NOAA Technical Report NESDIS 12

Utilization of the Polar Platform of NASA's Space Station Program for Operational Earth Observations

Washington, D.C.
September 1984

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

(Continued from inside front cover)

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Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

National Environmental Satellite, Data, and Information Service
John H. McElroy, Assistant Administrator

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UTILIZATION OF THE POLAR PLATFORM OF NASA'S SPACE STATION PROGRAM FOR OPERATIONAL EARTH OBSERVATIONS

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ABSTRACT

NASA's polar platform, one of the planned elements of the Space Station program, could contribute to the operational monitoring of the Earth's atmosphere, oceans, and land masses. The payload for the platform would include instruments derived from the current operational environmental satellites, ocean satellites that will be flown by several countries during the next decade, research programs and land satellite systems -- both governmental and commercial. These instruments may justify two polar-orbiting, sun-synchronous, astronaut-serviced platforms. The platforms would be at an altitude in the range from 700 to 900 kilometers and be at two equatorial crossing times, one early in the morning between 8:30 and 10:30 A.M. southbound and the second near noon, perhaps at 1:00 P.M. northbound. The platforms, which could be decoupled constellations of platform sections, will provide direct transmission data readout as well as readout via the Tracking and Data Relay Satellite. International cooperation is already an important element in earth observation systems and can be in the polar platform as well.

I. INTRODUCTION

The recent decision to proceed with the development of a manned Space Station program may provide a new vantage point in space from which to monitor the Earth's atmosphere, oceans, and land masses. There are three principal elements to NASA's planned Space Station program: (1) the permanently-manned Space Station and its peripheral equipment in a low-altitude orbit at 28.5 degrees inclination, (2) a man-tended co-orbiting platform in the same orbit to be used for materials processing and other experiments, and (3) a man-tended platform in near-polar, sun-synchronous orbit. In the following paragraphs, the last element will be referred to simply as the "polar platform." The polar platform is the subject of this paper. The other elements may satisfy some research needs in earth observations, or be used as a base for the staging of geostationary missions, but they are not directly applicable to operational earth observations.

The thesis of this paper is quite simple and straightforward, namely that the polar platform could be a major step in operational earth observations -- if it is explicitly designed to be such a step from the very outset -- and, further, that the operational payload for the platform is essentially known today. Hypothetical payloads and speculative missions are not required for the planning of a polar platform -- the payloads and requirements of the 1990's are known today and will be the direct result of the successful flight of operational and research missions during the 1980's. There is no technical obstacle to commencing now the development of a useful polar platform that could produce dramatic advances in the practical applications of space systems at the beginning of the 1990's. It is only a matter of setting this objective as a priority goal of the Space Station program.

In the next few paragraphs, the manner in which instruments could evolve from current and planned missions to the space platform will be discussed. Figure 1 will provide a guide to the evolutionary path the instruments will follow from their initial flights to deployment on the platform. This figure shows U.S. missions and two foreign missions, Europe's ERS-1 and Canada's Radarsat -- they are vital links in this progression. There are other foreign missions that will contribute to the progression as well, notably those of Japan, but a sufficient number of missions are shown in Figure 1 to convey more than adequately the principal message of this paper. Reiterating one point, the payload that will be discussed is the operational payload -- not the accompanying research payload that may also be present. Although some of the instruments discussed below are presently in a research stage, it is assumed that they will be ready for routine operational use during the era of the polar platform.

After the discussion of payloads, a review will follow of the platform servicing and data system characteristics that they will require and the opportunities available for commercial firms and international cooperation.

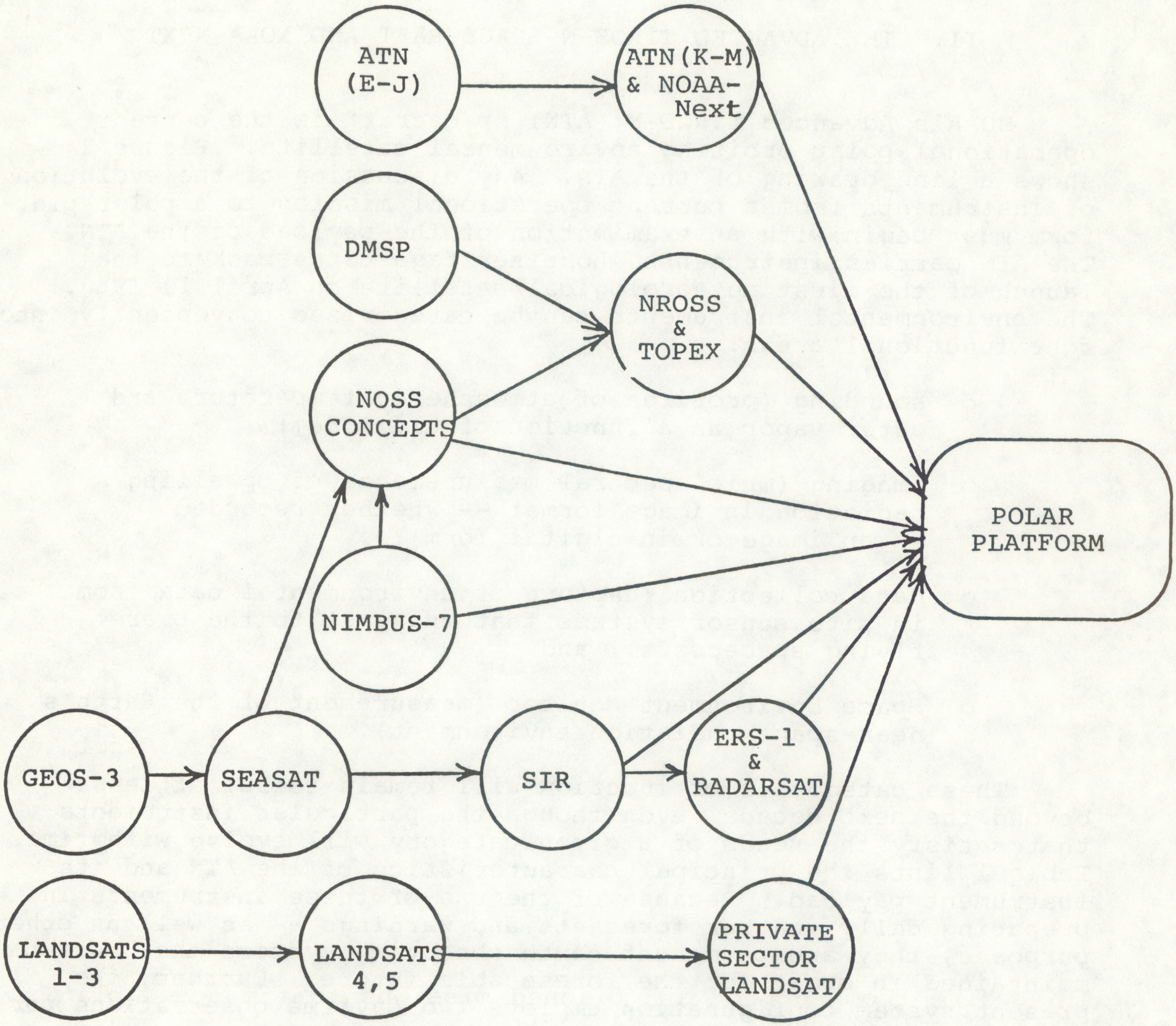


Figure 1. Flow of Instruments to Polar Platform

II. THE ADVANCED TIROS-N SPACECRAFT AND NOAA-NEXT

NOAA's Advanced TIROS-N (ATN) spacecraft is the current operational polar-orbiting environmental satellite. Figure 2 shows a line drawing of the ATN. Any discussion of the evolution of instruments from a current operational mission to a polar platform must begin with an examination of the payload of the ATN. The ATN carries instruments whose heritage dates back to the launch of the first meteorological satellite on April 1, 1960. The environmental instruments can be categorized conveniently into four functional areas:

- o sounding (profiles of atmospheric temperature and water vapor as a function of altitude);
- o imaging (multispectral measurements of upwelling radiation in image format -- whether recorded as an image or in digital form);
- o data collection (capture of environmental data from in situ sensor systems that transmit to the overflying spacecraft); and
- o Space Environment Monitor (measurement of the Earth's near-space radiation environment).

These categories of function will remain useful at least beyond the next decade, even though the particular instruments that satisfy the needs of a given category will evolve with time. Table 1 lists the principal characteristics of the ATN and its instrument payload. Because of the use of these instruments in preparing daily weather forecasts and warnings -- as well as other purposes, they are permanent earth observing systems that must be maintained in orbit for the foreseeable future. Further, the present system configuration employs two daytime observations per day and, hence, two equatorial crossing times. The presence in orbit of two spacecraft improves the robustness of the system and makes it less subject to losses of data continuity. The spacecraft characteristics and the data they produce are described in detail elsewhere.[1,2,3] The characteristics shown in Table 1 will be employed through NOAA-J, the third in the most recent procurement of polar-orbiters.

The next procurement of polar-orbiting environmental satellites, NOAA-K through M, continues the mission of the ATN series and augments it through the replacement of the obsolete MSU and SSU sensors by the Advanced Microwave Sounding Unit (AMSU). The ATN configuration will be retained, and a major block change to what has been referred to as NOAA-Next is planned to be made after NOAA-M. The characteristics of the instrument payload are given in Table 2, and are essentially the same as the preceding satellite, with the exception

Advanced TIROS — N

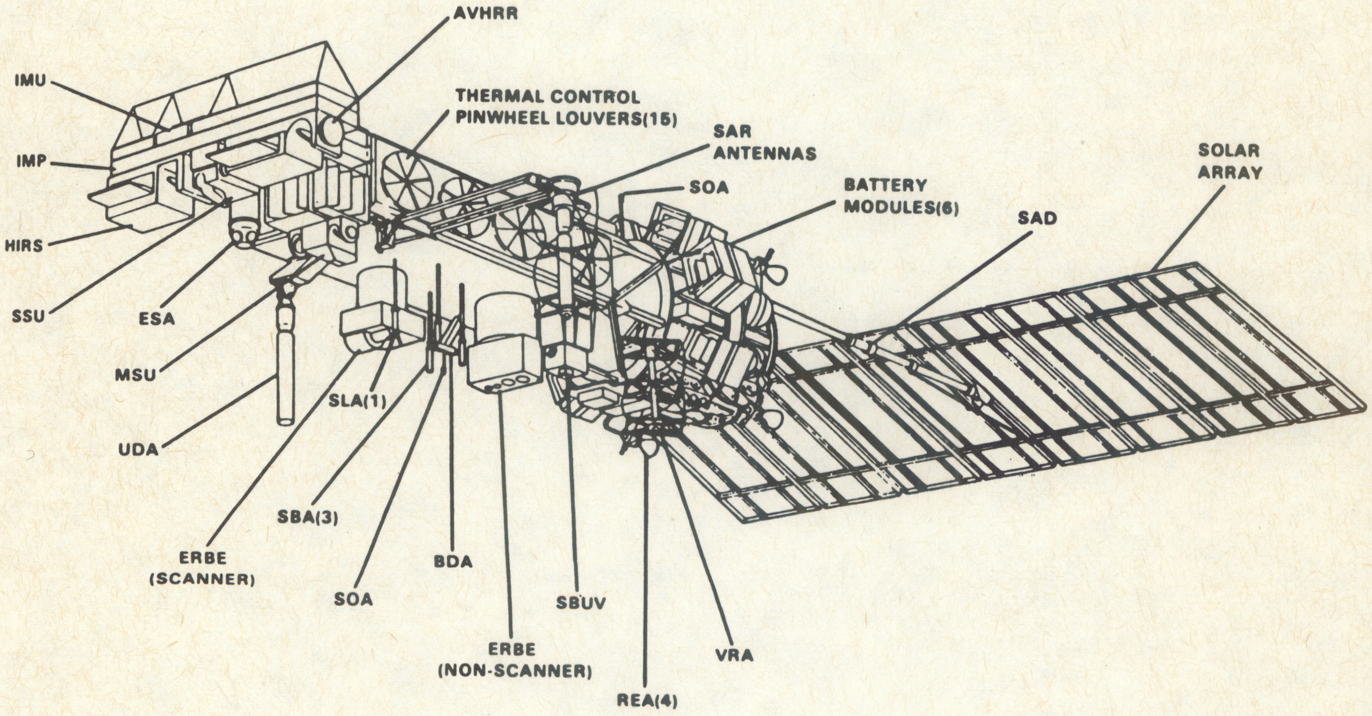


Figure 2. Line Drawing of Advanced Tiros-N

TABLE-1

TIROS-N/ATN

SENSOR	NUMBER OF CHANNELS/FREQUENCIES	SPECTRAL RANGE/ FREQUENCY RANGE	RESOLUTION	SWATH WIDTH	POWER REQUIREMENTS
AVHRR (Advanced Very High Resolution Radiometer)	5	.58 - 12.5 microns	1.1 Km	2700 Km	25.7 watts
HIRS/2 (High Resolution Radiation Infrared Sounder)	20	4.3 - 15.0 microns	17.4 Km	2240 Km	25 watts
SSU (Stratospheric Sounding Unit)	3	N/A	147 Km	1473 Km	15 watts
MSU (Microwave Sounding Unit)	4	50.3 - 57.05 GHz	109 Km	2347 Km	30 watts
ARGOS (Data Collection System)	N/A	136.77 and 137.77 MHz	N/A	2500 Km (radius)	3 watts
SAR (Search and Rescue)	N/A	121.5 and 24.30 MHz	N/A	2000 Km (radius)	57.2 watts
SBUV (Solar Backscatter Ultraviolet Radiometer)	12	252.0 - 339.8 NM	169.3 Km (11.3 degree IFOV)	--	12 watts
ERBE (Earth Radiation Budget Experiment)	8	0.2 - 50 microns	67.5 Km (3 x 4.5 degree IFOV)	Horizon to Horizon	45 watts
SEM (Solar Environmental Monitor)	N/A	N/A	N/A	N/A	8.4 watts

TABLE-1 (CONTINUED)

TIROS-N/ATN

SENSOR	WEIGHT	DIMENSIONS	DATA RATE	APPLICATION
AVHRR	27.3 Kg	.30 x .64 x .32 meters	2.66 Mb/s	Sea surface temperature, cloud delineation, vegetation, sea ice, snow cover, aerosols
HIRS/2	33.2 Kg	.41 x .65 x .46 meters	2.88 Kb/s	Atmospheric temperature, water vapor, and ozone profiles
SSU	12.5 Kg	.27 x .29 x .26 meters	480 b/s	Measure upper atmosphere weighting functions
MSU	31.8 Kg	.58 x .38 x .23 meters	320 b/s	Measure atmospheric temperature profile under cloud covered conditions
ARGOS	--	--	400 b/s	Collect and transmit environmental data from gauges on land and at sea
SAR	39.2 Kg	--	2.4 Kb/s	Broadcast distress signals from planes and ships
SBUV	38.2 Kg	.50 x .31 x .36 meters .33 x .22 x .31 meters	320 b/s	Vertical distribution of ozone
ERBE	61 Kg	.46 x .50 x .61 meters .35 x .40 x .59 meters	1120 b/s	Earth Radiation budget on synoptic and planetary scale
SEM	13.6 Kg	.13 x .12 x .36 meters .19 x .21 x .12 meters .07 x .30 x .28 meters	160 b/s	Monitor solar emissions and the variability of the earth's magnetic field

TABLE-2

NOAA K-M

SENSOR	NUMBER OF CHANNELS/FREQUENCIES	SPECTRAL RANGE/ FREQUENCY RANGE	RESOLUTION	SWATH WIDTH	POWER REQUIREMENTS	WEIGHT
AMSU-A	15	23.0 - 90.0 GHz	40 Km	2240 Km	110 watts	50 Kg
AMSU-B	5	90.0 - 183.0 GHz	15 Km	2240 Km	70 watts	27.3 Kg

TABLE-2 (CONTINUED)

NOAA K-M

SENSOR	DIMENSIONS	DATA RATE	APPLICATION
AMSU-A	.61 x .71 x .30 meters .71 x .61 x .91 meters	3 Kb/s	All-weather atmospheric profiles (temperature)
AMSU-B	.50 x .64 x .66 meters	6 Kb/s	All-weather atmospheric profiles (water vapor, precipitation) and ice

Note: NOAA K-M will carry all instruments listed under advanced TIROS-N (Table 1) with the exception of the SSU, MSU, and the ERBE. The AVHRR will gain a sixth channel in 1.6 micron range. The ARGOS system may be expanded to accommodate more platforms.

of the addition of the AMSU sensor, a slight modification to the AVHRR bands, and a modest increase in the capacity of the ARGOS system.

