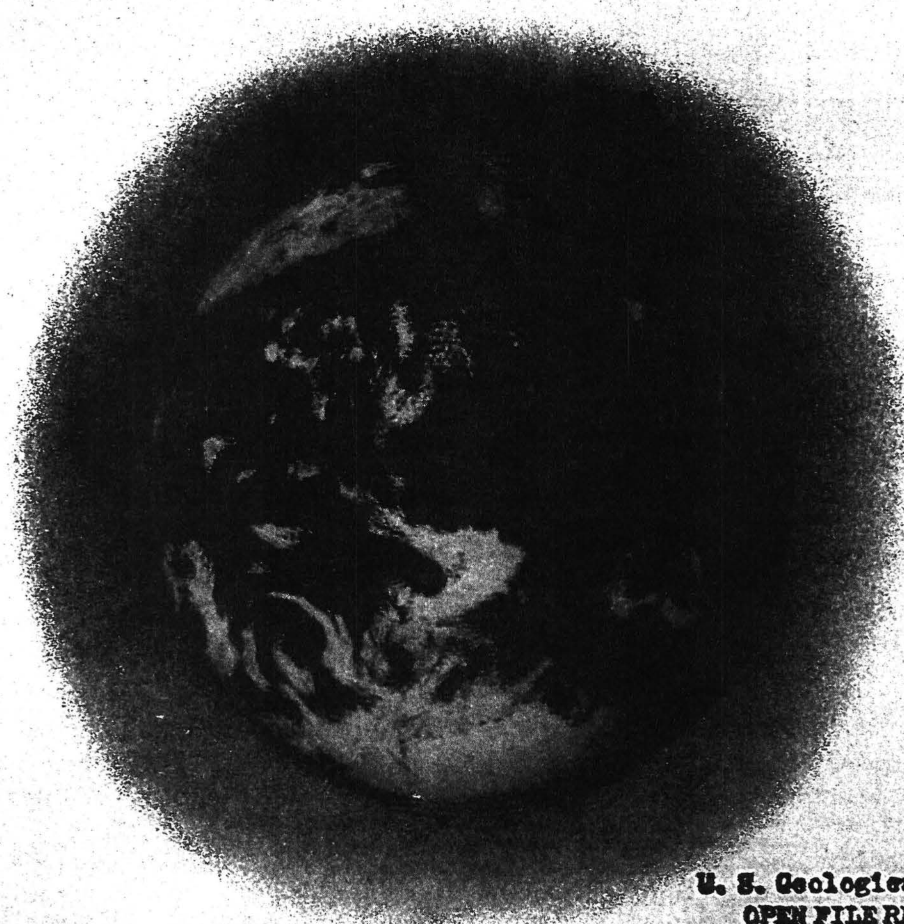
EA-5

PROJECT REPORT
EAST ASIA INVESTIGATION
(IR)EA-5

PROGRESS IN REMOTE SENSING AS IT APPLIES TO MISSIONS OF COMMITTEE FOR COORDINATION OF JOINT PROSPECTING FOR MINERAL RESOURCES IN ASIAN OFFSHORE AREAS



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PROGRESS IN REMOTE SENSING AS IT APPLIES TO MISSIONS OF COMMITTEE FOR COORDINATION OF JOINT PROSPECTING FOR MINERAL RESOURCES IN ASIAN OFFSHORE AREAS

By

William A. Fischer

U.S. Geological Survey

The project report series presents information resulting from various kinds of scientific, technical, or administrative studies. Reports may be preliminary in scope, provide interim results in advance of publication, or may be final documents.

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PROGRESS IN REMOTE SENSING AS IT APPLIES TO MISSIONS OF COMMITTEE FOR COORDINATION OF JOINT PROSPECTING FOR MINERAL RESOURCES IN ASIAN OFFSHORE AREAS

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INTRODUCTION

The major thrusts of investigations of the use of space data for understanding our Earth continue to focus on the land and near-shore environments. This is expectable; people live on the land, draw most of their resources from the land or near-shore areas, and in these areas environmental degradation or improvement are most clearly observable

An exception to this focus of investigation was the launch of Seasat, a satellite dedicated to marine investigations. Seasat was short lived but the data produced strongly supported the use of imaging radar for land investigation, and, although studies are incomplete, suggest eventual benefits for the navigator, searchers for marine resources, and mariners--provided that the data and/or interpretations can be available to the marine users shortly after collection. In this regard, the positive steps now being taken in Southeast Asia to establish reception, processing, and interpretation centers are a major development.

REMOTE SENSING ADVANCES

The major advance in remote sensing this past year has been the computer integration of geophysical and Landsat data into three dimensional models (attachment A). This capability, first demonstrated by Huntington and Green of CSIRO, Australia, strongly supports the need for closer affiliation between the geologist and geophysist in land and near-shore investigations. The three images in attachment A reflect magnetic data and do not show topography.

The demonstrated capability of Landsat to observe subaqueous features at depths of 22 meters or more (attachment B), and thus facilitate charting of near-shore areas is, perhaps the development of greatest relevance to Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP) interests. Shallow seas are becoming increasingly important from a resources standpoint, yet are the most difficult to chart. Landsat may help to provide for the safety of survey ships in these waters and improve knowledge of shoal configurations that are of interest to geologists and others.

Planned and recently conducted United States initiatives in space observations of the Earth are listed and described in attachment C.

Other major advances that seem to be emerging, and are relevant to the missions of CCOP, are: 1) a better understanding of the ancestral history of the Earth and related fundamental structures of the Earth; and 2) the importance of these structures in the localization of energy and ore deposits, including deposits forming at this time.

A number of scientists are reporting large Earth structures (?), some of which have been postulated (Hobbs, 1904) but which we had never seen before the advent of routine observations of the Earth from space. These observations are supported by limited amounts of geophysical and geological data that may or not be relevant, as they have commonly been focused on relatively shallow targets within the Earth's crust and have been interpreted without the guidance of orbital data.

The principal suppositions that seem to emerge are: 1) the Earth was heavily bombarded by interstellar objects, objects from within the solar system, or from collision with primordial "moons (Alfv'en and Hannes and Arrhenius, 1976); 2) these events caused (probably by relatively rapid change in rotational rate of the Earth) systematic fracture systems in the Earth's crust and mantle; and 3) continuing "slow" change in rotational rate (coupled with Earth tides) would provide a mechanism by which these old, deep (circular and linear) features remain visible at the present surface.

In the analysis of Landsat and other imagery acquired from space, circular, linear, and curvilinear features, ranging in size from tens to thousands of kilometers have been observed that may extend to great depths, and are probably quite old. There is a growing body of evidence that some of these structures have served as conduits for mineralizing fluids to the surface or near-surface, have controlled petroleum-related facies distribution at depth, and may be related to current geothermal activity and geologic hazards. The fact that some can be discerned on repetitive satellite images adds to the credibility of these interpretations.

The question then arises as to why we see these possible ancestral features. One plausible answer has been provided by S. Gutman (oral commun., 1978), who remarked that at Landsat scale (1:1,000,000), the crust of the Earth is proportionately only 50 mm thick; thus, assuming some constant source of energy, such as Earth tides, it is not unreasonable to expect to see evidence of deep-seated features at the surface on Landsat scenes.

The largest and probably the oldest of these apparent features are probably impact structures, some of which are mapped and described by Norman, Price, and Chukwa-Ike (1977) in a paper titled "Astrons--the Earth's oldest scars?" A map of these features adapted from Norman and Price is shown as figure 1. In this paper, Norman states "one cannot justify scaling up such events as granite or salt intrusion to the required size (of the features we see), and we need to look for another explanation."

Lowman (1976) states "To argue that the Earth escaped such bombardment (as is clearly evident on images of the Moon, Mars, Venus, and Mercury) is envoking magic or divine intervention." This argument is reinforced by the fact that the Earth has higher density than the other planets or the the Moon. The conclusion is inevitable: the Earth was heavily bombarded probably in Archean time and possibly continuing heavily into early Cambrian time and diminishing thereafter.

The largest impact structure that some scientists believe they see in the United States is in the mid-continent region and is approximately 1300 km in diameter, implying a depth of 300 km below datum and a crater rim perhaps 200-300 km above datum at time of formation. The fact that many major petroleum provinces in the United States, the Anadarko Basin, the Denver Basin, and Williston Basin, some of the West Texas fields and some of the Illinois fields, as well as the Mesabi ore deposits, lie near the rim of this structure constitutes a working hypothesis that for scientific and/or economic reasons is worthy of investigation.

Linear features, which may or may not be associated with or related to major impact, are classified by Hodgson (1978) in accord with thoughts of E. N. Permyakov (1949) and G. N. Katterfield (1976) as follows: 1) global (belts of lineaments); 2) regional (lineaments); and 3) local (such as systematic joints). Hodgson further comments on time relationship of the fracture network, "... into global-oldest-local-youngest." Hodgson goes further to consider the origin of these features, and states:

"In the past, the present author (Hodgson) has favored the tidal fatigue hypotheses although it now appears from the new regional fracture data derived from the Landsat (ERTS) experiment that, even though this may be a primary mechanism in producing joints in new rocks, the primary imposition of the pattern is gentically related to the systematic and non-systematic changes in the shape of the Earth through time as required primarily by changes in the rate of rotation of the Earth."

Accepting this hypothesis, the possible causative events that led to possible rotational rate changes were explored. These include: magnetic torquing, close pass-by of celestial objects, isostatic change, change in the universal gravitational field and impact. Possible systematic changes in rotational rate, such as compression and heating of the protoplanetary interior, followed by gravitational downleaching of heavier fractions or loss of angular momentum to the moon (Fairbridge, 1967), are considered too slow to account for the end results, although the loss of angular momentum to the moom may provide the continuing mechanism by which ancient features remain visible. The consensus is that impact and

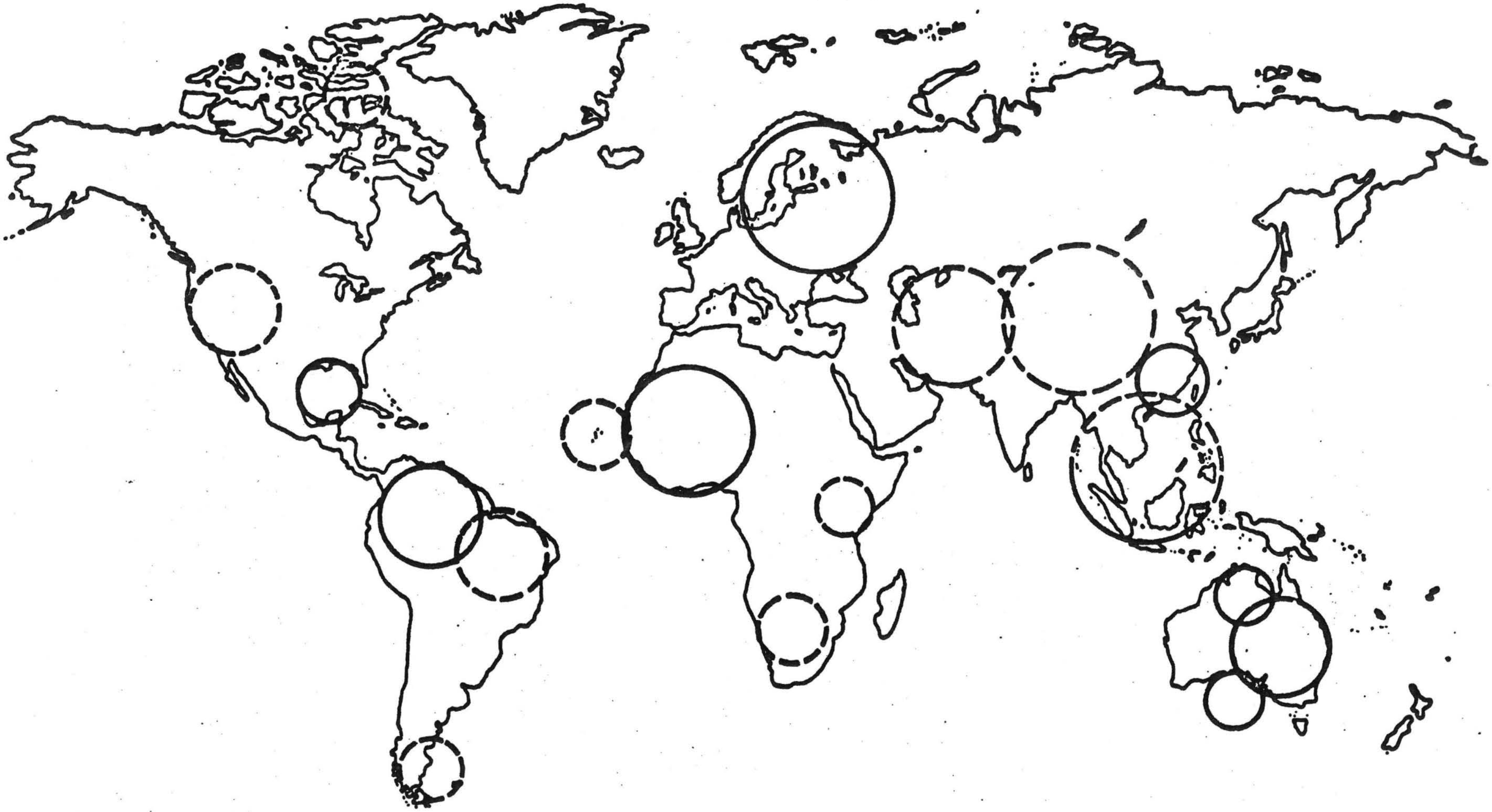

Figure 1--map taken from Norman, Price and Chukwu-Ike (1977) showing major circular features that they have interpreted on the Earths' surface.

