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# USE OF SATELLITES IN COASTAL ENGINEERING

by


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and

Dennis W. Berg



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PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

# USE OF SATELLITES IN COASTAL ENGINEERING

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## ABSTRACT

Although coastal engineers have taken great strides in understanding and quantifying the complex coastal phenomena of the coastal zone, we are hampered severely by a lack of basic information of the coastal wave and current climate and a lack of understanding of the coastal processes of most of the coastlines of the world.

Even the processes governing changes in the waters adjacent to our major cities are only modestly understood. The basic reason for this is a lack of "tools" or techniques to make measurements in the coastal zone.

A new concept in data gathering has been generated using earth satellites. These satellites may observe areas of the coast and adjacent seas during times when other methods of sensing would be very difficult or essentially impossible. This paper describes the unmanned Earth Resources Technology Satellite (ERTS) which will be in orbit in 1972 and also the manned Skylab Satellite which will be in operation shortly thereafter.

We are particularly interested in exploring possible international cooperation using the ERTS and subsequent satellites in coastal engineering and coastal processes with qualified investigators, by providing satellite imagery of desired locations over an extended period of time and by exchanging technical evaluations of satellite imagery developed in research programs in

this country. In the ERTS data, resolving power will be in the range of 80 meters and so will be suitable for generalized information or gross coastal process. Subsequent satellites are expected to have greatly enhanced capabilities.

USE OF SATELLITES IN COASTAL ENGINEERING

In other areas of the world we are faced with continued urban expansion along exposed coast and in protected bays and estuaries. In these areas new developments often upset delicate littoral balances. In order to minimize the effect of developments on the coastal environment and to provide a sound basis for coastal planning and design, engineers and scientists are continually striving to understand and quantify the processes and forces that operate in the coastal zone. Traditionally, this has been accomplished by detailed in-situ studies of relatively localized areas. These methods have contributed substantially to our knowledge but evaluation of imagery remotely obtained from high altitude platforms has made us aware that synoptic surveillance may greatly enhance our study efforts (Figure 1). The unmanned Earth Resources Technology Satellite (ERTS) is expected to provide an opportunity to develop these techniques.

NASA'S EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS) PROGRAM

According to present planning, data from the first ERTS will be available in 1972. These data will provide synoptic multispectral images which can be used for a wide variety of application studies and experiments.

The ERTS observatory will carry two sensor systems, a line-scanner with four spectral channels and a return beam vidicon system providing three spectral channels, and a data relay system.

NASA will receive, process, store, and distribute copies of all data collected from the multispectral sensors in the form of high quality film images and/or digitized data on computer-readable magnetic tape.

The return beam vidicon (RBV) camera and multispectral scanner (MSS) subsystems will furnish independent views of the earth directly below the satellite to data acquisition stations on the ground. Two wide-band video tape recorders will store up to 30 minutes of picture information for delayed readout.

Since the spacecraft will be in a sun synchronous orbit, the images will be obtained at the same local time on each pass. The shutters of the RBV cameras will be timed to take pictures every 25 second which will result in approximately a 12 nautical mile overlap in direction of flight. The design criteria called for a minimum image sidelap of 10 nautical miles. The final orbit definition resulted in an image sidelap of approximately 14 miles at the equator. However, the sidelap increases relative to distance from the equator. At 45 degrees north or south latitude the sidelap will be about 50 miles.

It might be interesting to discuss the selection of the orbit for the ERTS A and B missions. The overall mission requirements were established to give synoptic coverage, repetitive coverage, and also a reasonable resolution capability. Another problem which had to be considered was the space to ground communication. These communications depend upon a line of sight between the satellite and the receiving station. Since the tape recorder can only be turned on for a specific period of time due to power constraints, the satellite altitude had to be sufficiently high to make maximum use of communication. These parameters led to the selection of an orbital altitude in the range of 500 nautical miles. Given that range the exact altitude and orbital configuration was developed. It was found that an altitude of 481.6 nautical miles resulted in an exact repeating ground trace every day. Fourteen separate ground tracks are generated and then repeated each day. By moving to a slightly higher or lower altitude, the ground tracks no longer exactly repeat but will shift gradually each day until complete earth coverage is eventually obtained.

With an altitude greater than 481.6 nautical miles, day to day ground track progression is to the west. This occurs because the orbit period is increased. It takes longer to make a revolution about the earth and the earth rotates to the east through a slightly larger angle between equatorial crossings of the satellite. Thus, the nominal orbit altitude will be slightly higher than 481 nautical miles. The final computations resulted in an altitude of approximately 492 nautical miles which provided complete coverage in 251 revolutions. The spacecraft will orbit the earth fourteen times each day and the ground track will proceed westward producing global coverage each eighteen days (Figure 2). Since it is desired to maintain the scale variations in sensor imagery to less than 10 percent between maximum and minimum altitude, the accentricity of the orbit is nominally zero.

The three RBV cameras will view the same 100-mile square ground scene from the observatory (Figure 3), but they will be sensitive to different spectral bands within the total region from 0.48 to 0.83 microns (Figure 4). When the cameras are shuttered, images will be stored on photo-sensitive surfaces within each vidicon camera tube, then scanned to produce video outputs. The cameras will be scanned in sequence requiring about 3.5 seconds to read out each of the three images. To produce overlapping images of the ground along the direction of satellite motion, the cameras will be reshuttered every 25 seconds.