Returning to the flow chart in Figure 1, the Advanced Very High Resolution Radiometer (AVHRR), the AMSU, the High-Resolution Infrared Radiation Sounder (HIRS), the ARGOS data collection and platform location system, the satellite-aided search and rescue system called SARSAT, and direct data transmission functions would be carried from NOAA-H through -J to NOAA-K through -M and on, via NOAA-Next, if that generation is necessary, to the polar platform. The same instrument categories mentioned earlier apply -- with the addition of one for the SARSAT system. The above sequence is obviously dependent upon the schedule for the deployment of a polar platform. That schedule dictates, at least in this scenario, whether one additional generation of spacecraft needs to be inserted. This affects expenditures for nonrecurring design costs and, quite probably, dual compatibility between an expendable launch vehicle (ELV) and the Space Shuttle.

The ATN and NOAA-Next satellites have meteorological observations as their first objective, but only as the first rather than the exclusive objective. The instruments that provide meteorological observations also provide measurements of sea surface temperature, sea ice, snow cover, and an assessment of the condition of the Earth's vegetation. Fishing fleets use the data to determine areas having a greater likelihood for a sizable catch. Maritime shippers use the data to determine the most fuel-efficient routes -- either by avoiding opposing currents or joining favorable ones. Drought monitoring aids in the projection of later crop shortages and the identification of areas where foodstuffs should be prepositioned in anticipation of those shortages.

The sensors are used also in analyzing insect breeding grounds, soil moisture, volcanoes, and either the potential for or the existence of brush and forest fires.[4] These are only some of the nonmeteorological applications of environmental satellite data. As noted above, the satellites also serve as the home for the search and rescue system that directs aid to crashed aircraft and ships in distress. This multidisciplinary application of the sensors would be carried over to the polar platform.

In addition to the operational sensors, NOAA-F and NOAA-G will carry two experimental sensors in support of the climate research program. The two sensors are the Solar Backscatter Ultraviolet Radiometer (SBUV) and the Earth Radiation Budget Experiment (ERBE). The first of these measures global ozone distributions, while the second studies the radiation balance between incoming and outgoing energy. They will transition in some form to continuing operations to support the necessarily long-term measurements of the climate program, and are, therefore, a source of measurement requirements for the polar platform.

A final element that should be noted is that the satellites carry subsystems supplied by foreign governments at no cost to the United States. The United Kingdom has provided the Stratospheric Sounding Unit (SSU) for many years, and is now developing a major section of the AMSU. France provides the data collection and platform location system, ARGOS. Canada and France provide the search and rescue transponder and on-board processor, respectively. Canada is also examining the provision of an instrument that would serve as the long-term follow-on to the SBUV, and which would continue the monitoring of global ozone distributions. Thus, the ATN and NOAA-Next satellites are international in their make-up and multidisciplinary in their application. Further, literally hundreds of ground stations in numerous countries receive data directly from the satellites, so the application of their data is even more international than their make-up. Therefore, from some perspectives, a not insignificant step has already been taken toward a polar platform. Indeed, if the ATN and/or NOAA-Next satellites were serviceable -- and NASA's Space Transportation System (STS) capable of providing servicing at that altitude -- there would be little that distinguishes them from a small-scale polar platform.

III. DEFENSE METEOROLOGICAL SATELLITE PROGRAM

The Department of Defense has its own polar-orbiting weather satellite system that is called the Defense Meteorological Satellite Program (DMSP). The satellite is similar in construction to the ATN, but employs a different instrument payload. Military support requirements differ from those of the civil sector and lead to payloads that are quite dissimilar. One of its planned instruments, the Special Sensor Microwave Imager (SSM/I), is deserving of note here because it is also planned to be a part of the Navy Remote Ocean Sensing System (N-ROSS). The SSM/I provides all-weather measurements of ocean surface wind speed, ice edge location, and precipitation amount.

The DMSP also carries a temperature sounding system called the Special Sensor Microwave Temperature Sounding (SSM/T) and a water vapor sounding system called SSM/T-2. The SSM/T and SSM/T-2 functions are assumed to be subsumed by the AMSU in later discussions in this paper.

IV. GEOS-3, SEASAT, NIMBUS-7, AND SIR

The ATN, NOAA-Next, and DMSP satellites contribute to the understanding of the two fluid media that dominate man's existence, the atmosphere and the hydrosphere, but more to the former than the latter. The hydrosphere, particularly the ocean, has been the subject of a number of experimental NASA missions. These have provided the foundation for several planned missions that will be discussed in the next section; they are also a part of the direct heritage of the instrument complement proposed later for the polar platform.

The GEOS-3 mission was built upon the Skylab radar altimeter experience and was the first satellite aimed specifically at ocean measurements. With an altimetric precision of some 30 to 40 centimeters, it provided the first clear view of the potential of altimetric measurements.[5] It prepared the community for the 5-8 centimeter precision provided by the Seasat altimeter. Radar altimetry of the ocean provides data on the shape of the marine geoid, subsurface features through gravity-induced surface variations, surface currents, significant wave height, and surface wind speed (but not direction).[6] Figure 3 shows a line drawing of the Seasat spacecraft, and Table 3 lists its principal characteristics and those of its instruments.

In addition to continuing at higher precision the altimetric measurements of GEOS-3, Seasat also carried a Synthetic Aperture Radar (SAR), a wind scatterometer called the Seasat-A Satellite Scatterometer (SASS), a Scanning Multichannel Microwave Radiometer (SMMR), and a Visible and Infrared Radiometer (VIRR).

The SAR provided imagery of the ocean with a spatial resolution of 25 meters and showed deep ocean wave patterns, water-land interaction processes, and provided surface elevation contours for the Greenland and Antarctic ice sheets. The SASS provided measurements of ocean surface wind speed with an accuracy of 2 meters per second over the range from 4 to more than 26 meters per second. The SMMR, which is also on the Nimbus-7 satellite, provides all-weather sea surface temperature measurements and also monitors atmospheric water vapor. The SSM/I mentioned above under the discussion of the DMSP has enhanced characteristics over those of the SMMR. The VIRR provided supporting data to assist in the interpretation of the information gained from the other instruments.

The unique suite of instruments that was flown on Seasat led to the extensive planning conducted for the National Oceanic Satellite System (NOSS), which in turn has led to the N-ROSS satellite that is being developed jointly by the U.S. Navy and NASA. The SAR and SASS would flow from Seasat to N-ROSS to the polar platform. The functions provided by the SMMR and the VIRR will be met by other instruments. The Seasat SAR also led to the Canadian plans for a Radarsat later this decade,[7] and the European Space Agency's (ESA) ERS-1 satellite which will include a scatterometer and a SAR in the same instrument.[8] More will be said of these two satellites in the next section.

The Nimbus-7 satellite carried, in addition to the SMMR mentioned above, a Coastal Zone Color Scanner (CZCS). The CZCS is a visible- and infrared-multispectral radiometer whose bands were chosen to correspond to strong organic absorption features or spectral regions where such features are absent. This permits the observation -- after suitable analysis -- of chlorophyll-a and phaeopigment-a concentrations and, hence, provides a measure of biological productivity. The successor to the CZCS is the Ocean

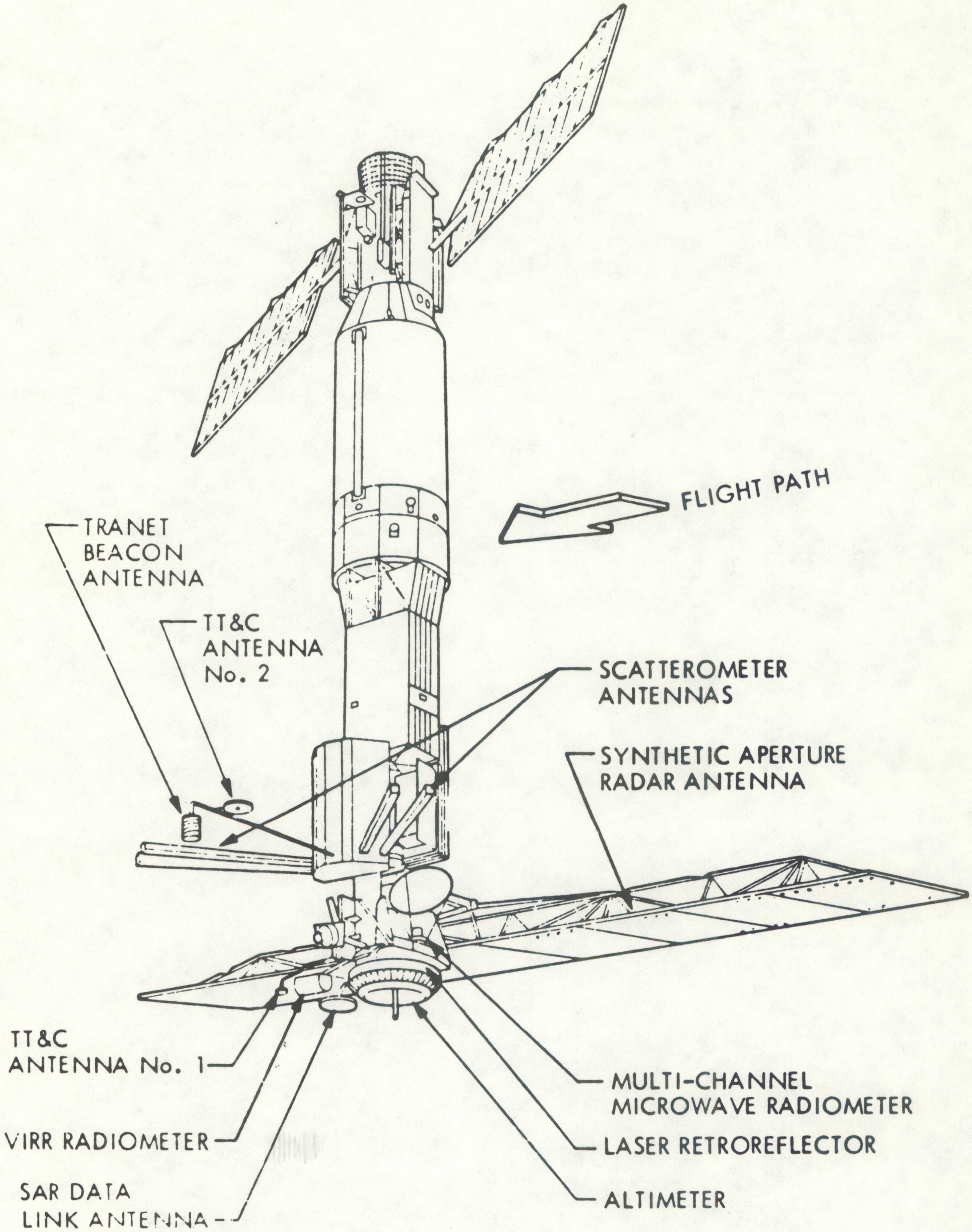


Figure 3. Line Drawing of Seasat

TABLE-3

SEASAT-A

SENSOR	NUMBER OF CHANNELS/FREQUENCIES	SPECTRAL RANGE/ FREQUENCY RANGE	RESOLUTION	SWATH WIDTH	POWER REQUIREMENTS
Radar Altimeter	1	13.5 GHz	10 cm (wave height)	nadir viewing	177 watts
Scatterometer	4	14.6 GHz	50 km	500 km (each side)	140 watts
SMMR (Scanning Multichannel Microwave Radiometer)	5	6.6 - 37.0 Ghz	16 x 25 km 87 x 144 km	900 km	60 watts
VIRR (Visible and Infrared radiometer)	2	0.40 - 12.5 microns	3 - 5 km	1800 km	10 watts
SAR (Synthetic Aperture Radar)	1	1275 MHz	25 meters	100 km	574 watts

TABLE-3 (CONTINUED)

SEASAT-A

SENSORS	WEIGHT	DIMENSIONS	DATA RATE	APPLICATION
Radar Altimeter	95 Kg	1 meter diameter (antenna)	8.5 Kb/s	Ocean topography
Scatterometer	60 Kg	--	2.0 Kb/s	Surface winds
SMMR	42 K	--	2 Kb/s	Sea surface temperatures, sea ice, rainfall
VIRR	20 Kg	--	12 Kb/s	Ocean temperatures, coastal features, cloud delineation, ice edge
SAR	128 Kg	10.74 x 2.16 meters (antenna)	120 Mb/s	Ice topography

Color Imager (OCI) and is suitable for a near-noon orbiting polar platform. Nimbus-7 also carried the predecessor instrument to the SBUV that will fly on NOAA-F and NOAA-G, and a Total Ozone Mapping Spectrometer (TOMS). Figure 4 shows a line drawing of Nimbus-7 and Table 4 provides a listing of the satellite parameters and those of its instruments.

NASA has also carried out a number of experiments using instruments in the Space Shuttle's payload bay. Among them are the two Shuttle Imaging Radar (SIR) experiments. Using technology quite similar to that of Seasat, they have continued measurements interrupted by the brief lifetime of that mission. Some of the most striking results have been obtained in arid regions where the radar pulses have shown an unexpected ability to penetrate the dry surface layers and expose geologic features beneath them. It is also evident that radars which are optimized for measurement of ocean phenomena are not necessarily optimized to measure land phenomena. For this reason, later paragraphs of this paper will distinguish between the two using the terminology SEASAR and GEOSAR, for ocean and land, respectively.