isostatic change, whatever its cause, are the only possible causes having sufficient energy to change the rotational rate of the Earth. S. Gutman (oral comm., 1978) has provided approximations of the energies involved in several of these processes. A change in rotational rate of 1 second per day, if accomplished in one day, would provide 10^{33} ergs, a similar rotational change in one year would provide 10^{26} ergs of energy. In constrast, tidal friction amounts to only 10^{-18} ergs per second per day.

Assuming that the age vs length relationships postulated by Hodgson and others are correct, and further assuming that the probabilities of transport of mineral fluids and control of paleofacies at depth increase with age, the logical next step should be an investigation of "global," linear, curvilinear, or spiral features to determine their economic significance.

Hodgson's regional lineament classification constitutes a secondary set of regional "fractures" which he says are not deflected or disturbed by folds. This observation suggests that these features predate the fold structure of the Earth and (as the global features) are of early age, may extend to intercontinental dimensions, and warrant cooperative study. Some observations suggest that these "structures" are derivatives of more fundamental "global" structural belts. As such, their mapping and economic evaluation is also a recommended activity.

It seems only logical to assume that, if indeed these large circular and linear features exist and if they have economic significance, they should be as important in the marine as in the land environment. Therefore, their study is relevant to the missions of CCOP.

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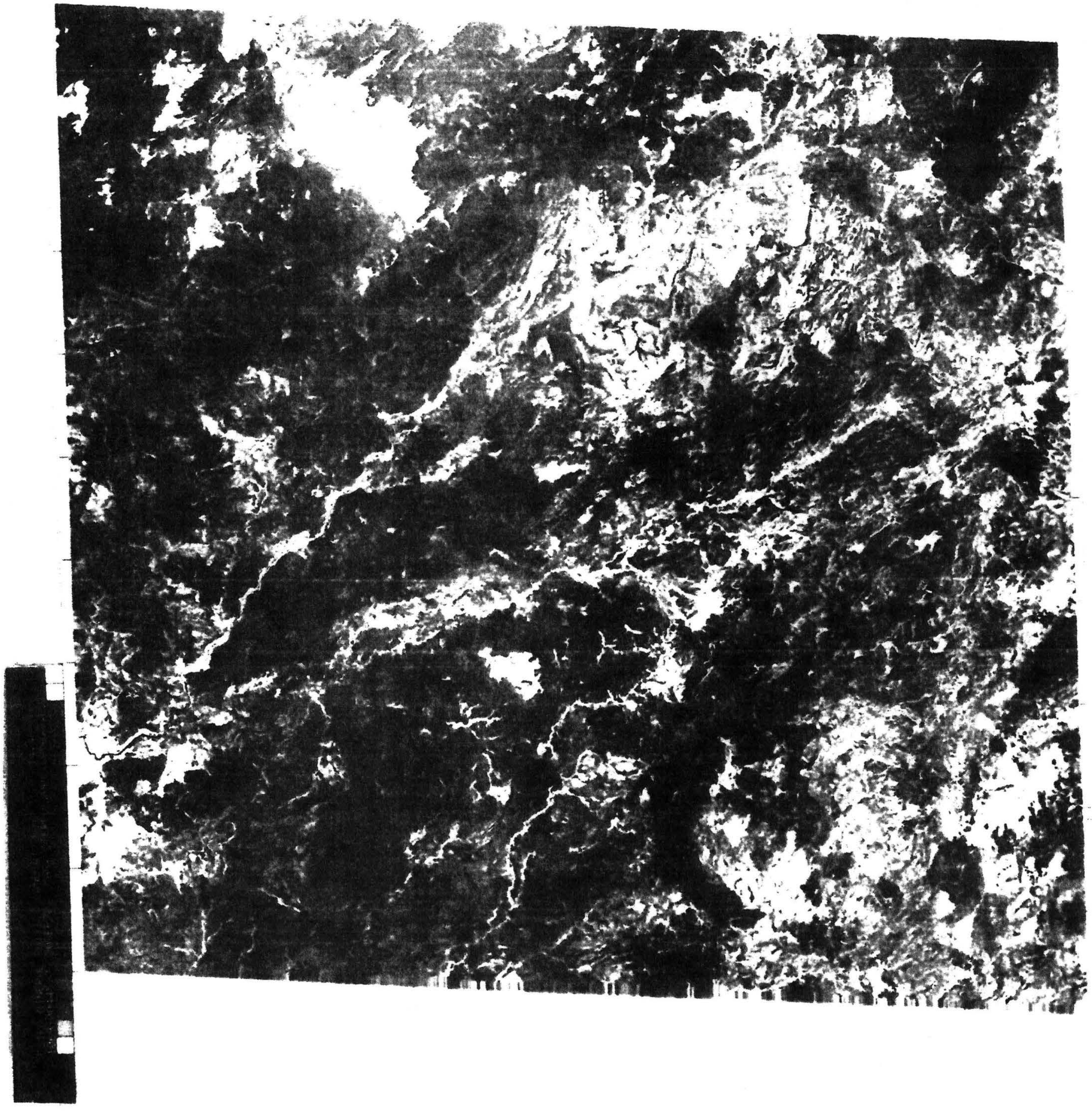
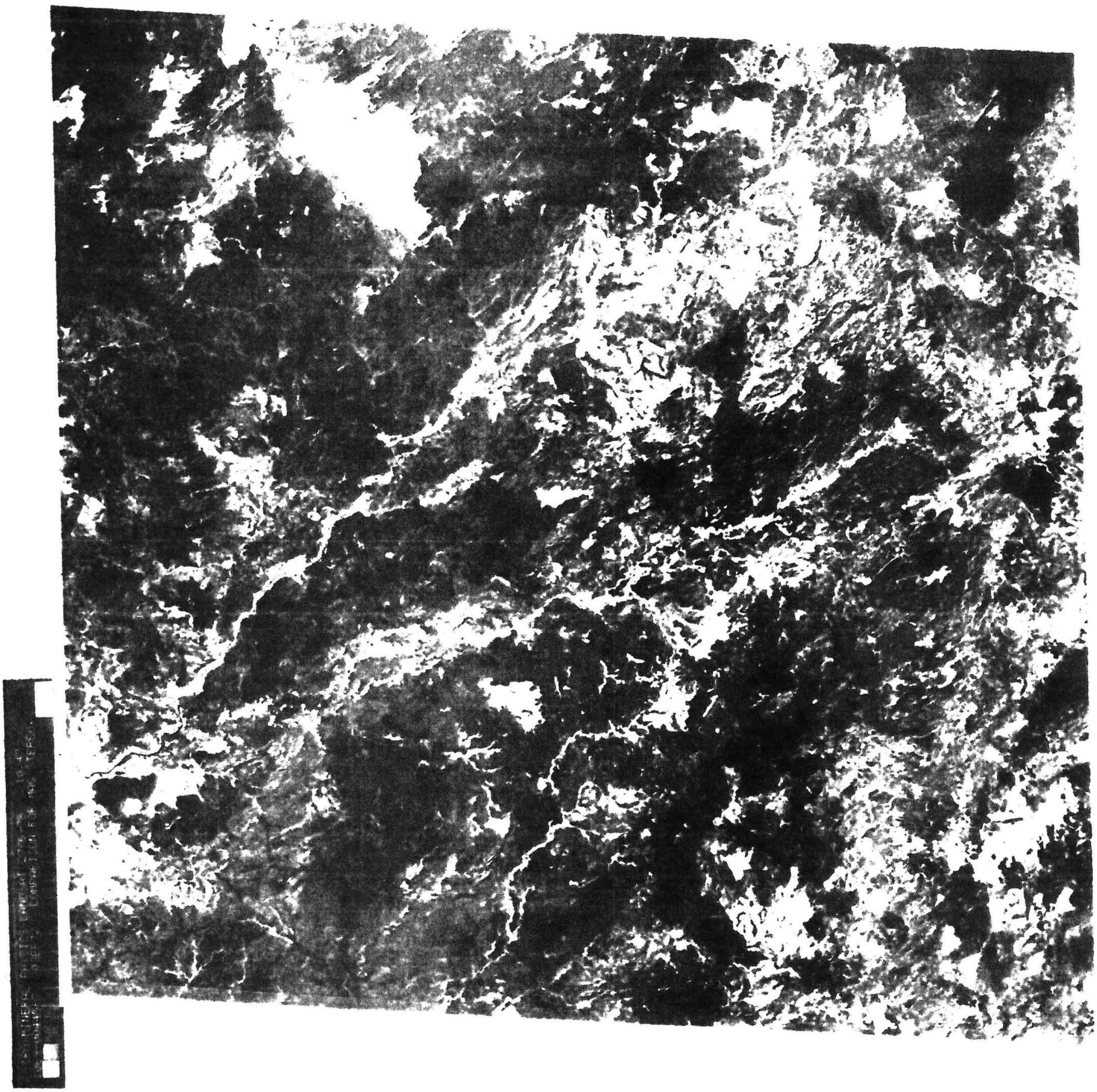
ATTACHMENT A

