NASA TM-80103

NASA Technical Memorandum 80103

NASA-TM-80103 19800010396

MISSION AND SENSOR CONCEPTS FOR COASTAL AND OCEAN MONITORING USING SPACECRAFT AND AIRCRAFT

W. L. Darnell

JANUARY 1980

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

1 Report No NASA TM-80103	2 Government Accession No	3 Recipient's Catalog No
4 Title and Subtitle Mission and Sensor Concepts for Coastal and Ocean Monitoring Using Spacecraft and Aircraft		5 Report Date January 1980 6 Performing Organization Code
7 Author(s) W. L. Darnell		8 Performing Organization Report No
9 Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665		10 Work Unit No 11 Contract or Grant No
12 Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13 Type of Report and Period Covered Technical Memorandum 14 Army Project No
15 Supplementary Notes		

16 Abstract

A concept was developed for a 1990 oceanic mission which places strong emphasis on coastal monitoring needs. The concept assumes the use of one active spacecraft in orbit and one on standby plus airplanes and data collection platforms which provide continuing complementary coverage and surface truth. Maximum use of NOSS technology was assumed. Coastal and oceanic measurement needs expressed in past studies and conferences were considered in detail to define measurement goals for the prospective mission. To meet these goals, NOSS sensors were augmented with a pointable visible-IR sensor. Aircraft were provided with cameras and laser, MSS, and microwave sensors. For spacecraft coverage, a Sun-synchronous orbit at 98.5° inclination and an altitude of 750 km was proposed. Two optional 2-spacecraft orbit combinations were also studied for improved coverage characteristics.

17 Key Words (Suggested by Author(s)) coastal monitoring, oceanographic satellite, pollution monitoring, remote sensing		18 Distribution Statement Unclassified - Unlimited Subject Category 48	
19 Security Classif (of this report) UNCLASSIFIED	20 Security Classif (of this page) UNCLASSIFIED	21 No of Pages 46	22 Price* $4.50

*For sale by the National Technical Information Service, Springfield, Virginia 22161

SUMMARY

This report describes the results of a study to define new mission and sensor concepts for a 1990 oceanic observation program, which places strong emphasis on coastal monitoring needs. The concept assumes one active spacecraft in orbit and one in a backup inactive mode. Aircraft and Data Collection Platforms remain active in a complementary support role in the coastal zone. Maximum use has been made of the Seasat and National Oceanic Satellite System (NOSS) technology.

Coastal and oceanic measurement needs expressed in past studies and conferences were considered in detail to define measurement goals for the prospective mission. User requirements were grouped according to five major interests which apply to coastal and oceanic data users: physical oceanography, weather, bioresources, pollution, and shoreline phenomena. Bioresources and pollution interests required the most stringent surface resolutions. Current NOSS-type sensors would need to be augmented with a special pointable, visible-IR sensor to meet such demands. The Multispectral Resource Sampler was proposed to meet this need. On airplane platforms, laser sensors, multispectral visible scanners, microwave sensors, and cameras are proposed.

Orbit designs which would meet mission needs were studied. The proposed orbit is Sun-synchronous with an inclination of 98.5^{o} and an altitude of about 750 km. These orbit parameters provide a repeat cycle of about 3 days which is desired. Two optional orbit sets, which use two simultaneously active spacecraft were also studied because of their attractive surface coverages. One set is a Sun-synchronous and non-Sun-synchronous orbit combination, at 750-km altitude. This set combines the best of ocean and coastal coverage needs. The other set is two Sun-synchronous orbits at 775-km altitude providing a 1-1/2-day global coverage for improved repeat coverage.

INTRODUCTION

Remote monitoring of U.S. coastal zones and global oceans has been of interest for more than a decade. Numerous studies have been funded to define objectives and measurement goals for such missions. The result of these studies was the Seasat program. Seasat was launched June 26, 1978, carrying five sensors to achieve day/night ocean viewing and global ocean coverage every 36 hours. However, a major power failure aborted the mission after only 106 days in space. On October 23, 1978, the Nimbus 7 spacecraft was launched. It was the first U.S. satellite dedicated to the monitoring of our environment and thus, included water sensing. Two of its six sensors now provide temperature and limited spectral data over the oceans on a 6-day cycle. Other current satellites which provide data over the ocean include the Landsat series. Landsat 2 and 3 provide limited multispectral data over the oceans on a combined 9-day basis. Later, the Landsat-D satellites will continue this coverage but Landsat sensors are dedicated to and designed for Earth resources sensing over land. Likewise, the meteorological satellites

SMS, GOES, NOAA, and TIROS-N, which provide sea-surface temperatures, do not provide sufficient data in many ways to satisfy our basic coastal zone and ocean monitoring needs.

In response to this need, a second national ocean-monitoring satellite has now reached the advanced planning stage. This National Oceanic Satellite System (NOSS) (ref. 1),is a cooperative endeavor between NOAA, DOD, and NASA, and if successful, would be launched in 1985. NOSS is not expected to be a copy of Seasat 1 but would incorporate some sensor changes in its basic complement and may incorporate some experimental sensors. NOSS is being planned as a 5-year mission involving the use of two satellites, one in orbit and one on standby. The NOSS would bring significant advancements in data-handling concepts and facilities.

In light of these developments, future oceanic missions must now be examined. New sensor concepts will be available and understanding of the difficult coastal zone measurements will be advanced. More sensing of coastal zone parameters would be warranted and feasible in future oceanic missions.

Coastal zone measurement needs differ from those of either open ocean or inland areas. In comparison to ocean needs, the coastal zone phenomena are often more dynamic, requiring more frequent monitoring and broader measurement ranges. Due to the physical boundaries, a finer spatial resolution is generally desired for coastal zone measurements than for those over the open ocean. In comparison to measurements taken over land, using optical sensors, coastal water radiances are weaker requiring sensors with greater signal gains. Specialized bands in both visible and infrared are desirable to maximize measurement capabilities in the coastal zone.

This report describes the results of a study to define mission and sensor concepts for a 1990 oceanic mission which places a strong emphasis on coastal monitoring needs. Both coastal and oceanic measurement needs expressed in past studies and conferences were considered in detail to establish the measurement goals. A broad prospective sensor complement is proposed, based strongly on the past Seasat and NOSS studies. Compatible sensor platforms are defined which include both spacecraft and aircraft. This combination was considered necessary to conduct a comprehensive mission. Spacecraft orbit designs that meet the mission goals are discussed and illustrated.

ABBREVIATIONS AND ACRONYMS

ALT	Altimeter
AOL	Airborne Oceanographic Lidar
CZCS	Coastal Zone Color Scanner
DCP	Data Collection Platform

FOV	Field of View
GPS-PAC	Global Positioning System-Processor and Computer
IR	Infrared
LAMMR	Large Antenna Multichannel Microwave Radiometer
MMS	Multimission Modular Spacecraft
M^2S	Modular Multiband Scanner
MRS	Multispectral Resource Sampler
NAS	National Academy of Science
NOAA	National Oceanic and Atmospheric Administration
NOSS	National Oceanic Satellite System
SAR	Synthetic Aperture Radar
SCAT	Scatterometer
SMMR	Scanning Multifrequency Microwave Radiometer
STAS	Surface Truth Acquisition System
STDN	Space Tracking and Data Network
STS	Space Transportation System (Shuttle)
TDRSS	Tracking and Data Relay Satellite System
TRS	Teleoperator Retrieval System
VIRR	Visible and Infrared Radiometer
VIS	Visible
WTR	Western Test Range

STUDY ASSUMPTIONS AND GUIDELINES

This study was initiated to help guide future decisions by NASA and others in evaluating the best sensor complement and mission approach for a future coastal zone and ocean mission. Seasat 1 mission plans have been used as a guide. A large amount of data from the Jet Propulsion Laboratory (JPL) Seasat-B study (refs. 2, 3, 4, 5, and 6) also were considered in this study. The main reference, however, has been the NOSS report (ref. 1) generated through the combined inputs of NASA, NOAA, and the Department of Defense. In the NOSS concept, one spacecraft will be placed in orbit via the Space Transportation System (STS) with a second spacecraft on standby to achieve a 5-year mission. Spacecraft retrieval or in-orbit repair are possible follow-on options in the NOSS concept. The NOSS mission flight time is in the mid-1980's. Therefore, a follow-on mission is reasonable in 1990.

Guidelines followed in this study were:

1. Apply mission measurement goals as defined from studies investigated in following sections of this report.

2. Maximize use of developed technology and technology inheritance, thus reducing development risks, time, and costs. Continued use of the NOSS sensor complement or some variation is assumed.

3. Assume two spacecraft, one launched in 1990 from WTR in a polar-type circular orbit and the other remaining on the ground for later callup. Continuous ground support from aircraft and data-collection platforms will be employed to complement the active spacecraft. Use of the Multimission Modular Spacecraft launched by a Shuttle will be assumed.

In the future, coastal activity will certainly not diminish. Navigational, natural resources, commercial, and environmental interests must be considered. The coastal zone of the U.S. generally can be defined as the coastal waters and adjacent shorelines of the coastal states, including transitional and intertidal areas, salt marshes, wetlands, and beaches (Coastal Zone Management Act of 1972). Further, the outer boundary of the coastal zone often is taken as the point where water depth reaches about 200 meters. However, the U.S. territorial boundary is now set 200 miles from shore and in this study was considered the U.S. coastal zone outer boundary.

The capability for true coastal monitoring by remote sensors would introduce some important changes from that of the current NOSS mission concept. For example, in this study, visible spectrum sensors have been proposed with higher surface resolutions and with commandable pointing capability. These steps were taken after carefully analyzing coastal and ocean user's needs reported in studies of the past 15 years. These data were surveyed chronologically to understand trends and assimilate results.

MEASUREMENT REQUIREMENTS

Formation of "seawater measurement requirements" for spacecraft began as early as 1964 when more than 150 oceanographers gathered at the Woods Hole Conference on Oceanography from Space (ref. 7). Only five general requirements were formulated then: geoid, waves, ice, currents, and temperature. A study conducted in 1968 for Johnson Space Center (ref. 8) identified 26 requirements. The same year, two other studies, one for NASA/NAS (ref. 9), and one for Langley Research Center (LaRC) (ref. 10) identified 12 requirements. In all three 1968 studies, coastal-zone requirements were prominent in addition to oceanographic requirements. Three independent contract studies were performed for LaRC in 1970-71 to define coastal and oceanographic measurement needs (refs. 11, 12, 13). Two of the three contractors (refs. 11 and 12) developed a prioritized listing of the parameters desired, and the accompanying accuracy and frequency considered necessary for each parameter. The parameters are shown in table I. The most recent survey of user needs was made by JPL in 1976 (ref. 3) pertaining to the Seasat-B study. JPL's study, based on interviews with 40 potential users, gave little emphasis to coastal-zone needs, but recommended water color sensing. In 1977, NOAA provided a summary of its marine environment data needs (ref. 14) for 1980-1985 and beyond. The report dealt particularly with oceanographic needs, because the impetus of the study was for remote ocean data, but the authors indicated that many additional coastal measurements also were needed. The measurement needs listed in the JPL and NOAA studies are shown in table II.

Of all the studies reviewed, the four in tables I and II were considered the most applicable to the measurement goals of a coastal oceanic mission of the 1990 time period. Comparison of these four studies shows considerable agreement exists as to types of measurements although the priority of the measurements differ. Twenty-three different measurements were identified although some appear redundant, such as bioassays, plankton and fish. Many measurements may be difficult or impossible to sense presently but may be realistic goals for a 1990 mission.

Coastal oceanic measurements can be grouped according to five major categories of user interests. These categories are Pollution, Bioresource, Weather, Physical Oceanography, and Shoreline. The 23 measurement goals have been listed in table III according to these user interests. This matrix readily shows where sensors might be selected to serve multiple user needs. An important complication arises at this point, however. The temporal and spatial resolutions desired for each user interest category vary from one study to another. Therefore, for the purpose of designating resolution goals for sensors, the ranges of resolutions found in the JPL, Virginia Institute of Marine Science, and Ocean Data System studies (refs. 3, 11, and 12) were used. The NOAA study resolutions were not included in this assimilation because these data were broken down by discipline and geographical areas; this made the assimilation impractical. The range of spatial resolutions from the other three studies are given in table IV, while the temporal resolution ranges are given in table V. Thus, table III shows desired coastal and ocean measurements from the most applicable measurement studies, while tables IV and V show the range of spatial and temporal resolutions which apply to these measurements. The spatial resolutions for pollution and shoreline interests are the highest (generally between 10 and 1000 m), while those for oceanographic interests are lowest (generally from 1 to 10 kilometers). Temporal resolutions needed for pollution interests are the highest (hours), while shoreline interests are the lowest (days to weeks).

New coastal measurement goals for this mission were established by segregating applicable measurement parameters from those of table III. The selection was based on the assumption that the pollution, bioresource, and shoreline interests represented the basic coastal zone measurement needs.

Therefore these measurement needs have been taken in this study as measurement goals requiring new sensor approaches beyond those established for NOSS. These new coastal measurement needs are summarized in figure 1 along with the surface resolutions desired for each. The anticipated NOSS measurement capability for these measurements also is shown in figure 1 by the hatched tabs intruding from the right. This indicates graphically that although the NOSS sensors have a coarse measurement capability for many of the coastal parameters listed, the capability is basically outside the range of surface resolutions needed (10-800 m). A future oceanic and coastal mission must attempt to respond throughout the resolution ranges needed.

The general conclusion drawn from these results has been that 1990 mission sensors must be capable of providing a wide field of view (FOV) for some needs while for other needs they must offer high surface resolution. Further, some areas must be viewed on a high-frequency basis while other areas will require only updates. In short, the sensor complement must provide a variety of coverage capabilities, and be able to respond within the scale of the U.S. coastal zone.

The following sections describe sensor/platform concepts which would respond to the coastal needs as well as to the oceanic needs.

PROSPECTIVE OCEANIC AND COASTAL SENSORS

Sensors considered for this mission included the options considered for the NOSS, shown in table VI. Seasat 1 sensors are shown for comparison. Note that the Synthetic Aperture Radar (SAR) used on Seasat 1 was dropped and that the Visible and Infrared Radiometer (VIRR) will be replaced by the Coastal Zone Color Scanner (CZCS). The Seasat Scanning Multifrequency Microwave Radiometer (SMMR) is now the NOSS LAMMR. The sensor options which are likely to fly on NOSS at this time are designated by an asterisk. Approximately 25 percent of the NOSS total sensor complement (power, mass, and data capacity) may be reserved for new or modified sensors that are considered "proof-of-concept" types, providing funds are available. Other candidate aircraft and spacecraft sensors of both operational or developmental types are listed in tables VII and VIII. Where known, the operational sensor's spatial coverage, mass, and power are included.