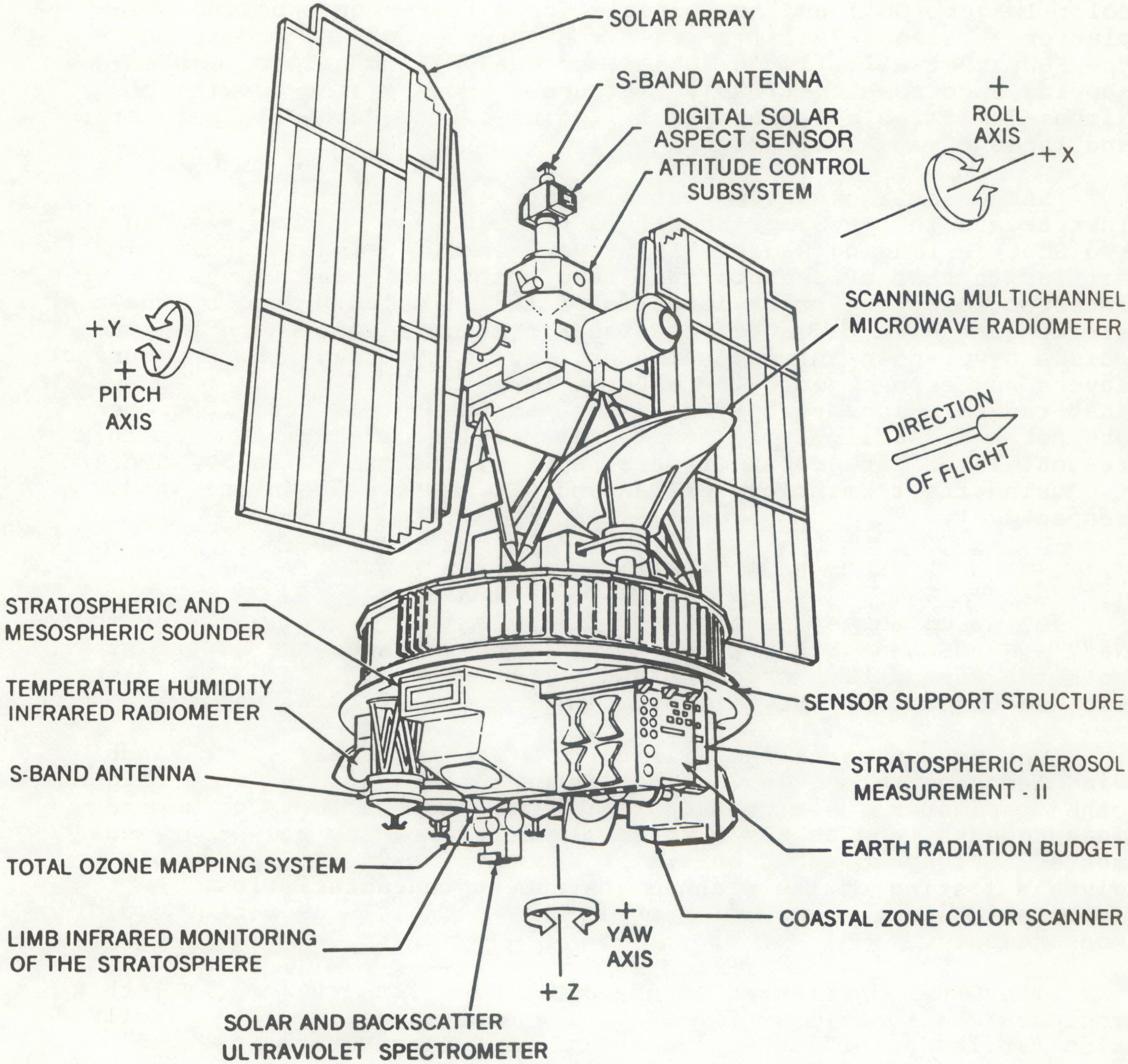
V. N-ROSS, ERS-1, TOPEX, AND RADARSAT

As noted above, Seasat and other missions have given rise to the Navy's N-ROSS and ESA's ERS-1. These two missions are important from both the perspective of the measurements they will make, but also because of the way they illustrate the value of cooperation.

The N-ROSS satellite will carry a scatterometer for sea surface wind and wave velocities, an altimeter for significant wave height and other parameters, a microwave radiometer for sea surface temperature measurements, and an SSM/I for all-weather sea ice and other measurements.[9] Figure 5 shows an artist's concept of N-ROSS and Table 5 gives a listing of the planned instrument characteristics. An important aspect of the mission is the nominal 2-day repeat cycle for measurements.

The ERS-1 carries an Advanced Microwave Instrument (AMI) that includes the functions of a SAR and a scatterometer. The satellite also carries an altimeter and an infrared Along-Track Scanning Radiometer (ATSR). ERS-1 also has a nominal 2-day repeat cycle. Figure 6 shows a line drawing of the planned configuration of the satellite and Table 6 lists the characteristics of the satellite and its payload.

If the parameters of N-ROSS and ERS-1 are properly coordinated, the nominal 2-day repeat cycle of the satellites is converted to daily global ocean coverage. This is of major significance to the preparation of nowcasts and forecasts to support the maritime community. It should be noted that such coordination does not impact national objectives or the cost of the missions, but it dramatically



Nimbus 7 Observatory

Figure 4. Line Drawing of Nimbus-7

TABLE-4

NIMBUS-7

SENSOR	NUMBER OF CHANNELS/ FREQUENCIES	SPECTRAL RANGE/ FREQUENCY RANGE	RESOLUTION	SWATH WIDTH	POWER REQUIREMENTS
THIR (Temperature Humidity Infrared Radiometer)	2	IR	6.7 - 20.0 km	2610 km	8.5 watts
CZCS (Coastal Zone Scanner)	6	VIS/IR	0.825 km	1566 km	11.4
SMMR (Scanning Multichannel Microwave Radiometer)	5	Microwave (6.6 - 37 GHz)	30.0 - 97.5 km	900 km	61.6
ERB (Earth Radiation Budget)	22	.2 - 50.0 microns	150 km	--	36.3
LIMS (Limb Infrared Monitor of the Stratosphere)	6	6.4 - 14.9 microns	1.8 x 18 km -3.6 x 28 km	N/A	24.5
SAMS (Stratospheric and Mesospheric Sounder)	12	2.7 - 100 microns	--	N/A	23.0
SAM II (Stratospheric and Aerosol Measurement II)	1	.98 - 1.02 microns	--	N/A	0.8
SBUV/TOMS (Solar Backscatter Ultraviolet and Total Ozone Mapping Spectrometer)	12 (SBUV) 6 (TOMS)	160 - 400 nm (SBUV) 312 - 380 nm (TOMS)	-- --	200 km	20.0

TABLE-4 (CONTINUED)

NIMBUS-7

SENSOR	WEIGHT	DIMENSIONS	DATA RATE	APPLICATION
THIR	9.1 Kg	.19 x .18 x .40 meters .18 x .17 x .15 meters	25 Kb/s	Moisture content of upper troposphere and stratosphere
CZCS	41.9 Kg	.78 x .53 x .37 meters	800 Kb/s	Map ocean chlorophyll concentrations
SMMR	53.3 Kg	Two .15 x .33 x .20 meter modules One .15 x .17 x .20 meter modules One Antenna, .80 meter diameter	2 Kb/s	Sea surface temperature, near surface winds, sea ice, snow, rainfall, soil moisture
ERB	32.7 Kg	.33 x .36 x .48 meters	450 b/s	Earth Radiation Budget on synoptic and planetary scales
LIMS	67.3 Kg	--	4 Kb/s	Vertical distribution of temperature and O_3, NO_2, HNO_3, and H_2O from lower stratosphere to lower mesosphere
SAMS	60.6 Kg	--	150 b/s	Vertical distribution of temperature and CO_2, H_2O, N_2O, CH_4, CO, and NO in the stratosphere and mesosphere
SAM II	17 Kg	.36 x .20 x .51 meters	700 b/s	Vertical distribution of stratospheric aerosols in polar regions
SBUV/TOMS	89.1 Kg	.36 x .26 x .56 meters .33 x .20 x .15 meters	650 b/s	Vertical distribution of ozone, incident solar ultraviolet irradiance and backscattered ultraviolet

NAVY REMOTE OCEAN SENSING SYSTEM (N-ROSS)

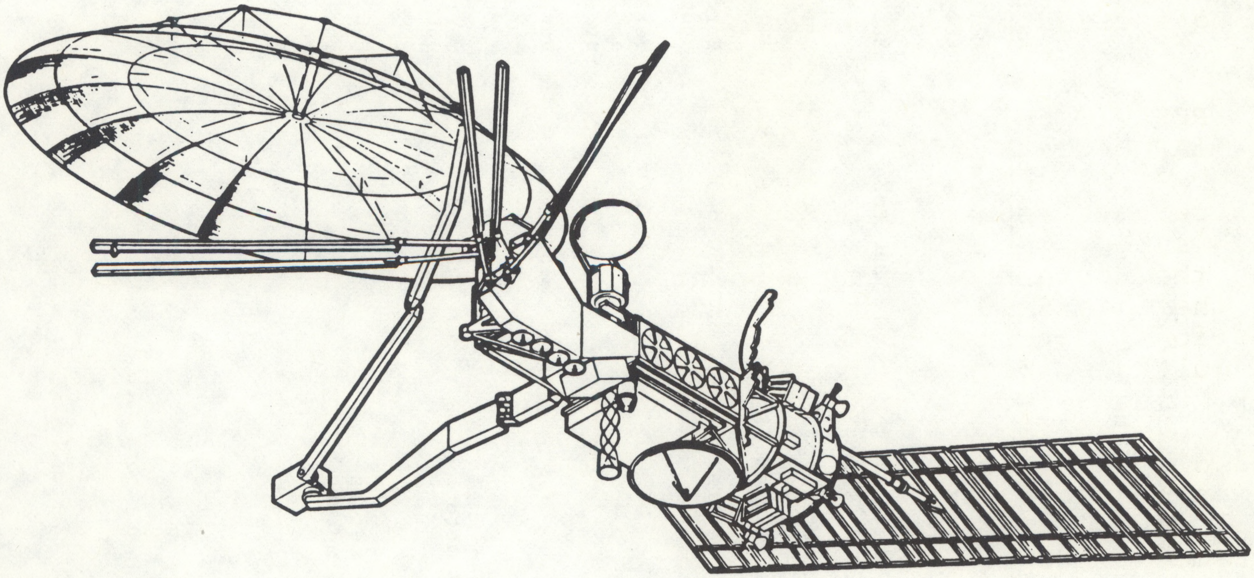


Figure 5. Line Drawing of N-ROSS

TABLE-5

N-ROSS

SENSOR	NUMBER OF CHANNELS/FREQUENCIES	SPECTRAL RANGE/ FREQUENCY RANGE	RESOLUTION	SWATH WIDTH	POWER REQUIREMENTS
RA (Radar Altimeter)	1	13.5 GHz	3.5 cm (wave height)	nadir view only	113 watts
SSM/I (Special Sensor Microwave Imaging)	4	19.3 - 85.5 GHz	25 Km	1394 Km	36 watts
SCATT (Scatterometer)	4	13.995 GHZ	25 Km	600 KM (each side)	240 watts
LFMR (Low Frequency Mircrowave Radiometer)	2	5.2 - 10.4 GHz	2.5 Km	1400 Km	50 watts

TABLE-5 (CONTINUED)

N-ROSS

SENSOR	WEIGHT	DIMENSIONS	DATA RATE	APPLICATION
RA	90.9 Kg	.50 x .34 x .25 meters	8 Kb/s	Sea surface topography
SSM/I	55 Kg	.66 meters (antenna diameter)	3.6 Kb/s	All-weather sea surface temperatures, ice edge, precipitation
SCATT	147.7 Kg	3.10 x .10 x .15 meters (x6) 1.15 x .55 x .31 meters	2.0 Kb/s	Sea surface winds
LFMR	56.8 Kg	5.9 meters (antenna diameter)	14.0 Kb/s	Sea surface temperature (high resolution)

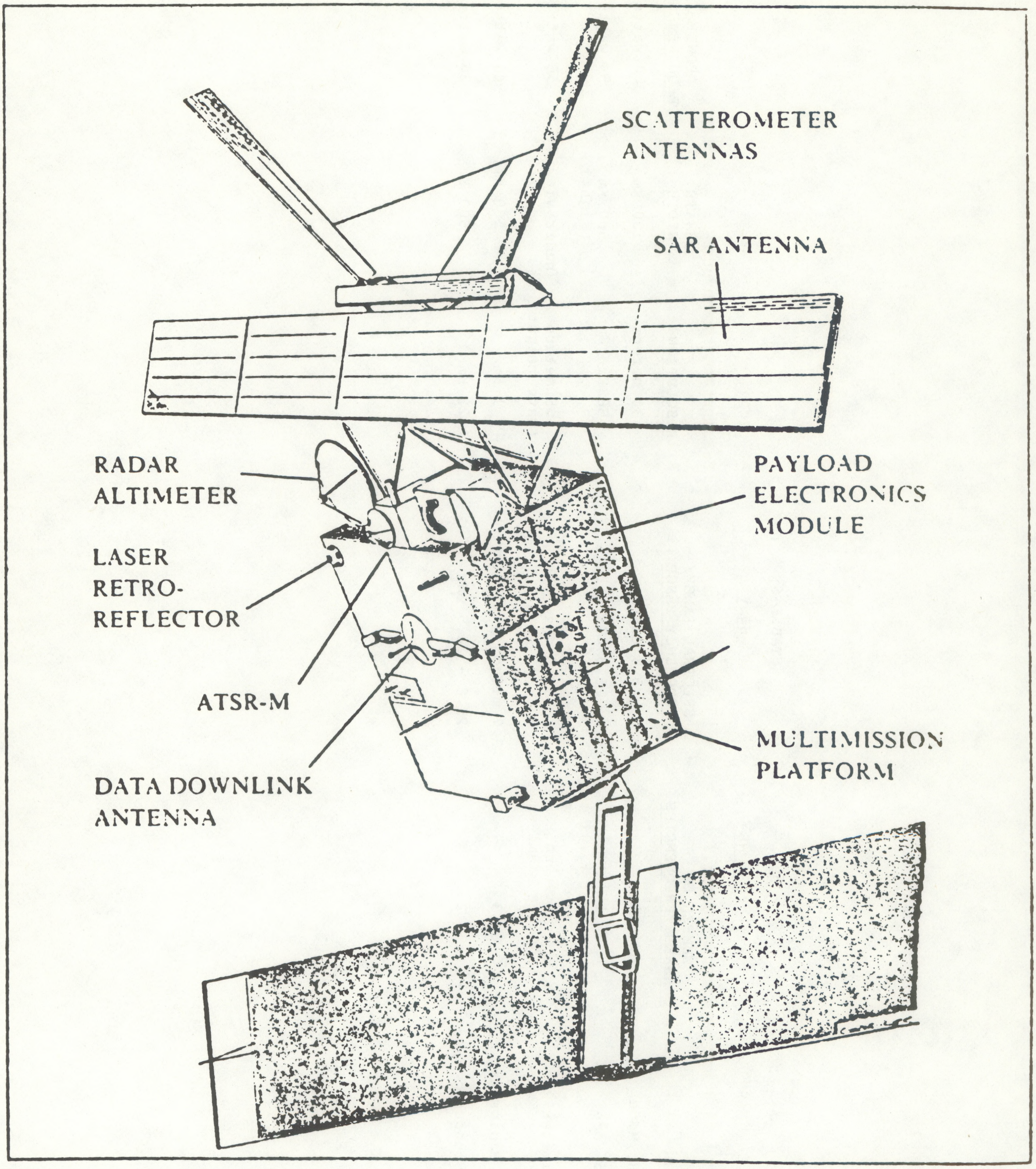


Figure 6. Line Drawing of ERS-1

TABLE-6

ERS-1

SENSOR	NUMBER OF CHANNELS/FREQUENCIES	SPECTRAL RANGE/ FREQUENCY RANGE	RESOLUTION	SWATH WIDTH	POWER REQUIREMENTS
AMI* - SAR* Mode	1	5.3 GHz	30 meters	100 Km	300 watts
AMI - Wind Mode	1	5.3 GHz	50 Km	500 Km (right)	54 watts
Radar Altimeter	1	13.5 GHz	.5 meters (wave height)	nadir viewing	50 watts
ATSR* - M Radiometer	3	3.7 micron - 12 micron	1 Km	500 Km	48 watts
ATSR - M Sounder	2	23.8 - 36.5 GHz	22 Km	500 Km	30 watts

TABLE-6 (CONTINUED)

ERS-1

SENSOR	WEIGHT	DIMENSIONS	DATA RATE	APPLICATION
AMI* - SAR* Mode	--	10m x 1m (antenna)	100 Mb/s	Ice topography, geologic structures
AMI - Wind Mode	--	2.5m x 3.6m (antenna)	15 Mb/s	Surface winds
Radar Altimeter	--	1.2m (Antenna diameter)	--	Sea surface topography
ATSR* - M Radiometer	33 Kg	--	205 Kb/s	Sea surface temperature
ATSR - M Sounder	21.5 Kg	--	205 Kb/s	Atmospheric profiles

*AMI - Active Microwave Instrument
*SAR - Synthetic Aperture Radar
*ATSR - Along Track Scanning Radiometer

increases their value. The availability of wide swathwidth SSM/I data from both N-ROSS and the DMSP system provides a further positive linkage between the two systems that greatly enhances the data set as well. It is expected that the success of these missions will create a strong demand from the maritime community for a continuation of these data. This demand can lead to the incorporation of the instruments from N-ROSS and ERS-1 on the polar platform.

