater than 370 MeV and alpha particles with energies greater than 850 MeV.

The instruments will have a data mode and a commandable inflight calibration mode. For all instruments, the calibration will be accomplished by introducing precision electrical signals into the front end (magnetometer sensor coils, x-ray electrometer-preamplifier, and EPS/HEPAD preamplifiers) to establish the gain stability of the instrument electronics. The HEPAD will have an additional check with an integral isotope source.

E. COMMUNICATIONS

The GOES-Next spacecraft data communications system will function similarly to that of the current GOES communications. The onboard communications system will perform the following functions:

- Transmission of imager and sounder data to the Command and Data Acquisition station at a data rate of about 2.1 Mbps
- Transmission of Earth-located, calibrated imager and sounder data for receipt at product processing centers
- Transmission of the weather facsimile signals
- Reception of command signals from the Deep Space Network (DSN) and CDA sites
- Transmission of telemetry

1. Imager/Sounder Link

The output serial bit streams of the sounder and imager will be transmitted in phase quadrature on the S-band carrier wave by the redundant sensor data transmitter. The spacecraft signal will be received at the CDA station, where it will be demodulated by the Operational Ground Equipment (OGE). Figure IV-5 shows the proposed ground system configuration for GOES-Next operations. After processing by the OGE, the new signal (calibrated, Earth-located data) will be uplinked from the CDA to the spacecraft. It will be received by the S-band receiver and the redundant S-band receiver and converted to the appropriate transmit frequency. Before being multiplexed and retransmitted to the user stations by the S-band transmit antenna, it will be prefiltered (to separate it from the other uplinked signals). The signal format will be compatible with the mode AAA frame synchronizers used today. Ranging will be performed in an ongoing way by the OGE, using the processed data stream relay.

Figure IV-6 shows the data paths for raw and processed data from the imager and sounder. The figure also provides some additional information about GOES I communications frequencies and data rates.

2. Weather Facsimile

After preparation, the WEFAX product will be uplinked to the spacecraft from the CDA. The spacecraft path will be the same as that used for the processed data relay except that the WEFAX will be separated through a different filter and will be amplified separately. It will be combined in the output multiplexer and retransmitted to the user stations.

F. DATA COLLECTION SYSTEM

The data collection system includes the equipment required to relay interrogations from the CDA to data collection platforms and their return responses. An ultrahigh frequency (UHF) antenna, S-band/UHF and UHF/S-band transponders, S-band multiplexers, and S-band antennas that will be shared with other services constitute the data collection system.

1. DCP Interrogation

At the CDA, one and/or two-phase modulated 100 Hz bit streams will be combined at the S-band transmitter and transmitted to the spacecraft. The signals will be received in the S-band receive antenna, amplified, and downconverted in the S-band receiver, which is part of the communications system. The signal will be applied to one of two redundant transponders. It will then be amplified and transmitted by the satellite through its UHF system. The data collection platform will receive the signal and reply appropriately.

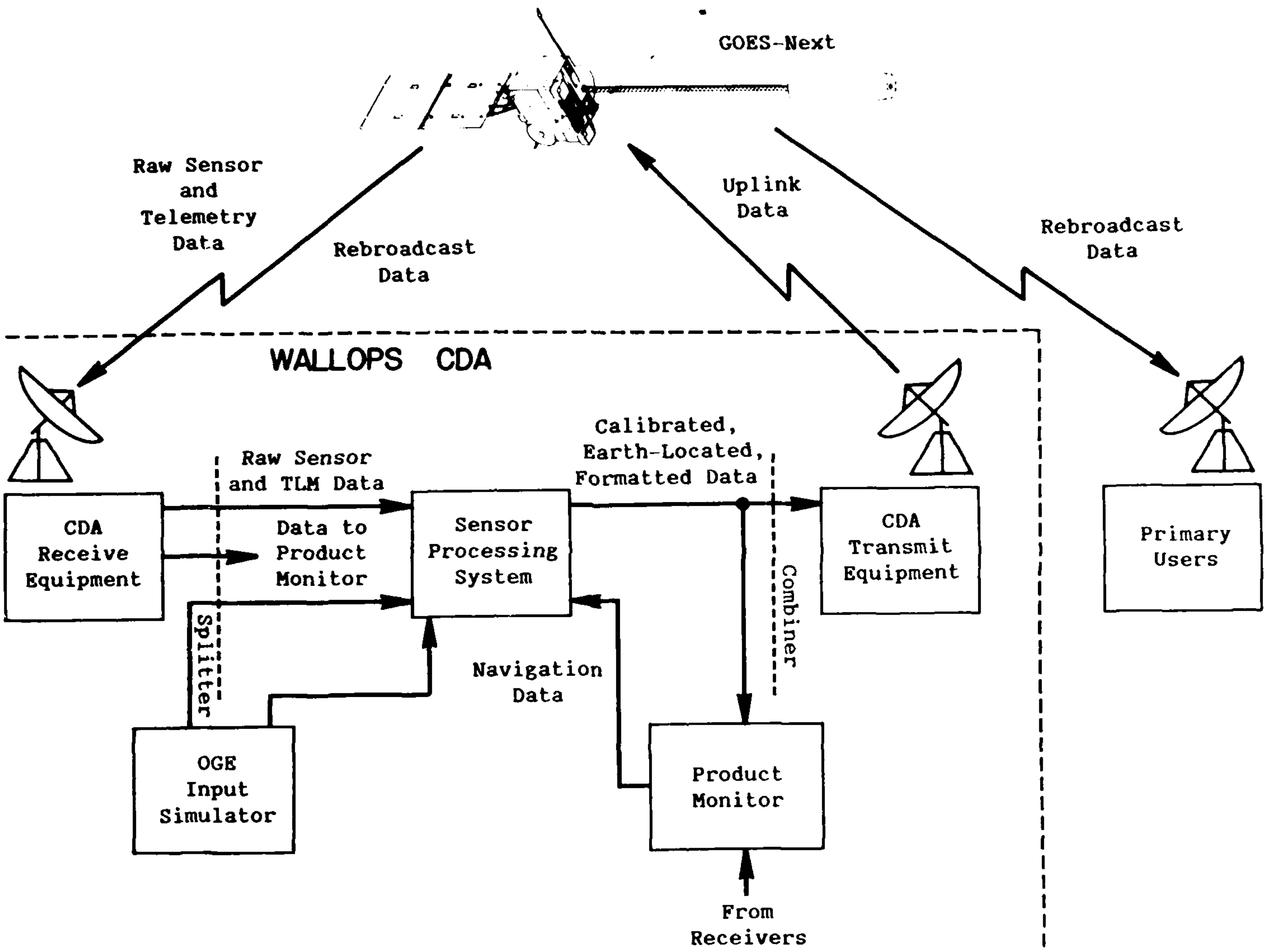
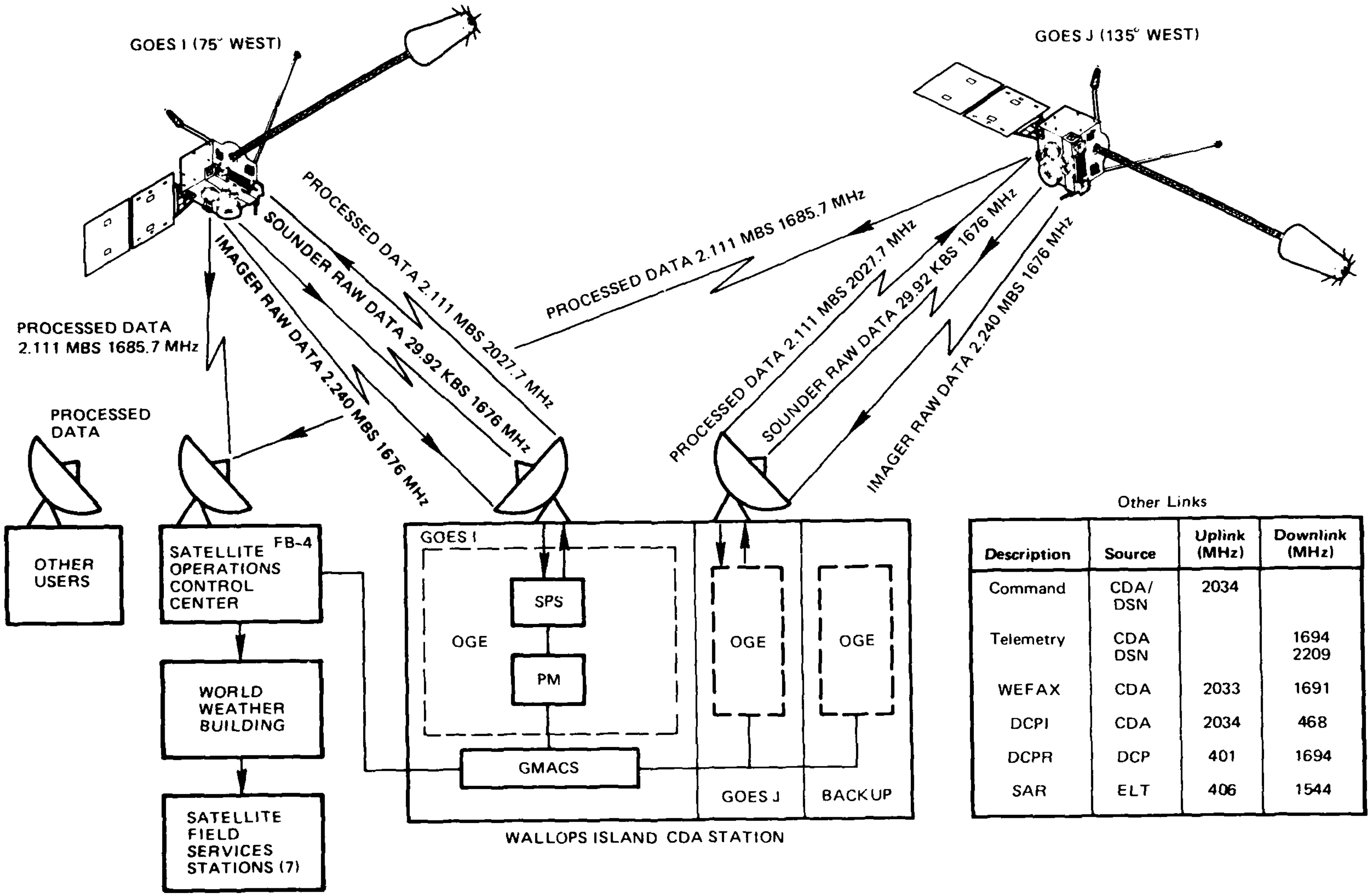