Proposed Sensors for Oceanic and Coastal Monitoring

A proposed sensor complement was developed from table VI, and from tables VII, and VIII, for oceanic and coastal needs, respectively. The sensor complement, which includes both spacecraft and aircraft types, is detailed in table IX. In addition, for spacecraft, there are sensing systems for data collection from surface data gathering systems, and for precision orbit determination.

Spacecraft sensor selection considerations.-The NOSS sensors were given first priority in the selection of proposed spacecraft sensors, but new sensors or variations were adopted where necessary to meet coastal-oriented user needs. The Scanning Multifrequency Microwave Radiometer (SMMR), Altimeter (ALT), Radar Scatterometer (SCAT), and Coastal Zone Color Scanner (CZCS) shown in table IX are early options of NOSS sensors. These have been selected as basically oceanic sensors for the proposed mission. The selected options of the SMMR, ALT, SCAT, and CZCS help to meet spatial resolution improvements desired by the coastal-oriented users yet take into account development risks (ref. 1) associated with the improvements.

The coastal user needs stressed in figure 1 applied to near-shore waters as well as to outer coastal waters (or even open waters in some cases). To accommodate the near-shore part of this dual requirement the new Multispectral Resource Sampler (MRS) is proposed. The MRS (ref. 15) is under development by GSFC. Because it uses the later linear array detector technology, exceedingly good surface resolution (15 m) and sensitivity are anticipated at low mass and power requirements. Further, it will offer 20 visible band choices in five combinations which are selectable from the ground. These bands can include polarization filters. The MRS will have a ±40° crosstrack pointing capability for repeat coverage and ±55° along-track pointing for "dwell" coverage and stereo viewing. It should be provided with programmable pointing capability to maintain track on prearranged targets or on geographical zones of high interest such as the coastlines, where the orbit tracks permit. This feature incorporates the added flexibility of steering the sensor's FOV out of the Sun-glitter cone. The CZCS would provide complementary coarse resolution (600 m) and broad FOV sensing using IR and VIS wavelengths to cover the outer coastal waters.

As a support system, the Surface Truth Acquisition System (STAS) will be needed to gather surface-truth data and emergency-condition data being beamed upward from the web of data collection platforms in the water. It has been assumed that both anchored and floating data collection platforms will be an important part of the overall mission concept. Table IX shows the anticipated capability for the STAS to communicate with surface collection platforms, research ships, etc.

The Global Positioning System-Processor and Computer (GPS-PAC) is needed for precision orbit determination mainly for the ALT determinations of sea topography. To achieve accuracies of 10 cm, the GPS, laser retroflector, and a second satellite for triangulation could be used as well as S-band radar.

Airplane sensor selection considerations.- Airplane sensors were considered necessary to provide adequate local coverage and proper spatial resolution for inner-coastal monitoring. Airborne sensors must be used to provide mission flexibility and to allow timely coverage over special coastal points of interest, for example, to accommodate a periodic monitoring emphasis on the coastline, or inner coastal zone. Several sensors should be available to meet different coastal needs.

The Airborne Oceanographic Lidar (AOL) was selected particularly for its capability to perform vertical profiling, current detection, and environmental sensing in a highly localized area. AOL is currently in a state of development toward an operational instrument in either the bathymetric or fluorosensing mode (ref. 16) through simple switching. In the bathymetric mode, the laser beam can penetrate to depths of 6 to 10 meters; in the fluorosensing mode, the return signal can be divided into 40 spectral channels for spectrographic analysis in the water. The AOL is limited currently to low altitudes and a relatively narrow FOV. Incorporation of a more powerful laser and an operationally modified design is needed. This would easily be possible by 1990.

The Modular Multiband Scanner (M^2S) could be used when broader coverage, and coverage farther from the coastline is desired. The M^2S (ref. 17) is an 11-band operational spectrometer with sensing capability ranging from the UV into the IR including the thermal IR. The M^2S can be used at altitudes to 4.6 km when carried on medium-size business aircraft. The scan mirror of the M^2S is roll compensated to provide better scene control. As an airplane sensor, it is well proven for coastal and environmental needs.

The Zeiss RMK-A is an aerial mapping camera that can be used with the AOL or M^2S to locate and document their data sites and can provide high-resolution maps of ground features. The Zeiss-RMK-A can accommodate four choices of aerographic film and a range of filters. Together with either the AOL or M^2S, the Zeiss RMK-A can comprise a very powerful monitoring tool for airplanes.

For salinity measurements and good temperature measurements on an inner coastal scale, an L/C-Band Radiometer has been incorporated in the airplane complement. Advanced technologies will provide pushbroom, multibeam coverage. Wind field support data would be needed and the Zeiss-RMK-A would supply documentation of data sites.

SENSOR SUPPORT PLATFORMS

The satellite platform planned for future near-Earth payloads is the Multimission Modular Spacecraft (MMS) developed by GSFC. The MMS was not used on Seasat 1. It is fully compatible with the Space Transportation System (STS) (Shuttle) and can be combined with mission-unique equipment to provide support for peculiar mission needs. This support can include add-on options such as tape recorders, computer memory, and propulsion modules. A complete description of the MMS and its options is given in the MMS User's Guide (ref. 18).

The MMS must be boosted to the desired injection altitude (700-850 km) from the STS parking orbit (278 km) by an intermediate propulsion system. The Teleoperator Retrieval System (TRS) (ref. 19) is one candidate to handle and deploy low-altitude STS payloads, although a special-design propulsion system can also be considered. The TRS can provide impulsive velocity and attitude control thrusting, using up to four propulsion kits, if necessary, with approximately 690 kg of hydrazine in each.

The coastal oceanographic mission concept envisioned in this report, using the sensors proposed in table IX includes spacecraft, airplanes, and data collection platforms. The basic support requirements imposed by the proposed sensor complement on spacecraft and airplane platforms are given in table X. Discussion of platform designs to meet these needs follows. Data collection platforms are discussed only in terms of their operational use.

Spacecraft Platform

This study assumed the use of the MMS with the STS, launched from the Western Test Range (WTR), and the use of the TRS for placement of the spacecraft in an orbit of approximately 700-850 km altitude. The STS would carry the spacecraft, the sensor payload, and the TRS to the parking orbit. Using only the integral propulsion kit of the STS, a 100 percent capacity payload delivery of about 14,500 kg is possible for high inclination orbits, but the 75 percent effective loading is 10,875 kg. For comparison to this latter figure, a typical breakdown of the spacecraft/experiment/TRS mass requirement is shown in table XI. A total payload mass of 1111 kg was allowed to provide for a 25 percent mass margin to be reserved for growth or other sensors. About 525 kg of ascent propellant are required to boost the spacecraft to an 800-km orbit, but 644 kg have been allowed to cover contingencies or a higher injection orbit (850 km).

For electrical power, a four-panel, roll-up solar array has been assumed in this study. This array is sized to deliver 4600W at the end of 3 years in orbit aside from losses. This design would provide about 1200 W for experiment use (>100 percent margin). To allow for Sun occultations in the orbit, approximately six 50 ampere-hour batteries will be required. This can be accomplished (ref. 1) by using two baseline MMS power modules instead of the nominal one.

Data handling, resulting from the operation of two to three sensors with outputs in the megabit per sec range, would impose an overwhelming data load on the Tracking and Data Relay Satellite System (TDRSS) S-band transmissions. Therefore, two NASA standard tape recorders with 4.5×10^8 bit capacity each would be needed. Part of the sensor output could be preprocessed or formatted onboard for easier transmission. Consequently, additional computer processor and memory units have been assumed in addition to that of the baseline MMS. In the event transmission to one of the TDRSS is not possible, communication to the Space Tracking and Data Network (STDN) stations could be provided as a backup.

A sizable structural module must be added to the baseline MMS on which the solar arrays, antennas, and some sensor equipment can be located. With this module, additional wiring and thermal control would also be needed.

Airplane Platforms

Table XII shows several classes of commercially available propeller and jet airplanes and their cargo handling and flight characteristics (ref. 20).

Propeller airplanes are lower in initial cost than jets, but jets have greater speed and sometimes greater range. These airplanes can all be supplied with factory-built auxiliary fuel tanks, and alternators to extend performance.

Support requirements imposed by the proposed airborne sensors would be dependent on whether all three sensors were carried simultaneously. Table X shows that the AOL, which is presently in a developmental state, is quite heavy and requires a high power level. Only the largest of the two airplanes of table XII could accommodate the present AOL. On the basis of an operational AOL of the 1980's, many airplanes shown in table XII may be capable of the job. When only the M^2S or L/C-Band Radiometer and Zeiss RMK-A would need to be flown, any of the listed aircraft could be used.

Airplanes will have the versatility to fly the sensors on regular mission runs or to provide special coverage of pollution episodes or disaster events. Airplanes can provide the very high ground-resolution data because of their low altitudes relative to satellites. This may require numerous passes to provide the required area coverage. In this manner, shoreline points of special interest around the coasts can be seen daily. This approach could require a fleet of airplanes, however, for high-density coverage of the coastal zone. Yet, this approach can be cost-effective and efficient (ref. 21). Unless a large number of sensors were to be carried simultaneously on the planes, power and volume requirements would not present a problem. Data-handling requirements, however, could become astronomical, if continuous recording of high data rate sensors was attempted. Highly accurate position fixing of the airplane platform would be a problem also where the airplane operates farther from land. In fact, open ocean sensing well off shore by airplanes does not appear feasible for routine observations, but is excellent for disaster events. In marine water monitoring, the airplane should be considered complementary to the spacecraft platform but not a replacement.

Data Collection Platforms

When equipped with in situ marine sensors, Data Collection Platforms (DCP's) are the third support platform proposed. DCP's can provide in situ ground-truth data that remote sensors must have for calibration and frequent verification. In addition, the DCP's data can be taken with the frequency, and at the precise control point needed. In situ sensors could also be used to send a signal if dangerous pollution or weather conditions have been detected.

Highly automated platforms would be necessary to take advantage of a widespread distribution of the DCP's. The data could then be stored on the platform in a preprocessed form, and automatically relayed to the satellite or airplane when in communication range. In other cases, free-drifting platforms can be used in the water to obtain data on local winds and currents, while the overflying satellite or airplane provides a position fix on the platform's location. Improvement in the environmental sensor is necessary at this time, however, to permit long-term, dependable operation in brackish and saltwater environments. Local users could be responsible for maintaining the sensors and DCP's in their area, and thus, have a stake in gathering successful data. This approach will require compatible data receiving systems on the spacecraft and aircraft to gather DCP surface data. Surface data also could be gathered from ships and large data buoys on a continuous basis.

PROSPECTIVE ORBIT DESIGNS

The orbit design requirements for a 1990 coastal oceanic mission appear to be slightly different from those used for Seasat 1 (ref. 21). Orbit inclination requirements for Seasat 1 were ultimately dictated by the needs of the ALT and the SMMR. The two criteria were that intersections between the ascending and descending nodes of the spacecraft track be of sufficient angle to provide good surface-slope determinations by the ALT in two directions, and secondly, that the SMMR's coverage reach latitudes of at least ±72° for ice and other near-polar observations. The altitude requirements for the Seasat 1 orbit were based on orbit lifetime, tracking signal strengths, and sensor signal strengths. Ultimately, a non-Sun-synchronous, circular orbit of 108° inclination and 794-km altitude was chosen for Seasat 1. An approximate 3-day repeat was used which provided global coverage with the altimeter every 152 days.

The final selection of orbit has not been made for the NOSS mission at this time. Primary considerations at this time are a Sun-synchronous orbit at 98.2° inclination and 700-km altitude, and for non-Sun-synchronous orbits at about 87°, 93°, or 108° inclination and altitudes of 700-900 km.

An important factor, which must be considered for a coastal oceanic orbit, is the ability to provide good upwelling light sensing, for maximal detection of material within the water. The visible sensors mentioned previously will need to view upwelling light with mid-morning to afternoon Sun conditions. Generally the orbit design must provide for sensing over the water areas when solar-elevation angles of greater than 30° exist. These conditions suggest the use of a circular, Sun-synchronous orbit with an equatorial crossing time chosen to favor the measurement latitude of maximum interest. At the same time, it is recognized that the SCAT, SMMR, and ALT may be better served by non-Sun-synchronous orbits which provide varying time-of-day coverage.

Important orbit preferences for sensors discussed in this report are:

INCLINATION CONSIDERATIONS	SENSOR
• Large crossing angles between ascending and descending nodes	ALT
• High-latitude coverage for ice, snow fields	SMMR
• Sun-synchronized overflights of sites	CZCS, MRS
• Ocean areas not sampled repeatedly at same major tidal cycle	ALT
• Sun elevation angles not less than 30°	CZCS, MRS

ALTITUDE CONSIDERATIONS	SENSOR
• Orbit trim maneuver not oftener than 1/mo	ALT
• Higher altitudes for long-tracking window	ALL SENSORS
• Higher altitudes for orbit stability	ALT
• Altitude changes not greater than 50 m/s	ALT
• Lower altitudes for increased signal	ALT, CZCS, MRS
• Higher altitudes for longer orbit lifetime	ALL SENSORS

The proper orbit should allow, among other things, contiguous surface coverage by the sensors between closest orbit tracks. Figure 2 illustrates how the equatorial distance between closest orbits varies with the number of orbits per day and how this affects orbit repeat cycle. For comparison, the swathwidth capability of the proposed sensors, including the MRS is also shown, using the orbit spacing scale. The SMMR, SCAT, and CZCS swathwidths are well matched with orbit-repeat cycles of 2 to 3 days, while the ALT swathwidth matches a repeat cycle that is 160 to 170 days. About 60-day repeat cycles are required for a match of the MRS swathwidths, but this is a pointable sensor, not responsible for contiguous coverage. An obvious solution for the ALT is to use either a compromise Q-value, or a repeat cycle of about 3 days which includes an extra longitudinal precession of about 18.5 km each repeat, sufficient to precess around the globe in the 160 to 170 days. The latter is proposed for this mission.

Other orbit design factors affecting Q-value are altitude and inclination. The effect of orbit inclination depends on whether Sun-synchronous or non-Sun-synchronous orbits are chosen. Non-Sun-sunchronous orbits are more strongly affected by inclination angle. Figures 3 and 4 show the effect of both altitude and inclination on Q-value for non-Sun-synchronous and Sun-synchronous orbits, respectively. Near-polar inclinations appear most favorable for achieving altitudes in the range of 750 km, assuming Q-values of about 14-1/3 are desired. The Sun-synchronous orbit case for a Q-value of 14-1/3 has an altitude of about 775 km.