But N-ROSS and ERS-1 are not the only ocean-related missions under study. NASA is planning a dedicated altimeter mission, TOPEX, specifically designed for the determination of the ocean circulation. It will have an improved altimeter (2 cm precision) and a unique orbit (63 degree inclination and 1300 km altitude) in order to enhance accurate tracking and the determination of the global tides. An experimental GPS-based system planned to give sub-decimeter tracking accuracy is proposed to be carried aboard. Given a successful mission, it will then be possible to continue TOPEX-quality observations of ocean circulation by using a similar altimeter and GPS tracking package, but aboard a platform of opportunity -- even one in a sun-synchronous orbit.

Canada is currently evaluating a mission called RADARSAT. This mission is targeted at four sets of applications of a SAR: operations in sea-ice covered waters, basic oceanography, renewable resource assessments, and detection of nonrenewable resources. It, combined with ERS-1, further SIR flights on the Space Shuttle, and a Japanese mission, called JERS-1, will provide ample experimentation to justify the continuation of SAR missions, both SEASAR and GEOSAR, on an operational basis.

VI. LAND SATELLITE SYSTEMS

The systematic observation of the land masses of the Earth from space began with Landsat. Only sporadic coverage was provided by the manned missions prior to that time. Through the decade of the 1970's, the Multispectral Scanner (MSS) was the principal sensor employed for this purpose. This was augmented in the early 1980's by the Thematic Mapper (TM) on Landsats 4 and 5.[10] Figure 7 shows a line drawing of Landsats 1 and 4, and Table 7 provides a summary of the characteristics of their sensors.

Scheduled for the mid-1980's is the French SPOT system, which has characteristics which complement those of Landsats 4 and 5. SPOT has fewer spectral bands, but higher spatial resolution than Landsat -- and provides offset pointing and stereo capability as well. Figure 8 shows a line drawing of SPOT and Table 8 describes its sensor characteristics.

One of the potential life-limiting mechanisms for the MSS/TM class of sensor is the large mechanically-moving mirror that produces the scan perpendicular to the orbit track, i.e., the cross-track scan. Research and development activities have been directed at the production of an all solid-state sensing device

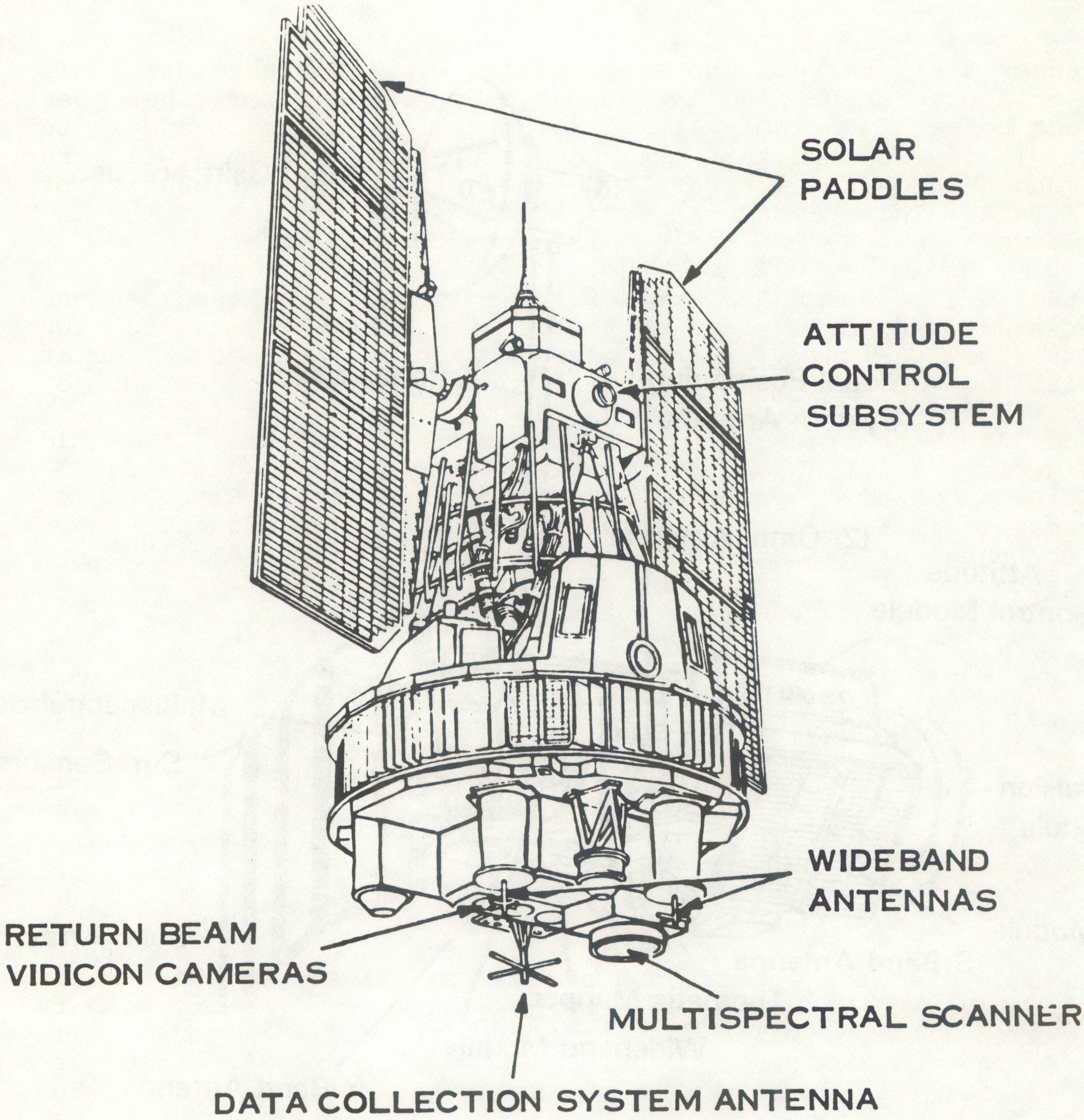


Figure 7.(a) Line Drawing of Landsat 1

Landsat-4 Flight Segment

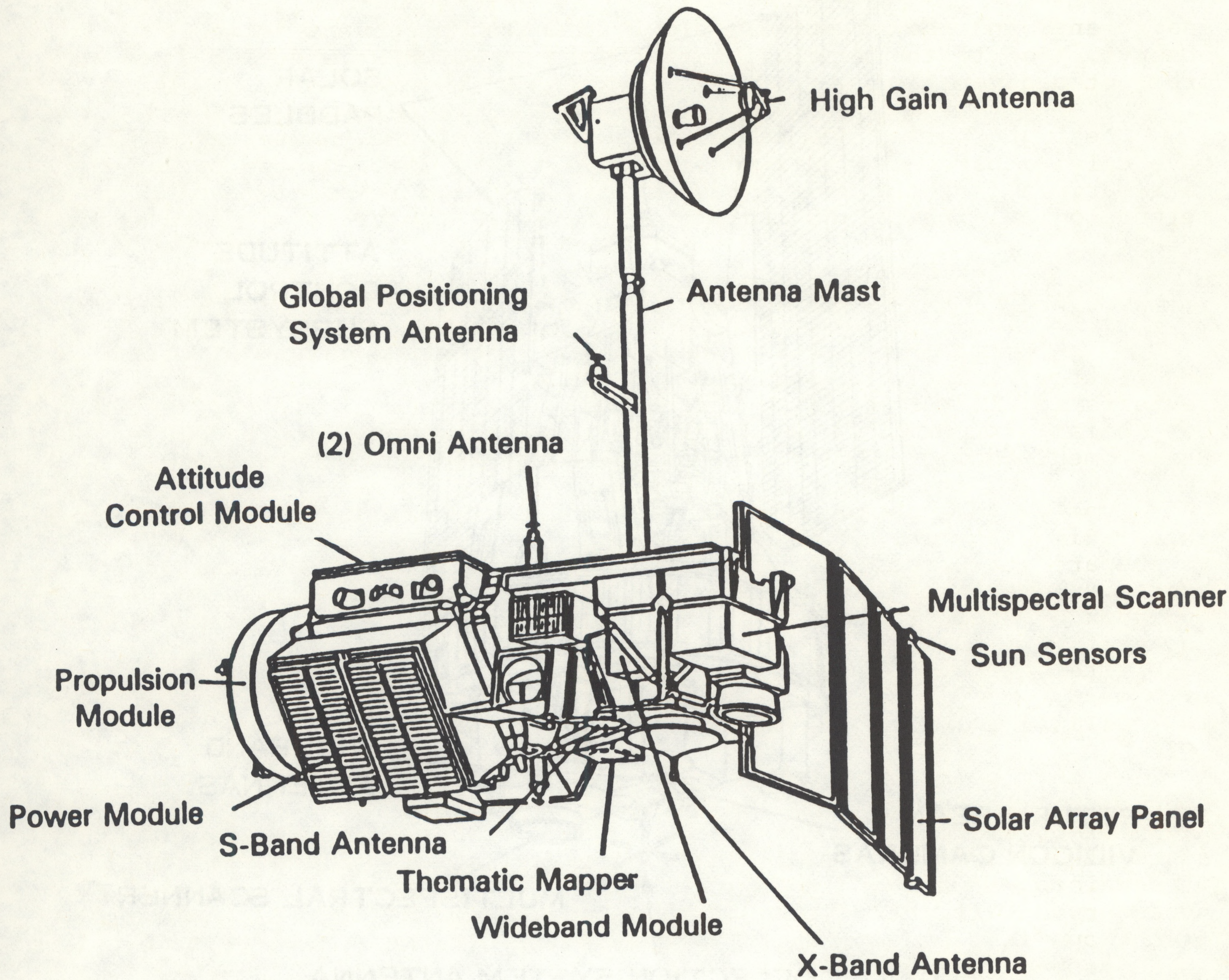


Figure 7. (b) Line Drawing of Landsat 4

TABLE-7

LANDSAT

SENSOR	NUMBER OF CHANNELS/FREQUENCIES	SPECTRAL RANGE/ FREQUENCY RANGE	RESOLUTION	SWATH WIDTH	POWER REQUIREMENTS
RBV[1] (Return Beam Vidicon	1	0.5 - .75 microns	40 meters	185 Km	174 watts
MSS[2] (Multispectral Scanner)	4	0.5 - 1.1 microns	80 meters	185 Km	82 watts
TM[3] (Thematic Mapper)	7	.45 - 2.35 microns (6 channels) 10.4 - 12.5 microns (1 channel)	30 meters 120 meters (thermal)	185 Km	300 watts

TABLE-7 (CONTINUED)

LANDSAT

SENSOR	WEIGHT	DIMENSIONS	DATA RATE	APPLICATION
RBV[(1)]	92.3 Kg	.54 x .26 x .78 x 3 meters .15 x .15 x .2 meters .15 x .15 x .25 meters	6.4 Mb/s	Land use, urban planning, mapping, agriculture, forestry, water resources, geology, mineral resources
MSS[(2)]	66.1 Kg	.17 x .15 x .10 meters .59 x 1.26 x .54 meters	15.06 Mb/s	Same as above
TM[(3)]	245.9 Kg	1.1 x 0.7 x 2.5 meters	84.9 Mb/s	Same as above

(1) On Landsat 1-3 (with slight variations between satellites)

(2) On Landsat 1-5 (with slight variations between satellites)

(3) On Landsat 4-5

called the Multispectral Linear Array (MLA) or pushbroom line scanner.[11] It is anticipated that this technology will eventually become the standard for multi-spectral imaging devices. The flexible type of imaging instrument that would benefit from flight on a polar platform would almost certainly be of the MLA class.

The land sensing system could be a major beneficiary of the availability of a man-tended platform in polar orbit. The economics of the Landsat system were the subject of a long controversy that has extended to the utility and value of future systems, both governmental and private. If the cost of placing a sensor on an existing platform and maintaining it through in-orbit servicing were dramatically less expensive than launching and maintaining a dedicated satellite in orbit, the economic analysis of land sensing systems would shift in a very favorable direction.

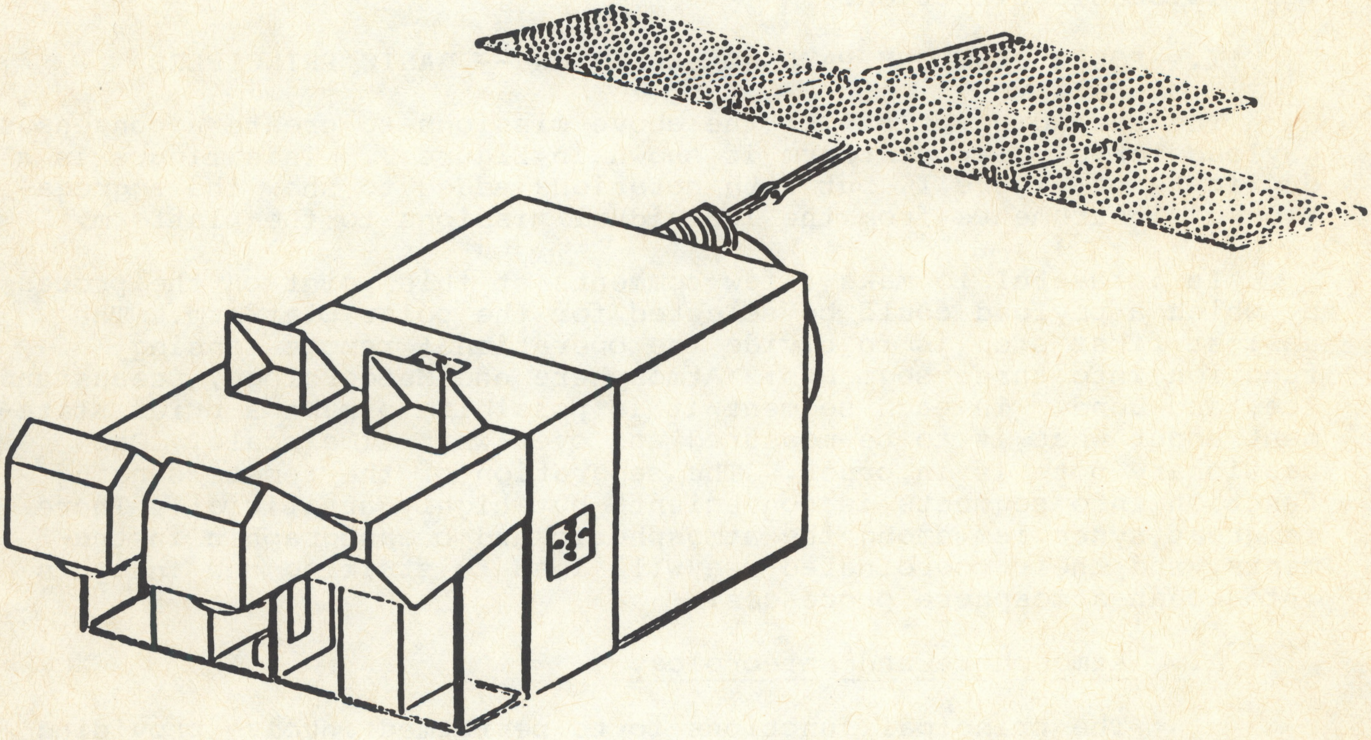
VII. POLAR PLATFORM PAYLOAD SELECTION -- BASIC PRINCIPLES

The cascading of all of the above missions to create a consensus payload for a polar platform is shown in Figure 9. This figure is a duplicate of Figure 1, but with notations added to show the aggregation of instruments from the individual missions to the platform.