Figure IV-5
GOES-Next Ground Segment Configuration



Other Links

Description	Source	Uplink (MHz)	Downlink (MHz)
Command	CDA/ DSN	2034	
Telemetry	CDA DSN		1694 2209
WEFAX	CDA	2033	1691
DCPI	CDA	2034	468
DCPR	DCP	401	1694
SAR	ELT	406	1544

PM — PRODUCT MONITOR
SPS — SENSOR PROCESSING SYSTEM
GMACS — GOES MONITORING AND CONTROL SYSTEM
CDA —COMMAND AND DATA ACQUISITION

Figure IV-6
GOES I, J, K Data Transmissions

2. DCP Report

Upon receiving interrogation signals or internal time pulses, the DCPs will transmit a coded signal on one of 244 UHF channels receivable by the satellite. After conversion to S-band, the data will be transmitted directly to the user or to the CDA for demodulation and decommutation. Further distribution to other users will be made from the World Weather Building in Camp Springs, Maryland.

G. SEARCH AND RESCUE

The function of the Search and Rescue system is to detect the presence of distress signals and to relay them to Search and Rescue Satellite-Aided Tracking (SARSAT) ground stations. It will supplement the capability of the system on polar-orbiting satellites by providing immediate alerting, though without determination of location.

The system will consist of:

- A receive antenna shared with the DCS
- Redundant receivers and transmitters
- A separate circularly polarized (helix) L-band transmit antenna
- Permanently cross-strapped transponders and transmitters

A coded emergency signal with a bit rate of 400 bps will be uplinked from an Emergency Locator Transmitter (ELT) or Emergency Position Indicating Radio Beacon (EPIRB) in the 406 MHz band. It will be received by the spacecraft's UHF antenna and separated from other signals before processing within the Search and Rescue receiver, where it will be amplified. The signal will be converted in frequency and transmitted via the L-band transmit helix antenna. On the ground, the signal will be received at the Mission Control Center (MCC), where it will provide an immediate alert of emergency conditions to center personnel.

H. TELEMETRY AND COMMAND

The telemetry, command, and ranging functions will be provided by the digital command decoders and telemetry encoder, in conjunction with the hardware elements of the communications system. Command signals will be uplinked from either the CDA or DSN ground station, received by means of an omniantenna, and demodulated in the active redundant command receivers. Each of the redundant decoders will continuously sample the output of each command receiver, providing a reliable cross-strapped configuration.

Satellite telemetry, including the SEM data, will be transmitted by one of two redundant transmitters that may be selected by the ground command.

I. ATTITUDE AND ORBIT CONTROL SYSTEM

The attitude and orbit control system (AOCS) will consist of a two-wheel momentum bias system (with a third reaction wheel for redundancy) for precision on-orbit control. The wheels will be augmented with a set of bipropellant thrusters for momentum reduction and transfer orbit control. The system will consist of three equipment groups: sensors, electronics, and actuators.

A momentum bias control was chosen in favor of a zero momentum type of attitude control for these satellites by Ford. The latter type requires the complication, and possible wear-out, of a gyro system that would have to operate throughout the mission to provide yaw orientation. Yaw is controlled on the momentum bias system without the use of a gyro. System momentum will be removed by magnetic torquing and one to two firings of the propulsion system each day.

A unique feature of the system proposed by Ford and ITT is the means for minimizing the disturbing effect of mirror slewing on the registration between the imager and sounder data sets. These disturbances are significant. Instead of attempting to control them with the spacecraft attitude and orbit control system, an algorithm resident in the spacecraft microprocessor system will input a signal into the imager and sounder scan mechanism drive controls. These controls will then adjust the mirror drives to compensate for the disturbances, as opposed to trying to eliminate them. Close registration between the imager and sounder data sets is thus maintained.

An important requirement of the GOES-Next system is to provide and maintain the geographical location of imager and sounder data with a high degree of accuracy. The image navigation process consists of two steps. First, a pixel will be located in terms of azimuth and elevation relative to the instrument's reference optical axes. This reference will then be transformed to the orbital reference axes. In the second step, the pixel position relative to the reference orbital axes will be transformed into Earth longitude and latitude. These two steps will require knowledge of the orbital position and the attitude of the reference optical axes as a function of time.