To illustrate surface coverage patterns from such orbits, a Sun-synchronous orbit with h = 775 km and i = 98.2°, and two non-Sun-synchronous orbits (i = 84°, h = 752 km) and (i = 87°, h = 757 km) are shown in figure 5. The orbit node crossing angles, a serious concern for the ALT, can be seen for each of the orbits of figure 5. The Sun-synchronous orbit (i = 98.2°) provides the largest crossing angles of the three orbits shown. The proposed system option for the ALT could provide highly improved crosstrack slope resolution on the surface beyond that of the Seasat 1 ALT, thus greatly reducing the crossing angle restriction. Figure 6 shows the same three orbits from the polar view (north and south), and compares the polar coverage capabilities of the three orbits, where ice viewing is important. It must be recognized that the SCAT and LAMMR sensors will provide up to 5° to 6° of sidetrack coverage (see table IX).

Since it can be assumed that the MRS needs a Sun-elevation angle (SEA) of at least 30° to provide a sufficient level of upwelling light from the water, figure 7 shows the percent of days each year when a 30° or greater SEA exists at any latitude. Several important points can be made: at up to ±36.5° latitude, a daily period of 30° or greater viewing exists on a year-round basis; at ±60° latitude only about 1/2 of the days each year allow such viewing. Above ±79° latitude, the available days per year of such viewing drop below 20 and reach zero at ±83.5° latitude. As shown in figure 8, viewing could occur only during the summer months in the polar areas. The result is that visible sensors can be used effectively only up to latitudes of about ±75°, and the upper reaches of these latitudes can be monitored only during the local summer months.

A computer analysis was made to compare the visible sensing potential for each of the three previously mentioned orbits. This was done by comparing the viewing opportunities afforded a nadir-viewing sensor in each orbit. A viewing opportunity occurred for each degree of latitude flown over. If the SEA condition was 30° or greater anytime during the pass, a successful viewing opportunity occurred. For each orbit, a full year of opportunities was considered. The percent of successes was generated as a function of orbit latitude. Figure 9 shows these results for the three orbits, but with the data averaged over 5-degree latitude blocks. On an annual basis, the Sun-synchronous orbit provided 62 percent more successful opportunities than the 87° orbit and 54 percent more than the 85° orbit.

A final consideration in the design of an orbit is the need for good solar illumination on the deployed solar panels which provide spacecraft power. The solar energy available will depend on the fraction of the orbit which is in sunlight versus that occulted by the Earth. The orbital factors involved are: orbit altitude and inclination, equator crossing time, and time of year. Figure 10 shows how the orbit fraction in sunlight for the three sample missions discussed thus far, varies with the time of year. The results for the Sun-synchronous orbit are highly dependent on the local time selected for equatorial crossing. Assuming crossing times around 12 noon, which are generally preferred, the Sun-synchronous orbits are seen to provide the lowest orbit fraction in sunlight.

The assumed concept for this mission called for two spacecraft; one spacecraft would be active while the other is a backup. However, several attractive combinations using two active spacecraft should be considered. These can provide particularly desirable coverage of oceanographic and coastal parameters. Two such combinations are proposed here. One combination would be a Sun-synchronous and non-Sun-synchronous orbit set, with each spacecraft using the same circular altitude to provide consistent sensor footprints. If the altitude of 750 km were chosen, the respective orbits could be the following:

Orbit element	Sun-synchronous	Non-Sun-synchronous
Altitude, km	750	750
Inclination, deg	98.399	82.35
Semi-major axis, km	7128	7128
Period, sec	5996.4	5996.5
Q, orbits per day	14.408	14.333
Repeat cycle, days	≃2 1/2	≃3

These data show that the orbits are nearly alike except in repeat cycle and inclination angle. These two parameters, however, produce different solar conditions for the two orbits. Thus, visible sensing could be emphasized on the Sun-synchronous orbiting spacecraft while microwave and IR sensing could be emphasized on the non-Sun-synchronous spacecraft.

A second, attractive,two-spacecraft combination is to fly both spacecraft in Sun-synchronous 3-day orbits (775-km altitude), which are phased to produce global coverage in 1-1/2 days. This could be accomplished by initiating the orbit of spacecraft-B at a point midway between the first and second orbits of spacecraft-A and at 1-1/2 days later. When the 3-day repeat pattern of coverage is complete for each spacecraft, the equatorial distance between minimum (filled-in, not consecutive) tracks would be only 466 km. The CZCS, SCAT, and SMMR would view 86 percent of the equatorial area daily with this two-spacecraft combination. At latitudes beyond ±31°, 100 percent coverage would be achieved daily. The MRS, which would have a swathwidth of about 15 or 30 km, would be used on a pointable basis to cover important ocean or coastal targets with an excellent capability for repeat views from many nearby orbits.

CONCLUDING REMARKS

This study has shown measurement needs and mission approaches for a 1990 oceanic mission which provides emphasis on coastal zone monitoring. Studies of marine monitoring interests over the past 15 years were surveyed. Most of these studies defined monitoring needs in the coastal zone, as well as the open ocean. All measurement needs were grouped according to five major monitoring interests: shoreline, pollution, bioresources, weather, and physical oceanography. Pollution and bioresource needs, which interrelate strongly, are the most demanding from the resolution standpoint. The NOSS will concentrate on oceanographic monitoring mainly; although it will carry the CZCS for limited coarse coastal sensing. It has been proposed that a follow-on oceanographic mission have a sensor complement which is more responsive to the scale and needs of coastal areas. Specifically, sensors must be included which provide very high spatial resolution, as well as sensing in the visible spectrum.

To meet both coastal and oceanographic mission goals, a broad spacecraft sensor complement was proposed. To provide versatility, airplane sensors and data collection platform sensors were required. The list of spacecraft sensors chosen included the SMMR, SCAT, ALT, CZCS, and MRS. Airplane sensors proposed were the AOL, M^2S, L/C-band radiometer, and the Ziess RMK-A camera.

Support platforms for the specified sensors can be supplied from systems now available or those which will be available before the mission time of 1990. The space support platform proposed is the MMS/STS/TRS combination. A review of business airplanes showed that for airborne support platforms, numerous selections can be made. Data Collection Platforms (DCP), which are included in the proposed mission concept, would automatically provide the vital surface truth data, or special in situ data, on a high-frequency basis. Improvements are necessary, however, in the state-of-the-art of marine water sensors on DCP's to permit long-term, dependable operation.

Orbit design for this mission required consideration of conflicting sensor needs. Because coastal science goals strongly favored selection of a Sun-synchronous orbit, this approach was proposed. Orbits with 3-day repeat cycles fit the swathwidths of the SMMR, SCAT, and CZCS, assuming about 750-km altitude orbits. The pointable MRS would look at targets of special interest instead of providing contiguous coverage. For illustration purposes, two non-Sun-synchronous orbits (i = 84° and 87°) and one Sun-synchronous orbit (i = 98.5°) have been used throughout as sample cases. In a computerized comparison of visible viewing opportunities between these orbits, opportunities were found to be more than 50 percent greater for the Sun-synchronous orbit than for either of the non-Sun-synchronous orbits. On the other hand, concerning an analysis on fraction of orbit time in sunlight to receive solar power, the Sun-synchronous orbit was the poorest of the three orbits.

In this study, two spacecraft were assumed, one in orbit and one on standby. Two optional schemes were proposed for the use of two simultaneously active spacecraft to improve coverage capabilities. One scheme involves one spacecraft in a Sun-synchronous orbit and the other spacecraft in a non-Sun-synchronous, highly inclined orbit at 750 km. The second scheme involves the two spacecraft in interlaced Sun-synchronous orbits of 775-km with a combined repeat cycle of 1-1/2 days.

REFERENCES

1. National Oceanic Satellite System - A Joint Effort By NASA, Department of Commerce and Department of Defense. NOSS Prog. Ofs., GSFC-NASA Code 485, March 1979.

2. Seasat-B Concept Study: Volume 1-Baseline and Option 1 Concepts: Volume 2-MMS/Agena Concepts. LMSC D 576012, Lockheed Missiles and Space Company, Inc., Space Systems Division, May 23, 1977.

3. Follow-on Seasat User Needs Report. NASA-JPL Doc. 624-1 (Contract NAS 7-100), October 6, 1976.

4. Nagler, Robert G.; Steinbacher, Robert H.; and Montgomery, Donald R.: Sensor Capability Handbook and Data Sheets, Volume I; July 18, 1977. Steinbacher, Robert H.; and Montgomery, Donald R.: Volume II; Performance Data Sheets, NASA-JPL Doc. 624-2, May 1977.

5. Nagler, Robert G.; and Schlue, John W.: Satellite Capability Handbook and Data Sheets. NASA-JPL Doc. 624-3, July 1976.

6. Sherry, Edwin J.: Follow-on Seasat End-to-End Data Systems Alternatives. NASA JPL Doc. 624-4 (Contract NAS 7-100), March 17, 1977.

7. Ewing, Gifford C., ed: Woods Hole Conference on the Feasibility of Conducting Oceanographic Explorations from Aircraft, Manned Orbital and Lunar Laboratories. NASA CR-64164, April 1965.

8. Hildreth, W. W.; Hollinden, A. B.; Weinstein, M.; and Shepphird, F. H.: Oceanography and Meteorology, vol. II. NASA-CR-95779, April 1968.

9. The Summer Study on Space Applications, National Research Council: Useful Applications of Earth-Oriented Satellites-Oceanography, Contract No. NSR 09-012-909, NASA/NAS. National Academy of Science, 1969.

10. Ludwick, E.; Cheney, L.; Clark, W.; Steen, E.; Hollis, W.; and Warren, P.: The Potential of Observation of the Oceans from Spacecraft. G. E. Missile and Space Division for National Council on Marine Resources and Engineering Development, March 1968.

11. Munday, John C., Jr.; Joseph, Edwin E.; Byrne, Robert J.; Dupuy, John L.; Wright, Thomas D.; Norcross, John J.; and Musick, John A.: Priority Problems and Data Needs in Coastal Zone Oceanography. NASA CR-111779, 1970.

12. Adams, D. A.; Fry, J.; Gurk, H.; Hudgens, J.; Newell, R.; Singleton, J.; and Smith, C. R.: Advanced Study of Coastal Zone Oceanographic Requirements for ERTS E & F. NASA CR-111823, 1971.

13. Hanna, William J.; Marshall, Harold G.; and Slowey, James F.; eds.: A Survey of the Problems and Research Needs in the Coastal Zone. NASA CR-111780, 1970.

14. Eskite, W. H., Jr., and DeRycke, R.: Ocean Data Requirements of the National Oceanic and Atmospheric Administration as Might Be Observed from Space, NOAA, 1977.

15. Schnetzler, Charles C.; and Thompson, Leslie L.: Multispectral Resource Sampler: An Experimental Satellite Sensor For The Mid-1980's. Proc. SPIE Technical Symposium, vol. 183, Huntsville, Alabama, May 22-24, 1979.

16. Bressel, C.; Itzkan, I.; and Nures, J. E.: Airborne Oceanographic Lidar System. Proc. 11th International Symposium on Remote Sensing of Environment, vol. II, Ann Arbor, Michigan, April 25-29, 1977.

17. Bendix Specifications 2368200-1 Rev. D-Modular Multiband Scanner M^2S. Doc. No. M^2S 1012, Bendix Corporation, April 1, 1974.

18. Multimission Modular Spacecraft (MMS) and External Interface Specification and User's Guide. NASA-GSFC Doc. 5-700-11, April 1978.

19. Molloy, R. J.; Tewell, J. R.; and Spencer, R. A.: Teleoperator Retrieval System. AAS Preprint 78-037. 1978 Goddard Memorial Symposium on Shuttle/Spacelab Utilization, March 8-10, 1978.

20. Taylor, W. R.; John,ed: Jane's All the World's Aircraft. 1977-78 edit., Franklin Watts, Inc., 1977.

21. Darnell, Wayne L.: Comparison of Capabilities and Costs of Dedicated Airplane and Spacecraft Missions for Remote Water Monitoring of U.S. Coastal Zones. NASA TM 74046, December 1977.

22. Cutting, E.; Born, G. H.; Frautnick, J. C.; McLaughlin, W. I.; Nelson, P. A.; and Thielen, J. A.: Mission Design for Seasat-A, An Oceanographic Satellite. AIAA 15th Aerospace Science Meeting Paper 77-31, Los Angeles, California, January 24-26, 1977.

TABLE I

REQUIRED COASTAL OCEANOGRAPHIC MEASUREMENT PARAMETERS

CONTRACTOR	VIMS* (Ref 11)	ODSI** (Ref 12)
DATE OF STUDY	SEPTEMBER 1970	FEBRUARY 1971
PRIORITY OF PARAMETERS		
1	Water temperature	Currents
2	Water color	Bathymetry
3	Salinity	Water temperature
4	Coastal vegetation, land use	Tides
5	Oil	Oil
6	Bathymetry	Sediments
7	Tides	Winds
8	Shorelines	Color
9	Shore topography	Plankton
10	Sea state	Salinity
11	Sea level (altimetry)	Precipitation
12	Ice	Vegetation
13	Fish	Air temperature
14		Fish
15		Bioassays
16		Nutrients
17		Topography
18		Water density
19		Freshwater inflow
20		Particulates
21		Metals
22		Waves

* Virginia Institute of Marine Science, Gloucester, Va.