It is useful to make a few comments at this point on the process by which a payload could be selected for the polar platform. The easiest first step is to divide the operational remote sensing function into three segments: Atmosphere and Meteorology, Oceans and Ice, and Land. In each segment it is possible to make a brief statement about what is to be measured and over what time scale. One cautionary note is in order. The separation of the remote sensing function into segments is convenient, but highly artificial. There is great synergism among the atmospheric and oceanographic instruments, and their coordinated use will lead to striking new insights into ocean-atmosphere processes.

A. Atmosphere and Meteorology

The principal functions to be performed involve providing quantitative data for numerical weather prediction, quantitative and qualitative imagery data for local readout, environmental data collection from in-situ sensors, and measurements related to climatic change. Under the present two-polar system, data are assembled for computer analysis twice a day. These analyses include data from radiosondes, surface observations, and satellite measurements. The fundamental physical problem is the measurement and analysis of a changing fluid medium on a frequent enough time scale to predict its future behavior. It is self-evident that continuing daily measurements are required. The payloads devised for the ATN and DMSP satellites have been tailored to achieve this goal and, with appropriate merger of some instrument functions, can be transferred directly to the polar platform. In order to achieve the required



SPOT Satellite. First Mission

Figure 8. Line Drawing of SPOT

TABLE-8

SPOT

SENSOR	NUMBER OF CHANNELS/FREQUENCIES	SPECTRAL RANGE/ FREQUENCY RANGE	RESOLUTION	SWATH WIDTH	POWER REQUIREMENTS
HRV (High Resolution Visible Range Instruments)	4	.50 - .89 microns	10 meters	60 Km	115 watts
					1200 watts*

TABLE-8 (CONTINUED)

SPOT

SENSOR	WEIGHT	DIMENSIONS	DATA RATE	APPLICATION
HRV	170 Kg	2.26 x 1.5 x 1.0 meters	50 Mb/s	Land use, urban planning, mapping, agriculture, forestry, water resources, geology
	650 Kg*	--		

* Entire payload (including two HRV's)

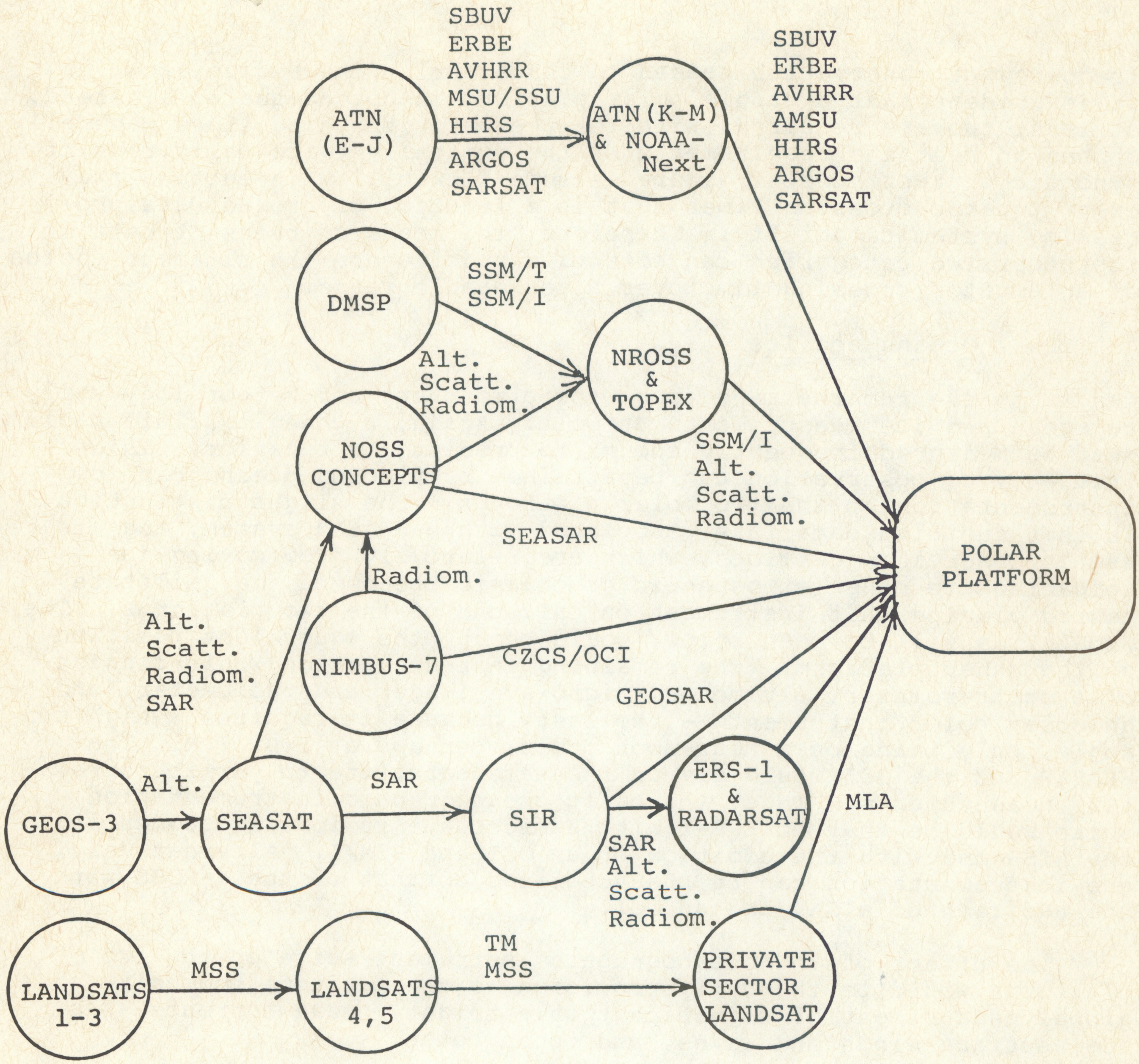


Figure 9. Flow of Instruments to Polar Platform

frequency of observation needed to characterize the medium, however, it is evident that a single polar platform is not adequate. Instead, at least two are required, with their equator crossing times generally chosen to meet the requirements of the nominally twice daily runs of synoptic weather models. There is some flexibility in setting the exact equator crossing times that is a function of ground data processing system capability. Therefore, the needs of users of data in the other two categories can effectively influence the ultimate choice of an equator crossing time over a reasonable range.

B. Oceans and Ice

The remarks made about the atmosphere and meteorology apply to ocean and ice measurements as well. Again, a changing fluid medium must be measured frequently enough to predict its behavior. This frequency of observation can be attained by placing oceanographic instrumentation on the two polar platforms. One slight distinction is that the high data rate associated with a SEASAR system, and its use in observing ice floes, which are relatively slow moving in comparison to other atmospheric or oceanic phenomena, may militate toward placing that instrument on only one of the two platforms. The GEOSAR, as will be seen below, would occupy the equivalent position on the other platform. The remaining instrumentation would consist of a scatterometer, altimeter, microwave imager and radiometer, and an ocean color instrument -- the last, because it requires a high sun angle, only being on a near-noon orbit, perhaps at 1:00 P.M. The SEASAR and the OCI would fly on the same satellite to permit correlative measurements. Thus, the basic oceanographic instrumentation suite would be that of ERS-1 with a microwave radiometer augmenting the ATSR and with the addition of an OCI and SSM/I. Alternatively, the instrumentation can be characterized as that of the N-ROSS with the addition of a SAR and an OCI.

The effect of the oceanographic instrument suite on the two platforms would be the daily provision to the maritime community of a global measurement of significant wave height, ocean currents, sea ice, surface winds and waves, and ocean color.

C. Land

The land measurements would be made principally with two instruments, the MLA and the GEOSAR. Unlike the daily global coverage requirements of the meteorological and oceanographic instruments (less the SEASAR), the more limited swath widths of the land instruments would limit their repeat coverage of a given spot -- in the absence of off-nadir pointing -- to nominally 16 to 18 days. On the assumption of 50 percent average cloud cover, the MLA would provide only monthly coverage of a given spot. The MLA would require a morning orbit, and the GEOSAR would share space on that platform to permit correlative observations with the MLA. Off-nadir pointing would be a likely capability to be included in the MLA to permit more frequent revisits of chosen areas. Again, the high data rate associated with the instrument, and the relatively slowly changing phenomena it would observe, lead to the conclusion that only one GEOSAR is needed in orbit at a given time.

The high spatial resolution measurements of the MLA system, which have only a coarse temporal resolution, will be complemented by land data derived from the medium resolution, but high temporal resolution, meteorological imager and radiometer that will evolve from the current AVHRR.

D. Other Payloads

Two of the auxiliary payloads -- the ARGOS data collection and platform location system and the SARSAT system -- require timely revisits to all parts of the earth, and therefore would be carried on both polar platforms. The third auxiliary instrument, the Space Environment Monitor (SEM), would also be carried on both platforms.

From the discussion of past missions and their instruments and this rudimentary review of observational requirements it is possible to prepare quite easily a strawman payload for a two polar platform system. A more complete listing of mission payloads is given in Appendix A, where Table A-1 lists the instruments that have flown in the past, are on present satellites, or are planned for future satellites. The table is accompanied by an acronym list.

VIII. POTENTIAL POLAR PLATFORM INSTRUMENT COMPLEMENT

At this point it is appropriate to consider in more detail the operational instrument complement that will have reached an adequate state-of-development for inclusion on the polar platform. Adequate state-of-development is defined by three criteria: (1) completion of development work on the space hardware, (2) completion, where necessary, of flight testing on the space hardware, and (3) readiness of the applications community to employ the data on a regular basis. It is assumed -- rather arbitrarily -- that the manned segment of the space station will fly first in 1992 and be followed by the polar platform shortly later, perhaps in 1994 --although that is later than current NASA planning dates. This implies that manufacture of the instruments would start in 1990, and that flight readiness would have been adequately established by that date. For some instruments, that date could be expedited considerably. Indeed, most could be begun during the next budget cycle, FY 1986.

The sensor payload will be categorized first by discipline (atmosphere and meteorology, oceans and ice, and land), while within each discipline the following instrument categories will be employed:

- o radiometers and imagers (visible, infrared, and microwave);
- o sounders (infrared and microwave); and

- active sensors (altimeters, scatterometers, and SAR).

The auxiliary instruments (space environment monitor, data collection and platform location systems, and search and rescue transponders and processors) will be included, as noted in the preceding section, on both platforms.

A. Atmosphere and Meteorology

The objective of the sensors in this discipline category is to continue the measurements being carried out currently by the ATN spacecraft with reasonable capability enhancements. Revolutionary increases in instrument capability are not forecast, but revolutionary utilization of data is.

1. Radiometers and imagers - There is no doubt that there will be a continuing requirement for a Medium Resolution Imaging Radiometer (MRIR) operating in the visible and infrared. The instrument will be a successor to the AVHRR flown on the NOAA-K through -M series of polar orbiters. Normal progress in the user community will lead to improving the spatial resolution from the current value of 1 kilometer to a smaller value of nominally 500 meters. The applications of this sensor quickly point out the basis for the cautionary note given above about the dangers in using discipline categories, because they span all of the three categories used here. The applications include:

- weather forecasting (particularly in remote areas and the developing world);
- precipitation estimation;
- global radiation balance studies;
- ice, snow, and frost mapping;
- sea surface temperature and ocean current mapping (in the absence of clouds);
- monitoring of hydrologic events;
- vegetation assessments; and
- continuation of the worldwide provision of Direct Sounder Broadcast (DSB), Automatic Picture Transmission (APT), and High Resolution Picture Transmission (HRPT) services.

The principal characteristics of the measurements provided by this sensor are daily global coverage, precise radiometric calibration, and multispectral coverage extending from the visible to the far infrared. The six-band AVHRR system with up to 10-bit quantization per band for the NOAA-K to -M series will be expanded to as many as 10 bands for the polar platform. The sensor would be placed on both the morning and afternoon polar platforms. For conceptual design purposes, the parameters given for the AVHRR in Table 2 can be employed to assist in scoping the payload requirements for a platform.

In the climate-related area, there are two instruments: (1) a global ozone measuring device and (2) an earth radiation budget radiometer. The Solar Backscatter Ultraviolet (SBUV) instrument was flown on Nimbus-7, and will also be flown on the ATN series into the early 1990's. The device provides data from which global maps of ozone concentration can be made. From these maps, long-term ozone trends can be estimated. It measures backscattered solar radiation in an 11.3 degree field-of-view in the nadir direction in 12 discrete, 1.1 nanometer wide, bands that are between 252 and 339.8 nanometers. The instrument proposed for the polar platform would be a follow-on instrument to the SBUV. Canada has expressed an interest in providing this device. For planning purposes, the general characteristics of the SBUV given in Tables 1 and 4 can be used. It will be referred to below as a Global Ozone Monitoring Radiometer (GOMR). Similarly, the Earth Radiation Budget Experiment (ERBE) can be used as the model for the second instrument. These two instruments require a high sun angle and would not, therefore, be flown on an orbit with an early morning crossing time.

2. Sounders - The sounding system on the present series of NOAA polar orbiters (NOAA-E through J) consists of the MSU and SSU sensors mentioned above and the High Resolution Infrared Radiation Sounder (HIRS). This complement is called the Tiros Operational Vertical Sounder (TOVS). As noted above, the NOAA-K through -M satellites will have the MSU and SSU sensors replaced by the AMSU. The new vertical sounder system will provide: (1) better definition and resolution of the temperature sounding below cloud cover, (2) the capability to identify and quantify precipitation, (3) improved atmospheric water vapor measurements, and (4) an indication of soil moisture and snow thickness. The HIRS sensor will continue as an adjunct to the AMSU because it provides improved temperature soundings in the lower troposphere in clear air, it is used for long-wave earth radiation balance measurements, and is also used to cross-calibrate the AMSU measurements.