The MSS will collect data by continually scanning the ground directly beneath the observatory (Figure 5). The width of the strip will be identical to the coverage by the RBV, 100 nautical miles. Optical energy will be sensed by an array of detectors simultaneously in four spectral bands (from 0.5 to 1.1 microns) on ERTS A, and an added fifth band (from 10.4 to 12.6 microns) for ERTS B. During ground processing, 100 by 100 nautical mile frames will be constructed from the continuous strip to correspond with the RBV information.

RBV and MSS data will be transmitted to the tracking stations at via dual wide-band (20 MHz) S-band data links where they will be recorded on magnetic tape. These tapes will be shipped daily to the NASA facility in Washington.

The data processing is possibly the most challenging aspect of the operation. ERTS A and B have simple sensors as compared with what we expect later but they still will have data rates three orders of magnitude greater than the present meteorological satellites. The return beam vidicom with an approximate 4,000 by 4,000 TV line format, produces 16 million elements per frame in each of its three spectral bands. With forecasted improvements and resolution over the next decade, data rates increase significantly. A two-to-one improvement in resolution results in a four-to-one increase in data, a four-to-one improvement results in a sixteen-to-one increase in data. Another factor of two can be applied if the numbers of spectral bands increase as expected from four bands to eight. This data rate increase strains the space to ground communications capability and impacts frequency allocations, radio frequency transmitter power and data processing. The data quantity forecasted for ERTS A and B dictate a new approach to data processing. Most of the satellites have transmitted data for ground processing by a digital computer. In ERTS it is forecasted that data will be generated at a rate of $10^{11}$ power picture elements per week. With today's computer tapes systems this would mean more than 300,000 roles of computer tape per year. Each return beam vidicon picture would take a full role of tape. Multispectral scan data would be able to place three pictures on one tape. In order to reduce these processing problems it is intended that the data will be selectively collected, that analog and hybrid processing will be used extensively, and that digitizing will be retained for specific analysis needs only. In effect, the mass data storage will be provided through converting digital response to pictorial images, thereby using photo generation as a safety valve for an otherwise unmanageable or at least very expensive computer configuration. In this way the digital computer controls the process but it is in itself not the process.

It is anticipated that close to a half million master images will be processed and stored at the data processing facility (DPF) each year. The storage and retrieval system will aid the user in selecting only those images that will be of significance to him. Functions to be performed within the DPF include:

(1) <u>Conversion</u>

Bulk Processed - All images will be corrected for geometric and radiometric errors and printed in black and white. Twenty percent of bulk-processed images will be printed in color.

Precision Processed - Film master images of RBV and MSS frames selected by the user can be further corrected and transformed into selected map coordinates and precisely annotated with ground location tick marks.

Special Processed - Computer-readable tape records will be made from a selection of bulk and precision processed images.

(2) <u>Working Storage</u>

All data at the DPF will be logged and maintained in active storage for efficient access on a user's request.

(3) <u>User Services</u>

Users will have access to all DPF data through several files to provide efficiency in searching areas of interest. Some of these aids are:

Browse Files - Complete microfilm file for all images arranged by date and location.

Coverage Catalog - Listing of U. S. images that are returned over an 18-day orbit cycle. This catalog will be updated on a regular schedule.

DCS Catalog - Listing of information available from the remote earth platforms.

(4) <u>User Products</u>

Data requests from users will be photo-processed in either black and white or color from copies of images stored in the master file. Samples of bulk and precision imagery and color composites will be available to aid the user in selecting the most usable material.

(5) <u>Standard Format</u>

Images on the standard format will be to a scale of 1:1,000,000 of the 100-mile square image area. Annotation supplied with each image will include such useful information as identity of the sensor, spectral band, date and time of exposure, sun angle, and location.

A general view of the observatory configuration is shown in Figure 6. Nominal orbit parameters are shown in Figure 7.

Several of the coastal engineering experiments planned in the United States by the Corps of Engineers are described in the following section.

Near-Shore Processes Study of the California Coast

The specific goal of the proposed study is to develop additional information on coastal processes based on remote sensing. The four study elements are: (1) nearshore currents, (2) estuarine exchange, (3) seasonal river discharges, and (4) waste dump dispersion. These elements are related by the observable phenomena which define them. It is felt that the basic set of remote sensing data types can be applied to all the study elements of interest. Along the California coast, test cells have been selected where concurrent sea truth and aircraft measurements may be made with respect to ERTS overflights. Automatic and semiautomatic data processing enhancement techniques will be utilized to obtain maximum pertinent information from the data. Methods of obtaining the proposed objectives are set out in the summary of technical tasks which follows.

The anticipated result of this study will be a body of information relating remote sensor measurements from spacecraft and aircraft platforms of topics of interest and importance in coastal engineering. The specific anticipated results include: (1) Evaluation of space and airborne remote sensors for definition of California nearshore processes acting to transport sediment and pollutants, and their dispersion characteristics, (2) Evaluation of automatic and semiautomatic data interpretation techniques for information extraction and to provide correlation of sensor data (space or aerial) to nearshore processes, (3) Evaluation of ERTS A data (and supporting aircraft sensor data) for the improvement of any capabilities in coastal engineering, (4) Application of information derived in this study to current programs, and (5) Defining of future requirements for remote sensing and space observation programs such as sensors, resolution, observation frequency and spectral content.