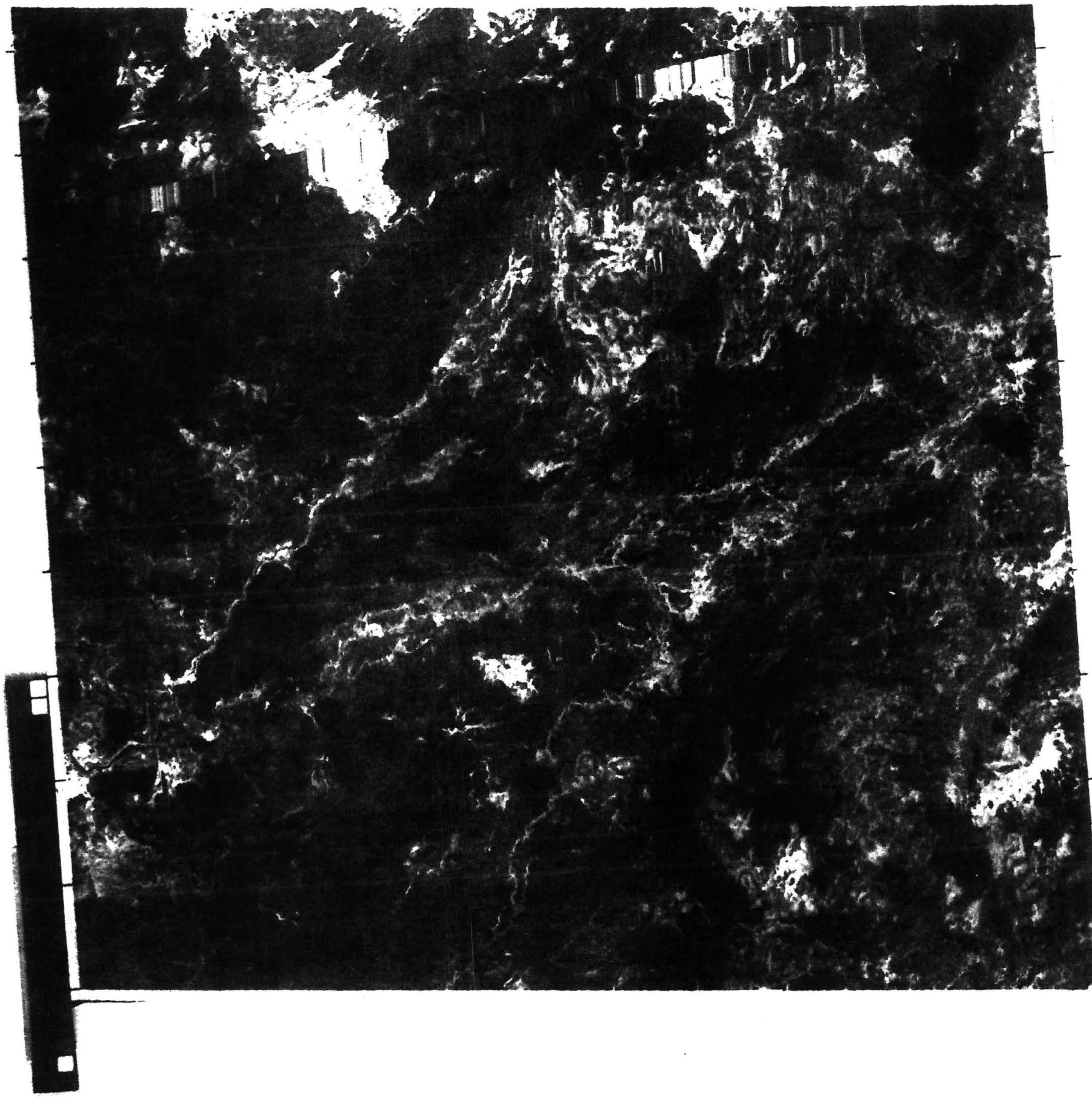
The images comprise a stereo triplet and can best be viewed under a mirror stereoscope. The image marked L is an undistorted 1/4-Landsat scene of a part of northwestern Australia; this should be viewed on the left. Apparent topography on images R-T and G-R reflects only the magnetic field, and is not a function of topography. The image marked R-T has parallax introduced proportionate to the total magnetic intensity (note circular and linear features in the lower right hand corner). The image marked R-G has parallax introduced proportional to the magnetic gradient; this image may be substituted for the R-T image and viewed on the right.



One-quarter undistorted Landsat scene of a part of Australia.



R-G



12th International Symposium on
Remote Sensing of Environment,
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Vol. 1, n. 755-764.

ATTACHMENT B

LANDSAT IMAGES OF PART OF THE U.S. TRUST TERRITORY OF THE PACIFIC ISLANDS AND OTHER PACIFIC OUTLYING AREAS

W. D. Carter and J. M. DeNoyer

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ABSTRACT

At the request of the Department of the Interior, the National Aeronautics and Space Administration (NASA) acquired Landsat images of the U.S. Trust Territories of the Pacific. Images of the Western Caroline Islands include Yap, Ngulu Atoll, and the Palau Islands (including Angaur and Babelthaup Islands on the south and the Velasco Reef area on the north). Images of the Samoa Islands include the islands of Tutuila, Manua, Rose, and Swains Island of American Samoa and Savai'i and Upolu of Western Samoa. Fonualei Volcano and the Vava'u Group of the Tonga Islands were also imaged.

The data were provided as 70 mm positive film transparencies which were initially screened for land areas and selected images were enlarged to 1:1,000,000-scale film negatives and printed as black and white paper prints. The film negatives were used in producing color composite transparencies by the diazo process. Using blue for band 4, yellow for band 5 and red for band 7, the diazo color composite shows the exposed island areas as red, shallow water reefs as green and deep water reefs as blue. Comparison with limited soundings on available hydrographic charts of the area demonstrate that the deepest parts of the Velasco reefs were at least 6.3 fathoms (36 ft. or 12 m) below the ocean surface.

Computer compatible tapes of some of the best images were selected for experimentation using interactive computer analysis systems.

INTRODUCTION

While most of the land areas of the major continents of the world have been recorded on multispectral scanner (MSS) images since the launches of Landsat-1 on July 23, 1972, and Landsat-2 on January 22, 1975, many smaller areas of the world have not received much attention. This is especially true of the small islands of oceanic areas that are distant from Landsat reception stations and which require the repetitive use of satellite tape recorders to retrieve the images. Although these are remote, many are being subjected to mineral exploration, resource and land use development and a variety of external and internal pressures by growing populations and greater resource needs.

In spite of the fact that the Landsat system was designed primarily to map land areas, recent attention has been paid to its application in improving hydrographic charts of marine coastal and island areas. Early work in the clear marine waters of Florida demonstrated that light penetration of water peaked at 0.48μm (Duntley, 1963). In the Bahamas, Brown and others (1971) and later work of the NASA/Cousteau experiment (Polcyn, 1976) demonstrated and validated inferences that high gain Landsat band 4 (0.5-0.6μm) and band 5 (0.6-0.7μm) images could be useful in the delineation of submarine morphology.

Polcyn (1977) demonstrated that "depths to 22 meters were reliably verified at accuracies within 10 percent of measured values". More recent work by Hammack (1977) has demonstrated that Landsat data can be of significant value in refining the planimetry of existing hydrographic charts and useful in finding uncharted submerged reefs, such as the newly discovered

Colvocoresses Reef on the Chagos Archipelego in the western part of the Indian Ocean. This is especially significant when one considers the value of cargoes now being carried on deep draft super-tankers and other large ships navigating the seas.

It was with the above considerations in mind that the U.S. Geological Survey requested that NASA attempt to provide coverage of the U.S. Trust Territories and other islands of the Pacific, specifically the Western Caroline Islands and the islands of American and Western Samoa (Figure 1). In order to maximize solar reflectance of shallow submarine bottom features it was requested that bands 4 and 5 be set in a high gain mode.

It is the intent of this paper to bring this new data to public attention by listing the best images available (see Table 1) and also to discuss some of the preliminary experimental work that has been initiated by the EROS Program team as a result of the data collection effort.

INVENTORY OF IMAGES

The Western Caroline islands of Micronesia include the Yap Islands, Ngulu Atoll, Velasco Reef, Kayangel Islands, Palau Islands and the Sonsorol Islands. They lie in a narrow northeast trending belt between latitudes 4-0°N and longitudes 132-137°E. The islands of Western Samoa consists of Savai'i and Upolu. American Samoa includes the Manua Islands, Tutuila Island, Swains Island, Rose Atoll, and Sand Island. The Vava'u Group is part of the Tonga Islands. The Samoa Islands lie in an east-west trending belt between latitudes 11°-17°S and longitudes 167°-174°W. Table 1 provides the Landsat path, row and image numbers, their date, geographic location and descriptive comments considered to be most important.

EXPERIMENT PROCEDURE

Seventy millimeter positive film transparencies were carefully screened and land areas were noted by T. Ragland of the EROS Program at the Goddard Space Flight Center. All data were sent to the EROS Program office where they were screened and geographically located by the author. Land areas and submarine parts of atolls were located from the National Geographic Atlas of the World (Third Edition, 1970) and available hydrographic charts (Figure 2). Band 4 (0.5-0.6μm) data was reviewed for submarine features and band 7 (0.8-1.1μm) images were checked for land surfaces. Of 170 images acquired during the period approximately 25 were sufficiently cloud-free to be considered valuable for either land use or ocean bottom information.

Optical Analyses: The selected images were photographically enlarged to 1:1,000,000 scale negative film transparencies and then reproduced as color positive contact composites using the rapid diazo foil technique and evaluated. By reversing the standard color composite procedure (band 4 - Yellow, band 5 - Red, band 7 - Blue) to band 4 - Blue, band 5 - Yellow, band 7 - Red, it was possible to show land areas as red, shallow marine reefs and atolls as green and deeper submarine features as blue. A demonstration of this color technique was best displayed on images 2913-00162 and 2913-00164 of the Velasco Reef and Palau Islands area (Figures 3, 4 and 5). This experiment suggests that the standard image color compositing recipe is not optimum for studies of submarine features, and that the option described above should be considered as an alternative.

From the selection process standard Landsat color composites (1:1,000,000-scale) were ordered for comparison with the diazo composites. Computer compatible tapes (CCT's) of selected images were ordered for more detailed studies.

Computer Analyses: The Landsat computer compatible tapes (CCTs) of the Velasco Reef and Palau Islands were analyzed by J. M. DeNoyer, D. Gehring, and G. Hansen using the analytical computer systems at the EROS Data Center, Sioux Falls, South Dakota. The land areas were studied using the four MSS bands and a principal components program in which the first three principal reflectance classes are defined by statistical analysis of subscenes, each covering an area of about 30 by 30 km. In the subscenes red denotes forest vegetation, blue represents forest vegetation in shadow and green indicates open grassland and low bush areas. Cultural features were displayed in white.

The reefs and shallow water channels surrounding the Palau Islands and Velasco Reef were analyzed by using only the high gain MSS band 4 data in a set of 6 computer subscenes which not only maximized the inherent resolution of the system but also provided optimum coverage of the area. Density analysis of the data, based on the calculations by Polcyn (1976) and with reference to soundings shown on hydrographic charts of the area, provided an approximation of relative depths within the subscenes. Three dimensional isometric displays enabled the selection of mappable depth ranges that could be shown as form lines representing the submarine features. These were displayed on the cathode ray tube and printed through a laser beam recorder as positive film transparencies. Form line maps that correspond to 0-2 m, 3-5 m, 6-8 m, 9-11 m, and 12-14 m depth ranges were made for each depth range within each subscene (Figure 6).. Each depth interval was assigned a specified color and processed as a color diazo positive. Each set of color positives for each subscene were superposed and registered to display the form lines as an approximation of contours. The color code used for the display is shown in Table 2.

The color diazo composite "sandwiches" clearly display the surface variations within the reef and neighboring channels and correlate reasonably well with existing large scale hydrographic charts. Enlargement of the transparent form-line overlays to the scale of the charts also enables rapid identification of areas where the imagery indicates that the charts should be revised. Statistical evaluation of the accuracy of these new experimental products is in progress.

CONCLUSIONS

Hammack (1977) used optical enhancement and visual comparison methods to revise hydrographic charts and found that Landsat was extremely useful in identifying uncharted reefs and correcting the position and geometry of charted reefs. He also found that Landsat resolution (80 m) was too low to identify small navigation hazards.

The simple color diazo process used herein to show relative depth of submarine features is useful for first "look" evaluation and data selection. It suggests that further experimentation in color enhancement and perhaps new color assignments to bands 4, 5 and 7 should be considered for high-gain Landsat scenes where submarine features are subject to investigation.

Digital form-line maps, based on assignment of relative density measurements to approximate depth ranges, appear to show the morphology of bottom features with reasonable reliability. When superposed on existing hydrographic charts of the same scale they appear to "fill in" between recorded soundings and suggest areas where soundings and contours may need to be revised. Further refinements of the technique along with statistical evaluation of accuracy with published bathymetric data are planned. Indication of where additional soundings should be made in questionable areas may increase the value of Landsat data as a hydrographic charting tool.