In operation, CDA range, landmark, and star measurements will be processed at the ground station to determine the orbit and attitude of the satellite, and the pointing directions of the instruments. These parameters will be transmitted to the satellite processor, which will use them to develop image motion compensation bias signals that will cause the instrument to coregister pixels of repeated images of the same selected imaging/sounding areas.

J. PROPULSION

The satellite propulsion equipment will be an integrated bipropellant system that will perform apogee thrusting and all reaction control functions, including station keeping, station change, and final boost from geostationary orbit. A PAM-D solid motor will provide thrust for perigee injection.

K. RESPONSIVENESS TO MISSION REQUIREMENTS

The Ford-proposed GOES-Next design has been judged by NOAA as meeting stated mission requirements and specifications. The key factors influencing this judgment are outlined in the paragraphs that follow.

1. Earth-Sensing Mission

The GOES I, J, K design will put atmospheric soundings from geosynchronous orbits into routine operational use, simultaneously with the imaging operation being conducted from the same spacecraft. Flexibility is provided in selecting the size and location of the Earth scenes to be scanned by the imager and sounder; this flexibility concurrently allows the scene revisit frequencies to be achieved that have been specified as necessary for NWS operations. Design provisions for the accuracy, calibration, Earth location, and coregistration of imager and sounder data supply improvements over current capabilities and meet or exceed stated mission requirements.

2. SEM Mission

The SEM package of four instruments is based on proven designs and is improved by the addition of modern components. The Solar X-ray Sensor will benefit from sun-tracking from a three-axis stabilized platform, compared to sun-viewing from a spinning platform. The boom-mounted magnetometer will be out of the immediate stray magnetic fields of the main spacecraft body and its electrical components. Data accuracy and data calibration methods are improved.

3. Other Missions

The GOES I series design continues and improves the margins of the data collection system used to relay observations from remote platforms; weak platform signals and signals from Earth-edge locations will have an increased likelihood of being received. WEFAX service will be continued and will meet new demands because the WEFAX transmission will not interfere with other spacecraft functions; the ability to provide concurrent broadcasts of WEFAX and processed data will increase the WEFAX duty cycle greatly. The geosynchronous SARSAT mission will be continued by the GOES I series of spacecraft.

4. Additional Factors

The GOES I, J, K procurement makes use of the Nation's Shuttle capability. Shuttle optimization is included in the design, improving the ratio of overall costs to launch costs. Newer technology, the use of many identical components in the imager and sounder, and heritage experience with the spacecraft, instruments, and systems increase the reliability and reduce the risk of this new series. On-orbit lifetimes of 5 to 7 years are expected.

The new design has sufficient versatility included to offer opportunities for contributing to research goals while fulfilling the operational mission. The design allows for an expanded instrument complement; specific provisions for a possible Solar X-ray Imager have been made, and the addition of other instruments, such as a lightning mapper, solar total energy monitor, or multichannel microwave radiometer, is possible.

V. CONCLUSIONS

The GOES program has been rich in success; it has become an indispensable ingredient of environmental service and research activities carried out at national and international levels. The performance of the present series of GOES spacecraft has attracted a clientele of dedicated users who have shaped their operations to rely on GOES input. This clientele foresees opportunities for gaining further advantages from GOES through the use of more modern technology and achievable improvements in sensors and space systems. NWS, as the prime GOES user, has stated the case for these improvements and has supplied the specifications for achieving them. NOAA has accepted these NWS specifications as being representative of the general user community's needs and has used them as the baseline requirements that the GOES-Next system must satisfy.

The Government's recent selection of the Ford Aerospace and Communications Corporation as the provider of the GOES I series of spacecraft confirms that NWS specifications can be met at acceptable cost and realized in operations, beginning in 1990. The spacecraft design allows sufficient margin for mission growth to accommodate the additions of any instruments that have the potential for NOAA's deployment on GOES through the end of the century. The GOES I series will remain in service at least until that time.

APPENDIX A

PRESENT GOES--CHARACTERISTICS AND PRODUCTS

APPENDIX A

PRESENT GOES--CHARACTERISTICS AND PRODUCTS

A. GENERAL

The present GOES system is designed to meet a set of observational requirements stated by the Department of Commerce on Feb. 3, 1970. Table A-1 is a summary of these requirements.

The meteorological imaging capabilities of the present GOES are keyed to the capabilities of the Visible and Infrared Spin-Scan Radiometer. The VISSR is a dual-band (visible and infrared) spin-scan imaging device used for day and night cloud cover images. By viewing a number of images in rapid succession, storm growth and movements can be observed and wind speeds (and directions) can be deduced. In addition, the present GOES system meets the minimum requirements for space environment monitoring and data collection as stipulated in table A-1.

In late 1980, the GOES system began to use the VISSR Atmospheric Sounder. The VAS retained the VISSR imaging capability; however, the infrared channel capabilities were expanded by using a more complex detector configuration together with selectable narrow-band optical filters. The optical filters are sensitive to the effects of atmospheric constituents, which makes it possible to determine not only the surface and cloud top temperatures, as in VISSR, but the three-dimensional structure of the atmospheric temperature and water vapor distribution. VAS was developed by NASA in response to a request from NOAA for a capability to provide such information on a continuous basis.

The VAS is capable of providing, on a limited basis, geometrically precise time sequences of multispectral images from which cloud and water vapor motions can be tracked, and from which cloud top and surface temperatures can be more accurately determined. When the VAS is not in the VISSR imaging mode, it can be programmed to obtain data to determine atmospheric temperature and moisture profiles from dwell sounding swaths. These can then be located and timed to track hurricanes, severe storms, and other targets of opportunity.

B. APPLICATIONS OF GOES IMAGERY

During the 11 years of GOES operations since its initiation in May 1974, many useful applications of GOES imagery have been developed and implemented. The following paragraphs describe merely a few of these valuable applications. Table A-2, which is located at the end of this appendix, is extracted from NOAA

Technical Memorandum NESS 109. It summarizes the current catalog of NESDIS products and services acquired from GOES satellites.

1. Winds Aloft

A very useful meteorological product is information about the speed and direction of winds aloft. Using GOES images directly, a meteorologist selects an area of a GOES sector that experience suggests contains clouds that can be tracked over time. On succeeding GOES images, the same geographic area is found and registered. Average cloud displacements per time interval are computed, leading to the determination of wind vectors. The wind vectors are assigned an atmospheric height, based on cloud top temperature and other information. These data are then provided as input to the National Meteorological Center's numerical weather prediction models. The local wind field can also be used on a regional scale to update synoptic forecasts.

The extraction of wind field information from GOES data makes it possible to determine this important atmospheric parameter over large areas such as oceans, where conventional measurements are sparse or nonexistent.

2. Enhanced Image Display

Another important application of GOES imagery is derived from an enhanced display, by which high-altitude clouds with very cold tops are located and identified in the imagery by color or shadowing. This type of cloud typically indicates severe electrical storms and may be associated with the occurrence of tornadoes, hail, and heavy rain. The enhanced display, combined with geographical/political boundary gridding, rapidly locates these storms, facilitating tracking and the development of public warnings.