## NEARSHORE CURRENTS

The detection, direction, and dispersion patterns of nearshore currents are of great interest to many users, including the U. S. Army Coastal Engineering Research Center (CERC), to aid in the prediction of sand transport, outfall dispersion, and general effects on coastal structures. Theoretical studies of beach behavior, supporting design, location, and maintenance of coastal structures are of great importance. Beach behavior is to a large degree a reflection of the littoral processes acting upon it. Prime among these are the currents which act as directive and motive forces for sand and fine sediment transport.

Created when water in one area becomes higher than another, either from density difference or by tide, wind, and streams inflow effects, currents existing within the surf zone, directly outside the surf zone, and even a considerable distance offshore all affect the shore indirectly or directly. Since waves in deep water cause a net volume transport in the direction of travel, ultimately this water strikes a reasonably impermeable boundary (shore) and is deflected. A discrete current arises from the "piling up" of water at the shore. Generally this current is confined to the surf zone, and runs at an acute angle to the wavefronts driving it. A large volume of water "piling up" against the shore results in rip currents carrying water and sediment offshore into dispersion areas. Transport outside the surf can occur in a longshore fashion as well (Shepard and Inman, 1951, Trask, 1955). Classically a littoral cell is set up where material moved offshore by a rip is brought back onshore by the "downstream" wave action between one rip and another. However, a net transport of material can occur as evidenced by seasonal movement of large volumes of sand offshore and onshore (Engle, 1966), and by the filling and the flushing of submarine canyons such as at Newport Beach, California. The net offshore flow probably results along the bottom during stress storm conditions but bottom currents may be reflected by near surface turbidity. Even when sediments have been removed from the seasonal littoral cycle, it appears that movement occurs across the breadth of the inner shelf (Engle 1966), hence, the utility of broad areal ERTS A type coverage. Many investigators feel that sand fields offshore in the zone where storm waves remove sand constitute a major downstream sand transport mechanism. If this is so, then offshore currents play an important part along with wave action in putting the sand fields in motion. In certain areas of the California coast, the major contributors to the formation of rip currents are edge waves, induced by the non-linear interaction of breaking waves. These waves are under study in specially designed test facilities at the U. S. Army Engineers Waterways Experiment Station (WES), Vicksburg, Mississippi. These tests are sponsored by the California Division of Highways with the purpose of developing design criteria for perched beach-highway construction in nearshore areas of Southern California. A variety of factors affect the development and characteristics of nearshore currents and transport; e.g., offshore topography, coastline shape, direction of waves, size of waves, shape of waves, and season. It is planned to study these grosser currents for relating sea truth (LEO), (Berg 1968) nearshore turbidity patterns which are determined from ERTS A, since determination of current elements within the turf zone are beyond the ability of ERTS A to resolve (spatially).

ESTUARINE EXCHANGE

Population centers generally develop around estuarine areas with virtually all of the world's estuaries having been affected by humans. Within the estuaries, normal siltation processes have been accelerated by nearby onshore construction, dredging, and increased upstream erosion. Pollutants derived from population centers either by direct sewage discharge, industrial discharge, or storm water overflow systems commonly are emptied into the nearest available estuary. Great quantities of pesticides and fertilizers are added directly to the rivers or are transmitted there via storm drain runoff. In general, this material enters the estuary and is dillluted to some extent. Tidal cycles and the currents induced thereby act with the fresh water outflow to provide a complex flushing or exchange situation. Materials entering into the estuary may act as nutrients or may be toxic; hence, overgrowth of algae or other plant types may occur. Removal of wastes from the estuary waters may be accomplished by sedimentation, diffusion, exchange, chemical or biologic conversion, or it may remain intact in the estuary. Of prime importance is the volume of water--tidal or river--available for removal to the sea. The rate of influx of fresh water from a river varies greatly; conditions within the estuary change in response. In southern California the rate inflow is sporadic and generally low. Only in times of storm do large amounts of fresh water flood the estuaries. Probably the dominant factor is the tide. In general the main problems to be studied in estuaries are the water movement, the mixing processes, and the distribution of salinity which results. In this proposal we are interested in the water movement out of estuaries.

Remote sensors constrain us to seek any type of tracer which shows mixing in the surface layer; hence, such models as have been developed (e.g., Ketchum 1951), generally based on cross section of temperature and salinity effects, are not directly applicable. Instead we are left with dyes, pollutants, and differential suspended sediment concentration to demarcate the surficial difference between water masses and their mixing. Although some investigators claim that estuarine turbidity shows little relationship to the volume of freshwater input, the areal distribution of mixing turbid water in the ocean adjacent to estuaries increases in marked proportion to the freshwater influx as shown by storm effects off southern California. Temperature, which along with salinity defines density, hence giving information on currents and mixing, is useful in terms of remote sensing only in the surface layer because of the observational constraints.

It is also important to know the fate of those natural "tracers" removed beyond the estuaries. Estuaries are generally floored by fine sediment; hence, their waters are quite turbid, in some cases ranging from 60 mg/l to 1g/l of suspended solids. Indeed estuaries are excellent sediment traps. In the main the particulates are moved into suspension by tidal action. In contrast to the turbidity of an estuary most open shelves have suspended solid concentration on the order of a few mg/l.

Suspended sediment often times acts as a scavenger for nutrients and pesticides. Clays absorb pesticides, hydrocarbons and other organics as well as heavy metals and radioisotopes. In addition, the same currents which act upon the dissolved wastes such as those described also act upon the suspended sediment. Hence, a natural tracer is available to track in a gross fashion the transport/characteristics of estuaries flushing, and to perhaps give information on the dispersion/residence time characteristics. Transport and long-term disposition of urban wastes from estuaries is quite important, as well as knowledge of flushing rates for a short-term determination of quantities of noxious material which can be dumped and flushed (Ingram, 1956).