TABLE I: LIST OF BEST AVAILABLE LANDSAT IMAGES
OF PARTS OF THE U.S. TRUST TERRITORIES OF THE PACIFIC AND VICINITY

Image No.	Date	Location Name	Comments
2877-00181 P114-R 054	17 June 77	Kayangel Islands Palau Island	Palau District (cloudy) Western Caroline Islands
2877-00183 P114-R 055	17 June 77	Palau Islands	Palau District, Western Caroline Islands (very cloudy)
2887-20173 P071-R 070	27 Jun 77	Tau, Manua Islands	American Samoa
2888-20232 P072-R 070	28 Jun 77	Tutuila Island	American Samoa (cloudy)
2889-20281 P073-R 068	29 Jun 77	Swains Island	American Samoa
2889-20283 P073-R 069	29 Jun 77	Savai'i Island	Western Samoa
2889-20290 P073-R 070	29 Jun 77	Savai'i and Upolu Islands	Western Samoa
2890-20341 P074-R 069	30 Jun 77	Savai'i Island (west end)	Western Samoa
2905-20164 P071-R 070	15 Jul 77	Tau, Manua Islands	American Samoa
2893-00053 P112-R 053	3 Jul 77	Yap Islands	Yap District Western Caroline Islands
2904-20110 P069-R 070	14 Jul 77	Rose Atoll	American Samoa
2913-00162 P114-R 054	23 Jul 77	Velasco Reef Palau Islands	Palau District Western Caroline Islands
2913-00164 P114-R 055	23 Jul 77	Palau Islands	Palau District Western Caroline Islands
2914-00225 P115-R 056	24 Jul 77	Sonsoral Islands	Palau District Western Caroline Islands
2925-20271 P073-R 070	4 Aug 77	Savai'i and Upolu	Western Samoa
2926-20322 P074-R 069	5 Aug 77	Savai'i (west tip)	Western Samoa
2929-00033 P112-R 053	8 Aug 77	Yap Islands	Yap District Western Caroline Islands
2929-00040 P112-R 054	8 Aug 77	Ngulu Atoll	Yap District Western Caroline Islands

TABLE I: (Continued)

Image No.	Date	Location Name	Comments
2940-20090 P069-R 070	19 Aug 77	Rose Atoll	American Samoa
2943-20251 P073-R 068	22 Aug 77	Swains Island	American Samoa
2943-20254 P073-R 069	22 Aug 77	Savai'i Island	Western Samoa
2943-20260 P073-R 070	22 Aug 77	Savai'i and Upolu	Western Samoa
2944-20312 P074-R 069	23 Aug 77	Savai'i Island	Western Samoa (west tip)
2947-00030 P112-R 054	26 Aug 77	Ngulu Atoll	Yap District Western Caroline Islands

TABLE II: COLORS USED FOR SPECIFIC BATHYMETRIC INTERVALS IN THE FORM-LINE MAPS OF SPECIALLY PROCESSED LANDSAT MSS BAND 4 IMAGES OF THE VELASCO REEF AND PALAU ISLANDS, PALAU DISTRICT, WESTERN CAROLINE ISLANDS

0-4 m	-	Brown
5-9 m	-	Green
10-14 m	-	Orange
15-19 m	-	Red
20-24 m	-	Blue

ACKNOWLEDGEMENTS

The procedure described herein are the results of a team effort. T. Ragland and the author screened the data; the author and L. Jeffris prepared the initial diazo color composites. The computer compatible tapes were analyzed by J. M. DeNoyer with Dale Gehring and G. Hansen of the EROS Data Center. The color diazo composites of the form-line maps showing relative depth intervals were processed by J. Schloderer.

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LIST OF ILLUSTRATIONS

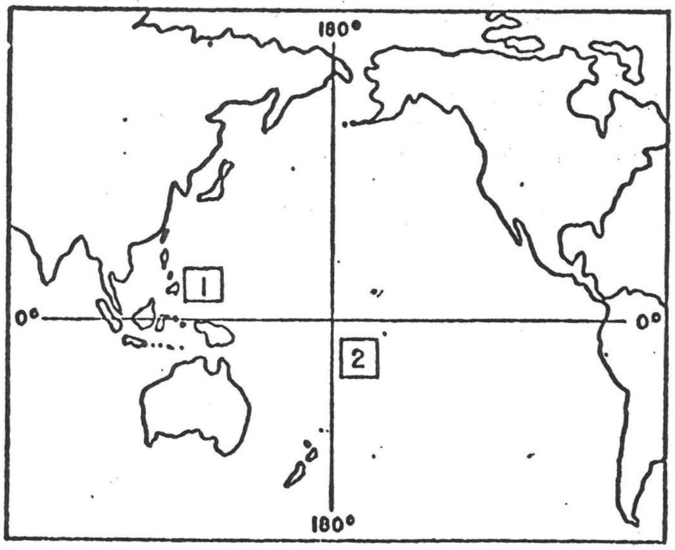


Figure 1: Index map of the Pacific Ocean showing areas where Landsat-2 high gain images were obtained. Area 1 - Western Caroline Islands; Area 2 - American and Western Samoan Islands

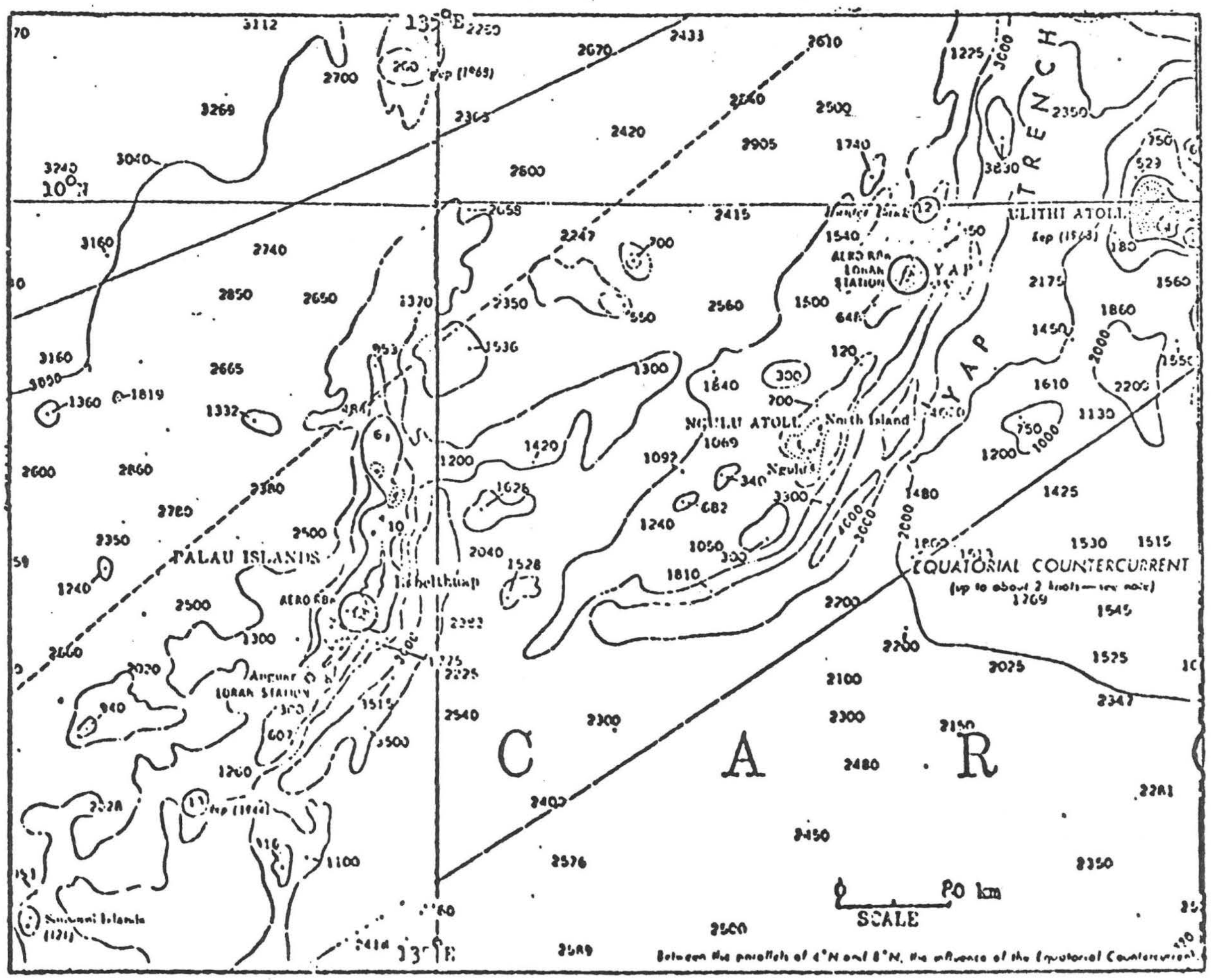
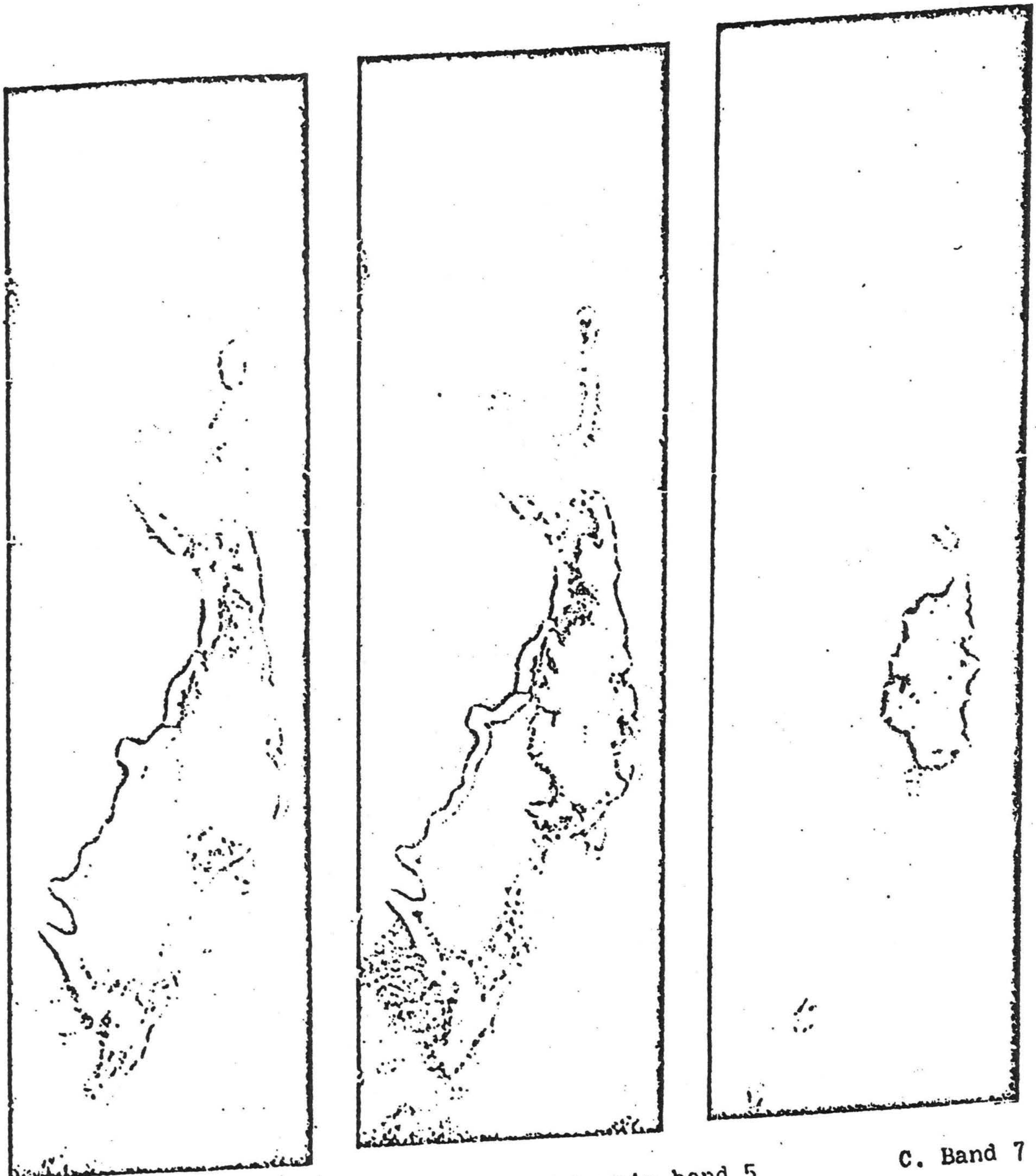


Figure 2: Part of DMA Hydrographic chart No. 525 of the Palau Islands District of the Western Caroline Islands



A. High gain Band 4 .B. High gain band 5 C. Band 7

Figure 3: Black and white mosaics of the Palau Islands group from Velasco Reef on the north to Anguar Island on the south. Parts of images E 2913-00162 and 2913-00164 dated 23 July 1977.
Scale 1:1,000,000