The overall purpose of the new sounder system is to contribute twice-daily measurements to the numerical forecast models. These models will require in the 1990's a measurement spacing between soundings of 10 to 50 km for regional models, 150 km for global models, and 250 km for global climate studies. These resolutions are accommodated by the AMSU/HIRS combination. The parameters of that combination, given in Table 2, can be used for initial planning purposes for a polar platform. The sounder system will be designated the Advanced TOVS, or simply the ATOVS.

3. Active Sensors - In the time frame of the initial deployment of a polar platform, it is not anticipated that active sensors will be available for atmospheric measurements. The active sensors flown for oceanographic purposes will provide surface wind speed and direction. One candidate for later flight would be a coherent infrared laser radar system -- usually called "Windsat" -- that is intended to measure the global tropospheric wind field with a horizontal resolution of 1 km.[12]

B. Oceans and Ice

The objective of the sensors in this discipline category is to produce a timely, globally-synoptic view of the world's oceans, and to provide mesoscale analyses of areas of special importance, e.g., the Extended Economic Zone. They will continue the measurements carried out in the latter half of the 1980's by such spacecraft as N-ROSS, TOPEX, Geosat, ERS-1, RADARSAT, JERS-1, MOS-1, etc.

The particular benefits and improvements in ocean activities that will result from this suite of instruments will include, as outlined by Hussey:[13]

- o Improvement of sea surface temperature and water mass analyses that will aid in the location of productive fishing areas.
- o Improvement in location of thermal currents and eddies which will aid in the routing of ships and forecasting the movement of oil spills.
- o Improvement in ocean wave analyses and forecasts which will assist in vessel routing and provide better information for offshore oil and gas platform operations and construction projects.
- o Improvement in sea ice boundary analyses which will aid fishing operations near the ice edge.
- o Improvement in sea ice concentration analyses and forecasts which will improve polar ship routing and the utilization of ice breaker capabilities.
- o Improvement in water mass definition; routine measurements of chlorophyll will aid in the tracing of ocean mesoscale and circulation features.
- o Improvement of fishery management capabilities through near real-time measurements of chlorophyll and sea surface temperature.

- Improvement of numerical weather forecasting; all-weather sea surface winds and temperatures will improve the definition of the baseline conditions from which numerical forecasts are made.

- The instrument suite will provide improved inputs to the National and World Climate Research Programs through global scale ocean measurements.

- Improvement in the forecasting of severe storms -- through the measurements of surface winds and temperatures underneath the extensive cover of storms at sea.

The next few paragraphs will discuss the specific instruments and their characteristics. The sounder category is included because no special sounding instruments, beyond those discussed in the preceding discipline category, are required for ocean and ice measurements.

1. Radiometers and Imagers - Three instruments are included in this category: (1) an Advanced Microwave Radiometer (AMR), (2) an SSM/I, and (3) the OCI.

The AMR will be derived from the LFMR of the N-ROSS mission and the earlier planning for the Large Antenna Multichannel Microwave Radiometer (LAMMR) of the proposed NOSS program.[13] The LAMMR will have seven frequencies (4.3, 5.1, 6.6, 10.65, 18.7, 21.3, and 36.5 GHz) and operate at both polarizations to produce 14 measurement channels. The 4-meter diameter offset parabolic antenna will rotate at 60 rpm, with a receiving field-of-view offset 43.6 degrees from nadir. It will produce sea surface temperature measurements with a 25 km spatial resolution and a 1.5 K temperature resolution over a 1350 km swath width. Wind speed will be determined over a range 0 to 50 m/s, with an accuracy of 2 m/s or 10 percent, whichever is greater at 17 km resolution. Sea ice concentration will be measured to within +15 percent at 9 km resolution and classified as new, first-year, or multiyear ice. The thickness will be estimated to within 2 um. Atmospheric water vapor will be measured to within 0.2 gram/cm^2 at 9 km resolution.

The LAMMR requires adequate space for the 4-meter diameter antenna and protection from radio frequency interference. It also is rather heavy in comparison to most of the other instruments mentioned in this paper -- 350 kg. It will require 150 to 200 W of power. The nominal data rate for the sensor is 100 kbps.[13]

It may be desirable to complement the precise all-weather sea surface temperature measurements of the LAMMR with the potentially very precise measurements of the Along-Track Scanning Radiometer (ATSR) that will be flown on ESA's ERS-1. This instrument uses an innovative scanning approach to derive an improved atmospheric correction and offers the possibility of providing accuracies near 0.3 K.[8]

The SSM/I is the same instrument previously mentioned above. Because its characteristics have already been provided, no further discussion will be given here.

The OCI will be an improved version to that previously flown on the Nimbus-7 satellite. Proposals are currently being examined to fly the sensor on either the French SPOT-3 satellite or a future NOAA polar orbiter. If either opportunity is pursued, even greater flight experience would precede the deployment of the sensor on the polar platform. The improved CZCS would consist nominally of a 9 spectral-band instrument (8 channels in the visible and near-infrared wavelengths and one channel in the thermal infrared). It would employ a 500 to 800 meter spatial resolution, and all 9 detectors would view the same resolution element simultaneously. Measurements of chlorophyll would be made in the range of 0.05 to 100 mg/m^3 with an accuracy within a factor of two. The diffuse attenuation coefficient, a measurement of sedimentary distributions, will be measured over the range 0.01 to 6 um^{-1} also with an accuracy of a factor of two. The general physical parameters given before for the CZCS can be used for approximate sizing of the instrument and its support demands. A logical question would be whether the OCI bands could be combined with those of the MRIR mentioned in the preceding discipline category. A preliminary assessment suggests that the signal-to-noise requirements differ radically between the two instruments. Further, as a result of its scene lighting requirements, the OCI is adversely affected by sunglint effects to a greater extent than is the MRIR, and may require offset pointing to ameliorate this. For these reasons, the most cost-effective approach appears to be building two tailored instruments rather than one general purpose instrument.

Active Sensors - Three active sensors will be included in the payload: (1) an altimeter, (2) a scatterometer, and (3) the SEASAR. Their characteristics will be outlined below.

The altimeter will be essentially a duplicate of that flown on the N-ROSS mission, which is itself a duplicate of the Geosat altimeter. The altimeter will provide 8-cm accuracy in the altitude measurement, significant wave height to an accuracy of 0.5 meter, and wind speed to 2 m/s. The characteristics of the N-ROSS altimeter given in Table 5 can be used for initial planning purposes. An alternative approach would be to use a TOPEX-quality altimeter, but that can be left to a later decision. The N-ROSS altimeter would meet all operational requirements currently perceived.

Similarly, the scatterometer will continue the measurements made by N-ROSS and use the same basic six-beam design. Again, the characteristics of the N-ROSS scatterometer, or NSCAT, are given in Table 5.

The SEASAR would build upon the advances in satellite Synthetic Aperture Radar technology gained from missions beginning with Seasat in 1978 and culminating with SIR-D anticipated to fly on the Space Shuttle at the end of this decade. The Seasat SAR and SIR-A (1981) were both single frequency (L-band), horizontally polarized, and had fixed incidence angles when viewing the surface (20 degrees from vertical for Seasat and 50 degrees from vertical for SIR-A). SIR-B, scheduled for launch in 1984, will also operate in L-band and be horizontally polarized, but its incidence angles will be adjustable between 15 and 60 degrees. SIR-C, scheduled for launch in 1987, will be characterized by dual frequency, multiple polarization as well as adjustable incidence angles, and SIR-D will have the additional capability of many frequencies.[14] Other planned satellite missions with SAR capabilities include Europe's ERS-1 (1988) which will operate in C-band and have a fixed incidence angle of 20 degrees from vertical, Canada's RADARSAT (1990) which will also operate in C-band but with adjustable incidence angles ranging from 20 to 45 degrees from vertical, and Japan's JERS-1 (1991) operating in L-band with a fixed 33 degree incidence angle. The SEASAR proposed for the polar platform would allow multiparameter observations similar to SIR-D using combinations of frequencies, polarizations, and incidence angles that work best for ocean monitoring. Possible applications include observations of surface winds, wave structure, upwelling, currents, fronts, bottom morphology, oil slicks, entrained materials, and coastal refraction.[15]

Land - The sensors in this discipline category will continue the comparatively high-resolution measurements carried out by the Landsat series, the Shuttle-borne SIR series, and the instruments that will result from the current activities to create a private entity in civil land remote sensing from space. In the following, two sensors will be discussed: (1) an MLA-based high resolution multispectral imager and (2) the GEOSAR.

Under one proposal, the MLA would have 10 meter spatial resolution, 20 nanometer spectral resolution, on-orbit spectral band selection (8 of 32), in-track stereo to provide two aspect data for terrain relief information, and cross-track viewing for rapid revisitation of scenes.[16] Also, desirable would be a wavelength range of 0.45 - 12.5 um, 0.1 pixel band-to-band registration and a swath width of 185 kilometers.[17] The MLA would be used for agriculture, forestry, range resources, land use and mapping, geology (rock types, soils, volcanic deposits, and landforms), water resources monitoring and environmental monitoring (surface mining, reclamation, pollution, and natural disasters).

The GEOSAR would be the same instrument as the SEASAR (see discussion above) but would operate with combinations of frequencies, polarization, and incidence angles that are optimum for land remote sensing. The GEOSAR would complement the MLA and be used in cartography, forest monitoring, structural and lithologic mapping, and to study water surfaces, soil moisture, glaciers, crops, and rangelands.

IX. THE ISSUE OF ORBITS AND THE NUMBER OF PLATFORMS

In the above discussion there are a number of implicit and explicit assumptions made about the desirable orbits for the polar platforms. First, global synoptic coverage -- whether of the atmosphere or ocean -- requires frequent revisits to all points on the globe. Current practice is to have a morning and afternoon satellite. The NOAA polar-orbiting environmental satellites currently are in an 800 km, sun-synchronous orbit. One satellite, under plans that will be implemented later in the 1980's, will cross the equator northbound at 1:30 in the afternoon. The second satellite crosses the equator southbound at 7:30 in the morning. These orbits provide the desired lighting conditions and data that are timely to the numerical weather forecasting models.

In any consideration of combining payloads, the obvious issue is the compatibility of the orbital requirements. The afternoon orbit is relatively inflexible -- insofar as moving it farther away from noon. At a 1:00 P.M. crossing time, it is well suited to the meteorological and oceanographic missions, because both perform synoptic analyses, and also meets the high solar elevation angle requirement for the OCI, GOMR, and ERBE. Further, the high solar angle also aids in some agricultural assessments. In the following discussion, it will be assumed that the high-resolution land measurements will be carried out using an early-morning equator crossing time, but this is an issue that will need to be revisited at some point. Some in the community would argue that an MLA-like instrument should be carried on both platforms.

The early morning civil meteorological and oceanographic measurements are somewhat more flexible in the choice of an equator crossing time, and the needs of the land sensors can be given greater weight. In this instance, the Landsats have successfully operated from approximately 8:30 A.M. to 9:30 A.M., while the French SPOT system is planning a 10:30 A.M. equator crossing time. Some in the geological and mapping community would prefer earlier times,[18] while others in the agricultural community would prefer later. No attempt will be made here to make a decision on a particular time; it only needs to be noted that compromises to reach a common morning time do not appear impossible.

Thus, reducing the number of equator crossing times to two does not appear to be implausible. Likewise, employing sun-synchronous orbits appears reasonable as well. There are measurements that can benefit from nonsun-synchronous orbits, but they do not provide convenient orbital parameters for aggregating sensors for other purposes and are likely to remain in the domain of specialized satellites and instruments. A more serious issue is that of altitude. More will be said of this in Section XIII below from the perspective of repair and servicing. From the perspective of the sensors, however, it seems clear that minimally satisfactory orbits begin at 700 km and become increasingly more favorable up to about 1000 km or somewhat beyond.

Attainable instrument swath width and the need for most of the sensors to provide global repeat coverage both militate toward an altitude well above the maximum range of the Space Shuttle and -- very importantly indeed -- well above some of the conceptual plans for other elements of the Space Station program. Appendix B provides a summary of past, present, and planned remote sensing satellite orbital parameters. For purposes of the discussions in this paper, it will be assumed that the required altitude is in the range of 800 to 1000 km.

When the above considerations are combined with those of the preceding section, the two-platform configuration described in Table 9 results.

X. RELATIONSHIP TO GLOBAL HABITABILITY, IGBP, AND FUTURE LARGE-SCALE ENVIRONMENTAL PROGRAMS

There have been a number of recent proposals addressing the use of space systems to obtain a complete global view of the Earth, and to examine the Earth from the viewpoint of a coupled, interactive system. One of these is NASA's Global Habitability program.[19] A second is the International Geosphere-Biosphere Program.[20] In both instances, a major, multidisciplinary spaceborne remote sensing system is required. Further, a number of major environmental research studies will continue to evolve requiring similar remote sensing capabilities, such as the World Ocean Circulation Experiment (WOCE). A recent study by the Joint Oceanographic Institutions outlines a decade-long research strategy for the period 1985-1995,[21] and is certain to be followed by even more intensive research programs in the Space Station era -- beyond 1995. When the requirements of these programs are aligned with the remote sensing capabilities of the two-platform system described in the preceding two sections (with the expectation that research payloads could also be accommodated on the platforms as well), essentially all the needs of these programs can be met. In many instances, indeed, an instrument will be meeting simultaneously both the needs of an operational community, e.g., the civil maritime industry, and the research community. The raw or preprocessed data needed are in many instances the same; it is the subsequent processing and utilization that distinguishes among the various communities of users.

XI. DATA PROCESSING AND TRANSMISSION SYSTEM IMPLICATIONS

Earth observations systems have been plagued by shortsighted approaches to data processing and distribution. Any worker in the field of remote sensing can provide his or her set of horror stories Rather than dwell on them here, a few basic principles will be stated that seem necessary for the Space Station era.

Anyone who asserts that it is good fiscal policy to ensure that the ground data processing system for a multihundred million dollar system be only capable of meeting the minimum research needs -- and that all redundancy and reasonable margin in terms of throughput

TABLE-9

ORBITAL CHARACTERISTICS OF A TWO POLAR-PLATFORM

EARTH OBSERVATIONS SYSTEM**

Discipline Category/ Instrument***	Afternoon Platform 1:00 P.M. Local Time Northbound*	Morning Platform 8:30 to 10:30 A.M. Southbound*
Atmos. and Met.		
1. MRIR	X	X
2. GOMR	X	
3. ERBE	X	
ATOVS		
4. - HIRS	X	X
5. - AMSU	X	X
Oceans and Ice		
6. AMR	X	X
7. SSM/I	X	X
8. OCI	X	
9. ATSR	X	X
10. Altimeter	X	X
11. NSCAT	X	X
12. SEASAR	X	
Land		
13. MLA		X
14. GEOSAR		X
Other		
15. ARGOS	X	X
16. Search & Rescue	X	X
17. SEM	X	X

* Instrument Totals (AM platform) - 1765.3 watts, 795.5 kg, 273.113 mbs (includes 270 mbs for MLA and GEOSAR)

(PM platform) - 1458.7 watts, 864.6 kg, 123.914 mbs (includes 120 mbs for the SEASAR)

** The orbital altitude is assumed to be 800 to 1000 km

*** An acronym list is found in Appendix A capacity be carefully expunged from the system -- has missed one of the great lessons of the first twenty-five years of space activity. Whether the system is called experimental or operational, the ground data processing system must be capable of reliably and efficiently passing the data through to the user. There is no advantage to be gained through backlogs of data. In research missions, sensors age with time and require attention. Researchers need to test their plans as early in a mission as possible against the often unpleasant reality of actual data. Data that accumulates -- rather than being immediately used -- often are never used, or carry flaws that go undetected for so long that the information content of the data is not recoverable. In operational systems, where data are used to govern actions, they must be timely. One need only consider what a difference it would have made if a small percentage of total project cost had been invested in the original Landsat data processing system so that data were processed as they were received. It would have been possible to observe an event, analyze it, and react to it in a timely manner -- rather than restricting all analysis to months and years-old data. There is no doubt that the perception of the utility of the Landsat data would be quite different today had that been done.