Estuarine studies encounter two primary variations, temporal and spatial. A time series data set is necessary when dealing with a problem that varies on a seasonal, semidiurnal, diurnal, monthly and yearly basis. In addition, random effects occur based on wave and wind direction perturbations with suspended solids during the day. Spatial variability occurs in terms of large-scale structure of coastal water masses, and small to large scale random variations due to turbulence.

The best case of estuarine data collection would be to develop a time series of data over a long period, with large amounts of synchronous sampling at each time datum. The basic assumption needed to use remote sensing however, is that either the surface layer is representative of exchange (probably not wholly true) or that knowledge of surface layer excursion and dispersion with selected cross sections information is representative. A combination of simplifying assumptions, synoptic satellite data, selected aircraft overflights, and concurrent sea truth observation at selected points will provide a viable approach.

SEASONAL RIVER DISCHARGES

Southern California streams serve as a reservoir for sediment most of the year and during storm periods debouch great quantities of detrital material into the coastal transportation system. Southern California has a semiarid climate with easterly moving storms coming across the coast from the Pacific during the season of rainfall (October through April). These storms rise rapidly up the precipitous mountain ranges sometimes producing tremendous rains. Debris flows containing material ranging from pebbles to 10-foot boulders are moved during resultant flash floods (Slosson, 1960). The principal drainage systems crossing the coastal areas have their source in these mountain ranges and are located a relatively short, steep distance from the sea coast. Although urban centers cover the alluvial fans fronting the ranges, detrital material is still transported -- even along the concrete lined drainages -- albeit in reduced volumes.

Flood regulation and conservation storage dams across major streams, debris dams and basins and concreted major channels all cut down the amount of material replenishing the beaches. Hence, the influx of sand, silts, etc., as well as much coarser material is primarily of a seasonal nature. An exact correlation between suspended fines and bed load transport is not yet determined. However, it is intuitively felt that there is a "relation" to be developed, and the CERC has an effective contract with the University of Southern California to collect and analyze data on the material contributions and distributions of a southern California watershed, the San Juan Capistrano River.

Following stormy periods turbid plumes have been located many miles further into the open ocean than usual

A

time series study of plume long-term distribution as a result of nearshore currents, as well as major features such as the California current and counter-current systems is a definite ERTS A application.

For example, water flowing out of the Santa Ana River is fresh water with a heavy load of suspended sediment of mostly clay-sized particles. Some sand-sized sediment is carried by traction and saltation (i.e., slow flow along the bottom or by bouncing along the bottom) short distances seaward where it is transported downcoast in the surf zone. The fine-grained sediment floats on top of the more dense salt water. Since turbulence increases the rate of diffusion of this fine material, the fresh water with its sediment is spread over vast areas before settling to the bottom. As the suspended particles slowly settle out the turbidity dissipates. The littoral drift is toward the bottom of the photographs as evidenced by the lack of turbidity above the river mouth. The offshore current is transporting the sediment downcoast. The turbid water which is discoloring the sea surface in the center of the picture and which extends up current from the mouth of the river is probably fine-grained surface sediment which has been carried up current by an offshore wind. The dark spot in the center of the photograph possibly indicates an accumulation of sediment concentrated by a wind vortex.

Sediment from the Santa Ana River to the right of the picture, Figure 4, is being disseminated along the beach and off the coast. At least four distinct water discoloration boundaries (cells) can be observed resulting from sediments flowing from the Santa Ana River. In the center of the picture a possible oil leak is present as evidenced by the dark black splotch in the light brown sediments. The sediment patterns are most likely related to tides or changes in water velocity and water volume flowing out of the Santa Ana River. As the sediment laden fresh water contacts the salt water, flocculation occurs and settling results. Since there is little turbulence, fresh water with its sediment load is spread out over vast areas before flocculation and settling removes it from the surface. Along the beach the littoral currents are moving sediments by traction and saltation. The sediments are being deposited on the beach, in the submarine canyon off Newport Beach and against the Newport Harbor breakwater as the current velocity is lost and the sediments are allowed to settle out.

DREDGE SPOIL DISCHARGE

As man combats the siltation processes in his chosen estuaries, harbor channels, and rivers, and as he attempts to rid himself of his urban waste products, near coast dumping occurs. Of course, if one is to dump products, it is nice to be assured that they do not return. In many cases one cannot be so assured because knowledge is lacking on the coastal currents to make prediction analysis of dispersion and ultimate disposition.

Studies by Calloway (1970) in the Gulf of Alaska, relate gross current features to the fate of oily ballast water and slop oil dumps in the water adjacent to the Pacific Coast of Alaska. Calloway's conclusions were that there was no really safe place to dump refuse even in the middle of the North Pacific -- eventually the material will turn up on the beach -- if in transit the wastes do not diffuse away, disintergrate and fall to the bottom, or merely degrade and become indistinguishable.

These conclusions were based on drift bottle, wind rose, and computed surface circulation (geostrophic calculations). Geostrophic surface currents are computed from a knowledge of the vertical density distribution at sample points with broad separation. Although these calculations cannot be duplicated from satellite information -- differing spectral properties are inherent in the (e.g., gulf stream) currents and various surficial water masses and a distribution pattern may be obtained which, especially on a synoptic basis -- may provide similar information. Such determination is felt to be well within the ERTS A capability, and combined with timed waste discharges in the offshore waters a great deal may be learned.