3. Special GOES Products

NESDIS meteorologists use GOES data and imagery to support the National Meteorological Center and to provide products and services to the oceanographic and hydrologic communities.

- National Meteorological Center support. Cloud-motion vector field "winds" are derived by computerized image analysis as well as by manual measurements of cloud motion as seen in video animation and through interactive processing techniques. Cloud patterns are analyzed for moisture fields over the northeast Pacific and northwest Atlantic Oceans. GOES images are analyzed to determine frontal positions, their movements, and their intensities.

- National Flash Flood Program support. Estimates of heavy precipitation are derived from GOES data by using interactive processing techniques. These data are transmitted to NWS forecast offices in near-real time and are used as critical guidance information for flash flood watches and warnings.

- Oceanographic services. Twice weekly, during the winter, GOES and polar orbiter cloud-free imagery over the Great Lakes are analyzed to determine the extent of ice-fast and ice-free areas as well as the navigable passageways (leads).

- Gulf Stream Wall Bulletin. GOES (and polar orbiter) imagery are used to produce a Gulf Stream Wall Bulletin. This bulletin, produced three times a week, informs mariners of the position of the zone where the fastest currents are found. It also shows the locations and sizes of warm and cold eddies.

- Hydrological services. GOES (and polar orbiter) data are used to produce maps and charts that depict the snow cover in selected river basins. These are used in run-off forecasting, flood prevention, water resource planning, etc.

Another product is the U.S. Snow Cover Analysis. These charts are useful for forecasting lake inflow, water supply, flood watch, and drought monitoring.

C. DISTRIBUTION OF GOES PRODUCTS

GOES imagery is made available to users by:

- Direct broadcast. Users can receive "time stretched" VISSR signals directly from GOES. This requires complex and costly equipment. (There are 21 direct VISSR read-out stations in the world.)

- CDDF/GOES-Tap. NESDIS manages a Central Data Distribution Facility (CDDF) in Camp Springs, Maryland. The CDDF receives all GOES images, sectorizes them, and transmits the sectorized images to seven Satellite Field Service Stations by means of specially conditioned telephone lines. At the SFSS, images are reconstructed from these data. Imagery transmitted to an SFSS is available to other users by means of a service called GOES-Tap.

- Facsimile. A variety of GOES images and interpretive messages are routinely sent out over the conventional facsimile circuits of the National Weather Service.

- <u>WEFAX</u>. GOES provides a special service known as weather facsimile. This service uses a radio receiver/transmitter on the GOES to broadcast GOES, polar orbiter, and Meteosat images, as well as National Weather Service conventional meteorological analyses and prognoses. Ground stations anywhere in view of the GOES can receive these transmissions with a relatively inexpensive (modified) Automatic Picture Transmission receiver. There are about 1,000 APT stations and 200 GOES WEFAX receiving stations located throughout the world.

- <u>Other environmental data relay</u>. The GOES DCS provides for the collection of environmental data (other than satellite imagery or soundings) from remote areas in real time by the use of data collection platforms. Data collected and relayed by the GOES DCS include meteorological, hydrological, seismic, and oceanographic information.

Table A-1
Summary of Present GOES Observational Requirements

Requirement	Minimum	Evolutionary
I. REMOTE SENSING (near continuous)		
A. <u>Cloud Cover and Cloud Type Height</u>		
1. Frequency		
a. Earth's disk	hourly	--
b. Selected areas	10-min	--
2. Resolution		
a. Daytime	1 nmi 0.5 nmi	
b. Nighttime	4-5 nmi	0.5 nmi
1) Spatial	± 1 K at 300°	D+ 1 K at 300°
2) Thermal	± 4 K at 210°	D+ 4 K at 210°
3. Gray shades (visible)	16 64-256	
4. Location accuracy	5 km 1 to 2 nmi	
5. Timeliness 15 min (observation to user)	--	
B. <u>Space Environment Monitoring</u>		
1. Frequency and timeliness in real time	Near-continuous	--
2. Solar energetic particle		
a. Protons	1 MeV to > 500 MeV	--
b. Alpha particles	4 MeV to > 400 MeV	
c. Electrons	> 500 KeV	
3. X-rays	0.5 to 8A°	--
4. Magnetic field	± 400 Gamma	--
a. Resolution	0.1 Gamma	--
II. DATA COLLECTION		
A. <u>Number of Platforms</u>	3,000 each 6 hr	10,000 each 6 hr
B. <u>Message Lengths</u>	50-3,000 bit	50-3,000 bit
C. <u>Total 6-Hour Data</u>	350,000 to 600,000 bits	6 million bits
III. DATA BROADCAST		
A. <u>Broadband</u> (Satellite to CDA to satellite and to local user terminals)		
B. <u>Narrowband</u> (Satellite to WEFAX to local user terminals)		

Table A-2
NESDIS Geostationary Satellite Products and Services Summary

Product Description	Accuracy	Spatial Resolution	Map Scale	Geographic Coverage	Output Format	Schedule	User	Archive Location
I. IMAGE PRODUCTS: GEOSTATIONARY SATELLITES								
A. Full Disk (vis and IR):								
East GOES	—	4 km vis, 8 km IR	—	Pole to pole, 20 W. to 130 W.	Electrostatic display and archive tape	On hour and half-hour	NWS, NMC, NESDIS; government, universities, and private research	SDSD
West GOES	—	4 km vis, 8 km IR	—	Pole to pole, 80 W. to 170 E.	Electrostatic display and archive tape	At 15 and 45 min after the hour	NWS, NMC, NESDIS; government, universities, and private research	SDSD
B. Sectors (vis and enhanced IR):	—	1, 2, 4, and 8 km	—	Specific areas	Electrostatic display and archive tape	E. and W. GOES	NWS, NMC, NESDIS; government, universities, and private research	SDSD and Applications Lab.
C. Video Animation (vis/IR/IR-enhanced)	—	1, 2, 4, and 8 km	—	Specific areas	Video displays	In-house, daily; *others on request*	NESDIS-Applications *Lab., Synoptic* Analysis Branch, and NMC	Applications Lab. and SDSD
D. Daily Weather Picture	—	2 km vis, 8 km IR	—	Continental U.S.	Photographic display and weather summary	3 per day	Wire services, TV, and newspapers	NESDIS

Table A-2 (continued)

Product Description	Accuracy	Spatial Resolution	Map Scale	Geographic Coverage	Output Format	Schedule	User	Archive Location
II. IMAGE SERVICES: GEOSTATIONARY SATELLITES								
A. GOES Facsimile Displays (vis and IR)	—	Vis: 4 x 4 km IR: 4 x 8 km		Continental U.S.—55°-120° W. long. and 15°-60° N. lat.; Eastern U.S. and Atlantic—20°-90° N. long. and 15°-60° N. lat.; Southern South America—25°-80° W. long. and 10°-50° S. lat.; U.S. west coast and Pacific—115°-180° N. long. and 15°-60° N. lat.; Western U.S. and Pacific—105°-180° W. long. and 15°-60° N. lat.	Analog facsimile display	24-hour schedule	NWS, DOD, NESDIS; private meteorology, universities, research concerns	No archive
B. GOES WEFAX Link: GOES and NOAA Polar Orbiter Data in Vis and IR	—	8 km for GOES	1:80 M	Specified areas	Analog facsimile - satellite relayed broadcast	24-hour schedule	Foreign and domestic weather concerns with S-band receiving equipment	No archive
C. GOES Direct Readout	—	Same as full-disk and sector displays	--	Same as full-disk and sector displays	Digital data transmissions	Same as full-disk and sector displays	Foreign and domestic government, universities, commercial organizations, research concerns, amateur ground station operations	No archive
D. GOES-Tap VISSR Data	—	Same as full-disk and sector displays		Same as full-disk and sector displays	Analog data transmissions	Same as full-disk and sector displays	Private meteorology	No archive