There is another issue associated with data processing that arises in the context of the large international environmental experiments mentioned above. These experiments will generate truly huge and unwieldy data sets. Extracting the value from these data sets is going to involve the work of researchers in the academic community throughout the world. Few of those researchers are going to be able to support the storage and manipulation of these data. Further, the data sets resulting from the spaceborne instrumentation systems are not going to be self-sufficient either. They will require access to other large data bases of historical and correlative information. The effect of all of these considerations is that a careful systems engineering task must be carried out on the data processing, archival, archival access, and distribution system that will support the polar orbiters. One approach to addressing some of these problems will be discussed in the next section of this paper on a National Earth Observations Center.

Related to, but somewhat distinct, from the above is the issue of direct transmission services from a polar platform. Many of the instruments discussed above provide data that are highly perishable. These data cannot be funneled from the satellite back through a central processing facility in the United States and then distributed in a sufficiently timely manner--and over very expensive international communication links--to the numerous and varied classes of users. For this reason, a wide variety of direct downlink and recording capabilities must be provided. MRIR data in both APT and HRPT formats will be continuously broadcast. Oceanographic data will also be broadcast to ships at sea, particularly the OCI data in a format analogous to HRPT data. In addition, the present Direct Sounder Broadcast (DSB) transmission will also continue. These functions relate to the overall data network because, in addition to providing distribution of information to remote locations, they also require on-board data processing which will be a major issue in a polar platform system. The use of on-board processing will be aided by the use of a Global Positioning System (GPS) receiver and processer on each platform.

To provide some measure of the present international reliance on these services, it is appropriate to review the number of HRPT, APT, and DSB stations in operation. There are presently 85 HRPT stations, of which 52 are owned and operated by foreign governments. There are more than 900 APT stations in over 122 countries, with most owned and operated by foreign entities. Similarly, there are seven DSB stations in five foreign countries. In all three categories, more stations are being developed in many different countries.

In addition to the direct transmission of recorded and real-time data from the sensors, it is assumed that there will be in 1995 either an operational Tracking and Data Relay Satellite System (TDRSS) or an augmented ground tracking network to collect the global data set discussed above.

XII. A NATIONAL EARTH OBSERVATIONS CENTER

One of the characteristics that is inherent in a space platform is an aggregation of functions and sensors. A second is a high rate flow of data through a common channel or set of channels--even after the direct transmission functions mentioned above are considered. This might occur, for example, through a data relay satellite. A third characteristic is the need to process speedily the operational data, with a frequent ground rule that all data will be processed and delivered to the users within less than six hours of acquisition. A fourth characteristic will be the requirement to process, analyze, correlate, archive, and otherwise manipulate very large sets of environmental data. A final characteristic will be the need to provide access to these data by a global set of operational and research users.

All of this militates quite strongly toward the need for a very large and extraordinarily powerful central data processing facility--even when every opportunity for distributed processing by the user communities has been fully exploited. The system must be capable of rapidly processing the data from the platform, probably to the level of geophysical units or what is commonly called "Level II" data. Level II processing produces Geophysical Data Records with the data expressed in geophysical units at the full resolution of the particular satellite sensing instrument. Instrument transfer function and environmental effects are removed in the processing, and the data are time ordered, time tagged, and earth located (latitude and longitude).

The facility must also produce and distribute indices of available data sets (including some measure of the quality of the sets) and synoptic analyses that the user community can use in selecting what part of the massive quantity of data may contain the needed information. In many respects, the facility will be analogous to the National Weather Service in that a time-critical data flow must be carefully managed, with forecast and other guidance being widely distributed, and a set of synoptic charts being developed that provide first-order guidance for research or operations. The data upon which those charts are based are available for more intensive review, or for use by those who might find it necessary to verify or challenge the synoptic analysis. This analogy was first pointed out to one of the authors by Francis Bretherton during the course of an Earth System Sciences Committee meeting. The analogy is particularly pertinent because it sets a different tone to the type of data system that is required. To meet these needs, the system must be highly reliable -- with a corresponding high degree of redundancy --and sized to "pipeline" process the flow of data from the two platforms. A zero backlog rule should be imposed on the design.

In some respects, the facility will be similar to the Space Telescope Science Institute and the companion satellite control facility conceived of several years ago by NASA and its scientific advisors. In addition to being a terminus for the flow of data from the platforms, the facility must be continuously challenged and scrutinized by the community at large. One of the most effective ways to ensure a vigorous interaction would be to surround it with facilities for visiting scientists to come for brief or extended periods to carry out research projects with the data stream that is passing through the center. This would be complemented by relationships with distant academic, research, and industrial institutions which would connect in to the center via telecommunications. By the very nature of the payload that has been outlined in the preceding sections, the facility would be multidisciplinary and derive support from a number of agencies. In addition to the Federal operational agencies and the research community, the private sector would find it the most convenient point of access for the data that they could use in the development of value-added products.

It appears entirely plausible that a joint facility, called here a National Earth Observations Center, could be created that would serve the communities that will be reliant upon a two polar platform system. NASA and NSF could provide the support for the Center on behalf of the research community. NOAA would find this the logical home for its operational atmospheric and oceanic processing system. USGS could represent the interests of the geological community. While it is assumed that the facility would be a largely open civilian activity, it is expected that DOD would find it sufficiently useful to warrant support as well.

XIII. REPAIR AND SERVICING ISSUES

In discussing the ground data processing issues above, a strong emphasis was placed on reliability, redundancy, ease of access, and throughput capacity. Similar issues apply to the polar platform itself and the associated considerations related to servicing philosphy. The analogous parameters for the polar platform would be reliability, redundancy, ease of access, cost of access, frequency of access, and flexibility. This section will be devoted to those issues.

In the preceding sections of this paper, it would be accurate if a reader perceived that the authors are exceedingly enthusiastic and optimistic about the future of all types of remote sensing from space (atmosphere, ocean, and land). It would also be accurate for a reader to perceive that the authors see a potential for the polar platform to serve the needs of the remote sensing community. It is important to draw a careful distinction between these two statements. The authors find no ambiguity whatsoever in the value of earth observations, whether carried out by free-flying satellites or by using an astronaut-serviceable space platform. On the other hand, there is at most _potential value_ to the space platform. The degree of value will pivot around the economics and ease of servicing.

In the next few paragraphs, the characteristics needed in a polar platform will be reviewed, and the issues associated with servicing examined. On the assumption that a polar platform is a permanent facility that must outlive many generations of instruments, the first requirement is flexibility. Either through provision of excess capacity at the outset or the use of any of a number of modular construction techniques, the platform must have the capability to change and evolve. This flexibility must be designed into the system from the very start of the program and carried through with great care. It is not sufficient to provide simply a large unoccupied volume, or an inflexible thermal/mechanical/data interface connection, and leave it up to the user to make do. Further, a claim of flexibility of accommodation must be supported by demonstrated reasonableness of modification costs, when the inevitable changes must be made. If the system is built in such a manner that modifications necessitate major modifications and requalification of man-rated systems, there is little possibility of cost effectiveness.

It also does not appear self-evident to the authors that equipment developed for other purposes and satisfying other interface constraints is going to meld a priori into an effective polar platform. It is conceivable that flexibility and, as will be discussed next, reliability may lead to a platform configuration that is a constellation of smaller elements rather than a single large structure resembling the framework of a steel-reinforced building. If the satellite cluster approach were used, the segments would co-orbit in adequately close proximity to one another so that they would appear as a single point source to ground radio telemetry stations, and so that a single servicing mission could readily visit all segments. Interconnections among the segments could be made through microwave, optical, or cable links. These considerations cause the authors to approach with some caution the NASA plan to use elements from the inhabited station to construct the polar platform.

A second required platform characteristic is a high degree of reliability. The polar platforms and associated payloads will represent a significant portion of the civil space program activities. They are also a part that provides "payoff" rather than simply infrastructure. This large and very important investment must be protected from all plausible failures that would endanger that investment. Further, if the payload described in this paper were accepted, millions--even billions--of people would be relying upon the information being collected by the system. The data would be used in many life-threatening situations, so the platform cannot simply go out of service for a long period of time to await the repairperson or robot--as the Solar Maximum Satellite was able to do.

Reliability also implies redundancy, and redundancy requirements can be related to the time between servicing missions. The The time between servicing missions to a polar platform is a function of Shuttle capabilities from the West Coast and of the cost of using those capabilities. If the servicing missions are on a basically fixed schedule -- barring a major catastrophe on the platform -- the instrument complement must provide reliable service over a somewhat longer period to protect service continuity. If that period is similar to or even longer than current replacement launches, the loss of a "repair on-demand" or a "call-up repair/replacement" capability lessens slightly the attractiveness of a platform. If repair/ replacement schedules are long and inflexible, and the cost of a servicing mission is high in comparison to the sum of the satellite replacement and launch costs, then nearly all of the attractiveness of a platform vanishes. It is the potential to make the converse of that statement true that motivates the discussion in this paper. In order to begin to bound the economic considerations, it is necessary to examine current practice briefly. This will be the subject of the next several paragraphs.

The costs and complexity of satellites are increasing rapidly. Weather satellites have grown in cost from $25 million per satellite (excluding launch costs) to several times that cost in the 1990's. Table 10 gives a comparison in costs between instruments on two generations of environmental satellites, the Advanced TIROS-N (NOAA E-J) and the Advanced TIROS-N (NOAA K-M). It can be seen that in most cases the cost of sensors from one generation to the next has at least doubled. Further, launch costs are escalating rapidly. For the same satellites mentioned above, launch costs have climbed from $7 million per satellite to $30 million for the last of the Atlas series that will be used late in this decade. Costs for dedicated polar launches in the 1990's are indeterminably higher than

TABLE-10

PAYLOAD/COST SUMMARY

Advanced TIROS-N (ATN) - NOAA E-J

Instrument	Cost (1) ($M)	Design Lifetime
AVHRR/2	$1,343K	2 yrs.
HIRS/2I	$1,916K	2 yrs.
MSU	$1,912K	2 yrs.
SEM	$ 470K	2 yrs.
SBUV/2	$2,792K	2 yrs

NOAA-K-M - Projection (Costs are Estimates)

Instrument	Cost (2) ($M)	Design Lifetime
AVHRR/3	$2,483K	2 yrs.
HIRS/2I	$2,667K	2 yrs.
AMSU-A	$9,717K	2 yrs.
SEM	$2,100K	2 yrs.
SBUV/2	$5,600K	2 yrs.

(1) Operational follow-on instruments. Does not include NASA, first unit development costs.

(2) Estimate based on cost of previous instruments, expected inflation and expected improvements (example adding a 1.6 micrometer channel to the AVHRR).

$30 million, but the most optimistic expect a very large increase of at least 100 percent. The pessimistic deal in numbers more suited to astronomical dimensions than support costs for operational earth observation systems. Obviously, these numbers dramatically affect the economic analyses alluded to above.

While the geostationary satellite users have obtained some benefit from the past decade's development activities in launch vehicles and upper stages, the users of polar-orbiting satellites have seen little but reductions in capabilities, uncertainties about future launch vehicle availability, scant information about the ability to schedule launches when they are needed, and totally unpredictable--but rapidly escalating--costs. The predicted improvements that were much heralded in the early 1970's are notably absent in the middle 1980's. The remote sensing user community will therefore be looking for rigorous analyses of platform benefits, but will also be looking with some understandable skepticism about the underlying assumptions and the sensitivity of the analyses to changes in those assumptions. The uncertainties that users face in presently planning for the deployment of systems in polar orbit obviously relate directly to the cost and schedule for servicing a polar platform as well. Why one would persist in looking for new approaches to polar orbit operations, in spite of these uncertainties, is the subject of the next few paragraphs.

Because of the increasing costs of space systems, it seems less and less reasonable to discard adequately functioning subsystems and instruments just because other subsystems or instruments have failed, which is exactly what is currently done when an earth observations satellite is replaced. The current practice is dictated by a ranking of observational needs (with a breakpoint mandating replacement of the satellite) overlayed on the highly variable and differing lifetimes of the numerous instruments and subsystems that make up an earth observations satellite. Some 70 percent of the systems on polar-orbiting weather satellites are still serviceable when the satellites are decommissioned. The current expected life of a satellite is only 2 to 3 years.

Appendix C gives the history of the polar-orbiting environmental satellites back to 1960. A short recapitulation of recent satellite history serves to emphasize the vulnerability of these satellites to a single system failure. ITOS-1 and NOAA-1 were both retired when their momentum wheels failed. NOAA-2 was decommissioned due to the failure of two sensors. NOAA-3 through 5 were terminated by the failure of their recorders. TIROS-N failed because of the failure of the inertial measurement unit. NOAA-6 was placed in standby after two instrument failures. NOAA-7 is experiencing difficulties due to open shunts in the power system, and NOAA-8 has been lost because of the failure of the spacecraft master oscillator. In each of these cases, the satellites could have been designed for on-orbit repair and, with a favorable repair and servicing cost, could have been returned to service.

Successful on-orbit servicing involves other issues than simply designing the equipment for convenient repair and developing astronaut techniques for carrying out the task. The first issue is whether the service person -- or possibly robot -- goes to the platform (at the altitude of 800 to 1000 km given above) -- or the platform must return to Shuttle altitude for servicing. The former seems more reasonable from both the perspective of the burden on the platform and the need to remove it from service during any altitude change, but does require that either an astronaut or a robot journey 400 to 500 km above the Shuttle to carry out the servicing. This is a major technical challenge, which if accepted would have enormous and very positive ramifications for the exploitation of space.

From the discussions in this paper up to this point, it should be discerned that a large-capacity polar platform can create a phenomenal and revolutionary sensing capability, but so can large satellites. Further, there does seem to be a legitimate rationale for servicing satellites on-orbit, but if, and only if, the cost of carrying out that servicing is contained within calculable bounds. Aggregation of functions on a large platform (whether in a monolithic or cluster configuration) would seem to contribute to the cost-effectiveness of a servicing mission by allowing the sharing of costs among the instrument and platform providers. The potential for cost-effectiveness and increased capabilities is intriguing enough to warrant the most serious attention.

XIV. OPPORTUNITIES FOR COMMERCIAL ENTITIES

Nothing in the preceding should be construed to indicate that the polar platform and its payloads are the exclusive domain of the Government. There are obviously four major roles for the private sector, two certain and two potential: (1) a certain role is that of the system developer and operator (no significant space equipment manufacturing is done in house at present, and most operations control centers are run by contractors to the Government); (2) a second role that is certain is participation as a major data user and provider of value-added services (this is largely in the private sector today, and will be even more so in the 1990's); (3) a potential role is that of platform provider (Fairchild has proposed a Leasecraft system that could be a predecessor to a commercial platform operation); and (4) a further potential role is that of platform passenger on either a governmental or commercial platform (the economic analyses mentioned above apply equally well to a governmental or a commercial user of the platform; if the polar platform is the most cost-effective way to conduct business, then private firms will prefer to pay "condominium" fees to the platform operator rather that buying their own dedicated satellites).