Wind drift is superimposed on the net density related currents, usually an onshore component exists during the month. Surface drift can be 2-5 percent of the imposed wind speed, hence wind can be a dominant factor in the transport of surficial material. Since spoil dumps, etc., do not stay at the air/sea interface but mix gradually through the surface layer (and ultimately settle out), wind effects may or may not play an important part in bringing such dumps back to shore.

Releases and movement of sediment by coastal engineering projects such as damming, dredging, and filling influencing the coastal habitat occurs in the offshore area. Wastes discharges at depth or insufficiently far offshore can move inshore again and even be brought into the estuary bottom water moving out on the surface. Hence, information on source, amount, fate and shore effects of debris disposal is desirable. Numerical modeling is used to a degree but inputs to models are not always sufficient nor is the model always accurate.

POSSIBLE INTERNATIONAL COOPERATION

In many areas of the world, important coastal features are known to various coastal laboratories and stations. A cooperative program to study or observe these areas by obtaining satellite images of those areas where an ongoing sea-truth program is available may provide a means of improving our understanding of basic coastal processes. In these instances, the funding of the image interpretation would be the responsibility of each cooperative ogranization but the acquisition of the remotely sensed data could, within the constraints of the system, be obtained by the U.S. National Aeronautics and Space Administration.

CONCLUSIONS

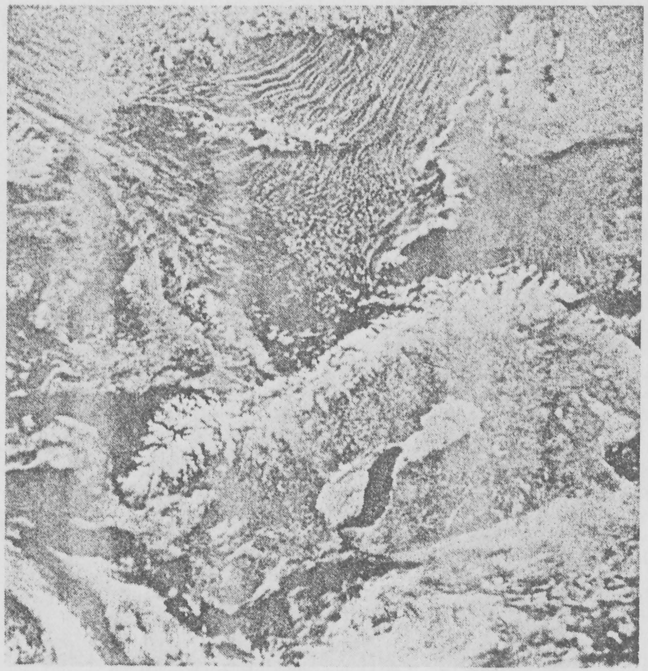
Based on the information and proposed experiments presented in this paper, the use of satellites to obtain information over vast coastal areas essentially simultaneously, looks very promising and should yield advances in understanding of coastal processes on a gross scale.

ACKNOWLEDGEMENTS

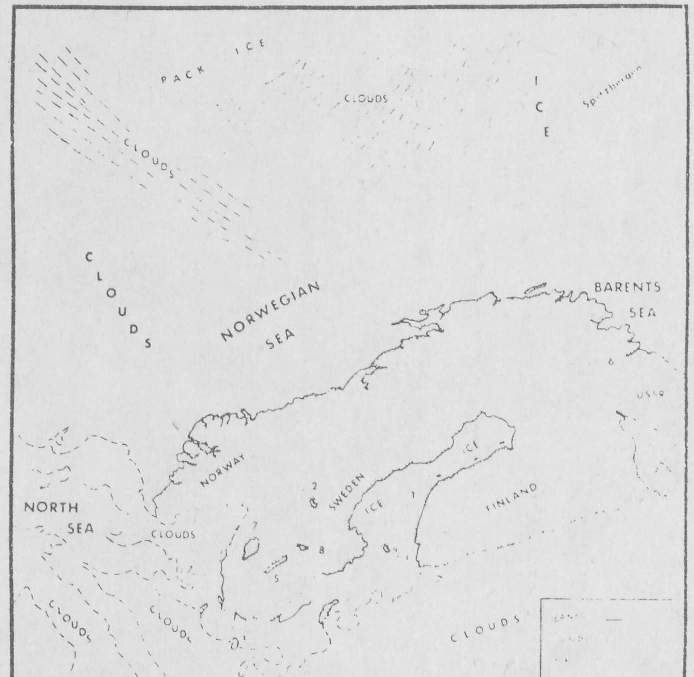
The material presented in this paper was largely obtained from the National Aeronautics and Space Administration (NASA) and from NASA proposed documents "Nearshore Processes Study - California Coast" and "California Coastal Processes Study Using Skylab Data." These two proposals are in a large part the work of Mr. Thomas E. Harrowby of the Space Division of North American Rockwell, Downey, California, and his supporting staff. The authors gratefully acknowledge the assistance given by the staffs of these organizations. The opinions presented are those of the authors and not necessarily those of the Corps of Engineers.