Table A-2 (continued)

Product Description	Accuracy	Spatial Resolution	Map Scale	Geographic Coverage	Output Format	Schedule	User	Archive Location
III. METEOROLOGICAL PRODUCTS AND SERVICES (GOES)								
A. Satellite Winds								
(From GOES): Low- , Middle- , and High-Level Cloud Motion Vector Field Messages	--	--	--	Global ocean areas	Raw numeric data, chart form, and cloud motion vectors, archive tape	0000 G.m.t. and 1200 G.m.t. daily for distribution at 0300 G.m.t. and 1500 G.m.t.	NMC, USAF, USN, NWS, NESDIS, and research concerns	SDSD
B. Weather Summaries and Bulletins								
1. Satellite Interpretation Message (SIM)	±6 nmi (8.4 km)	--	--	Continental U.S.	AFOS message	Washington, D.C. SFSS Kansas City SFSS Miami SFSS Honolulu SFSS Anchorage SFSS New Orleans SFSS San Francisco SFSS	Domestic weather operations	No archive
2. Satellite Precipitation Estimates	Approx. 10 mi	--	--	Continental U.S.	AFOS message	As required	NWS	NESDIS (1 year)
3. Cloud top and tropopause message	±3,000 ft	1° lat./long.	1:20 M	E. and W. GOES	AFOS message	4/day	NMC, NWS forecast offices and aviation interests	NESDIS-SAB (1 week)
4. Tropical disturbance summary	±30 nmi (42 km)	--	--	Atlantic and East Pacific (to 180°W.), West and South Pacific, Indian Ocean	GTS message	2/day/area	Foreign and domestic weather operations	No archive

Table A-2 (continued)

Product Description	Accuracy	Spatial Resolution	Map Scale	Geographic Coverage	Output Format	Schedule	User	Archive Location
IV. OCEANOGRAPHIC PRODUCTS (FROM POES AND GOES)*								
A. Sea Surface Temperature Products								
1. Sea surface temperature observations	±1.5 °C (absolute) ±1.5 °C (rel)	Nominal 50 km	—	Global	Computer disk Digital archive tape	Daily (disk) Weekly (tape)	NESDIS, NWS, international oceanographic services, environmental research, commercial fisheries	SDSD
2. Global sea surface temperature monthly observation mean	±1.5 °C (absolute) ±1.5 °C (rel)	2.5° lat./long. 250 km grid	—	Global	Computer disk Digital archive tape Contour analysis chart	Monthly (disk) Yearly (tape) Monthly (chart)	NESDIS, NWS, international oceanographic services, environmental research, commercial fisheries	SDSD
3. Sea surface temperature regional scale analysis	±1.5 °C (absolute) ±1.5 °C (rel)	2.5° lat./long. 250 km grid	1:22 M	1) 5° N.- 53° N. 52° W.- 100° W. 2) 15° N.- 63° N. 97° W.- 145° W. 3) 15° N.- 63° N. 142° W.- 170° E.	Computer disk Digital archive tape Contour analysis chart Photographic QC image	Weekly (disk) Monthly (tape) Weekly (chart) Weekly (photo)	NESDIS, NWS, international oceanographic services, environmental research, commercial fisheries	SDSD

* These products are primarily derived from POES data.

Table A-2 (continued)

Product Description	Accuracy	Spatial Resolution	Map Scale	Geographic Coverage	Output Format	Schedule	User	Archive Location
4. Sea surface temperature global scale analysis	±1.5 °C (absolute) ±1.5 °C (rel)	1.0° lat./long. 100 km grid	1:45 M	Global Charts - 30° x 30° lat./long.	Computer disk Digital archive tape Computer terminal display Contour analysis chart Photographic QC image	Daily (disk) Semi-monthly (tape) On-demand (terminal) Weekly (chart) Daily (photo)	NESDIS, NWS, international oceanographic services, environmental research, commercial fisheries	SDSD
Sea surface temperature climate scale analysis	±1.5 °C (absolute) ±1.5 °C (rel)	5.0° lat./long. 500 km grid	—	Global	Computer disk Digital archive tape Photographic QC image	Daily (disk) Monthly (tape) Daily (photo)	NESDIS, NWS, international oceanographic services, environmental research, commercial fisheries	SDSD
5. Great Lakes and coastal surface water temperature analysis	±1.5 °C (absolute) ±0.5 °C (rel)	1 km Great Lakes 5 km coastal zones	Varies with type of transmission	Great Lakes and U.S. coastal regions	Gridded analysis	Weekly	NWS, environmental research, commercial marine concerns	SDSD
B. Ice Charts								
Great Lakes ice charts	±5 km	1 km	Varies with type of transmission	Great Lakes	Gridded analysis	Weekly	Commercial marine transportation, USM, USCG, NMFS, research concerns	SDSD

Table A-2 (concluded)

Product Description	Accuracy	Spatial Resolution	Map Scale	Geographic Coverage	Output Format	Schedule	User	Archive Location
C. Ocean Current Analysis								
1. Gulf Stream wall bulletin and analysis	±5 km	1 km	Varies with type of transmission	U.S. coastal waters of the Gulf of Mexico and east coast	Teletype message, gridded analysis	5/ week	Coastal marine transportation, fisheries, USCG, recreation, and research concerns	SDSD WSFO/DCA
2. West coast thermal front analysis	±5 km	1 km	—	U.S. west coast out to 4° long.	Gridded analysis	2/week	Albacore tuna and salmon fisheries, environmental research concerns	SFSS - San Francisco, CA SOS/NWS - Seattle, WA
V. HYDROLOGICAL PRODUCTS (FROM GOES AND POES)								
A. River Basin Snow Cover Observation	±5%	1 km	—	Selected basins	Percent covered analysis	Daily and weekly, depending on basin	OH/NWS, Corps of Engineers, Soil Conservation Service, Bureau of Reclamation, USGS	SDSD
B. U.S. Snow Cover Analysis	±5 km	1 km	1:7.5 M and 1:10 M	Contiguous U.S. and southern Canada	Gridded analysis	2/week	Corps of Engineers, Joint Agriculture Weather Facility, NWS	SDSD
C. Northern Hemisphere Snow and Ice Chart	±5 km	1 km	1:50 M	Northern Hemisphere	Gridded analysis	Weekly (analysis) Monthly (mean)	USN, other marine interests, NWS	SDSD

APPENDIX B

FINAL DEFINITION OF GOES-NEXT
REQUIREMENTS--JULY 1983

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
Washington, D.C. 20233

E/SPD3:AS

JUL 14 1983

Dr. Burton I. Edelson
Associate Administrator for
Space Science and Applications
National Aeronautics and Space
Administration
Washington, D.C. 20546

Dear Burt,

I wrote to you on April 9, 1982, asking that NASA begin the procurement of the GOES-Next series to be available in 1989 or 1990. In June 1982 Harold Yates, in a letter to Les Meredith, then Acting Director of the Goddard Space Flight Center, spelled out specific details of the NOAA requirements for the GOES-Next. These requirements were to form the basis for detailed performance specifications.