** Ocean Data Systems, Inc., Rockville, Md.

TABLE II

REQUIRED OCEANOGRAPHIC MEASUREMENT PARAMETERS

STUDY GROUP	JPL* (Ref 3)	NOAA-NESS** (Ref 14)
DATE OF STUDY	OCTOBER 1976	JANUARY 1977
ORDER OF PRIORITY		NOTE - NO PRIORITY WAS SPECIFIED BY STUDY
1	Surface winds	Precipitable water
2	Water surface temperature	Precipitation
3	Gravity waves	Surface winds
4	Sea ice	Surface air temperature
5	Ocean color	Sea surface temperature
6	Currents (topographs)	Wave directional energy spectra
7	Atmos. temp. profile	Sea ice conditions
8	Atmos. moisture profile	Surface currents
9	Surface air pressure	Tides - astronomical and storm
10	Buoy data collection	Salinity at surface
11	Cloud cover	Chlorophyll
12	Cloud velocity	Turbidity
13	Marine geoid	Shallow water turbidity
14	Land features	
15	Soil moisture	
16	Salinity	
17	Radiation budget	
18	Subsurface lapse rate	

* Jet Propulsion Lab

** National Oceanic and Atmospheric Administration-National Environmental Satellite Service

TABLE III

MEASUREMENT PARAMETERS, LISTED ACCORDING TO MAJOR USER INTERESTS

MEASUREMENT PARAMETER	POLLUTION	BIORESOURCE	WEATHER	PHYSICAL OCEANOGRAPHY	SHORELINE
Water color	X	X			X
Plankton	X	X			X
Salinity	X	X		X	X
Bioassay	X	X			
Nutrients	X	X			
Particulates	X				
Metals	X				
Oil	X				
Water temp.		X	X	X	X
Bathymetry		X		X	X
Vegetation		X			X
Fish schools		X			
Wind dir.&vel.	X	X	X	X	X
Precipitation			X		
Water density			X	X	
Currents	X	X		X	X
Freshwater inflow	X	X			X
Ice				X	X
Tides	X			X	X
Waves				X	
Sea topography				X	
Land use					X
Sediments	X				X

TABLE IV

DESIRED SPATIAL RESOLUTIONS

MEASUREMENT PARAMETER	POLLUTION	BIORESOURCE	WEATHER	PHYSICAL OCEANOGRAPHY	SHORELINE
Water color	10-100m	1-10km			1-1000m
Plankton	20-50m	100-1000m			0.1-10km
Salinity	10-100m	100-1000m		0.1-10km	10-1000m
Bioassay	10-100m	100-1000m			
Nutrients	10-100m	100-1000m			
Particulates	10-100m				
Metals	10-1000m				
Oil	10-100m				
Water temp.		100-1000m	100-1000m	1-5km	100-1000m
Bathymetry		1-10km		1-10km	100-1000m
Vegetation		100m-10km			10m-1km
Fish schools		100-1000m			
Winds	10km	10km	10km	10-50km	1km
Precipitation			100m-10km		
Water density			1-100km	1-10km	
Currents	10-100m	100-1000m		1-10km	100-1000m
Freshwater inflow	10-100m	100-1000m			1-10km
Ice				100m-10km	100m-10km
Tides	100-1000m			100-1000m	100-1000m
Waves				100m	
Sea topography				1-10km	
Land use					10m-10km
Sediments	10-100m				1m-1km

TABLE V

DESIRED TEMPORAL RESOLUTIONS

MEASUREMENT PARAMETER	POLLUTION	BIORESOURCE	WEATHER	PHYSICAL OCEANOGRAPHY	SHORELINE
Water color	1/day	1/day			1/mo
Plankton	1/wk	1/wk			1/wk
Salinity	1/wk	1/wk		1/wk	1/wk
Bioassay	1/hr	1/day-1/wk			
Nutrients	1/hr-1/day				
Particulates	1/hr-1/day				
Metals	1/hr-1/day				
Oil	1/hr-1/day				
Water temp.		1/hr-1/wk	1/hr-1/day	1/day	1/day-1/wk
Bathymetry		1/mo		1/wk	1/mo
Vegetation		1/mo			1/mo
Fish schools		1/day-1/wk			
Winds	1/hr-1/day	1/hr-1/day	1/hr	1/hr-1/day	1/day
Precipitation			1/hr		
Water density			1/day	1/day	
Currents	1/day	1/day-1/wk		1/day	1/wk-1/mo
Freshwater inflow	1/day-1/wk	1/hr-1/day			1/day-1/wk
Ice				1/day	1/wk
Tides	1/hr			1/hr-1/day	1/day
Waves				1/hr-1/day	
Sea topography				1/2 day	
Land use					1/wk-1/mo
Sediments	1/day				1/wk-1/mo

TABLE VI

NOSS SENSOR OPTIONS

SENSOR CHARACTERISTICS	SEASAT 1 SENSORS	OPTION A	OPTION B	OPTION C	OPTION D
LAMMR	(SMMR)	*			
Antenna aperture (m)	0.8	4	3	4	2
Frequencies (GHz)	6.6, 10.7, 18, 21, 37	4.3, 10.65, 18.6, 21.3, 36.5, 91	Same as A	6.6, 18.6, 21.3, 36.5, 91	18, 22, 37, 90
Resolution (km)	150, 90, 53, 43, 27	36, 15, 9, 8, 7,3.5	47, 21, 12 11, 7, 3.5	23, 9, 8, 7, 3.5	18, 16, 14, 7
Scan (deg)	-3 to +47 (rt side)	360	360	360	360
Swath (km)	600	1350	1350	1350	1350
Mass/Pwr(kg/W)	42/80	350/150	260/150	340/140	140/100
Data rate (kbps)	2	100	100	35	12
Goals: Accuracy/Resol.					
Surface Temp. (^{o}K/km)	$\pm$ 1.5/150	$\pm$ 1.0/35	$\pm$ 1.0/35	$\pm$ 1.0/35	N.A.
Wind speed (m/s/km)	2/90	2/15	2/21	2/14	3/18
Ice cover (km)	27	7	7	7	14
Atmos. water vapor (km)	53	9	12	9	18
ALT					
Nadir beam:		*			
Altimetry precision (cm)	10	10	7	7	7
Ground resol. (km)	1.6 to 12	1.6 to 12	1.6 to 7.6	1.6 to 12	1.6 to 12
Off-nadir beam:					
Altimetry precision (cm)	-	-	35	18	18
Ground coverage (km)	-	-	25	50	50
Wind speed	<20%	<20%	<20%	<20%	<20%

*-Most likely for NOSS flight

TABLE VI-Continued.

SENSOR CHARACTERISTICS	SEASAT 1 SENSORS	OPTION A	OPTION B	OPTION C	OPTION D
ALT (Continued)		*			
Sea state $H_{1/3}$ accuracy	50 cm or 10%	50 cm or 10%	50 cm or 10%	50 cm or 10%	50 cm or 10%
Ground resolution (km)	>10	>10	>10	>10	>10
Currents, speed (m/sec)	15	15	10	10	10
Currents, direction (deg)	10	10	5	5	5
Ice coverage (percent)	10	10	10	10	10
Ground resolution (km)	<15	<15	<15	<15	<15
Mass/Pwr(kg/W)	94/164	164/168	170/168	200/168	220/168
Data rate (kbps)	8.5	8.5	17	20	20
SCAT		*			
Antenna per spacecraft	4	6	4	8	
Wind speed	± 2m/s or 10%	± 2m/s or 10%			
Wind direction (deg)	∓ 20	∓ 10			
Ground resolution (km)	≤50	≤50	<50	<50	
High-wind swath (km)	750 @ ± 200 km				
Low-wind swath (km)	500 @ ∓ 200 km	600 @ ± 70 km	600 @ ± 70 km	600 @ ± 70 km	
Mass/Pwr(kg/W)	102/135	224/309	297/312	446/340	
Data rate (bps)	540	<2k	<2k	<2k	
SAR					
Wave direction	TBD				
Wave length	TBD				
Ice resolution(m)	25				
Feature resolution (m)	25				
Currents	TBD	SAR will not be used on NOSS			
Salinity ppt, resol.(km)	-				
Frequency	L-Band				
Antenna swath (km)	100				
Mass/Pwr(kg/W)	80/421				
Data rate (Mbps)	>100				

TABLE VI-Concluded

SENSOR CHARACTERISTICS		SEASAT 1 SENSORS	OPTION A	OPTION B	OPTION C
VIRR					
Number of Channels	VIS	1			
	IR	1			
Wavelengths(μm)	VIS	0.4-0.7			
	IR	10.5-12.5			
Grd. resolution**(km)	VIS	2			
	IR	3.7	VIRR will not be used on NOSS		
Swath**(km)		1800			
Mass/Pwr (kg/W)		9/8			
Data rate		3.6 kbps			
CZCS					
No. of Channels	VIS		4	6*	8
	IR		2	2	4
Center wavelengths (um)			0.44,0.52,0.55 0.67,0.75, 11.5	0.40,0.44,0.52,0.56 0.64,0.685,0.75,0.88	
Grd. resolution (km)	VIS		0.6	0.6	0.4
	IR		0.6	0.6	0.4
Swath (km)			1200	1200	1200
Mass/Pwr(kg/W)			40/39	40/50	
Data rate			800 kbps	1.2 Mbps	6 Mbps

** Ground resolution and swath based on 750-km altitude.

TABLE VII

OPERATIONAL COASTAL OCEANOGRAPHIC SENSOR CANDIDATES

SENSOR	SENSING CHANNELS	MASS, KG	POWER, W
Spacecraft Types			
CZCS	4 VIS, 1 NIR, 1 Therm	40	39
MSS-3	2 VIS, 2 NIR, 1 Therm	64	55
RBV-3	2 VIS	60	160
Thematic Mapper	3 VIS, 2 NIR, 1 IR, 1 Therm	227	250
SAR	1 L-Band	80	421
SMMR (Seasat 1)	2 X-Band, 2 K-Band, 1 Q-Band	42	80
SCAT (Seasat 1)	1 Ku-Band	60	140
ALT (Seasat 1)	1 K-Band	70	150
AVHRR	1 VIS, 1 NIR, 1 IR, 1 Therm	27	27
Aircraft Types			
M^2S	8 VIS, 2 NIR, 1 Therm	113	740
L-band Radiometer	L-Band	140	330
AOL	1 VIS	680	6 KVA
Ocean Color Scanner	9 VIS, 1 NIR	226	7 amp-115V AC 2.5 amp-28V DC
I^2S camera	B&W, Color, I.R. Films	20	230
Zeiss RMK-A camera	B&W, Color, I.R. Films	45	224
Hasselblad camera	B&W, Color, I.R. Films	3.4	12
Vinten camera	B&W, Color, I.R. Films	6.3	280
Enviro-Pod	B&W, Color, I.R. Films	*	*

*Dependent on sensors carried

TABLE VIII

EXPERIMENTAL COASTAL OCEANOGRAPHIC SENSOR CANDIDATES

Aircraft and Spacecraft Types

SENSOR	ORGANIZATION
Advanced Ocean Color Sensor	GSFC-NASA
Advanced Airborne Ocean Lidar	WFC-NASA
Radar Ocean Wave Spectrometer	LaRC-NASA
Advanced Spacecraft Scatterometer	LaRC-NASA
Multipurpose Ocean Radar	GSFC-NASA
Multifrequency Ice Mapping Radar	LeRC-NASA
Advanced SAR	JPL-NASA
Swept Aperture Radar	APL
Surface Contour Radar	WFC-NASA
Surface Pressure Radar	GSFC-NASA
Rain Radar	GSFC-NASA
Advanced Scanning Multichannel Microwave Radar	GSFC-NASA
High Resolution Microwave Radar	LaRC-NASA
Stepped Frequency Microwave Radar	LaRC-NASA
Advanced Radar Altimeter	WFC-NASA
Subsurface Sounder	WFC-NASA
Fraunhofer Line Discriminator	USGS
Airborne Lidar Ocean Pollution Experiment	LaRC-NASA
L/C-Band Radiometer	LaRC-NASA
Multispectral Resource Sampler	GSFC-NASA

TABLE IX

PROPOSED SENSOR COMPLEMENT

SENSOR (OPTION)	MEASUREMENTS	ACCURACY	SURFACE RESOLUTION	SURFACE SWATH
	Spacecraft Sensors		Km	Km
SMMR (NOSS-C)	High wind speed, 7-50 m/s	2 m/s	14	1350
	Surface temperature	$1^{o}K$	35	1350
	Ice cover	1% (precision)	7	1350
	Precipitation over water	1 octave (precision)	9	1350
	Atmospheric water vapor	200 mg/cm^2 (precision)	9	1350
	Atmospheric liquid water	5 mg/cm^2 (precision)	9	1350
ALT (NOSS-B)	Geoid	7 cm	1.6-7.6	1.6-7.6
	Wind speed	<20%	<15	1.6-7.6
	Sea state	50 cm or 10%	10	1.6-7.6
	Ocean current speed	10 cm/s	TBD	1.6-7.6
	Current direction	5^{o}	TBD	1.6-7.6
	Ice cover	10%	<15	1.6-7.6
	Ice height	0.2m	TBD	1.6-7.6
SCAT (NOSS-A)	Low wind speed, 4-28 m/s	2m/s or 10%	25-200	1200
	Wind direction	10^{o}	25-200	1200
CZCS (NOSS-B)	Water temperature	$0.8^{o}K$	0.6	1200
	Turbidity	TBD	0.6	1200
	Chlorophyll	TBD	0.6	1200
MRS	Coastal chlorophyll	TBD	MODE 1 0.015	15
	Sediment, Turbidity	TBD	MODE 2 0.030	30
	Vegetation	TBD		
	Ocean dumps	TBD		
	Acid and sewage plumes	TBD		
	Oil	TBD		

TABLE IX- Concluded.

SENSOR	MEASUREMENTS	ACCURACY	SURFACE RESOLUTION	SURFACE SWATH
Spacecraft Support Sensors				
STAS	DCP positions	5km	-	-
	DCP data collection	-	8 DCPs simultaneously, or 200/Minute	1000 per orbit
GPS-PAC		5m		Zenith to 10^{o} below horizon
Laser Retroflector				$\pm 60^{o}$FOV
Airplane Sensors				
AOL	Bathymetry	0.3m (depth)	1.07 m RMS	$0\text{-}15^{o}$
	Oil	TBD	TBD	1-20 mr
	Fish			
	Chlorophyll, plankton			
	Currents			
	Acids, sewage			
M^2S	Chlorophyll, plankton			
	Acids		10.8 m at 4.3 km alt.	10.3 km at 4.3 km alt.
	Sediments			
	Oil			
	Vegetation			
Zeiss RMK-A Camera	Sea state		3.7-5.8m at 6km alt.	41-42km at 6km alt.
	Beach erosion			
	Shoreline features			
	Turbidity			
	Shore vegetation			
	Coastal structures			
	Ship identification			
L/C Band Radiometer	Salinity			≃2km at 6 km
	Temperature			

TABLE X

SUPPORT REQUIREMENTS FOR PROPOSED NOSS SENSOR COMPLEMENT

SPACECRAFT SENSORS	PREFERRED	SPECIAL	SUPPORT REQUIREMENTS		
Core Types	VERSION	MODIFICATION	KG	W	KBPS
SMMR	NOSS-C		340	140	35
ALT	NOSS-B		170	168	17
SCAT	NOSS-A		224	309	2
CZCS	NOSS-B		45	55	1.9K
MRS	New		55	55	15K
Support Types					
STAS	ARGOS		20	40	1
GPS			20	31	0.5
Laser Retroflector			15	-	N.A.
		Core and Support Total	889	518	≃17K
AIRPLANE SENSORS					
AOL			680	6KVA	100
M^2S			121	1.6KVA	67-670
Zeiss RMK-A Camera			45	224	N.A.
L/C Band Radiometer			<100	-	-

TABLE XI

POTENTIAL SPACECRAFT MASS BUDGET

SPACECRAFT ITEMS		MASS, KG
MMS baseline modules and equipment		746
MMS Options		
2-STDN/TDRSS NASA 5W transponders		11
2-NASA Standard 4.5 x 10^8 bit tape recorders		26
3-50 Amp-Hr batteries		150
Propulsion module (for orbit adjustment, includes propellant)		153
	Subtotal	1086
Mission Uniques		
Additional power module		128
Solar array, 4-15.2 m^2 wings for 4600 W EOL		120
Solar array drives, electronics		70
Added power distribution/regulation		35
High gain S-band and Ku-band antennas, booms		60
Low-gain STDN antennas (2)		2
Extra cabling		85
Additional thermal control		40
Experiment support module		611
Additional mechanisms		45
Remote interface units (22)		37
Computer memory units		55
	Subtotal	1288
Payload Allowance		
Core/complementary sensors		889
Growth sensors, (25% of total)		222
	Subtotal	1111
TRS Allowance		
Basic core (fully loaded)		1045
2 Impulsive thrust kits (dry)		357
Impulsive thrust propellant		644
	Subtotal	2046
	Grand Total	5531