Thus, there is no reason to characterize the polar platform as exclusively a governmental operation. With proper consideration for the users that can be served, and a successful system development -- from the perspective of user "friendliness" and cost-effectiveness --

the platform can be a major step in the utilization of space systems for all sectors of the economy, both public and private, both domestic and international. The latter will be discussed in the next section.

XV. OPPORTUNITIES FOR INTERNATIONAL COOPERATION

The propositions discussed in this paper are indeed ambitious. They are ambitious from the perspective of the deployment of the complex sensing system, the timely processing and distribution of the data that will result, and the demands they place upon the Space Station program. They may be beyond the capabilities and resources of any single nation. Because the polar platforms and their payload described in this paper are meant to provide a total view of the earth's oceans, land masses, and atmosphere, international cooperation is a natural and desirable avenue for sharing benefits and costs. Precedents for joint programs exist, and have been mentioned at a number of points above. The example of the Advanced Tiros-N is certainly germane. A further example is the activity being intiated under the annual Economic Summit.

At the conclusion of the Seventh Meeting of the Economic Summit of Industrialized Nations, held in June 1982 at Versailles, the Heads of State established a Working Group on Technology, Growth and Employment to identify areas for further cooperation among the Summit Members (Canada, Federal Republic of Germany, France, Italy, Japan, United Kingdom, United States, and the European Communities). Satellite remote sensing was one of 18 topics chosen for discussion, and the United States was selected as chair, with NOAA designated to be the U.S. expert point-of-contact.

The objectives of this panel are to exchange information on remote sensing programs and plans, to coordinate remote sensing programs and plans with a view to avoiding duplication of efforts, fostering compatibility of activities to enhance the value of these programs in addressing global phenomena, and promoting more efficient uses of budget resources. All of these are consistent with international participation in an earth observations system based on the polar platform.

In preparation for the 1983 and 1984 Summit meetings, reports have been completed for each of the 18 topics for consideration by the Heads of State. Within remote sensing, participants have discussed potential collaboration in support of polar-orbiting meteorological satellites and a number of other subjects. Two working groups have been formed for coordination of activities. They are the International Earth Observation Satellite Committee (IEOSC) and the International Polar-Orbiting Meteorological Satellite (IPOMS) group.

The IEOSC was established through the discussions in the Summit Panel of Experts on Remote Sensing from Space. In an effort to streamline coordination activities, the Summit experts agreed to establish a single group to replace the former Coordination of Land

Observing Satellites (CLOS), Coordination of Ocean Remote Sensing Satellites (CORSS), and the multilateral meetings on long-term planning for remote sensing satellites. IEOSC will provide a forum for the informal coordination of technical parameters of environmental, land, and ocean satellites. This broad mandate is appropriate since many remote sensing satellites can no longer be identified with only a single discipline. IEOSC membership is open to any country/agency with an approved remote sensing satellite program. The first meeting will be held in September 1984. Participants are expected to include Canada, the European Space Agency, France, India, Japan, and the United States. The IEOSC is a forum that could be used to discuss international participation in an earth-observing polar platform.

The 1984 Summit endorsed the creation of IPOMS to explore mechanisms for increased international cooperation in and support for polar-orbiting meteorological satellites, and to ensure the continuity of these satellites. Therefore, the IPOMS is intended to be more highly focused than IEOSC. Members of the group are agencies currently contributing to or planning to contribute to the U.S. civil operational polar-orbiting meteorological satellite system. Contributions can be either direct funding or (more likely) in-kind support. In reviewing possibilities for increased cooperation, the new group will consider the possible use of a polar platform as a carrier for meteorological instruments. NOAA chairs this group. Canada, Federal Republic of Germany, France, Italy, Japan, United Kingdom, and the European Space Agency are being invited to participate. Australia and Norway are considering membership as well. The first meeting will be in November 1984.

The above suggests there is good reason for optimism in seeking international cooperation in a polar platform intended for use in earth observations. Precedents have been established involving the contribution of hardware to operational weather satellites by a number of foreign countries. International coordinating bodies are in place that can serve as fora to advance these ideas further. International specialists in remote sensing and their parent agencies are prepared to discuss these issues in depth. Most importantly, the skills and projects are in place internationally that will make the polar platform a next logical step in remote sensing and the international community is both qualified and prepared to participate in that step.

XVI. CONCLUSIONS

The cumulative experience of many past, present, and future earth observations systems tha will be available by the early 1990's will make the use of an astronaut-tended polar platform a logical next step. If the platform proves to be an economic alternative to expendable satellites, it can serve as the carrier for a combined land, ocean, and atmospheric observation system of unparalleled capability. The need for frequently updated global synoptic models will militate toward the use of two platforms, both at an altitude of 800 to 1000 km, one using a morning southbound and the other using an afternoon northbound equator crossing time. The international community is prepared and can make a positive contribution to the deployment of the system. None of this can occur, however, without the vigorous support of NASA's Space Station program. NASA must accept some very hard technological challenges to make such a system feasible, and be prepared to regard needs of the remote sensing user community and the information they wish to gain with the same care that will be quite automatically devoted to caring for the Station's inhabitants and the creation of a permanent presence in space.

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APPENDIX A

Listing of Sensors

and Acronym List

TABLE A-1

SATELLITE SENSORS

SATELLITE	LAUNCH DATE	VIS/IR RADIOMETER	PASSIVE MICROWAVE RADIOMETER	ATMOSPHERIC SOUNDER	RADAR SCATTEROMETER	RADAR ALTIMETER	SYNTHETIC APERTURE RADAR	OCEAN COLOR RADIOMETER
ITOS	1972	VHRR, SR	0	VTPR	0	0	0	0
ERTS-A	1972	MSS, RBV	0	0	0	0	0	0
DMSP	1973	SAP	0	SEE	0	0	0	0
GEOS-3	1975	0	0	0	0	RAS	0	0
NIMBUS-6	1975	0	ESMR	HIRS, THIR, SCAMS	0	0	0	0
HCMM	1978	SR	0	0	0	0	0	0
NIMBUS-7	1978	0	SMMR	THIR, SAMS	0	0	0	CZCS
SEASAT	1978	VIRR	SMMR	0	SASS	ALT	SAR	0
TIROS-N	1979	AVHRR	MSU	TOVS (HIRS/2, MSU, SSU)	0	0	0	0
LANDSAT 5	1984	MSS, TM	0	0	0	0	0	0
GEOSAT	1985	0	0	0	0	RA	0	0
SPOT	1985	HRV	0	0	0	0	0	0
IRS-1	1985	LISS	0	0	0	0	0	0
DMSP/ATN	1985	OLS	SSM/I	SSM/T	0	0	0	0
MOS-1	1986	MESSR, VTIR	MSR	0	0	0	0	0
ERS-1	1988	ATSR-M	ATSR-M	ATSR-M	AMI	E-Alt	AMI	0
N-ROSS	1989	0	SSM/I, LFMR	0	SCATT	RA	0	0
TOPEX	1989	0	0	0	0	T-Alt	0	0
NOAA-NEXT	1989	AVHRR	AMSU-B	AMSU-A,B/HIRS-2	0	0	0	0
RADARSAT	1990	TBD*	0	0	TBD*	TBD*	SAR	0

* To Be Determined

ACRONYM LIST

ALT - Radar Altimeter
AMI - Active Microwave Instrument
AMR - Advanced Microwave Radiometer (proposed by authors)
AMSU - Advanced Mircowave Sounding Unit
APT - Automatic Picture Transmission
ARGOS - Data Collection System provided by French Center for National Space Studies
ATOVS - Advanced TIROS Operational Vertical Sounder (proposed by authors)
ATSR - Along-Track Scanning Radiometer - Microwave
AVHRR - Advanced Very High Resolution Radiometer
CORSS - Coordination of Ocean Remote Sensing Satellites
CLOS - Coordination of Land Observing Satellites
CZCS - Coastal Zone Color Scanner
DMSP - Defense Meteorological Satellite Program
DSB - Direct Sounder Broadcast
E-Alt - ERS-1 Altimeter
ELV - Expendable Launch Vehicle
ERBE - Earth Radiation Budget Experiment
ERBS - Earth Radiation Budget Satellite
ERS-1 - ESA (European Space Agency) Remote Sensing Satellite
ERTS-A - Earth Resources Technology Satellite
ESMR - Electrically Scanning Microwave Radiometer
ESSA - Environmental Science Services Administration
GEOS - Geodynamics Experimental Ocean Satellite
GEOSAT - Geodetic Satellite
GEOSAR - Geologic Synthetic Aperture Radar (proposed by authors)
GOMR - Global Ozone Monitoring Radiometer (proposed by authors)
GPS - Global Positioning System
HCCM - Heat Capacity Mapping Mission
HIRS - High Resolution Infrared Radiation Sounder
HRPT - High Resolution Picture Transmission
HRV - High Resolution Visible Range Instruments
JERS - Japan Earth Resources Satellite
IEOSC - International Earth Observation Satellite Committee
IGBP - International Geosphere-Biosphere Program
IPOMS - International Polar-Orbiting Meteorological Satellite Group
IRS-1 - Indian Remote Sensing Satellite
ITOS - Improved TIROS Operational Satellite
LAMMR - Large Antenna Multichannel Microwave Radiometer
Landsat - Land Satellite
LFMR - Low Frequency Microwave Radiometer
LISS - Linear Imaging Self Scan Cameras
MESSR - Multispectral Electronic Self Scanning Radiometer
MLA - Multispectral Linear Array
MOS-1 - Marine Observation Satellite
MRIR - Medium Resolution Imaging Radiometer (proposed by authors)
MSR - Microwave Scanning Radiometer
MSS - Multispectral Scanner
MSU - Microwave Sounding Unit
NIMBUS - NIMBUS ("cloud" in Latin)
NOAA - National Oceanic and Atmospheric Administration

NOSS - National Oceanic Satellite System
N-ROSS - Navy Remote Ocean Sensing System
NSCAT - N-ROSS Scatterometer
OCI - Ocean Color Imager
OLS - Operational Linescan System
RA - Radar Altimeter
Radarsat - Radar Satellite
RAS - Radar Altimeter System
RBV - Return Beam Vidicon
SAMS - Stratospheric and Mesospheric Sounder
SAP - Sensor AVE (Aerospace Vehicle Electronics) Package
SAR - Synthetic Aperture Radar
SARSAT - Search and Rescue Satellite
SASS - Seasat-A Scatterometer Sensor
SBUV - Solar Backscatter Ultraviolet Radiometer
SCAMS - Scanning Microwave Spectrometer
SCATT - N-ROSS Scatterometer
SEASAR - Sea Synthetic Aperture Radar (proposed by authors)
Seasat - Sea Satellite
SEE - Special Sensor E
SEM - Space Environment Monitor
SIR - Shuttle Imaging Radar
SMMR - Scanning Multichannel Microwave Radiometer
SPM - Solar Proton Monitor
SPOT - Systeme Probatoire d'Observation de la Terre
SR - Scanning Radiometer
SSM/I - Special Sensor Microwave Imaging
SSM/T - Special Sensor Microwave Temperature Sounder
SSU - Stratospheric Sounding Unit
STS - Space Transportation System
T-Alt - TOPEX Altimeter
TDRS - Tracking and Data Relay Satellite
THIR - Temperature-Humidity Infrared Radiometer
TIROS-N - Television and Infrared Observation Satellite
TM - Thematic Mapper
TOMS - Total Ozone Mapping Spectrometer
TOPEX - Ocean Topography Experiment
TOS - TIROS Operational Satellite
TOVS - TIROS Operational Vertical Sounder, (composed of MSU, SSU, and HIRS/2)
USAF - United States Air Force
VHRR - Very High Resolution Radiometer
VIRR - Visible and Infrared Radiometer
VTIR - Visible and Thermal Infrared Radiometer
VTPR - Vertical Temperature Profile Radiometer
Windsat - Wind Satellite
WOCE - World Ocean Circulation Experiment

APPENDIX B

Summary of Satellite Orbital Characteristics

TABLE B-1

SATELLITE ORBITS

SATELLITE	LAUNCH DATE	ALTITUDE	INCLINATION	TYPE	NODAL PERIOD	EQUATOR CROSSING TIME
ITOS	1972	1451 km	101.7 Degrees	Polar/Sun-Synch	114.9 Minutes	0900 LST
ERTS-A	1972	907	99.9	Polar/Sun-Synch	103.1	0850
DMSP	1973	837	98.8	Polar/Sun-Synch	101.6	0600 and 1200
GEOS-3	1975	843	115.0	General	101.8	N/A
NIMBUS-6	1975	1097	100.0	Polar/Sun-Synch	107.3	1200
HCMM	1978	620	97.8	Polar/Sun-Synch	96.8	1400
NIMBUS-7	1978	946	99.3	Polar/Sun-Synch	104.0	1200
SEASAT	1978	784	108.0	General	100.7	N/A
TIROS-N	1979	854	98.8	Polar/Sun-Synch	102.0	0730 and 1400 (2 satellite system)
LANDSAT 5	1984	706	98.9	Polar/Sun-Synch	98.9	0945
GEOSAT	1985	800	108.0	General	100.7	N/A
SPOT	1985	832	98.7	Polar/Sun-Synch	101.46	1030
IRS-1	1985	904		Polar/Sun-Synch		
DSMP/ATN	1985	837	98.8	Polar/Sun-Synch	101.6	1000
MOS-1	1986	909	99.1	Polar/Sun-Synch	103.2	1000-1100
ERS-1	1988	777	98.5	Polar/Sun-Synch	100.5	1015
N-ROSS	1989	830	98.7	Polar/Sun-Synch	101.0	0715
TOPEX	1989	1334	63.4	General	112.4	N/A
NOAA-NEXT	1989	821	98.8	Polar/Sun-Synch	102.0	0730 and 1300 (2 satellite system)
RADARSAT	1990	1001	99.5	Polar/Sun-Synch	105.2	0944

APPENDIX C

Operational Polar-Orbiting Environmental Satellite History

TABLE C-1

POLAR ENVIRONMENTAL SATELLITE HISTORY

TIROS SERIES (1960-1967)	LIFETIME
TIROS-1	2 months
TIROS-2	3 months
TIROS-3	3 months
TIROS-4	5 months
TIROS-5	12 months
TIROS-6	14 months
TIROS-7	32 months
TIROS-8	43 months
TIROS-9	25 months
TIROS-10	24 months

ESSA SERIES (1966-1973)	LIFETIME
ESSA-1	15 months
ESSA-2	56 months
ESSA-3	24 months
ESSA-4	12 months
ESSA-5	34 months
ESSA-6	24 months
ESSA-7	12 months
ESSA-8	87 months
ESSA-9	57 months

ITOS SERIES (1970-1979)	LIFETIME
ITOS-1	18 months
NOAA-1	8 months
NOAA-2	26 months
NOAA-3	33 months
NOAA-4	48 months
NOAA-5	32 months

TIROS-N SERIES (1979 - Present)	
TIROS-N	28 months
NOAA-6	63 months (1)
NOAA-7	39 months (1)
NOAA-8	15 months

(1) Still in operation.

NOAA TECHNICAL REPORTS

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NESS 92 Satellite Infrared Observations of Oceanic Long Waves in the Eastern Equatorial Pacific 1975 to 1981. Richard Legeckis, November 1982. (PB83 161133)

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