Between last June and early May of this year, the National Weather Service and the NESDIS, with assistance from NASA, GSFC, and our Office of Research and Applications, studied our projected requirements for the 1990s. From this study, the NWS and NESDIS developed a set of augmented requirements that should be implemented for this next generation of operational satellites. The budget process unfortunately has dictated that only the highest priority augmentations may be included in GOES-Next.

The requirements, as summarized in the enclosures, are to be used by GSFC to develop the detailed performance specifications for the procurement documents. These requirements have been carefully considered by the NWS and NESDIS. We believe improved forecasting services will result if the data requirements are met by the new system. Through our normal budget process, we have requested funding above our original baseline to defray the cost of the augmentation. I have confidence that the necessary funds will be made available and ask that you incorporate the new requirements in the RFP. Since final approval of our augmented system can only occur when the funding is made available, I will keep you informed as our budget request is examined up-the-line. If funds are not obtained, a retrenchment will obviously be required and our requirements will revert to the baseline described last June. Since we have already lost six months of the schedule in developing these new requirements, I hope any further perturbations can be kept to a minimum. We can delay no further if we are to guard against a service gap in the 1989-90 time frame.

In developing the GOES-Next RFP, it would be beneficial if NASA could develop an innovative approach that would allow contractors to propose augmentation beyond those required by the RFP. At the same time, we must provide a means to revert to the baseline described in the June 1982 Yates to Hinners letter if proposals exceed our budget. Though I can offer no definitive suggestion on how to implement these concepts within the NASA procurement regulations, I have asked our GSFC liaison staff to work with the Metsat Project to determine how best to approach this procurement. My April 1982 letter indicated that NOAA would be willing to accept a cost-type contract for the GOES-Next contract. I understand that there has since been a suggestion that we consider a fixed price type arrangement. I remain flexible on this subject and will be glad to discuss the situation with you after GSFC has completed their evaluation of the requirements and prepared a recommendation on how to best proceed. As to the number of satellites to be procured - the budget process has forced us to opt for a purchase of three. This means additional satellites must be bought four to five years following award of the GOES-Next contract. We shall budget in that manner.

As we move toward this next generation system, we must maintain close coordination between our agencies. As decisions are forthcoming, I will keep you advised; I trust you will do the same.

Sincerely yours,

John

John H. McElroy
Acting Assistant Administrator

Enclosures

cc: Dr. A. Calio
Dr. R. Hallgren - NWS
Mr. H. Yates
Mr. W. Keathley - GSFC

NOAA REQUIREMENTS FOR GOES-NEXT SATELLITE SERIES

The GOES-Next satellites shall be designed to provide an economical and stable platform for the instruments to be used in making measurements of the earth's atmosphere, its surface, cloud cover and electromagnetic environment. In addition, the satellite shall support data collection and distribution functions which form the basis for the ongoing operational system. It is our intention that we obtain a space segment consisting of operational satellites at two longitudes. The general requirements are outlined below:

1.0 INSTRUMENT OPERATIONAL PERFORMANCE REQUIREMENTS

1.1 Imaging/Sounding

It shall be practical to provide imaging and sounding services throughout the twenty-four hour day. Independence of functions is required so that imaging and sounding may be accomplished in an essentially parallel, simultaneous mode. Imaging/sounding requirements summarized below are described in more detail in the attachments. Capabilities described in the attachments, if beyond those summarized below are desirable augmentations, procurement of which should be pursued if NOAA budget guidelines are not exceeded. A capability for dissemination of full resolution imagery to the NOAA Suitland facility shall be provided.

1.1.1 Imaging

a) General Characteristics

A capability to obtain high resolution images shall be provided from visible (0.55 to 0.75 micrometers) infrared window (3.8 to 4.0 micrometers; 10.2 to 11.2 micrometers; 11.5 to 12.5 micrometers) and water vapor (6.5 to 7.0 micrometers) data. Characteristics of the imaging channels shall be as shown below:

Channel	Spectral Band (μm)	Subpoint Resolution	Signal to Noise/(NEΔT)
1	0.55-0.75	1 km	1:1.5 @ 0.5% albedo (6 bit precision)
2	3.80-4.00	4 km	1.4K 300K scene (10 bit precision)
3	6.50-7.00	8 km	1.0K 230K scene (10 bit precision)
4	10.20-11.20	4 km	0.35K 300K scene* (10 bit precision)
5	11.50-12.50	4 km	0.35K 300K scene (10 bit precision)

*1.4K; 200K scene

b) Timeliness

The GOES-Next design should minimize conflict between synoptic and mesoscale users of data. To accomplish this, it shall be practical to image the earth with each of the five channels within 60 degrees of great circle arc of the subpoint in 20 minutes or less. When full earth images, as defined above, are not required, it shall be practical to obtain data from limited geographic areas at an equivalent line rate (i.e., 50°N to 25°N in 4-5 minutes). Earth location data for each image shall be available to the end product user within 3 minutes of initiation of image data acquisition.

c) Earth Location Requirements

Nearly equal in importance to the specific instrument requirements for GOES-Next observations is the need to determine accurately and quickly the location of those observations in true earth coordinates.

Navigation accuracy of the GOES-Next imagery should provide a capability to measure cloud displacement between two successive images obtained 30 minutes apart to an accuracy of two to three meters per second. This implies a capability to coregister centroids of the field of view of two successive images, within 2 km with a goal of 1 km.

Earth location in an absolute sense for individual images shall be practical within 2 km (4 km accuracy shall be offered as an option, if determined to offer significant cost savings by potential contractors).

d) Channel to Channel Registration

Channel to channel misregistration of the IR channels within the imaging instrument, should not exceed one-tenth of a field-of-view (11 μ radians) using as a reference the FOV centroid for the individual channels.

1.1.2 Atmospheric Sounding

The sounder capability shall provide data that will be used by NOAA to determine the vertical temperature of the atmosphere from the earth's surface to the stratosphere and moisture vapor content profile from the surface to near the tropopause. It is necessary to compute these profiles to an accuracy comparable to that obtainable from the current generation of NOAA satellites.

a) General Characteristics

The GOES-Next sounder instrument shall have as a minimum fourteen channels with characteristics as outlined in the attached table. The field-of-view of each channel at nadir shall be 8 km x 8 km which is essentially that of the current VAS small detector capability (192 μ radian IFOV)

Table 1. GOES-NEXT Channel Specifications

Channel Number	Central Wavenumber ν (cm^{-1})	Bandwidth $\Delta\nu$ (cm^{-1})	Wavelength (μm)	Specified NEΔN $mW/(m^2\ sr\ cm^{-1})$
1	679	10	14.73	.87
2	691	12	14.47	.67
3	700	10	14.29	.72
4	710	10	14.08	.70
5	735	13	13.61	.56
6	748	16	13.37	.44
7	787	20	12.71	.38
8	892	50	11.21	.16
9	1365	50	7.33	.18
10	1467	140	6.82	.074
11	2213	35	4.519	.0086
12	2520	100	3.968	.0033
13	2671	100	3.744	.0036
14	14,367	1000	.696	0.1% Albedo

b) Areal Coverage

It shall be practical to obtain data within 60 degrees (great circle arc) of the satellite subpoint (i.e., 60°N to 60°S, and an equivalent distance east and west).

c) Timeliness

Contiguous data from any 3000 km x 3000 km area within the 60°N to 60°S meeting the signal to noise requirements of the table shall be obtainable in 40 minutes or less. Smaller areas shall be obtainable in proportionally shorter periods (i.e. 1000 km x 1000 km in 13 minutes or less).

d) Channel to Channel Registration

The channel to channel registration error, as a design goal, (centroid of individual FOV, when compared to the longwave window [892 cm^{-1}), shall be less than ±2 percent of the field-of-view width of each channel.