# NIMBUS 4

SCANDINAVIA



IDCS ORBIT 68 13 APRIL 1970




1 – GULF of BOTHNIA 4 – BORNHOLM 7 – L VANERN 10 – WHITE SEA
2 – L SILJAN 5 – L VATTERN 8 – L HJALMAREN
3 – GOTLAND 6 – MURMANSK 9 – AHVENANMAA

Fig. 1

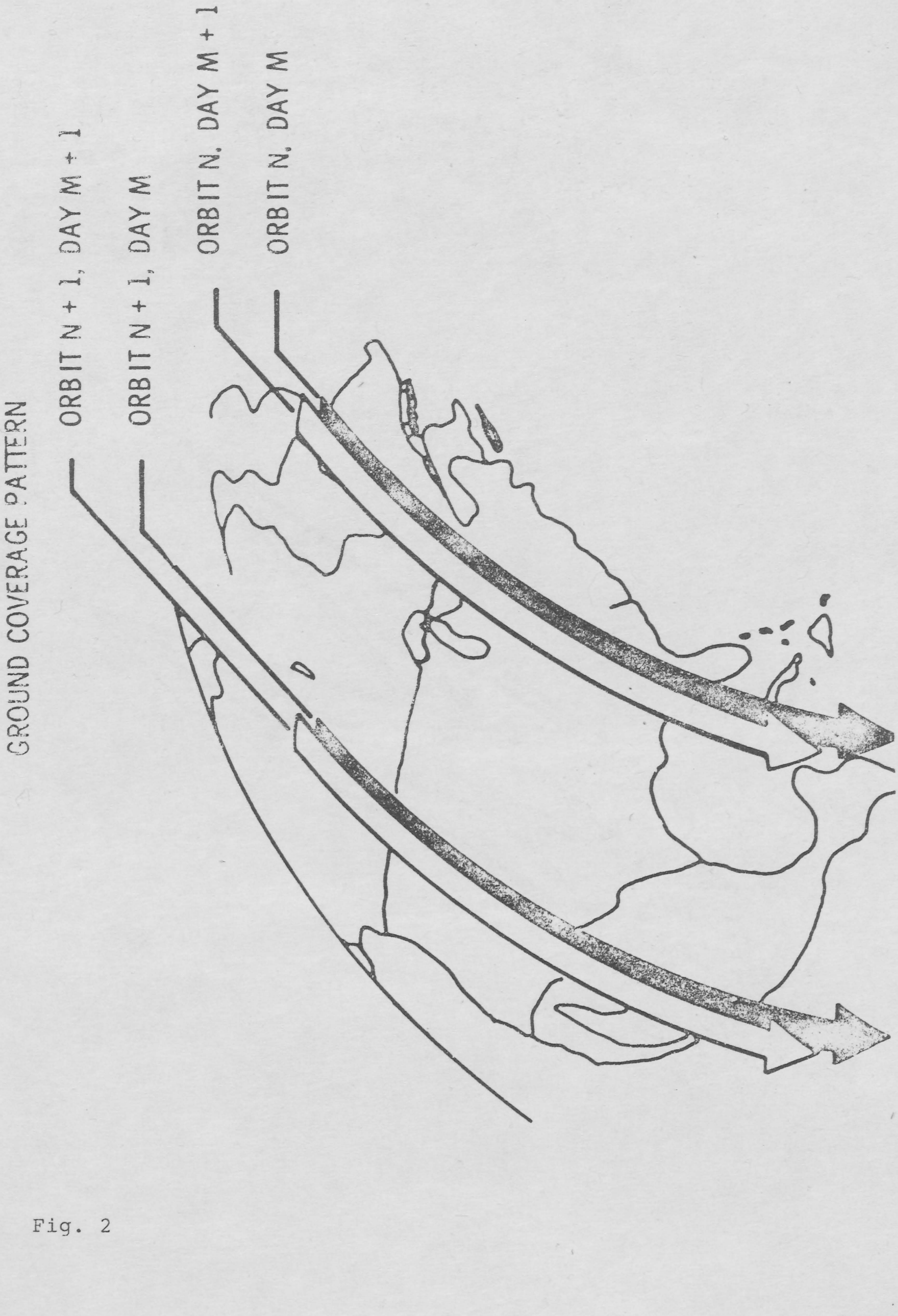

GROUND COVERAGE PATTERN
ORBIT N + 1, DAY M + 1
ORBIT N + 1, DAY M
ORBIT N, DAY M + 1
ORBIT N, DAY M

Fig. 2

Fig. 3

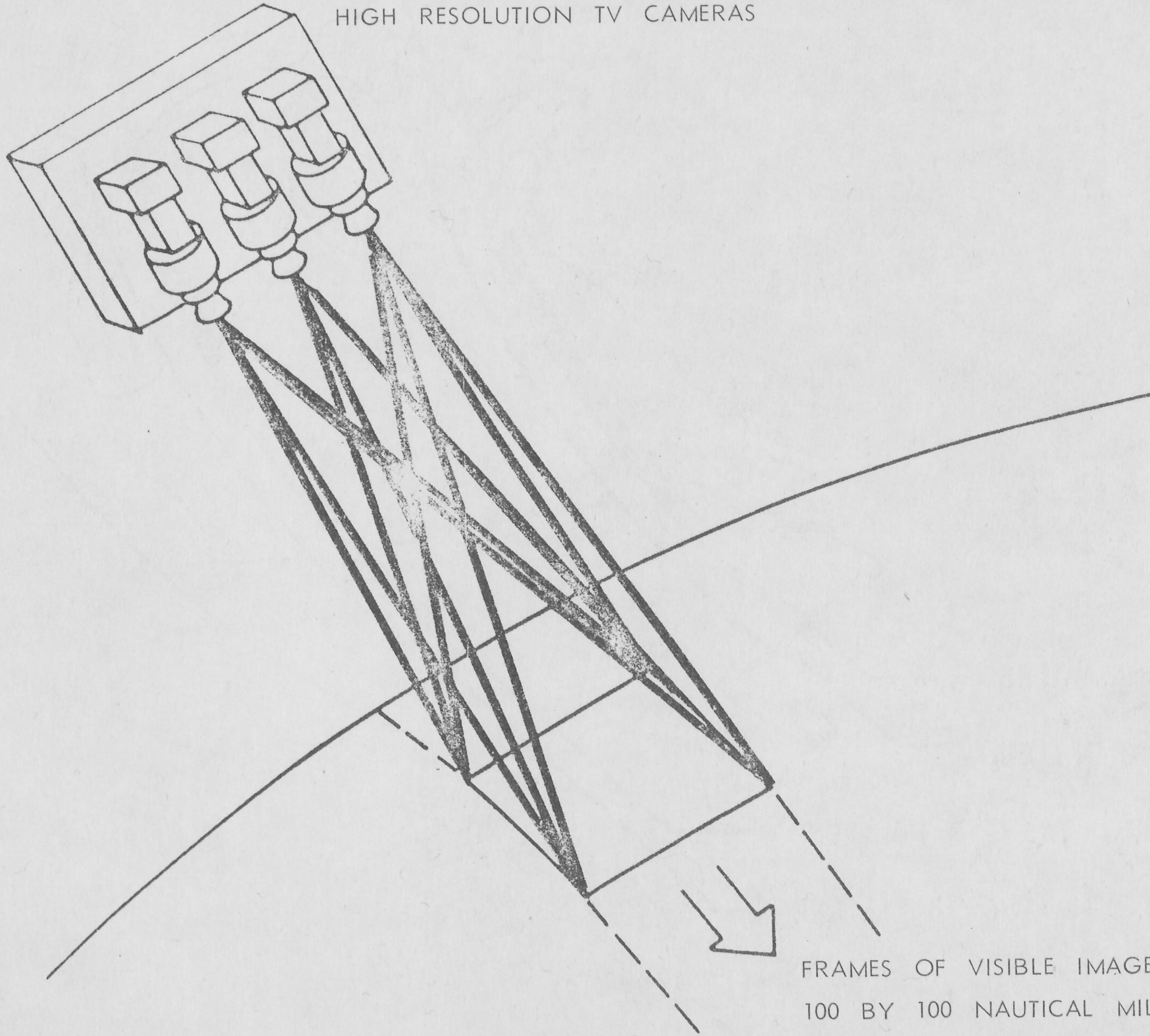

HIGH RESOLUTION TV CAMERAS