TABLE XII

TYPICAL BUSINESS AIRPLANES FOR AIRBORNE SENSORS

PERFORMANCE CHARACTERISTIC	AIRPLANE						
	CESSNA GOLDEN EAGLE 421 IIC	BEECH BARON 58P	PIPER PA-31T CHEYENNE	CESSNA CITATION I (JET)	GATES LEAR JET 24E	GATES LEAR JET 36A	ROCKWELL SABRELINER 80A (JET)
Maximum take-off mass, kg	3379	3992	4082	5375	5850	8164	9150
Empty mass equipped, kg	2074	2393	2257	2935	3186	4152	5103
Fuel capacity, l	806	809	1476	2393	2706	4201	4024
Payload mass*, kg	725	1017	764	720	718	992	1156
Cruise speed, km/h	450	362	393	649	774	817	850
Cruise altitude, km	7.6	4.6	7.6	<12.5	13.7	<12.65	12.0
Cruise range*, km	2317	1773	2739	2474	2343	5287	3239
Cabin internal size, m							
Length	4.42	6.97	4.90	5.33	5.28	5.77	5.79
Width	1.40	1.37	1.30	1.50	1.50	1.50	1.60
Height	1.29	1.45	1.32	1.32	1.32	1.32	1.60
Power supply, V/A	28/100	28/300	28/400	-	30/800	30/800	-

* Assumes fully fueled take-off

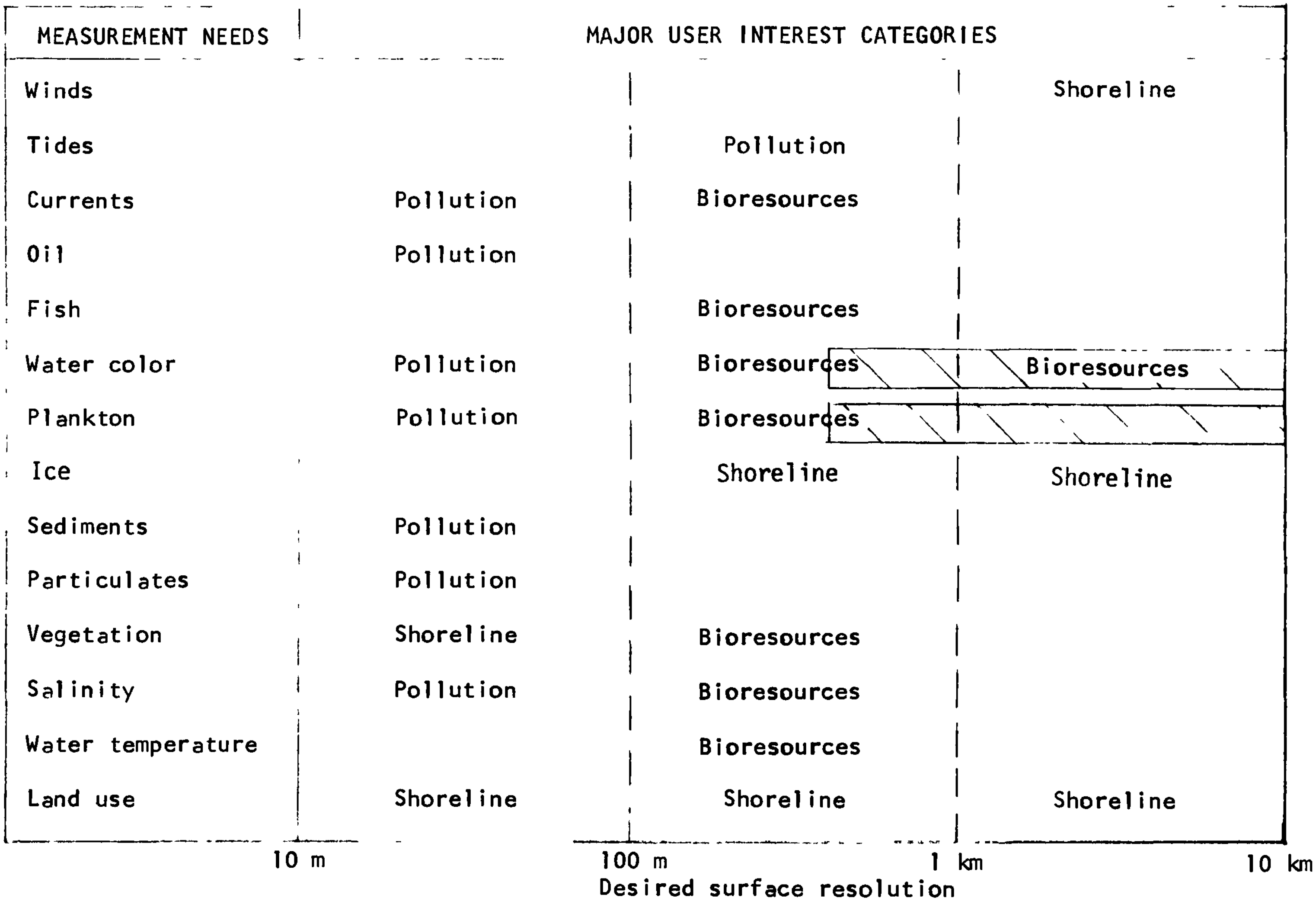


Figure 1.- Summary of coastal measurement needs. The major user interests served by each measurement are shown along with the range of desired surface resolution for each measurement. The measurement capability of the NOSS sensors within this range is shown by the hatch marks.

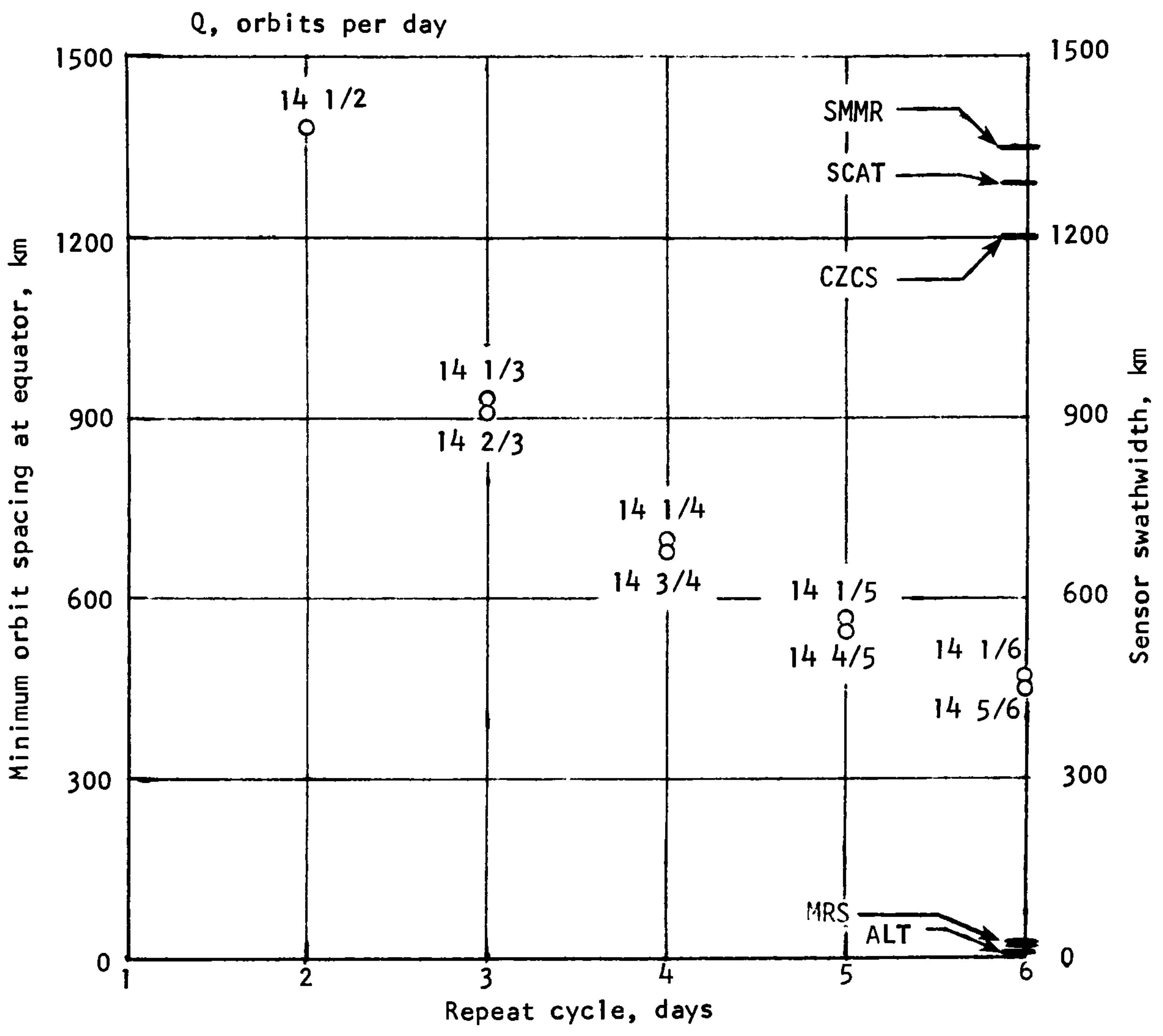


Figure 2.-Effect of Q-selection and repeat cycle on minimum orbit spacing. Proposed NOSS sensor swathwidths are shown for comparison.

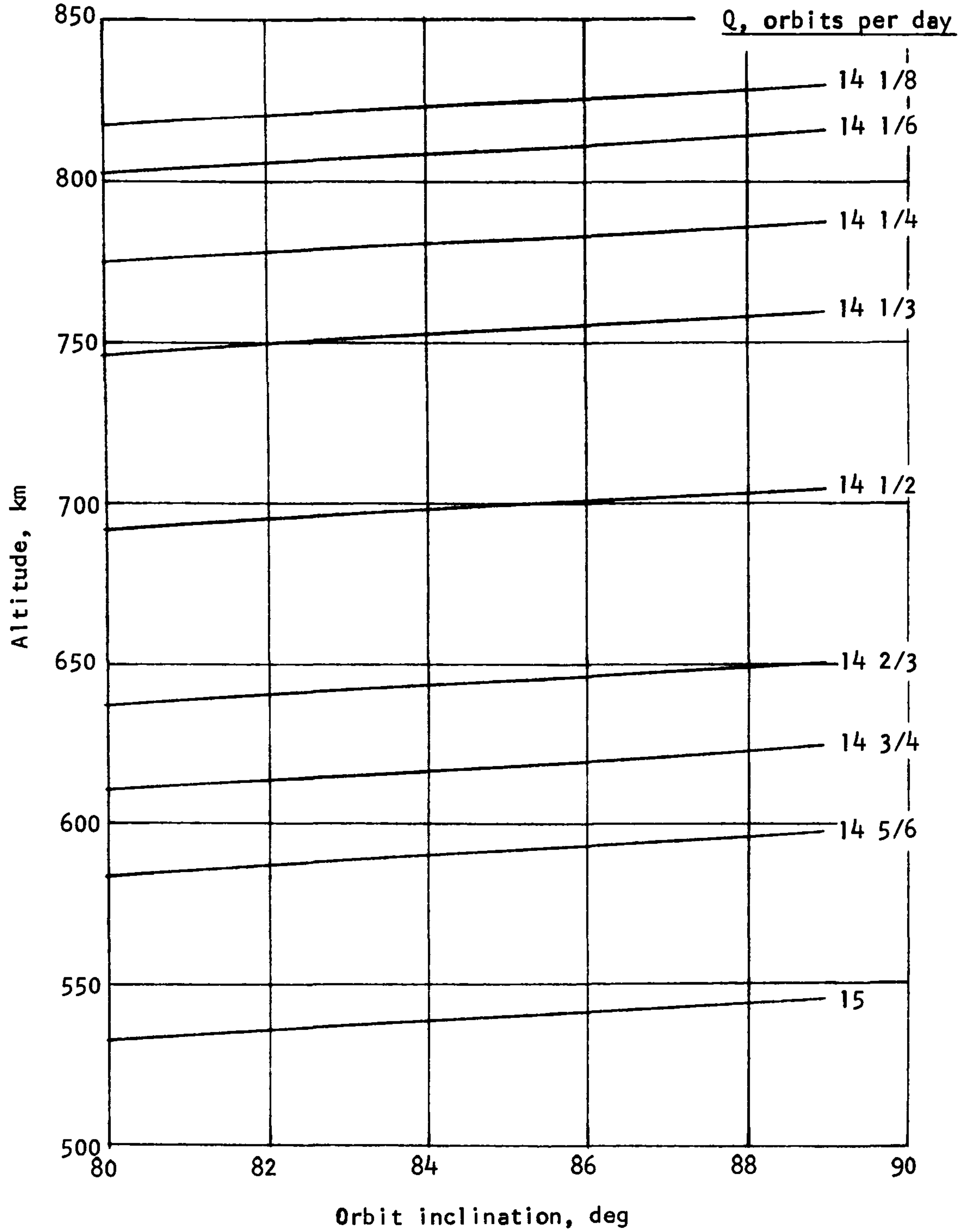


Figure 3.-Effect of altitude and inclination on Q-value for circular, non-Sun-synchronous orbits.