1.1.3 Space Environment Monitor

The Space Environment Monitor (SEM) shall provide the ability to monitor magnetic fields, assess solar x-ray flux and sense energetic particles. The SEM shall consist of three basic components.

a) A magnetometer - a biaxial flux-gate instrument with associated signal processing.

b) Solar x-ray sensor - an ion-chamber instrument designed to be sensitive to x-ray quantum energies in two bands.

c) Energetic particle sensor - consisting of three particle detector groups for measuring the flux of energetic electrons, protons, and alpha particles in the vicinity of the satellites.

d) A solar x-ray imager meeting the requirements of the attached system summary prepared by the Space Environment Laboratory shall be included as a proposal option, to be procured if technically feasible and cost remains within our budget envelope. As a second option the contractor shall propose inclusion of satellite bus components necessary to accomodate an instrument meeting these specifications. It should be assumed that the instrument will fly in the future. An instrument shall not be proposed other than for the total system.

1.1.4 Data Collection System

The Data Collection System (DCS) shall be capable of the interrogating platforms and receiving data from these or other appropriate noninterrogatable platforms. Characteristics of this system such as platform capacity, RF frequency and bandwidth, and data rate shall be unchanged from that of current generation GOES satellites. The intent here is to make the change in satellite essentially transparent to the data collection community.

1.1.5 Communications

A dedicated WEFAX capability shall be provided. The frequency allocation utilized for the current generation GOES satellites is available for the follow-on series to be procured. It is required that the characteristics of links (frequency, bandwidth, bit rate, etc.) to and from certain classes of users be made identical to those in use today. The systems to be retained with no changes are:

a) WEFAX: Transmission characteristics

b) DCS: Interrogation characteristics

c) DCS: Report characteristics - Here too, the intent is to make the system changes transparent to the users.

The transmission system should be developed in a manner conducive to meeting the baseline requirements of image gridding whether such data is first sent to the CDA for processing or is transmitted directly to the primary stations.

An option for flight of a search and rescue transponder system acquiring data at 406 MHz shall also be obtained. It shall be assumed that the downlink will utilize the 1544.5 MHz frequency allocated for SAR purposes.

2.0 SYSTEM CONSIDERATIONS

2.1 The design shall be flexible, in a manner that will not preclude eventual growth with the flight of an as yet undefined instrument.

2.2 Communications shall be limited to the frequency allocation assigned for the current generation GOES series, if practical.

2.3 The satellite throughout its useful lifetime shall be capable of maintaining orbital inclination on station to within 0.1 degrees. The capability to move the satellite to a new location at least once during each two years of its proposed orbital lifetime shall also be provided.

2.4 An appropriate means for determining orbit and attitude to the accuracy required to earth locate imagery shall be provided.

2.5 The performance of the system must be highly reliable, secure, flexible, and to the extent practical from a cost and operational basis, not subject to disturbances that will result in the loss of operational data.

3.0 GENERAL GUIDELINES

It is NOAA's desire that the system procured provide a reliable service at the least cost on a per year basis. It is not our purpose to constrain the proposals to a preconceived concept of how this should be accomplished. While certain constraints have been defined, it is our intention that other areas be left open to trade-offs by potential contractors. In computing costs per year for the service, the cost of the space segment, launch requirements and ground system modifications should be evaluated. Functional costs should be considered as appropriate to assure that a selected approach in itself does not require operating costs that will outweigh the savings accrued from the space segment procured.

Launch shall be constrained to the use of STS. It is our desire, however, that the proposer retain the responsibility for determining how best to take the satellite from the STS orbit to its final geostationary location.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
Washington, D.C. 20233

July 5, 1983 E/RA21:HEF

TO: E/SPD3 - Arthur Schwalb

FROM: E/RA21 - Henry Fleming Henry E. Fleming

SUBJECT: Final Specifications for the GOES-NEXT Sounder

The final specifications for the GOES-NEXT sounder are listed below.

1. Channel Selection

The fourteen channels, along with their spectral and noise specifications, listed in Table 1 represent the minimum number of channels that are acceptable. A larger number of channels, in which those in Table 1 are a subset, are highly desirable.

Table 1. GOES-NEXT Channel Specifications

Channel Number	Central Wavenumber ν (cm^{-1})	Bandwidth $\Delta\nu$ (cm^{-1})	Wavelength (μm)	Specified NEΔN mW/(m^2 sr cm^{-1})
1	679	10	14.73	.87
2	691	12	14.47	.67
3	700	10	14.29	.72
4	710	10	14.08	.70
5	735	13	13.61	.56
6	748	16	13.37	.44
7	787	20	12.71	.38
8	892	50	11.21	.16
9	1365	50	7.33	.18
10	1467	140	6.82	.074
11	2213	35	4.519	.0086
12	2520	100	3.968	.0033
13	2671	100	3.744	.0036
14	14,367	1000	.696	0.1% Albedo

2. Spectral Response

We suggest that a new type of instrumental spectral response specification be used. Each channel is characterized in Table 1 by a central wavenumber ν and a bandwidth $\Delta\nu$. Since the centroid of the response function is not nearly as critical as having narrowness and low wing response in the function, we require the response function (either relative or absolute response) have the following three properties:

a. that 72% of the area under the spectral response curve lie between ($\nu-\Delta\nu/2$) and ($\nu+\Delta\nu/2$),

b. that 96% of the area under the spectral response curve lie between ($\nu-\Delta\nu$) and ($\nu+\Delta\nu$).

c. the total area under the spectral response curve will be the area comprised of all nonzero response of one percent or higher of the maximum peak response.

Former specifications of spectral response emphasized point criteria, but we feel that area criteria better reflect the spectral throughput of the instrument. The first criterion above specifies the spectral region in which we want most of our energy transmission. The second criterion specifies the spectral region outside of which we want little, or no, energy transmission, and hence is a blockage criterion. Whenever these criteria are met, neither the exact location of the centroid nor the fine structure in the response curve are of concern to us . This is because the line structure in the spectral regions of interest is very dense and quite uniform.

Another change from past convention that we would like to see is in the presentation of the spectral response curves. In addition to the usual trace curves, we would like to have the spectral response curves given in the form of numerical tables with the response values given at every 0.1 cm^{-1} whenever there is a nonzero response of one percent or higher of the maximum peak response. This requirement can be relaxed for channels 10, 12, 13 and 14. Not only will this procedure overcome past problems of having to read curves of poor quality, but it also will insure that the calculations of the two areas, required by the two response criteria above, are repeatable by all concerned parties.