FRAMES OF VISIBLE IMAGERY OVER
100 BY 100 NAUTICAL MILE AREA

Fig. 4

# RBV CHARACTERISTICS

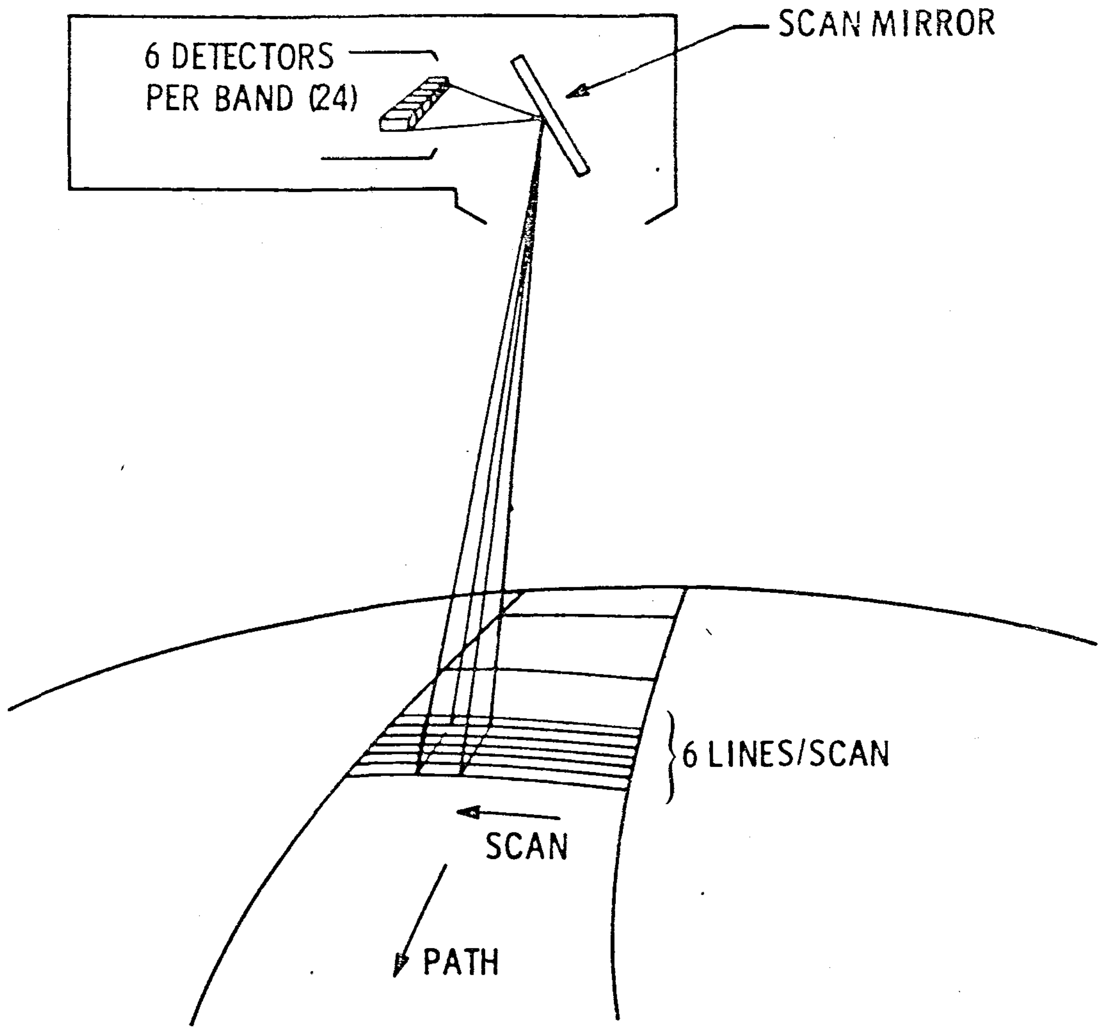
| | 1 | 2 | 3 |
|---|---|---|---|
| o SPECTRAL BANDWIDTH (MICRONS) | 0.48 - 0.575 | 0.58 - 0.68 | 0.69 - 0.83 |
| o READ OUT TIME (SEC.) | 3.5 | 3.5 | 3.5 |
| o TIME BETWEEN PICTURE SETS (SEC.) | 25 | 25 | 25 |
| o EXPOSURE TIME (MIL. SEC.) | 8, 12, 16 | 8, 12, 16 | 8, 12, 16 |
| o DATA: VIDEO, 3.5 MHz | | | |