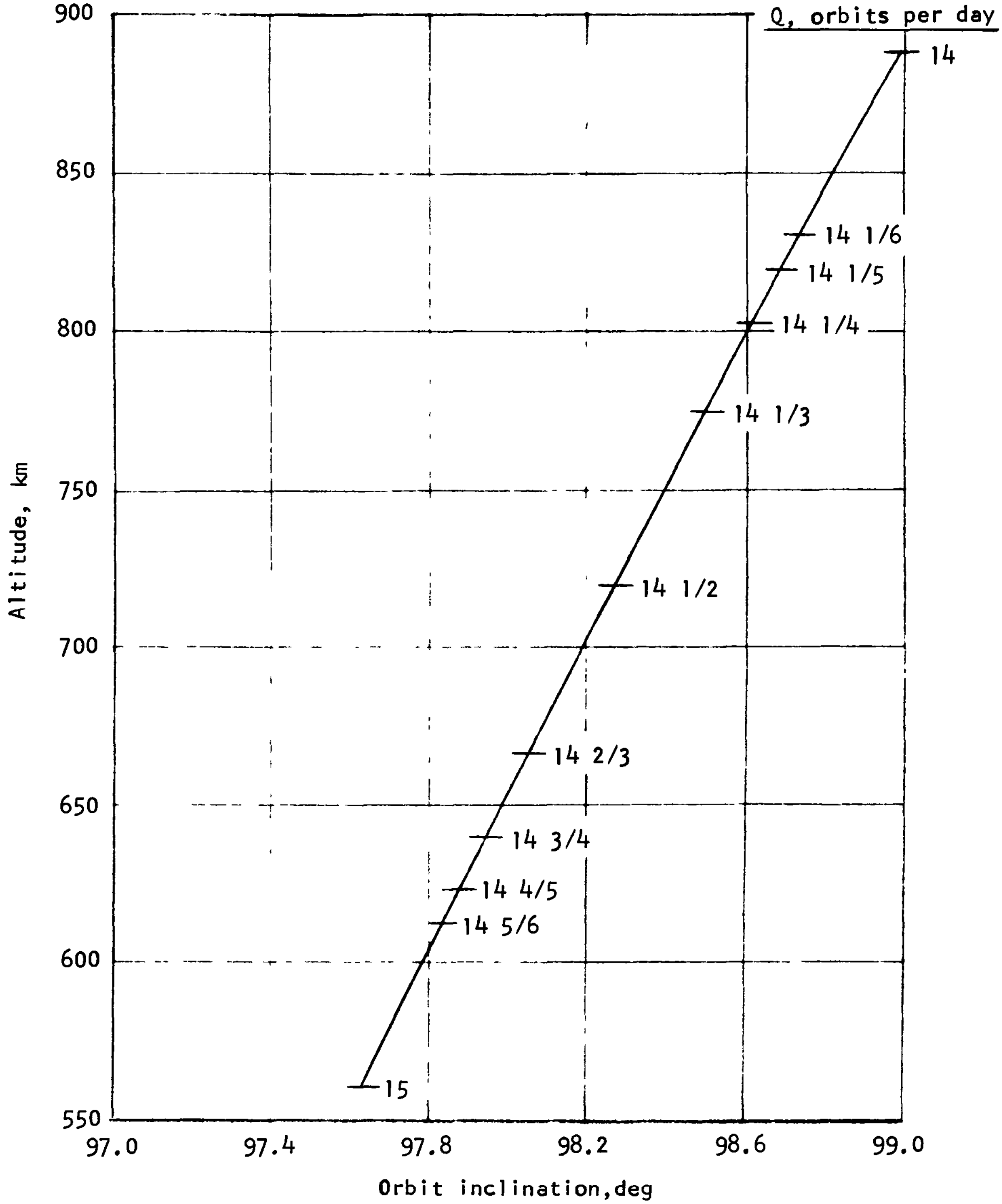
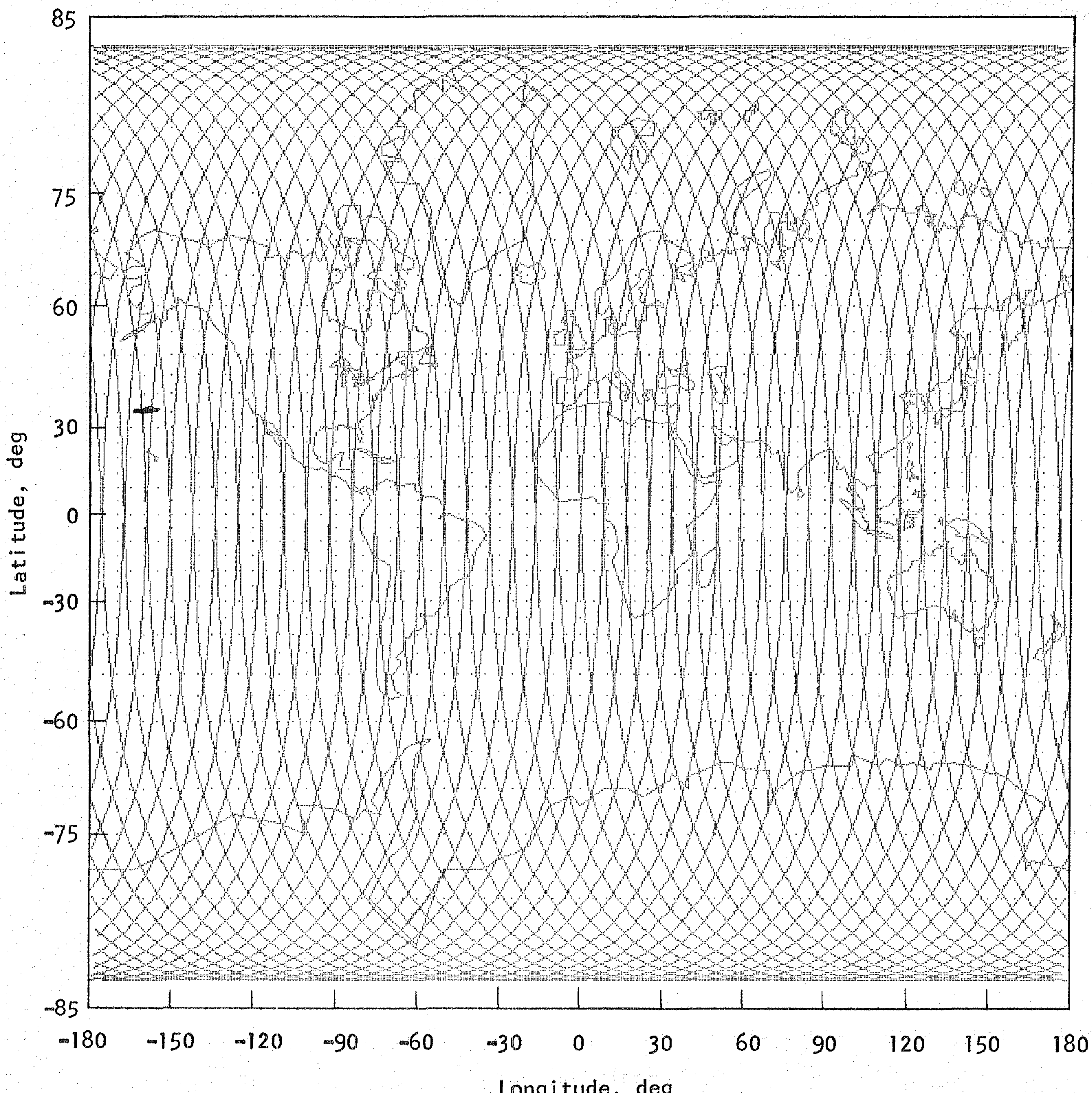
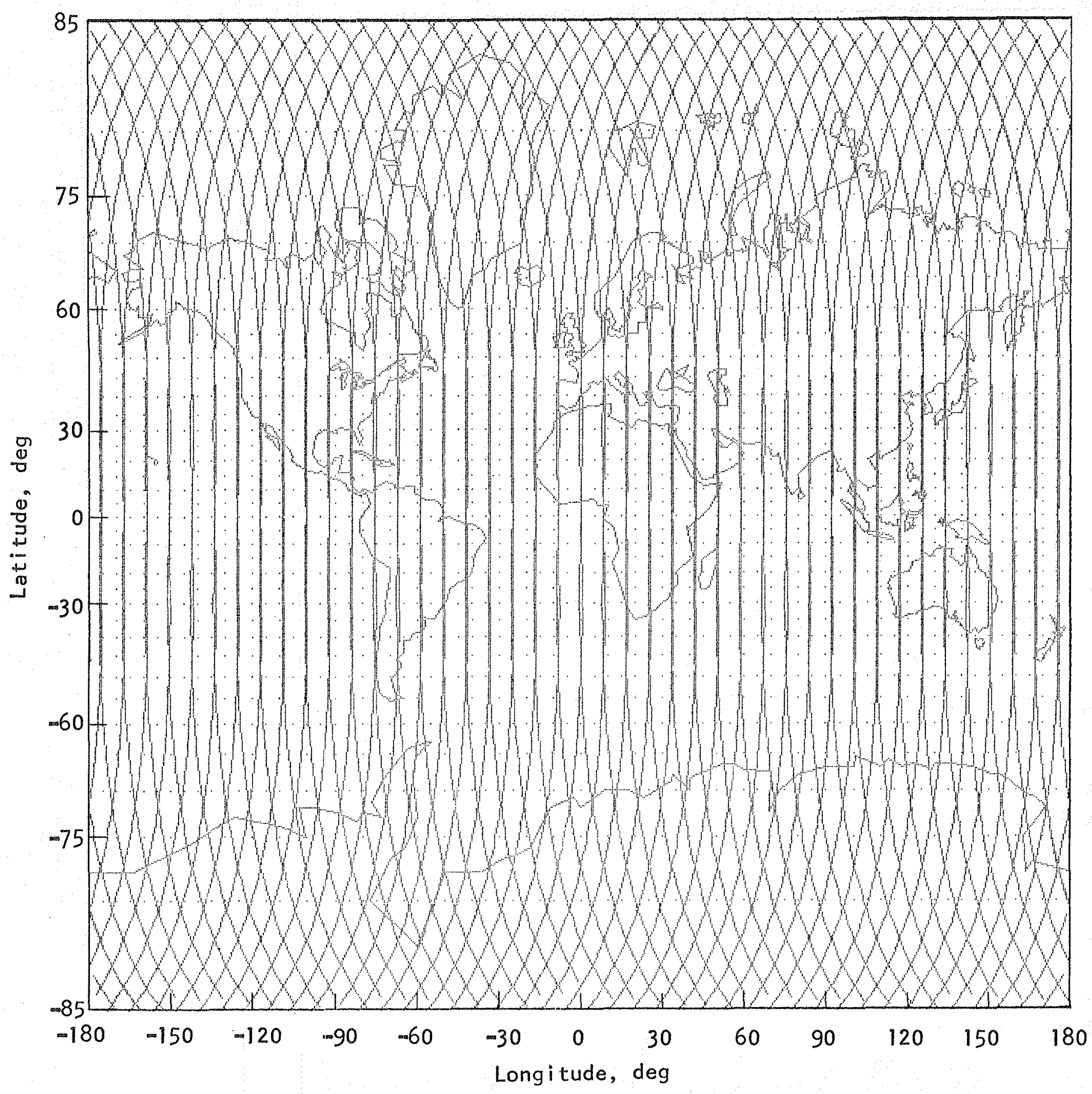


Figure 4.-Effect of altitude and inclination on Q-value for circular, Sun-synchronous orbits.



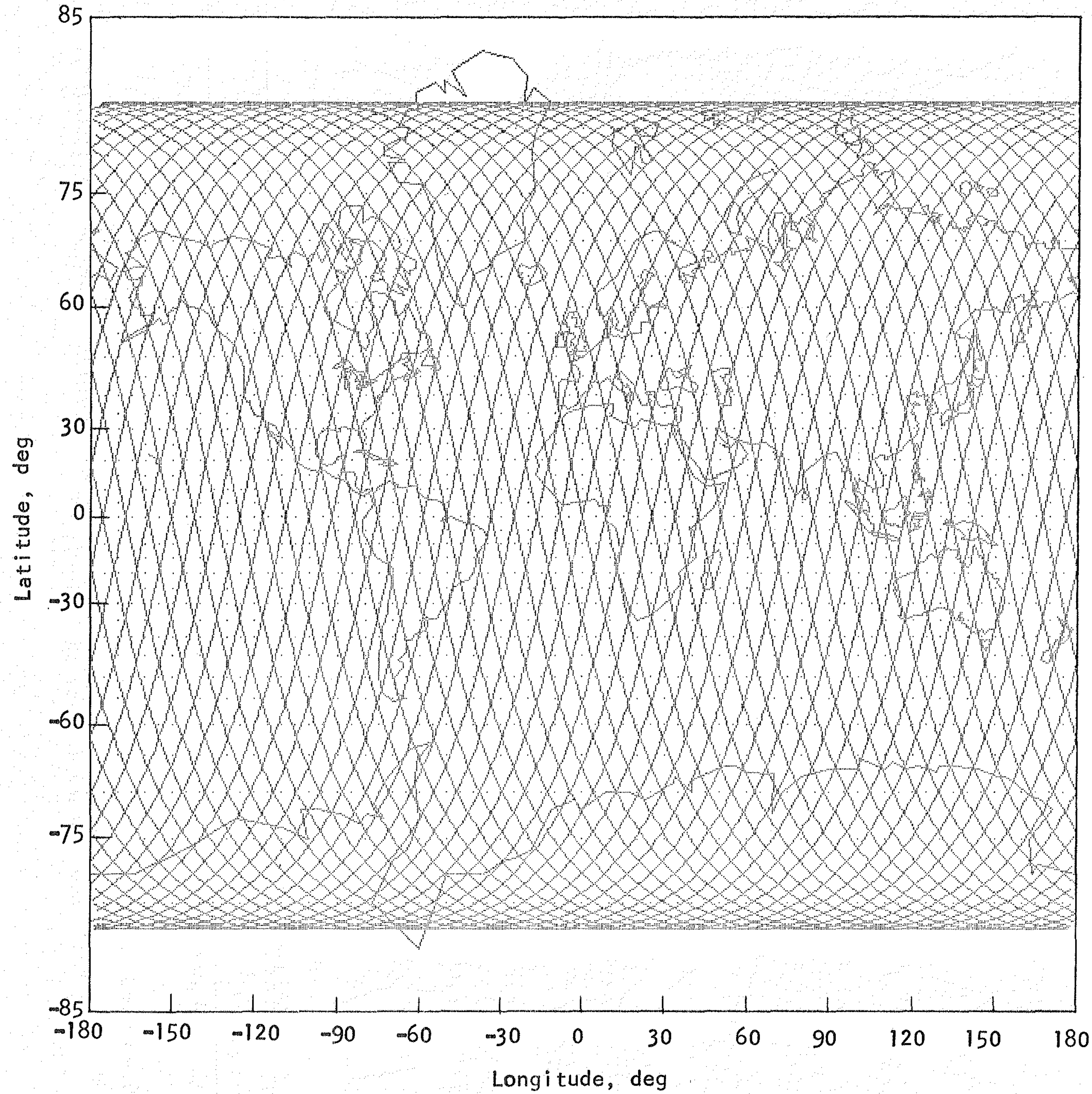
a) Orbit parameters: i=84^o, h=752 km, Q=14 1/3 orbits/day.

Figure 5.- Ground track coverage with 3-day repeat orbits, initiated at the equator, beginning at the Greenwich meridian on Jan. 1, 1983, at 12 noon. Ground tracks are shown on a Mercator projection.