3. Dynamic Range

The dynamic range of the radiance (or voltage) output for each channel will be determined by the equivalent blackbody temperature of the NEΔN on the low end of the range and the greater of the calibration blackbody temperatures or expected scene temperature on the high end. The maximum expected scene temperature can be determined by the temperature extremes given in Figure 25 of the U.S. Standard Atmosphere, 1976 on page 25, relative to the altitude of the peaks of the transmittance weighting functions. The peaks of the weighting functions for both the nadir position and the maximum zenith angle of 57° must be considered, and the larger of the two corresponding temperatures in Fig. 25 will be used.

4. Spatial and Temporal Resolution

Profiles of temperature and moisture from ground to tropopause, along with a lifted stability index, must be provided in both clear and partly cloudy areas. The profiles and index shall have a spatial resolution such that a retrieval and index can be obtained from any 60x60 km area. The area covered should be selectable (on command) and the total area can be as large as 3000 km x 3000 km (i.e., 25° latitude by 40° longitude). This larger area should be observed in a time period not to exceed 40 min and should be relocatable hourly. A time period of 30 min is highly desirable; the 40 min time period should be used only if necessary.

A more frequent sounding mode also is required in which a 1000 km x 1000 km area can be scanned repeatedly within 10 minute intervals (up to three times). This must be achievable within a total observational time of 30 minutes and can be accomplished by making the standard 3000 x 3000 km sounding area described above programmable to this more frequent mode.

5. Instantaneous Field of View

The instantaneous field of view (IFOV) should be circular or square and not exceed 8 km in diameter or width. This means that the instrument shall be such that when viewing a uniform target, at least 70 percent of the energy incident upon the detector shall be contained in a field of view (FOV) having a projected circular or square area on the earth in the nadir direction of not more than 8 km in diameter or width. Also, as a second requirement, at least 83 percent of the energy reaching the detector shall be contained in a FOV having a projected circular or square area on the earth in the nadir direction of not more than 10 km in diameter or width.

A single sounding grid size of 10 km, distinct from the IFOV, also shall be specified. Thus, the 60 x 60 km retrieval area cited in Section 4 consists of 36 single sounding grid boxes. Under the assumption that the 10 km sounding grid boxes are viewed sequentially, the 3000 x 3000 km area described in Section 4 constitutes an array of 90,000 IFOVs, which must be acquired within at most 40 min. Consequently, the maximum dwell time per IFOV (including all channels) is 0.0267 sec, including IFOV positioning time.

The channel-to-channel registration for each IFOV shall be such that the FOV radiometric response centroids shall be superimposed to within ± 2 percent of the total FOV width. Furthermore, to insure some uniformity in the FOV response functions, the half-power FOV channel width shall match the half-power FOV width of the other channels to within ± 1 percent.

6. Scanning

The GOES-NEXT sounder should have the capability to scan the surface of the earth, both with respect to latitude and longitude, in such a way that all 10 km sounding grid boxes be essentially contiguous in both directions. The grid boxes should be exactly contiguious at a distance of 5000 km from the subsatellite point on the earth in the viewing direction, and this specification should be met in all viewing directions.

The pointing (navigation) accuracy of the 60 x 60 km retrieval resolution area should have an absolute accuracy of one half of an IFOV. Furthermore, the positioning accuracy should be such that the distance between centers of adjacent IFOVs should not vary by more than one tenth the diameter of an IFOV. This applies to both the normal and frequent scan modes.

In addition, each of the 10 min. repeat scans in the frequent scan mode must be from the original starting point and in the same scanning sequence as in the original 10 min. scan, with a recyle accuracy of one IFOV. The instrument shall have the flexibility of increasing the effective dwell time by factors of 2 and 4 for the purpose of decreasing the NEΔNs.

7. Crosstalk and Memory

The output signal for each channel must be essentially independent of past signals in that channel and of past and present signals in all other channels. The output of each channel should not be in error by more than 25 percent of the NEΔN because of any previous signals in that channel or crosstalk from other channels.

8. Data Transmission

Transmission of the sounder data from satellite to ground must be totally independent of the imaging data, not only in the data stream, but also the transmission process itself should be separate. The sounder data must be transmitted in real time, and these data must be non-processed, raw data. The radiance readout signal should be quantized so that the one bit level is no more than one half the NEΔN. The transmitted sounder data snall include measurement voltage data, calibration data, and navigation data sufficient to determine radiance and location of each IFOV.

9. Advanced Options

The specifications just listed are based on conventional radiometry and are not intended to limit the instrumental approach. We have assumed that the question of developmental sounder capability on the GOES-NEXT spacecraft (referred to on Page 2 of the NWS April 1, 1983, document) is being addressed for the GOES-NEXT Working Group by some other committee.

APPENDIX C

GLOSSARY OF ACRONYMS

AIRMETS	-	Airman's Meteorological Information
AMTS	-	Advanced Meteorological Temperature Sounder
AOCS	-	Attitude and Orbit Control System
APT	-	Automatic Picture Transmission
ATS	-	Applications Technology Satellite
AVHRR	-	Advanced Very High Resolution Radiometer
CDA	-	Command and Data Acquisition
CDDF	-	Central Data Distribution Facility
DCP	-	Data Collection Platform
DCS	-	Data Collection System
DSN	-	Deep Space Network
ELT	-	Emergency Locator Transmitter
EM	-	Electronics Module
EPIRB	-	*Emergency Position Indicating Radio Beacon*
EPS	-	Energetic Particle Sensor
FACC	-	Ford Aerospace and Communications Corporation
GLAS	-	Goddard Laboratory for Atmospheric Sciences (NASA)
G.m.t.	-	Greenwich Mean Time
GOES	-	Geostationary Operational Environmental Satellite
GOES-Next	-	Next-Generation GOES Satellite
HEPAD	-	High-Energy Proton Alpha Particle Detector
HIRS	-	High Resolution Infrared Radiation Sounder
HIS	-	High Resolution Interferometric Sounder
IFOV	-	Instantaneous Field of View
IGFOV	-	Instantaneous Geographic Field of View

Insat	-	Indian Satellite
IR	-	Infrared
MCC	-	Mission Control Center
NASA	-	National Aeronautics and Space Administration
NEΔT	-	Noise Equivalent Temperature Difference
NEN	-	Noise Equivalent Δ Radiance
NESDIS	-	National Environmental Satellite, Data, and Information Service
NHC	-	National Hurricane Center
NMC	-	National Meteorological Center
NOAA	-	National Oceanic and Atmospheric Administration
NSSFC	-	National Severe Storms Forecast Center
NWS	-	National Weather Service
OGE	-	Operational Ground Equipment
PAM-D	-	Payload Assist Module, Delta Class
PM	-	Propulsion Module
RFP	-	Request for Proposal
SAR	-	Search and Rescue
SARSAT	-	Search and Rescue Satellite-Aided Tracking
SEM	-	Space Environment Monitor
SFSS	-	Satellite Field Service Stations
SIGMETS	-	Significant Meteorological Information
SMS-A	-	Synchronous Meteorological Satellite (Version A)
STS	-	Space Transportation System
T&C	-	Telemetry and Command

TIROS	-	Television and Infrared Observation Satellite
UHF	-	Ultrahigh Frequency
VAS	-	VISSR Atmospheric Sounder
VHRR	-	Very High Resolution Radiometer
VISSR	-	Visible and Infrared Spin-Scan Radiometer
WEFAX	-	Weather Facsimile System
WSFO	-	Weather Service Forecast Offices
XRS	-	Solar X-ray Sensor

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