1252

Fig. 5

MULTISPECTRAL SCANNER




20

1253

OBSERVATORY CONFIGURATION

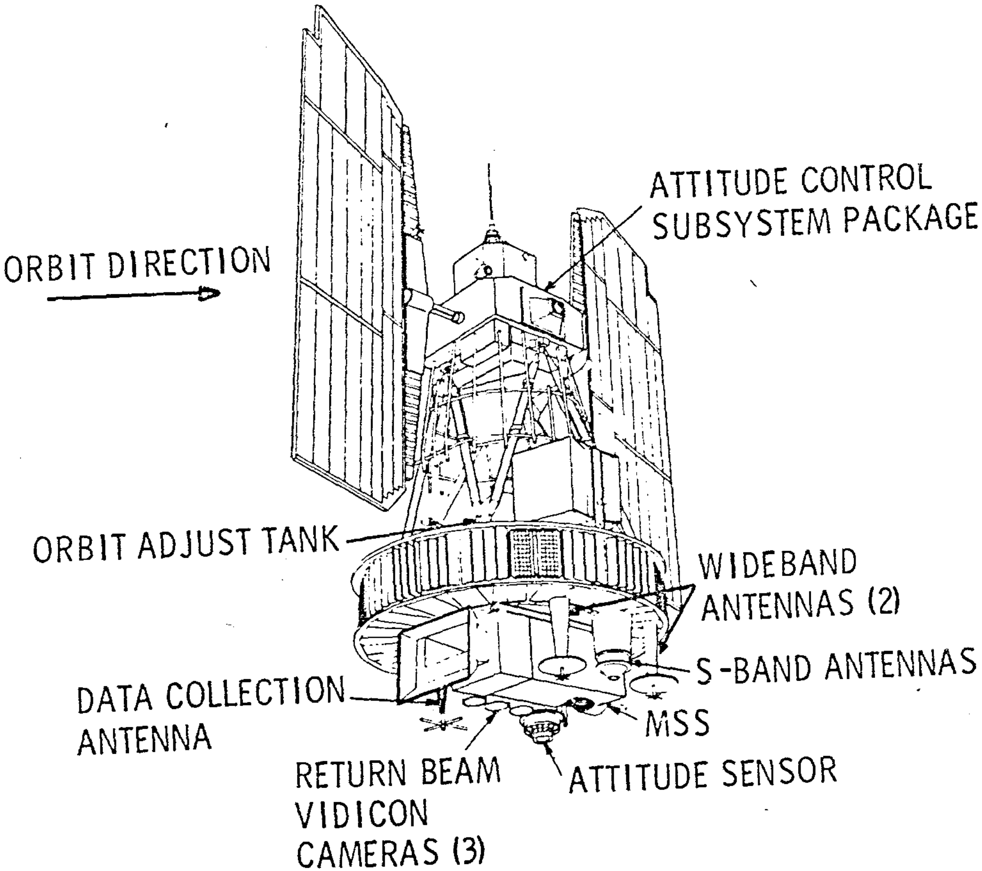



Fig. 6

Fig. 7

## NOMINAL ORBITAL PARAMETERS

| ORBIT PARAMETER | NOMINAL ORBIT |
|---|---|
| • ALTITUDE | 492.35 NM |
| • INCLINATION | 99.088 DEG |
| • PERIOD | 6196.015 SEC |
| • ECCENTRICITY | 0 |
| • TIME AT ASCENDING NODE | 21:30 |
| • COVERAGE CYCLE DURATION | 18 DAYS (251 REVS) |
| • DISTANCE BETWEEN ADJACENT GROUND TRACKS | 86.06 NM |