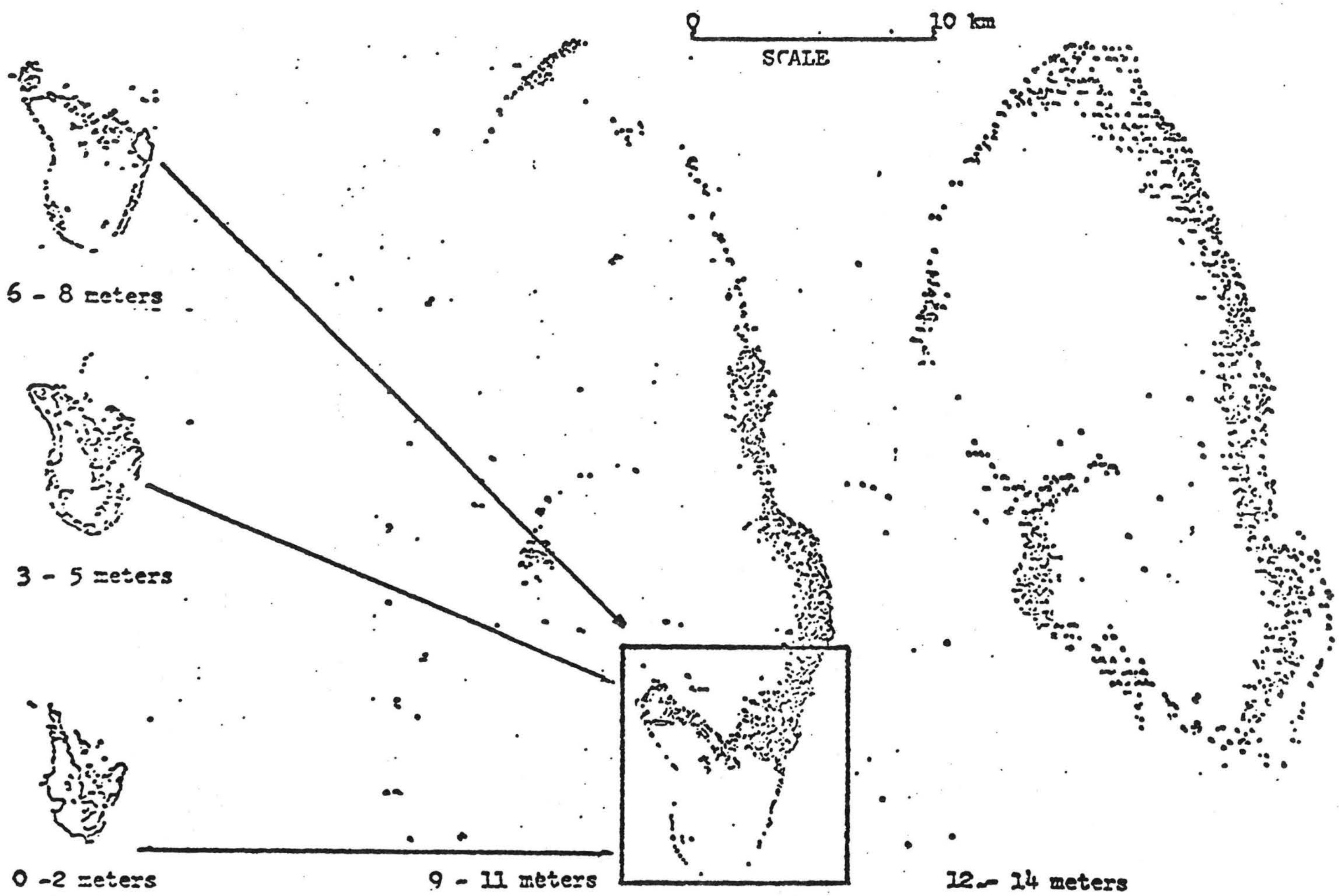


Figure 4: Digital form line maps of the Velasco Reef area, Palau Island District, Western Caroline Islands showing approximate depth ranges based on estimated water density and reflectance measurements. Scale approximately 1:350,000. Produced from a Landsat computer compatible tape of image no. 2913-00162 on a Gould printer using high gain bands 4 and 5.

ATTACHMENT C

FACT SHEETS ON UNITED STATES WEATHER AND EARTH OBSERVATION SATELLITES

TIROS (Television and Infrared Observation Satellite)
ESSA (Environmental Survey Satellite)

	Launch date	Coverage	Operation ended	Significance
TIROS-1	April 1960	55° N-S	June 1960	First cloud cover imagery from space
TIROS-2	November 1960		February 1961	
TIROS-3	July 1961		October 1961	
TIROS-4	February 1962		June 1962	
TIROS-5	June 1962	65° N-S	May 1963	
TIROS-6	September 1962		October 1963	
TIROS-7	June 1963		February 1966	
TIROS-8	December 1963		January 1966	Direct readout of cloud pictures to local ground stations
TIROS-9	January 1965	near-polar (96.4-98.6° inclination)	February 1967	Prototype of ESSA
TIROS-10	July 1965		June 1966	Global daytime cloud cover photography

TOS (TIROS Operational Satellite) System
Two ESSA satellites in orbit simultaneously

ESSA-1	February 3, 1966		May 1967	World's first operational satellite system
ESSA-2	February 28, 1966		October 1970	
ESSA-3	October 1966		October 1968	First AVCS
ESSA-4	January 1967	near polar (98-102° inclination)	December 1967	
ESSA-5	April 1967		February 1970	
ESSA-6	November 1967		November 1969	
ESSA-7	August 1968		July 1969	
ESSA-8	December 1968		March 1976	Was replaced by NOAA-5
ESSA-9	February 1969		November 1973	

SENSORS:

TIROS 1-10 and ESSA 1 and 2

	Resolution	Lens angle	FOV
Vidicon cameras	1-3.2 km	13-108°	120-1208 km
Low and medium resolution infrared radiometers			

ESSA 3-9

	Resolution	Lens angle	FOV
Advanced vidicon camera system (AVCS)	3.8-7.4 km		3330 km
Low resolution infrared radiometers			

PURPOSE: Development of operational meteorological satellite system
Vertical temperature and moisture soundings of the atmosphere

GROUND STATIONS: Wallops, Va., and Gilmore Creek, Alaska
Odd-numbered ESSA's transmitted from tape recorder
Even-numbered ESSA's transmitted directly from Automatic Picture Transmission (APT) system.

March 15, 1978

ITOS (Improved TIROS Operational System)

Individual satellites in the ITOS system have been called NOAA since the formation of the National Oceanic and Atmospheric Administration.

	Launch date	Ended operation	Significance
ITOS-1 (NASA's TIROS-M)	January 1970	June 1971	Prototype in second generation polar-orbiting system
NOAA-1	December 1970	August 1971	First NOAA funded operational satellite
NOAA-2	October 1972	January 1975	Carried all scanning radiometers
NOAA-3	November 1973	August 1976	Direct transmission of VTPR data
NOAA-4	November 1974		
NOAA-5	July 1976		Primary operational polar-orbiting satellite, backed up by NOAA-4

ORBIT: Sun-synchronous, near polar
Altitude: 1470 km (average)
Period: 115 minutes
Inclination: 102°
Orbits per day: 12.4

SENSORS:

ITOS-1 and NOAA-1:
- Advanced Vidicon Camera System (AVCS)
- 2-channel Scanning Radiometer (SR)
- Solar Proton Monitor (SPM)
- Automatic Picture Transmission (APT)
- Flat Plate Radiometer (FPR)

NOAA-2 to 5:	Wavelength (μm)	Resolution	Measurement
Very High Resolution Radiometer (VHRR)	0.60-0.70 10.5-12.5	1 km	cloud top temperatures ground and sea surface temperatures day/night
Scanning radiometer	0.40-1.1 10.5-12.5	4.2 and 8 km	same as VHRR but lower resolution
Vertical Temperature Profile Radiometer (VTPR)	15 (6 channels) 12 (1 channel) 19 (1 channel)		vertical temperature profiles of atmosphere, amount of cloud cover day and night
Solar Proton Monitor			solar proton flux, to estimate degree of sun's activity

PURPOSE: Observe, describe, and predict state of oceans, atmosphere, and sun
Global coverage twice daily of cloud patterns, surface temperatures, temperature profiles from surface to 30 km, and solar proton levels
Determine size and shape of Earth

GROUND STATIONS: Command and Data Acquisition (CDA) stations at Wallops, Va., and Gilmore Creek, Alaska
- SR - Taped data received at CDA's; also direct readout to suitably equipped stations within radio range of satellite
- VHRR - Primarily direct readout to S-Band receivers at CDA's and Redwood City, Calif. Onboard storage for 8 minutes of data per orbit
- VTPR - Transmitted to CDA's; processed at NESS, Suitland, Md.
- SPM - Relayed from NESS to Space Environment Laboratory in Boulder, Colorado.

DATA AVAILABILITY: National Environmental Satellite Service (NESS)
World Weather Building, Camp Springs, Md. 20031
SR and VHRR imagery, visible and infrared, as well as many special products such as mosaics, SST maps, ice analyses.

FOR MORE INFORMATION: The Operation of the NOAA Polar Satellite System, by
J. J. Fortuna and L. N. Hambrick
NOAA Technical Memorandum NESS 60
NOAA/NESS Office of Systems Integration
Washington, D. C.

TIROS-N (Television and Infrared Observation Satellite)

Third generation, polar-orbiting, operational weather satellite
Two-satellite system to replace ITOS system and provide all-digital data capability

EXPECTED LAUNCH: TIROS-N (NASA prototype): May 1978 to overlap ITOS and assure uninterrupted data
NOAA-A (operational): September 1978

ORBIT: Sun-synchronous, near polar; orbital descending nodes spaced about 60° longitude; one satellite orbits south across Equator in local forenoon, the other north across Equator in local afternoon for maximum daylight coverage

Altitude: 833 km Inclination: 102° Orbits per day: 14.2

SENSORS:

	Wavelength	Resolution	Measurement
TIROS Operational Vertical Sounder (TOVS) 2nd generation HIRS (High Resolution Infrared Radiometer Sounder)	20 channels		temperature soundings accurate to 1° C from surface to 50 km; water vapor soundings to 15 km; total ozone content of atmosphere
Advanced Very High Resolution Radiometer (AVHRR), 4-channel all-digital system	0.55-0.90 µm 0.725-1.0 µm 3.55-3.93 µm 10.5-11.5 µm	4 km and 1 km	cloud mapping; delineation of land/water and melting/non-melting snow, ice; sea surface temperature (SST); thermal mapping in cloudy areas (noise equivalent temperature difference of 0.20°K)
Space Environment Monitor (SEM)			electron, proton, and X-ray activity in near-Earth space

*Data Collection and Platform Location System (Argos) to monitor nearly 2000 platforms. Capable of tracking mobile platforms and collecting data from polar orbiting satellites.

PURPOSE:
- Improve long-range weather predictions
- Class-1 observations of sea surface temperature will increase tenfold (to 40,000/day) Resolution will increase to about 50 km
- SST fields will encompass U.S. 200-mile Conservation and Management Zone
- Weekly isothermal analyses of Great Lakes and U.S. Coastal Zone will be prepared from full resolution AVHRR data

GROUND STATIONS: Command and Data Acquisition (CDA) stations at Wallops, Va., and Gilmore Creek, Alaska.

DATA AVAILABILITY: NESS (National Environmental Satellite Service), World Weather Building, Camp Springs, Md. 20031

*For information on Argos contact: Michel Bourdeil or Mr. David S. Johnson, Director

Michel Bourdeil RCA-AED-MS-133 P. O. Box 800 Princeton, N.J. 03540 (609) 448-3400, ext. 2384	Mr. David S. Johnson, Director Code S NOAA/NESS F.O.B. 4, Room 2069 Washington, D. C. 20233 (301) 763-7190

Nimbus 1-6

Various meteorological and geophysical remote-sensing instruments and data transmission and processing techniques have been tested on Nimbus.