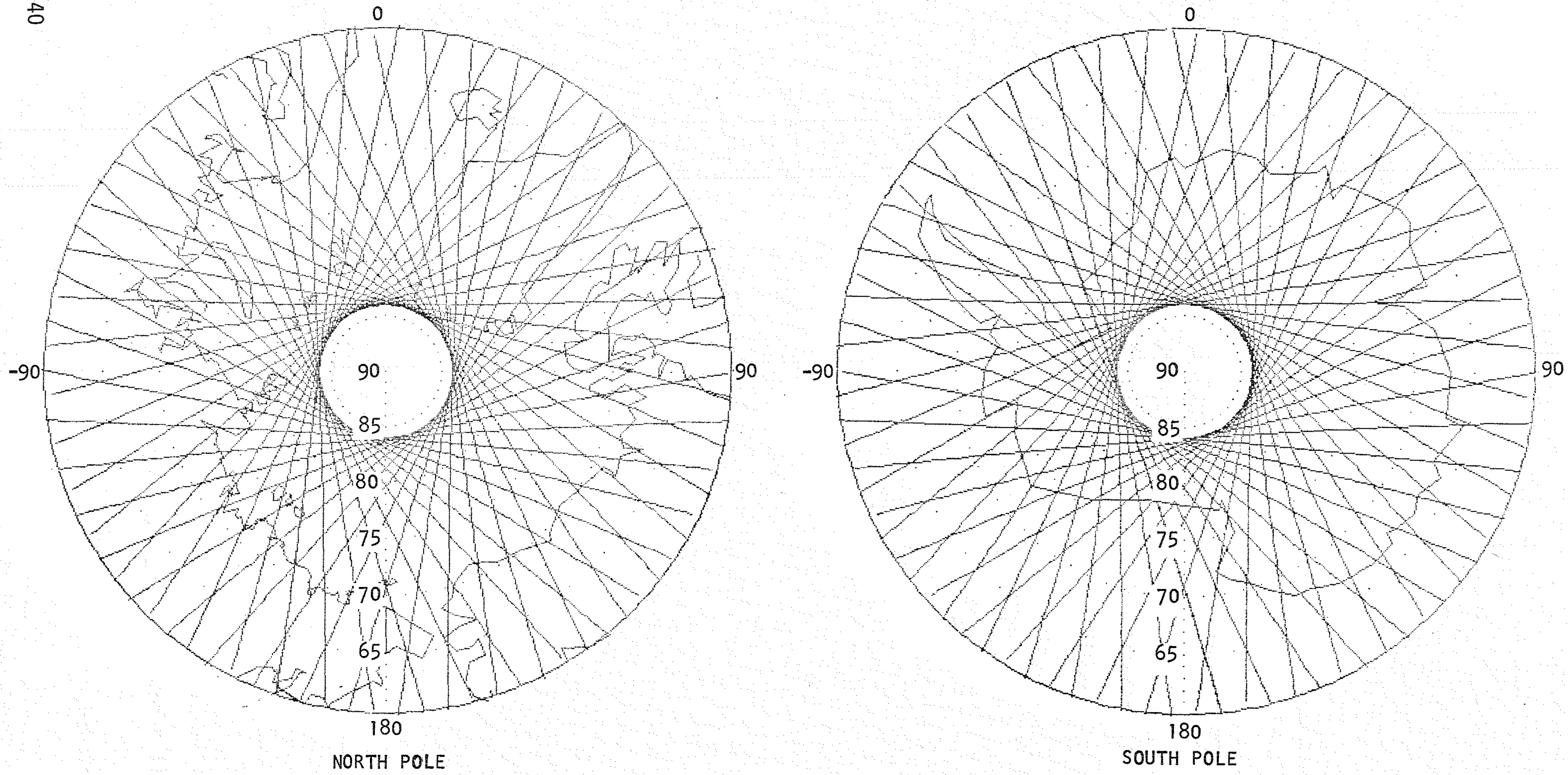
b) Orbit parameters: i=87°, h=757 km, Q=14 1/3 orbits/day.

Figure 5.-Continued.



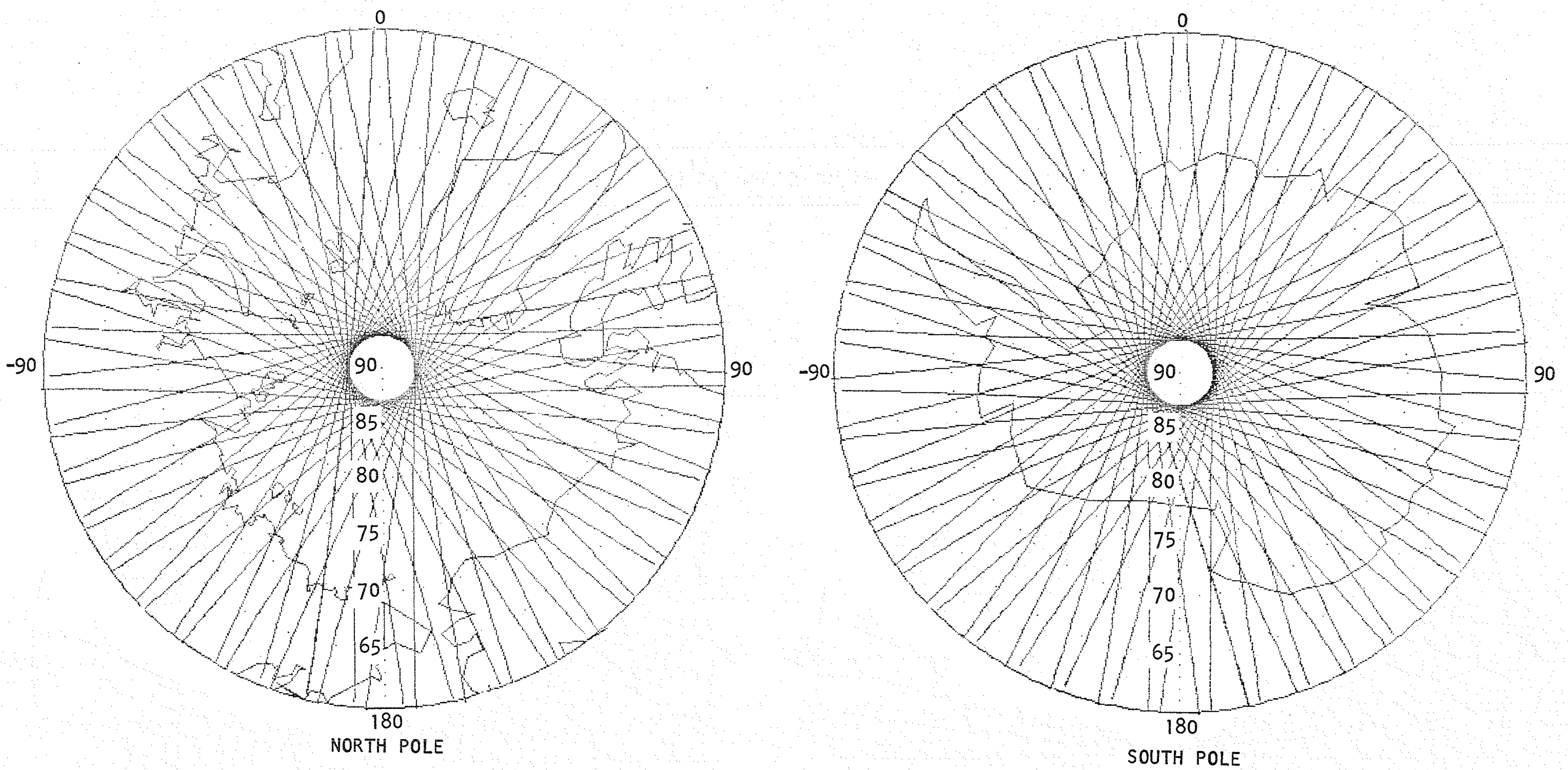
c) Orbit parameters: $i=98.5^{o}$, h=775 km, Q=14 1/3 orbits/day.

Figure 5.-Concluded.



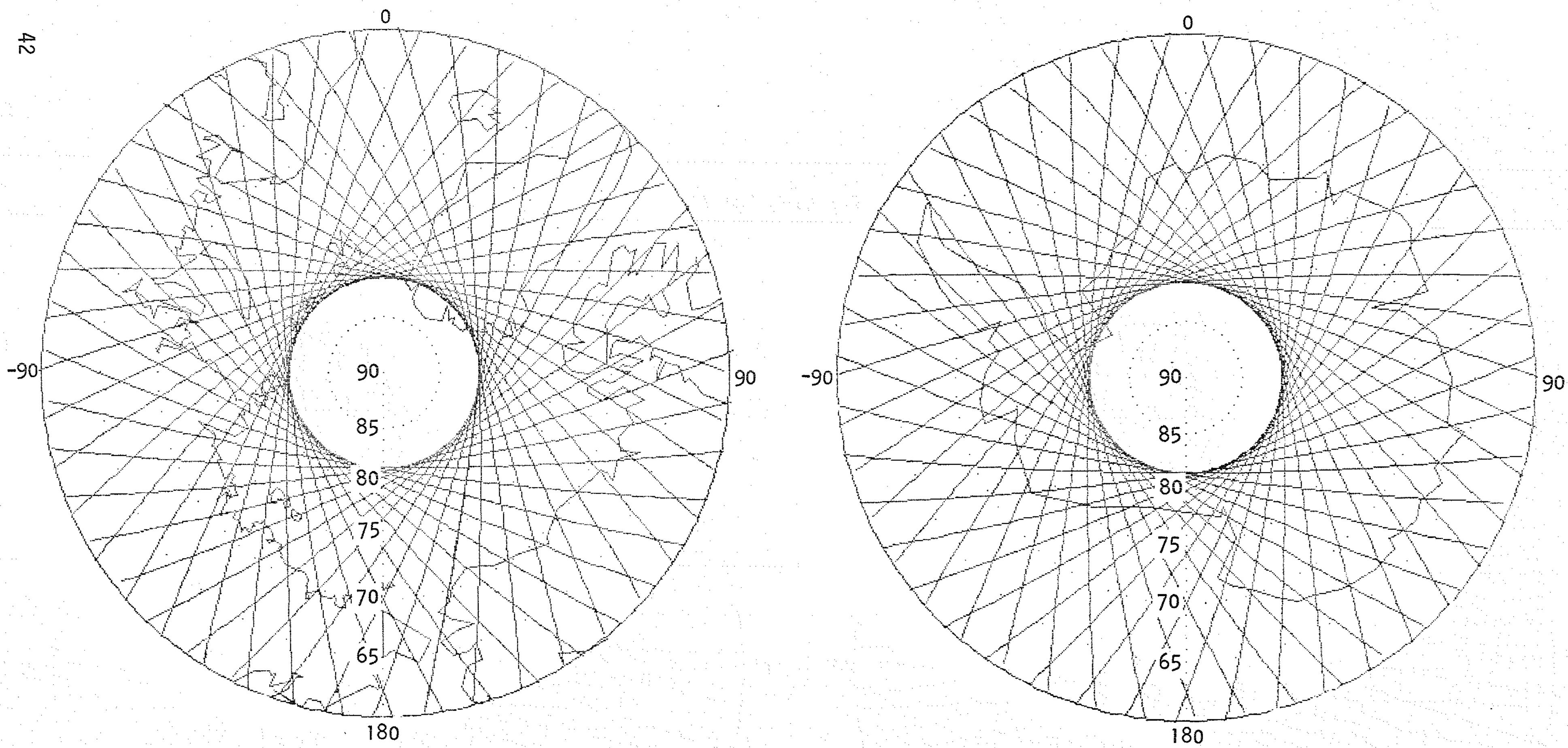
(a) Orbit parameters: $i=84^{\circ}$, $h=752$ km, $Q=14\ 1/3$ orbits/day.

Figure 6.- Ground track coverage with 3-day repeat orbits over the polar cap regions. Ground tracks are shown on Polar Stereographic projection. Outer numbers represent degrees of longitude; inner numbers are degrees of latitude.



(b) Orbit parameters: $i=87^{o}$, $h=757$ km, $Q=14\ 1/3$ orbits/day

Figure 6.-Continued.



NORTH POLE

SOUTH POLE

(c) Orbit parameters: i=98.5^{o}, h=775 km, Q=14 1/3 orbits/day.

Figure 6.-Concluded.

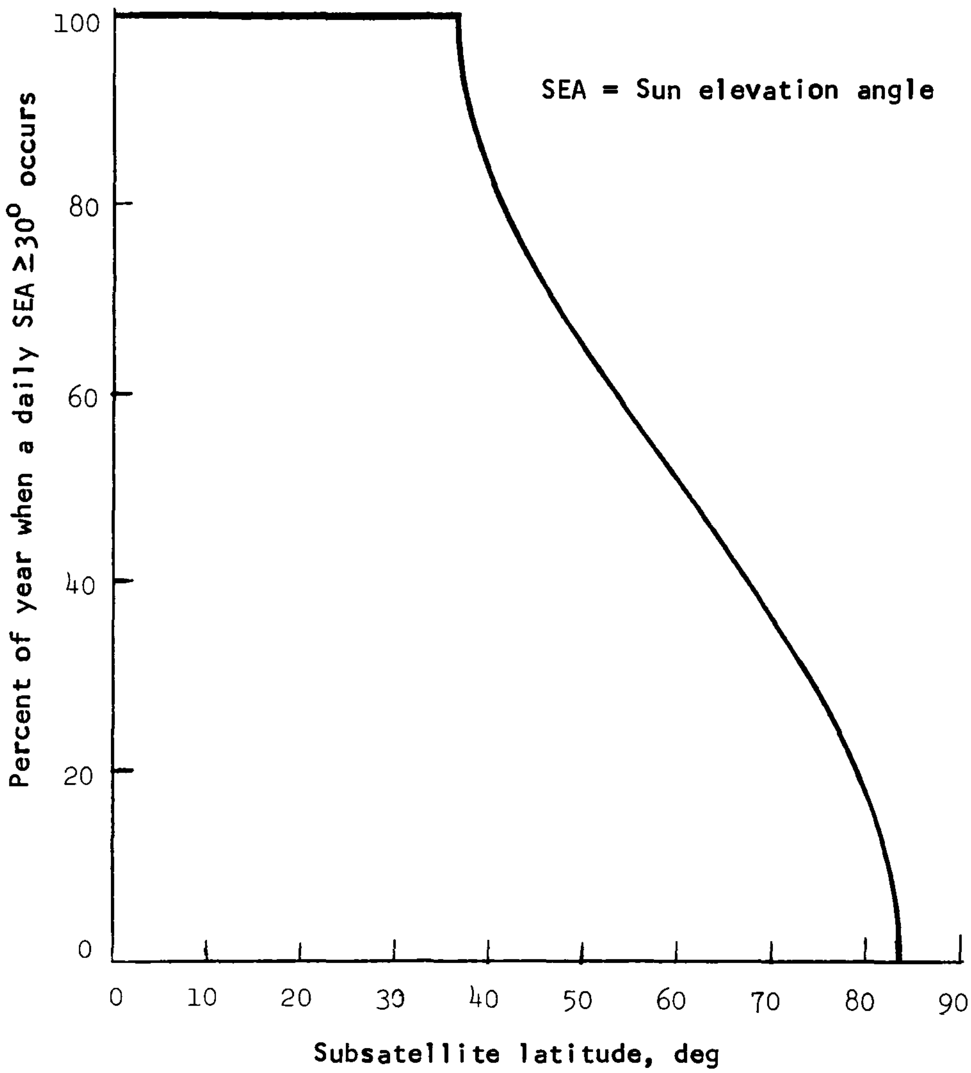


Figure 7.- Percent of year that a daily SEA $\geq 30^o$ exists, as a function of subsatellite latitude.