	Launch date	Ended operation	Significance
Nimbus 1	August 1964	September 1964	Carried AVCS, APT, and HRIR First nighttime cloud cover imagery
2	April 1966	November 1966	
3	April 1969	September 1970	First vertical temperature profile data of atmosphere on global basis
4	April 1970	one or more sensors still operating	
5	December 1972		NEMS and ESMR for vertical temperature profiles and sea ice boundaries through clouds
6	June 1975		Most sophisticated weather satellite to date

ORBIT: Sun-synchronous, nearly polar Altitude: 1100 km (average) Coverage: Global, twice daily Period: 107 minutes

DESCRIPTION: Butterfly-shaped; 2 solar paddles
3X size and weight of TIROS or ESSA
3 m high by 1.5 m diameter; weight, 373-909 kg

SENSORS:

	Wavelength	Resolution	Measurement
Nimbus 5 and 6:			
Temperature Humidity Infrared Radiometer (THIR)	11.5 m	8.2 km	Images of clouds; temperature of cloud tops, land, and sea surface
	6.7 m	22 km	Upper troposphere and stratosphere moisture; locate jet streams and frontal systems
Electrically Scanning Microwave Radiometer (ESMR)	single channel 250-mHz band centered at 37 gHz	25 x 25 at nadir to 160 x 45 km at extremity	Thermal microwave radiation from Earth surface and atmosphere water content of clouds distribution of sea ice
Data Collection System			Collects and relays weather data; tracks oil spills; rescue missions
Nimbus 6:			
Scanning Microwave Spectrometer (SCAMS)* 5-channel radiometer (improved Nimbus 5 NEMS) *operation ended 5/76	22.234, 31.63, 52.85, 53.85, 55.45 gHz	145 km at nadir to 330 km at extremity	Global maps of troposphere temperature profiles water vapor, ocean roughness
High Resolution Infrared Radiation Sounder (HIRS) 17-channel radiometer		to 25 m	Surface temperature vertical atmosphere temperature profile; vertical humidity profile
Limb Radiance Inversion Radiometer (LRIR) 4-channel multispectral scanning radiometer			Vertical distribution of temperature, ozone, water vapor
Earth Radiation Budget (ERB) 22-channel radiometer		accurate to 1% or less	View Earth and Sun to compute radiation budget
Pressure Modulated Radiometer (PMR) 2-channel; transmits radiance through gas-filled cells		vertical - 10 km at nadir; horizontal 500 km	Atmospheric temperature from 40-85 km altitude

FOR MORE INFORMATION:

Nimbus 5 Users Guide
R. R. Sabatini, Editor
NASA/GSFC, 1972, 59 p.

Nimbus 6 Users Guide
J. E. Sissala, Editor
NASA/GSFC, 1976, 59 p.

Nimbus G

EXPECTED LAUNCH DATE: August 31, 1978

ORBIT: Sun-synchronous, near polar; ascending node at about 1200 hours local time
Altitude: 955 km Inclination: 99.3°
Period: 104 minutes, with 6-day repeat cycle

PURPOSE: Integral part of Seasat-A program; Monitor pollution of air and oceans; Map sediments and coastal effluents; Long term weather prediction; Atmosphere/ocean interface

SENSORS:

	Wavelength	Resolution	FOV	Measurement	Sensor Scientist
Scanning Multi-channel Microwave Radiometer (SMMR) (to cover polar areas not covered by identical SMMR on Seasat)	6.6, 10.7, 18, 21, 37 gHz	33-245 km (spatial)	10°	sea-surface temperature, ocean rainfall snow and ice parameters, atmospheric water content	Dr. Per Gloersen, NASA/GSFC
Coastal Zone Color Scanner (CZCS)	0.43-0.45 µm 0.51-0.53 µm 0.54-0.56 µm 0.66-0.68 µm 0.70-0.80 µm 10.5-12.5 µm	800 m	1800 km	chlorophyll absorption chlorophyll correlation gelbstoffe (yellow substance) chlorophyll absorption surface vegetation surface temperature	Dr. Warren Hovis, NOAA/NESS
Solar and Backscattered Ultraviolet/Total Ozone Mapping Spectrometer (SBUV/TOMS)	2550-3400 Å (step scan) 1600-4000 Å (continuous scan)	50 km	11.33° 3°	stratospheric ozone profile global distribution of total ozone	Dr. Donald Heath, NASA/GSFC
Limb Infrared Monitor of the Stratosphere (LIMS)	6 channels 6-18 µm	0.5 mrad	2°	vertical profiles of temperature, concentrations of O_3, H_2O, NO_2 and HNO_3	Dr. James M. Russell III, NASA/Langley
Stratospheric Aerosol Measurement (SAM II) solar photometer	1 µm			distribution and optical properties of aerosols from 10 to 160 km	Dr. M. P. McCormick, NASA/Langley
Stratospheric and Mesospheric Sounder (SAMS)			100 x 10 km	vertical profiles of stratospheric CO_2, CO, NO, H_2O, N_2O, and CH_4	Dr. John Houghton, Univ. of Oxford, UK
Measurement of Air Pollution from Satellites (MAPS)				map global distribution of CO, CH_4, and NH_3 levels in troposphere	
Experiments continued from Nimbus 5 and/or 6:					
Temperature Humidity Infrared Radiometer (THIR)	6.5-7 µm 10.5-12.5 µm		21 mrad 7 mrad	infrared radiation from Earth; pictures and 3-dimensional mapping of cloud cover	
Earth Radiation Budget (ERB) 22-channel radiometer				compute radiation budget	
Data Collection System					

FOR MORE INFORMATION: Archival and publication plans for Nimbus G data will be reported in:

Nimbus-G Data Users Bulletin
Nimbus Data Applications System
Code 902, NASA/GSFC
Greenbelt, Md. 20771

Project Manager: Ron Browning
NASA/GSFC

April 15, 1978

DMSP (Defense Meteorological Satellite Program)

BACKGROUND: Formerly a U.S. Air Force system called DAPP (Data Acquisition and Processing Program), begun about 1968. Imagery declassified in December 1972.

Block 5-C: First operational system with two polar-orbiting satellites and a nighttime high-gain visual range Earth-imaging capability for city lights and aurora borealis. Phased out in 1977.

Block 5-D: First to achieve constant cross-track spatial resolution of scanner data for automated data processing and accurate Earth location of data.

LAUNCH DATES: First of Block 5-D series was launched in September 1976. It malfunctioned in orbit and was restored to operation April 1, 1977. Second satellite in system was launched June 24, 1977.

ORBIT: Sun-synchronous, near-polar

Inclination:	98.75°
Altitude:	832 km
Period:	102 minutes, with 25° longitudinal increments
Coverage:	Global, 4 times daily; one vehicle oriented for coverage at 0600 and 1800 hours, the other at 1200 and 2400 hours.

SENSORS:

	Resolution		Swath width
Scanning optical telescope system	Very high	high	
Visible (Block 5-C, 0.40 to 1.1 µm) (Block 5-D, 0.50 to 1.2 µm) Infrared (8 to 13 µm)	0.60 km	3.7 km	2890 km

Imagery characteristics: 2890 x 5560 km format
Cassini projection at 1:15,000,000, or enlargement to 1:7,500,000
Thermal resolution of 1.6° C displayed as 16 shades of gray

8-channel sounding radiometer provides vertical temperature and humidity profiles of the atmosphere and total ozone.

RECORDERS: Three digital tape recorders, each with capacity of 1.67×10^9 bits

SPACECRAFT: Block 5-D chassis with precision mounting platforms for sensors
Equipment support module (2 computers for onboard data processing)
Spent 3rd stage rocket motor and support for reaction control equipment
Solar cell array

Gross weight:	470 kg	(Double the weight and four times the payload
Payload:	140 kg	capacity of Block 5-C spacecraft)

GROUND STATIONS: Data received at USAF terminals and USN carriers
16 mobile receivers (direct readout only)
Readout, direct or stored, limited to 400 minutes of data per ground station
Spacecraft controlled from Loring AFB, Maine, and Fairchild AFB, Washington

PURPOSE: Global weather data to support military operations
Monitoring coastal areas
Oceanographic data

DATA AVAILABILITY: Videotapes available to DOD users only
Imagery of polar areas archived at World Data Center, Boulder, Colorado
Imagery of temperate areas archived at University of Wisconsin, Space Science and Engineering Center
For new imagery, or for more information, contact NOAA/NESS, World Weather Building, Camp Springs, Md. 20031

Users Guides: Dickenson and others, 1974, U.S. Air Force
Pike, 1975, Air Force Cambridge Research Labs (AFCRL-TR-75-0191)

ATS (Applications Technology Satellite)

	Launch date	Position at Equator	Significance	Operation ended
ATS-1	December 1966	150° W	First continuous black-and-white cloud cover imagery from geosynchronous orbit	October 1972
ATS-2	April 1967	unstable	Data not useful	
ATS-3	November 1967	69° W	First continuous color cloud cover imagery from geosynchronous orbit	October 1975 (SSCC)

ORBIT: Geostationary

Altitude: about 35,800 km
Inclination: 7°

SENSOR: Spin-Scan Cloud Camera (SSCC)

Resolution: 3.2 km (peak sensitivity in green band)
FOV: 15,000 km

DESCRIPTION: Cylindrical

Weight: 352 kg   Height: 137 cm   Diameter: 146 cm

PURPOSE: Forerunner of SMS/GOES weather satellite system. ATS-3 still sends data for Weather Facsimile Experiment (WEFAX)
Now used for medical communications in remote areas

GROUND STATIONS: Wallops, Va., Rosman, N. Car. (VHF band)

REMARKS: Viewed Earth only in daylight.

SMS/GOES

SMS (Synchronous Meteorological Satellite) is the NASA prototype in the GOES (Geostationary Operational Environmental Satellite) NOAA system

	Launch date	Significance
SMS-1	May 17, 1974	NASA prototype. First geosynchronous operational satellite with VISSR
SMS-2	February 6, 1975	Began first 2-satellite system for near-continuous viewing of U.S. and adjacent waters
GOES-1	October 16, 1975	First NOAA operational geosynchronous satellite
GOES-2	June 16, 1977	
GOES-C	May 1978 (in case of malfunction of orbiting spacecraft)	

ORBIT: Earth-synchronous (geostationary). One spacecraft positioned at 75° W (off Brazil), one at 135° W (south of Alaska), and one at 105° W (on standby)

Altitude: 35,800 km (average)
Inclination: Less than 0.5°
Coverage: 60° N-S. Western Europe and Africa westward to western Pacific Ocean, including all of North and South America

SENSORS:

	Wavelength (μm)	Resolution (km)
Visible Infrared Spin-Scan Radiometer (VISSR)		
Visible	0.55-0.70	0.80
Infrared	10.5-12.6	8.0 (temperature range 180-315° K)

Space Environment Monitor (SEM)
Magnetometer   Solar X-ray telescope   Energetic particle sensors

Meteorological data collection and transmission system from up to 10,000 platforms every 6 hours

DESCRIPTION: Cylindrical, with magnetometer extending 84 cm
Height: 231 cm   Diameter: 190.5   Weight: 305 kg

PURPOSE: Provides day and night cloud cover data every 30 minutes
Measures radiance temperatures of Earth and atmosphere
SEM data used to forecast space disturbances
Correlative data for Seasat experiments

DATA AVAILABILITY: Data transmitted to Wallops, Va., Command and Data Acquisition Station (CDA)
Weather data relayed to Department of Commerce World Weather Building, Camp Springs, Md., and disseminated to users via telephone system.
SEM data relayed to NOAA research labs in Boulder, Colorado.

FOR MORE INFORMATION: GOES/SMS Users' Guide, by R. P. Corbell, C. J. Callahan, and W. J. Kotsch
NOAA and NASA, Washington, D. C., 118 p.

April 15, 1978

Landsat 1, 2, 3

Initially called Earth Resources Technology Satellite (ERTS)

LAUNCH DATES: Landsat-1, July 23, 1972. Operation ended January 6, 1978.
Landsat-2, January 22, 1975.
Landsat-3, March 5, 1978.

ORBITAL ELEMENTS: Orbit: Circular, near polar
Inclination: 99.09°
Altitude: 919 km
Coverage: 82° north to 82° south
Period: 103 minutes, crossing Equator at 0930 hours, local time
Cycle: 18 days. Landsat-3 follows Landsat-2 by 9 days.