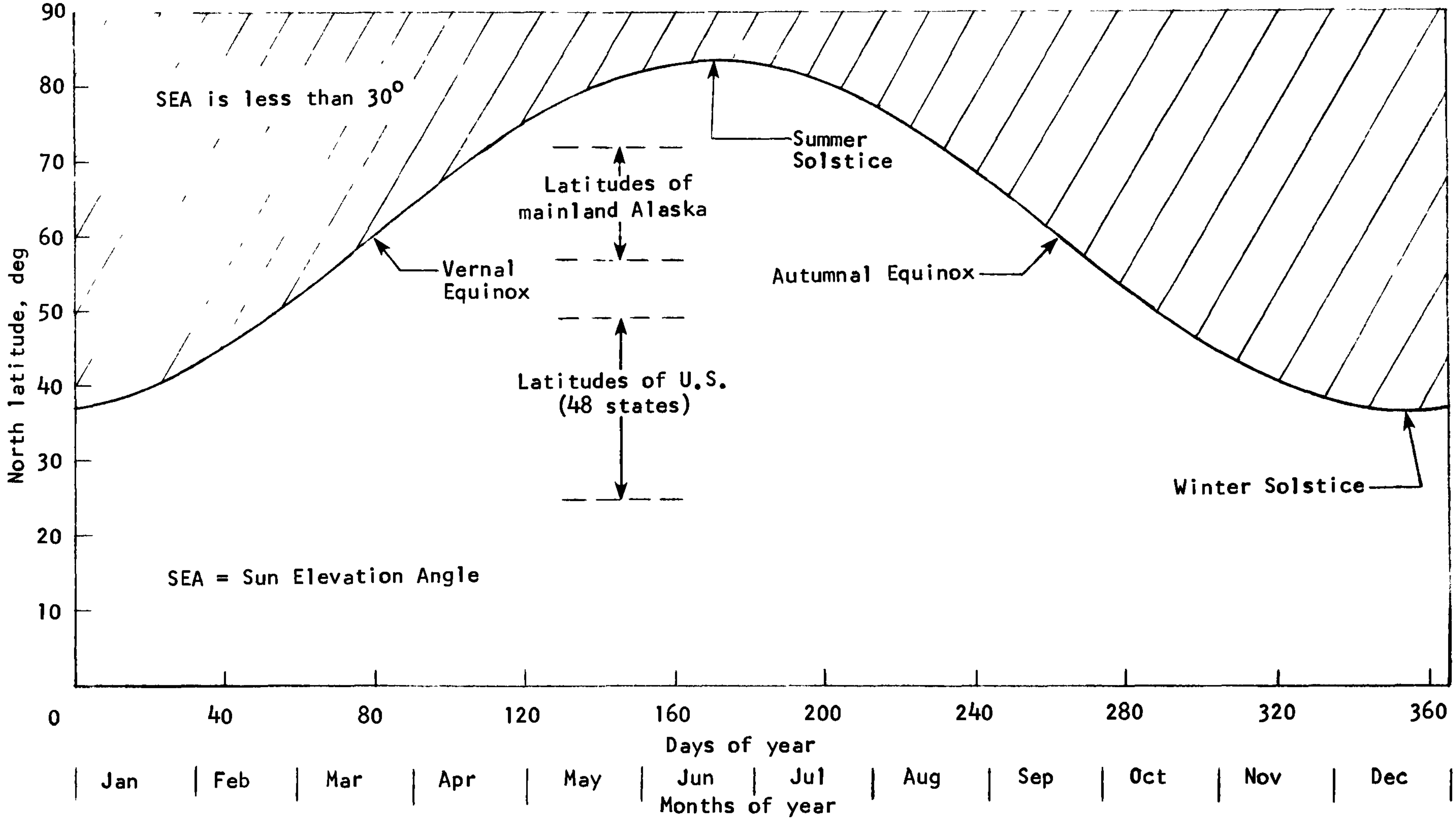


Figure 8.- Variation during the year of maximum north latitude for which a SEA$\geq 30^{\circ}$ occurs daily.

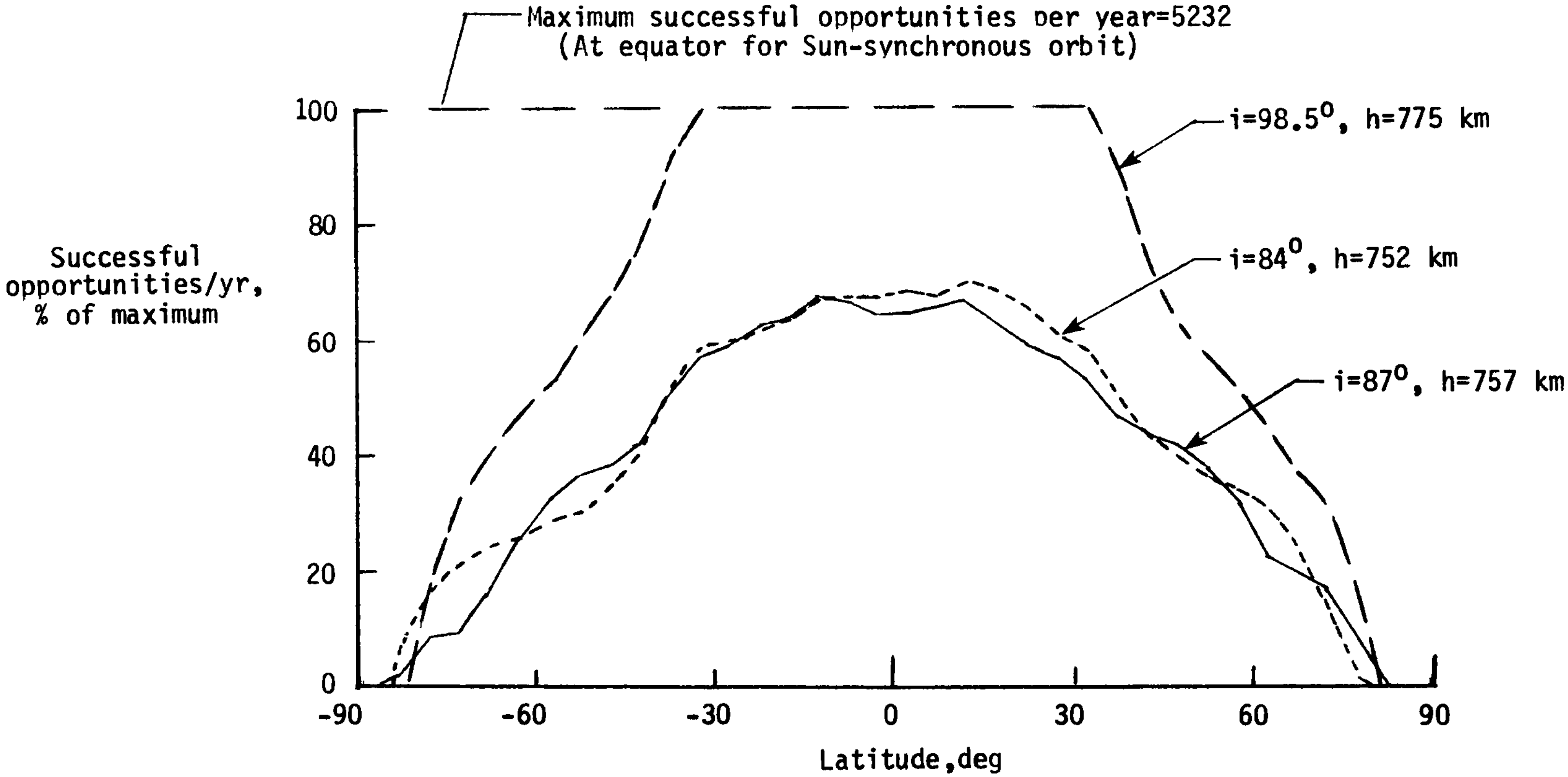
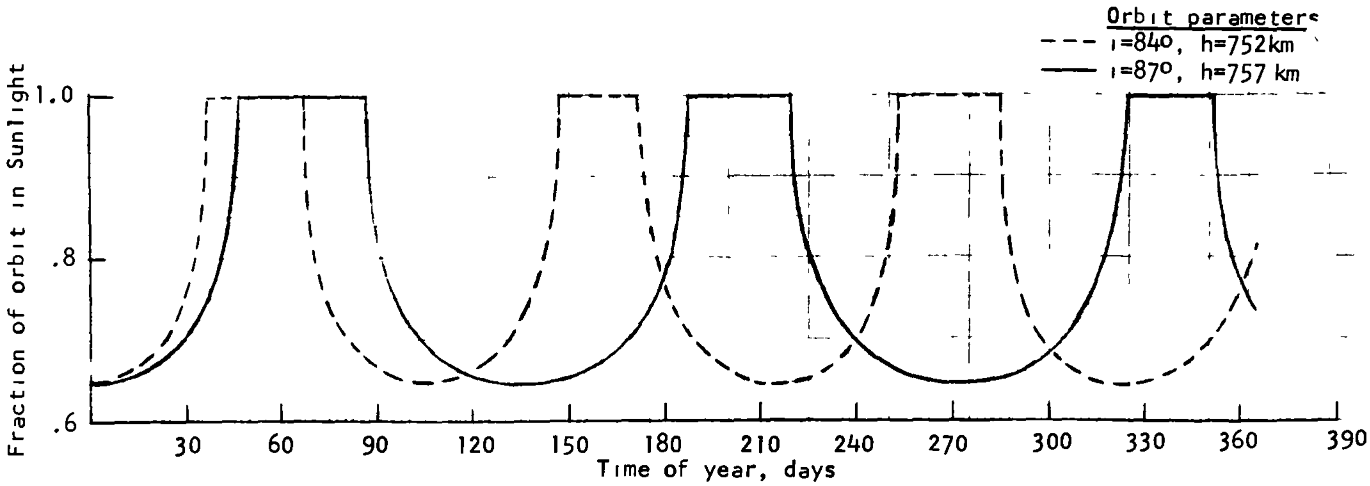
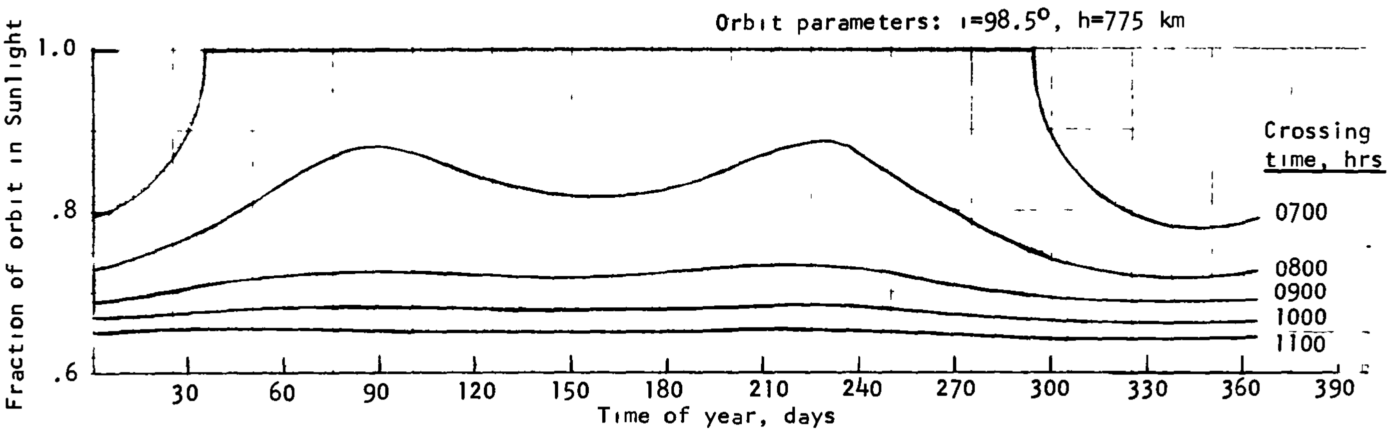


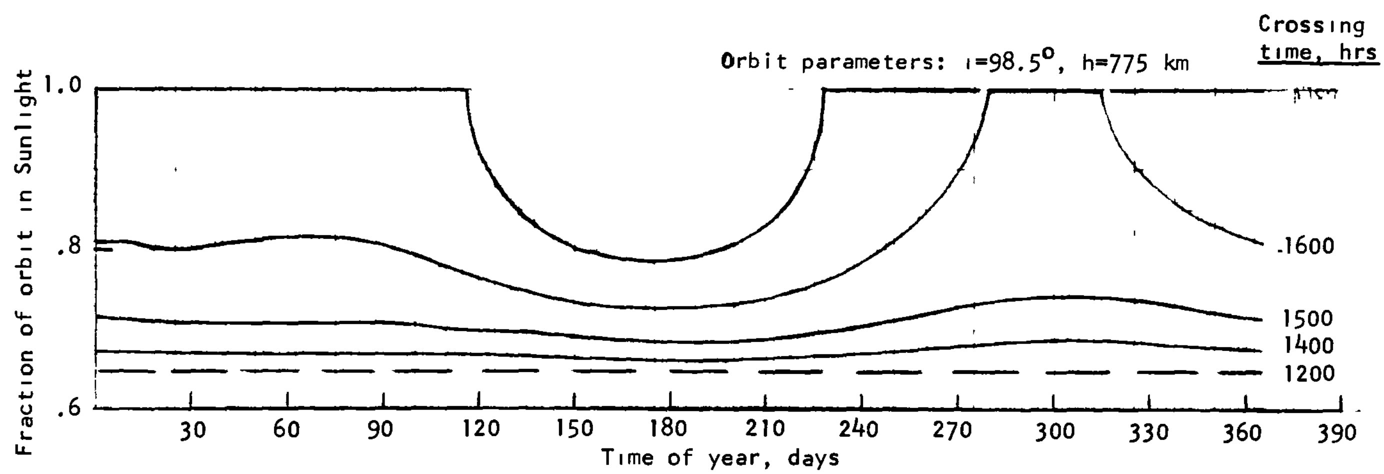
Figure 9.-Histogram of the Earth viewing opportunities when the SEA is greater than or equal to 30 degrees for three, 3-day orbit cases. SEA=Sun elevation angle.



(a) Non-Sun-synchronous orbits.



(b) Sun-synchronous orbits, morning equatorial crossing times.



(c) Sun-synchronous orbits, afternoon equatorial crossing times.

Figure 10.- Variation of orbit fraction in Sunlight with orbit parameters.

End of Document