SENSORS:

	Wavelength (μm)	Resolution	Image format
Return Beam Vidicon Cameras (RBV)			
Landsat-1 and -2, three RBVs:			Simultaneous view from 3 cameras of scene 185 x 185 km
Band 1	0.475-0.575 (blue-green)		
Band 2	0.580-0.680 (yellow-red)	80 m	14% sidelap at Equator
Band 3	0.690-0.830 (red - IR)		10% forward lap
Landsat-3, two RBVs	0.505-0.750 (panchromatic)	40 m	2 side-by-side images 98 x 98 km (4 RBV images coincide nearly with one MSS frame)
Multispectral Scanner			
Landsat-1, -2, -3			
Band 4	0.50-0.60 (green)		185-km strip image framed with 10% forward lap
Band 5	0.60-0.70 (red)		
Band 6	0.70-0.80 (near	80 m	14% sidelap at Equator, increasing toward poles
Band 7	0.80-1.1 infrared)		
Landsat-3 only:			
Band 8	10.4-12.6 (thermal IR)	240 m Range: 260°K-340°K	

2 wideband tape recorders (only one tape recorder operating on Landsat-2)

Data Collection System (from up to 1000 platforms, each with 8 sensors)
Terminated on Landsat-2 on launch of Landsat-3. Reinstated on Landsat-3.

DATA AVAILABILITY: All data received in the U.S. are in the public domain and can be purchased either as image products or as computer-compatible tapes from the Department of the Interior's EROS Data Center, Sioux Falls, S. Dak.

The EROS Digital Image Processing System (EDIPS) will be operational by late 1978. High density digital tapes supplied by NASA/GSFC will be converted by EDIPS high resolution laser-beam film recorder to first-generation master film products in 241-mm format, enabling EDC to deliver second-generation products to data users. CCT data from HDTs will also be formatted and recorded by EDIPS.

GROUND DATA ACQUISITION STATIONS: Existing: Fairbanks, Alaska, Goldstone, Calif., Greenbelt, Md., in the U.S. Prince Albert, Saskatchewan, and Shoe Cove, Newfoundland, in Canada; Cuiaba, Brazil; Fucino, Italy. Nearly completed: Shahdasht, Iran. Agreed upon but not yet operating: Argentina, Australia, India, Japan, Sweden, Upper Volta, and Zaire.

FOR MORE INFORMATION:

Landsat Data Users Handbook
Missions Utilization Office
Code 902, NASA/GSFC
Greenbelt, Md. 20771

Landsat Data Users Notes
Users Services
EROS Data Center
Sioux Falls, S. Dak.
57198

Landsat-3 Reference Manual
General Electric Space Div.
P.O. Box 8555
Philadelphia, Pa. 19101

Landsat-D

EXPECTED LAUNCH DATE: Early 1981, in Space Shuttle

ORBIT: Circular, near-polar
Altitude: Not yet determined (705-720 km)

SPACECRAFT: Multiple-Mission Modular Spacecraft (MMS)
Greater attitude stability (to within 0.01° compared to 0.7° for earlier Landsats) will improve geometric accuracy of data

PROPOSED SENSORS (with improved spatial, spectral, and radiometric resolution):

Multispectral Scanner (MSS)	Wavelength (μm)	Resolution	Swath width	Scenes/day	Data rate
5 bands					
green	0.50-0.60	80 m	185 km	200 (U.S.) 400 (World-wide)	15 mbps
red	0.60-0.70				
solar IR	0.70-0.80				
solar IR	0.80-1.1				
thermal IR	10.4-12.6	240 m			

For continuity of Landsat data

Thematic Mapper (TM)	Wavelength (μm)	Resolution	Swath width	Scenes/day	Data rate
7 bands					
blue-green	0.45-0.52	30 m	185 km	50 (U.S.) 100 (World-wide)	84 mbps*
green	0.52-0.60				
red	0.63-0.69				
solar IR	0.76-0.90				
solar IR	1.55-1.75				
solar IR	2.08-2.35				
thermal IR	10.4-12.5	120 m			

*Large volume of data from TM may require use of image compression techniques.

GROUND DATA SYSTEM: Will improve worldwide coverage by eliminating unreliable tape recorders and shorten time frame of delivering data to users.

Direct Readout Stations (DROS):

Existing, or with existing agreements - Prince Albert, Saskatchewan, and Shoe Cove, Newfoundland, Canada; Cuiaba, Brazil; Fucino, Italy; Shahdasht, Iran; Argentina, and India.

Being negotiated - Australia, Japan, Sweden, Upper Volta, and Zaire.

Downlinks: MSS - S-Band (~2 gHz)
TM - X-Band (~8 gHz)

Tracking Data and Relay Satellite System (TDRSS): To ground station at White Sands, New Mexico, to GSFC via Domsat for preprocessing, to EROS Data Center and other users.

DATA AVAILABILITY: Archived and distributed to public by EROS Data Center.

FOR MORE INFORMATION: Resource and Environmental Surveys from Space with the Thematic Mapper in the 1980's, 1976, Committee on Remote Sensing Programs for Earth Resource Surveys, National Research Council, available from NTIS as NRC/CORSPERS-76/1, 122 p.

CONTACT: Dr. V. V. Salomonson, Landsat-D Project Scientist
NASA GSFC, Code 913, Greenbelt, Md. 20771

March 15, 1978

Skylab

	Launch date	Crew	Duration
Skylab 1	May 14, 1973	Unmanned	Shuttle may attempt to reactivate in 1979
Skylab 2	May 25, 1973	Conrad, Kerwin, Weitz	28 days
Skylab 3	July 28, 1973	Bean, Garriott, Lousma	59 days
Skylab 4	Nov. 16, 1973	Carr, Gibson, Pogue	84 days

ORBITAL ELEMENTS:

Apogee:	439 km	Inclination:	50°
Perigee:	423 km	Period:	93.2 minutes
Velocity:	27,515 km/hr	Coverage:	50° N-S; scattered

SENSORS:

	Wavelength (μm)	Resolution	FOV	Film
Multispectral photographic camera (S 190 A)	0.50-0.60	30 m		B/W Pan
	0.60-0.70	28		
	0.70-0.80	67	163 km	B/W IR
	0.80-0.90	67		
	0.50-0.88	57		CIR
	0.40-0.70	24		Color
Earth terrain camera (S 190 B)	0.40-0.70	15 m		Color
	0.50-0.70	15	110 km	B/W
	0.50-0.88	30		CIR
Infrared spectrometer (S 191)	0.4-2.5			
	6.6-16			
				Products
Multispectral scanner (S 192)	0.41-1.35		69 km	Single band B/W images
	1.48-2.43		swath	3 band false color images; CCT's
	10.2-12.5			
	Wavelength (cm)			
Microwave radiometer/ scatterometer and altimeter (S 193)	2.2		11 km diameter circle	
				Temperature range
L-Band radiometer (S 194)	21	± 1.0°K		0-350° K

SPACECRAFT:

Skylab 1: Orbital workshop
Airlock module
Multiple docking adaptor
Apollo telescope mount

Skylab 2, 3, 4: Command and Service module (modified Apollo module)

Total weight of docked assembly: 87,600 kg

PURPOSE: Earth Resources Experiment Package (EREP)
Data collected over preselected test sites for 145 Principal Investigators
Solar experiments, medical experiments, student investigations

DATA AVAILABILITY: EREP data from Department of Interior's EROS Data Center, Sioux Falls, South Dakota
Solar data from U.S. Naval Research Laboratory

FOR MORE INFORMATION: Skylab Earth Resources Data Catalogue, 1974
NASA/JSC, Houston, Texas 09016
(GPO stock no. 3300-00586)

March 15, 1978

GEOS-3
(Geodynamics Experimental Ocean Satellite)

LAUNCH DATE: April 9, 1975

ORBIT: Circular

Altitude:

Apogee: 848 km
Perigee: 839 km

Inclination: 114.9°

Period: 101.7 minutes

SENSORS:

Radar altimeter (accuracy of 1 meter over water)
Coherent and noncoherent C-band transponders
S-band instrumentation
Laser retroreflectors
Doppler transmitters

DESCRIPTION: Octahedron 132 cm wide topped by truncated pyramid
16 solar cell panels
Gravity-gradient stabilization scissors boom assembly with end mass of 45 kg extends to 6.5 m in orbit plane

Height: 81 cm
Weight: 340 kg

PURPOSE:

Measure geometry of oceans, topography of surface, currents, and circulation.

Land and ice tracking.

Fulfill oceanographic, geodetic, and radar calibration requirements.

Used with ATS-6 in satellite-to-satellite tracking experiment.

March 15, 1978

LAGEOS (Laser Geodynamic Satellite)

LAUNCH DATE: May 4, 1976

ORBIT: Circular, highly stable (Drag effects of solar radiation, traces of Earth's atmosphere, or variation in gravity field minimized by density and small size.)

Altitude: 5790 km
Inclination: 110°

SENSORS: 426 retroreflectors made of high quality fused silica passively reflect laser light aimed from Earth

DESCRIPTION: Spherical, retroreflective, passive satellite

Diameter: 60 cm
Weight: 411 kg

PURPOSE: Earth dynamics; precise measurements over large distances (to within 0.1 m now, and to within 20 mm when measurement techniques are perfected)
Plate tectonics; measurements of rate and direction of movement of continental plates

REMARKS: Useful life expectance, a few hundred years.

CONTACT: (For data or information)

Chris C. Stephanides
NASA/GSFC Code 943
Greenbelt, Md. 20771

HCMM (Heat Capacity Mapping Mission)

LAUNCH DATE: April 1978 Expected lifetime: One year

ORBIT: Circular, sun-synchronous, crossing Equator at 0200 and 1400 hours
Altitude: 600 km
Cycle: 1½ to 3½ days, depending on field of view distortion and atmospheric interference at large angles to nadir
Coverage: To within 5° of poles (Data limited by range of ground stations)
Repeat coverage (day/night passes over given area within 24 hours) for thermal inertia measurements every 8 days

SENSOR:

	Wavelength	Resolution	Swath width	Data format
Heat Capacity Mapping Radiometer (scanner-adapted Nimbus 5 surface composition mapping radiometer)	0.50-1.1 μm 10.5-12.5 μm	600 m at nadir	700 km	1:4,000,000-scale imagery; Space Oblique Mercator Projection (SOM) Calibrated tapes, corrected or uncorrected

No tape recorder. Direct transmission, S-Band.

HCMR also flown over test sites on U-2, RB-57, and NC 130B aircraft to supply supportive data

SPACECRAFT: Weight: 130 kg Diameter: 76 cm
Height: 118 cm (solar paddles extend to 2.9 m)

PURPOSE: Measure reflected solar energy
Determine heat capacity of rock types
Monitor soil moisture, thermal effluents, plant canopy temperature, snow cover

GROUND STATIONS: Fairbanks, Alaska, Goldstone, Calif., Rosman, N.C., in the U.S. Shoe Cove, Newfoundland, Canada; Madrid, Spain; and Orroral, Australia.

DATA AVAILABILITY: Standing orders (day visible, day IR and night IR) and retrospective data (CCT's, day/night temperature difference images, thermal inertia images) sent from Goddard to Principal Investigators.

Standard products available to all will be listed in catalogs by National Space Science Data Center, Code 601, GSFC

FOR MORE INFORMATION:

HCMM Data Users Bulletin
Code 902, NASA/GSFC

Users Guide for direct readout
Applications, AEM-A, 1976, NASA/GSFC

Seasat-A

EXPECTED LAUNCH DATE: May 1978
Expected lifetime: One year.

ORBIT: Nearly circular, non sun-synchronous
Altitude: 790.17 km ± 50 m
Inclination: 108° nominal, 104°-108° range
Coverage: 72° north to 72° south
Period: 100.75 minutes
Orbits per day: 14.3
Orbit repeat (exact): 152 days

SENSORS: (must be aligned to within 0.07° and pointing angle known to within 0.035° with unobstructed view of Earth)

Active	Frequency/ wavelength	Resolution	Swath width/ FOV	Measurement
Synthetic aperture radar (SAR) (data limited to 60 min/day; direct readout only)	1274.8 gHz (L-Band, 25 cm) Polarization HH	25 m at 4 looks	100 km swath (on one side of spacecraft)	images and spectra of waves coastal, land, and ice imagery
Radar altimeter (improved from Skylab and Geos-3)	13.499 gHz	H 1/3=1-20 m	1.6 km (at nadir, on calm sea)	H 1/3=significant wave altitude (to ± 1 m) marine geoid (to ± 10 cm) tides, currents
Radar scatterometer (improved from Skylab)	14.599 gHz Polarization HH,VV	high gain 50 km low gain 200 km	one 500-km one 750-km (overlapping) one 280 km (at nadir)	speed and direction (to ± 20°) of winds under 20 m/sec
Passive				
Visible/infrared radiometer (from ITOS)	0.47-0.94 μm 10.5-12.5 μm	2 km 4 km	679 km (arc width) on one side of nadir	clouds, sea surface temperature within ± 2°C (day and night)
Scanning multi-frequency micro-wave radiometer (SMMR)*	6.6, 10.7, 18, 21, 37 gHz	21-121 km, major axis 14-79 km, minor axis	2127 km for ± 50 incidence angle	speed (7 m to 50 m/sec) and direction of winds over 20 m/sec; atmospheric vapor and liquid content; raindrop size and distribution sea surface temperature

*Identical instrument on Nimbus G to cover polar regions

Two tape recorders can store data (except SAR) from 2 orbits record at 25 kilobits/sec; downlink at 640 kilobits/sec (non SAR)

DESCRIPTION: Spacecraft bus (Agena) attached to sensor module and support structure
Launch vehicle: Atlas-F

GROUND STATIONS: U.S.: Fairbanks, Alaska; Goldstone, California; Merrit Island, Florida; Canada/CCRS: Shoe Cove, Newfoundland. ESA stations in Oakhanger, England, and Canary Islands may process SAR data (real time only).

PURPOSE: All-weather monitoring of ocean surface (all sensors)
Radar imaging of land surface
Commercial uses: Indicate fishing areas, route ships, time offshore drilling

DISTRIBUTION OF DATA: All but SAR: From Fairbanks to Navy's Fleet Numerical Weather Center, Monterey, Calif., via commercial communications spacecraft (in real time) to NOAA/NESS for public distribution.
SAR: From all stations via mail to JPL/SDPS to NOAA/NESS (processed image data only)

FOR FURTHER INFORMATION: NOAA Program Development Plan for Seasat-A Research and Applications, U.S. Dept. of Commerce, NOAA/NESS, March 1977 (GPO 1977-240-848/13)

Operational Oceanographic Satellites: Potentials for Oceanography, Climatology, Coastal Processes, and Ice, by Robert G. Nagler and S. W. McCandless, Jr., 1975, Jet Propulsion Laboratory, Calif. Inst. Tech., Contract NAS 7-100, NASA Office of Applications, 12 p.

March 15, 1978

MAGSAT

(Magnetic Field Satellite)

EXPECTED LAUNCH DATE: September 1979
Expected Lifetime: 4-8 months

ORBIT: Quasi sun-synchronous
Inclination: 97°
Apogee: 550 km
Perigee: 325 km

SENSORS: Alkali vapor scalar magnetometer, 15,000 to 64,000 gamma
Triaxial fluxgate magnetometer ± 64,000 gamma

System accuracy:
Scalar ± 3 gamma
Vector 6 gamma root sum squared (rss)

Telemetry downlink:
2282.5 - 2284.5 megahertz pulse code modulation (PCM)
8 bit words
312 K bit data rate

OTHER FEATURES: Deployable boom
Boom attitude transfer system with redundant self-calibrating 3-axis measurement to 5 arc sec
Magnetic spacecraft cleanliness at sensor: less than 1 gamma
Weight: 165 kg Power: 72 watts

PURPOSE: Scalar and vector magnetic field measurements will be used to:
Update maps of Earth's magnetic field
Produce geomagnetic field models
Produce crustal anomaly maps

REFERENCE: Langel, R.A., Regan, R.D., and Murphy, J.P., Magsat: A Satellite for Measuring Near-Earth Magnetic Fields: NASA, Goddard Space Flight Center, Preprint X-922-77-199.

CONTACT: Magsat Project
NASA/GSFC, Code 922
Greenbelt, MD 20771

Dr. Robert A. Langel, Project Scientist
Mr. Gilbert Ousley, Project Manager

DATA AVAILABILITY: National Space Sciences Data Center
NASA/GSFC
Greenbelt, MD 20771

April 15, 1978

Stereosat

BACKGROUND: Proposed as a NASA Applications Explorer Mission by the Geosat Committee.

Geosat Committee: Incorporated in 1976 as a nonprofit organization
Supported entirely by contributions from industrial firms
Seeks to consolidate industrial needs for pertinent, geologically related objectives into federally sponsored remote sensing programs

PURPOSE: Cloudfree stereoscopic multispectral coverage from space of the world's land mass to be obtained in a two-year period.
Useful for rock discrimination, structural interpretation, geomorphic analysis, and general geologic mapping.

EXPECTED LAUNCH DATE: Mission not yet approved

ORBIT: Polar, sun-synchronous
Altitude: 578 km
Period: 96.1 minutes

PROPOSED IMAGING SYSTEM: To provide black-and-white stereo coverage in near infrared in digital form to register with Landsat

Configuration - Single camera head, two telescopes, four sensors
Telescope - 600 mm, f/8 refractor
Sensor - Linear array of silicon photodiodes, 1872 elements

Full stereo angle - 60 degrees
Pixel footprint - 19.3 m along track by 16.7 m cross track
Swath width - 31.2 km

DATA TRANSMISSION: In real time through TDRSS
Backup data storage on 2 onboard digital tape recorders, each with 4×10^9 bit capacity; 8.1 mbps maximum rate

CONTACT: Dr. F. B. Henderson, III, President
Geosat Committee
690 Market Street
San Francisco, Calif.
94104

Space Shuttle

PURPOSE: Placement and recovery of satellites and free-flying laboratories
Service and repair of satellites in space
Reccue missions

ORBIT: Circular   Altitude: 185 to 1110 km   Mission duration: 7 to 30 days

ELEMENTS:

Orbiter ("Enterprise"): Serves as habitable space vehicle or aircraft for team of 3-7
Reusable after 2-week ground turnaround time
Weight: 68,000 kg
Dimensions: 37 m long; 17 m high; 24 m wingspan
Cargo bay: 18 m long x 5 m diameter
Capacity: 29,500 kg (285 cu m)
3 main engines

External tank (ET): Expendable; contains ascent propellant

2 solid rocket boosters (SRB's): Reusable; separation at 45.6 km; Recovered by parachute system

Spacelab: Multipurpose payload carrier for experiments conducted in space to begin in 1981
Being developed by 10 nations in European Space Agency (ESA)
Pressurized module; unpressurized pallet segments
Flown to and from orbit in cargo bay of Shuttle

ORBITAL FLIGHT TESTS (OFT's):

	Expected launch date	Inclination	Payload (kg)	Altitude (km)	Days	Crew
#2 Earthviewing*	7/79	32-40°	4550	165-275	to 5	2
#3 Long Duration Exposure (LDEF)	9/79	32-40°	9100 up 4550 down	275	to 7	2
#4 Astronomy	12/79	50-57°	10,000	415	to 7	2
#5 Multi-Mission Spacecraft (MMS)**	2/80	50-57°	10,000	415	7	3 or 4
#6 Physics	3/80	to be determined	10,000 to 25,000 up 10,000 dn	415	7	4

*Payload for OFT-2 will consist of:
MAPS (Measurement of Air Pollution from Space), gas filter correlation sensor
SMIRR (Shuttle Multispectral Infrared Radiometer), non-imaging
OCE (Ocean Color Experiment), low resolution digital images
NOSL (Nighttime Optical Survey of Lightning), 16-mm sound movie camera
AWSO (All Weather Surface Observations), modified Seasat SAR
**To be rescheduled, probably to OFT-6.

REMARKS: An Interim Upper Stage (IUS) is being developed by the U. S. Air Force to boost satellites into higher orbits.

DATA TRANSMITTAL: Tracking and data relay satellite system (TDRSS) after July 1980; NASA will retain ground station in Bermuda until TDRSS is proven, and station in Alaska until Shuttle launches into polar orbit are possible.

FOR MORE INFORMATION: Space Shuttle, NASA/JSC, Houston, Texas
SP-407, 89 p.
GPO stock no. 033-000-00651-9

April 15, 1978

Space Shuttle - Large Format Camera

Supported by Geosat Committee and USGS to provide high resolution stereo photography in limited geographic areas.

First flight scheduled for August 1980 on Shuttle mission STS-9 with French cartographic camera (Metric Camera).

Altitude:	300 km	Limitation:	Permits coverage of only 30° N-S.
Inclination:	28.5°		

SPECIFICATIONS: Photo-optical camera highly calibrated for cartographic photography

Focal length	- 30.5 cm
Image format	- 23 x 46 cm
Film emulsion	- Black and white, color, or color infrared
Base-height ratio	- 0.3 for high relief geological areas 0.9 to 1.2 for exaggeration of low relief
Resolution (photographic)	- Similar to Skylab's S-190 B camera 10 m - black and white 20 m - color 30 m - color infrared
Area photographed	- 225 x 450 km (from altitude of 300 km)

DATA RETRIEVAL: Film returned from short flights

CONTACT: Dr. Frederick J. Doyle
U. S. Geological Survey
MS 516, Reston, Va.
22092

March 15, 1978

Tracking and Data Relay Satellite System (TDRSS)

PURPOSE: To track and provide 2-way data communications with up to 22 satellites (except those with geosynchronous or highly elliptical orbits)
Wideband communications link for high data rates required by Landsat-D, Space Shuttle, and Spacelab.
Eliminate need for tape recorders, which have often malfunctioned
Save cost of modernizing and operating global network of ground stations.

LAUNCH DATE: July 1, 1980 (tentative), in 8th Space Shuttle flight, boosted by Interim Upper Stage

ORBIT: Geosynchronous. One satellite to be positioned over the Atlantic Ocean, and one over the Pacific Ocean.
Altitude: 33,000 km

SYSTEM: Identical spacecraft (advanced Westar) will carry payloads for NASA and Western Union. Two satellites will be configured on orbit for NASA use, two for Western Union use, and one for shared use as a spare.

High data rate users	Data rate		Satellite
Single access	forward	return	antenna
S-Band (2.0-2.3 gHz)	to 300 kbps	12 mbps	two 4.9 m gimballed antennae 2.5° beam
K-Band (13.8-15.1 gHz)	to 25 mbps	to 300 mbps Shuttle-geared service: a) 3 digital channels 50 mbps or b) 2 digital channels to 2 mbps and 4.2-mc analog or TV channel	
Low data rate users			
Multiple access S-Band	10 kbps	50 kbps	30-element phased array antenna 13.5° FOV

GROUND STATION: White Sands, New Mexico, for data reception
Landsat data to be transmitted via Domsat to Goddard for processing (to avoid backlog at White Sands).
Tracking network operations control center at Goddard

REFERENCE: Aviation Week & Space Technology, Oct. 17, 1977, P. 97, 99, 155, 157.

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London N 1 7LW, England. (U. S. Satellites, p. 723-740)

Aviation Week & Space Technology

Environmental Satellites: Systems, Data Interpretation, and Applications
U. S. Dept. of Commerce, NOAA/NESS S/T 76-2481, 66p.
GPO 210-801/425

Satellite Activities of NOAA 1977, 20 p.
U. S. Dept. of Commerce, NOAA/NESS Planning and Coordination Group
Washington, DC 20233

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Applications of Satellite Thermal Infrared Measurements to Earth's Resources, J. Cihlar and A. K. McQuillan, 35 p.
Canada Centre for Remote Sensing, Technical Information Service
717 Belfast Rd. Ottawa, Ontario, Canada K1A 0Y7

The Next Decade of Satellite Remote Sensing, Frederick J. Doyle, Photogrammetric Engineering and Remote Sensing, v. 44, no. 2, Feb. 1978, p. 155-164.

Data Collection Platforms:

Satellite Data Collection Newsletter
Dr. Enrico P. Mercanti
Code 952, NASA/GSFC
Greenbelt, MD 20771