Ucluelet, B.C.

PART IV

COASTAL, ESTUARINE, AND ENVIRONMENTAL PROBLEMS

Ocean Falls, B.C.

CHAPTER 115

REMOTE SENSING IN THE STUDY OF COASTAL PROCESSES

by
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ABSTRACT

The quantifiable determination of important coastal parameters remotely rather than by in situ measurements combined with automatic data reduction and analysis will result in a greatly increased understanding of the parameters being studied. This paper gives a progress report on joint Corps of Engineers-National Aeronautics and Space Administration (NASA) efforts to apply remote sensing in coastal studies. The devices used were multiband photography, the infrared scanner, the Side Looking Airborne Radar and various image enhancement and processing devices.

INTRODUCTION

The quantifiable determination of movement of sedimentary material along a coastline (or longshore transport) represents a major challenge facing coastal planners, coastal engineers and property owners.

Although littoral processes are conceptually understood, it is as yet not possible to adequately describe or quantify long or short term forecasts of the effects of improvements or modifications to the shoreline. In some instances, past shoreline changes have resulted in costly damage worth millions of dollars. Research in coastal processes at CERC is currently directed toward efforts to improve the state of the art on quantitative and qualitative approaches to this problem. These efforts are directed toward understanding of coastal phenomena based on extremely complex and relatively short lived in situ sediment transport measurements or experiments (such as radioisotope or fluorescent tagging of sand grains).

In addition to the examination of in situ sediment movement, it is also necessary to describe and quantify the major coastal processes which occur on a larger spatial basis.

The purpose of this study was to obtain imagery of a variety of coastal phenomena using available state-of-the-art devices, and to use appropriate enhancement and viewing equipment to evaluate the use of

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this imagery and techniques in the study of various coastal processes. On 4 October 1971 the National Aeronautics and Space Administration (NASA), Manned Spacecraft Center, Houston, Texas furnished the NASA 927 NP3A Earth Observation Aircraft Program research aircraft for a flight of the central and southern California coast. Seven flight lines were flown along the California coast using an RS-14 infrared scanner and photographic data runs with altitudes from 500 to 10,000 feet. A similar number of flight lines using Side Looking Airborne Radar (SLAR) offset roughly two nautical miles from the coast match the photographic flight lines and are flown at an altitude of 5,000 feet. The NASA 927 aircraft is an experimental platform in which may be installed a number of optical electronic or other experimental sensing packages. Photographic equipment consisted of four KA-62 cameras and two RC-8 metric cameras. Various filter/film combinations were employed to optimize imagery.

The RS-14 scanner is a radiometer that optically/mechanically scans successive contiguous lines across the flight path and records simultaneously in two spectral intervals the energy reflected or emitted by earth features. This device includes internal calibration sources and a number of thermal infrared detectors which may be used as desired. For this particular flight, wave lengths from 8 to 14 μm were recorded on film and wave lengths from 3 to 5.5 μm were stored on analog tape.

The 16.5 GHz (SLAR) is a radar mapping device which transmits a series of pulses of 16.5 GHz radiation in a narrow fan shaped beam from an antenna mounted on the aircraft. The transmitted pulses alternate between horizontal and vertical polarization and back scatter energy is received in both polarizations. The device produces a photograph-like image and was operated to optimize and enhance water and wave action return. Of particular interest to coastal investigators is the onboard navigation system which automatically controls aircraft flight on selected latitude and longitude points.

The multiband and infrared imagery was processed on an I^2S multiband camera film viewer (MCFV) in Houston at the NASA Manned Spacecraft Center. This device is a high resolution 1,000 line system scanning three channels of multiband imagery. The MCFV provides a calibrated output from each of the three channels for viewing in composite true color analog, false color and digitized enhanced false color. By use of this device imagery from the three channels of coastal data were synergistically combined to produce the desired enhancements. Examples will be shown of various enhancement combinations.*

Ground/sea truth measurements were also taken. These measurements include observations at Project LEO sites and special measurements at selected points within the flight areas. Experiments are limited to the

*Color flight imagery shown in Vancouver Conference. Presentation could not be included in this presentation.

coastline of the State of California. Work was sponsored jointly by the NASA and the Corps of Engineers, Coastal Engineering Research Center.

NASA FLIGHT

On 4 October 1971 the National Aeronautics and Space Administration (NASA) Manned Spacecraft Center (MSC), Houston, Texas, furnished the NASA 927 NP3A aircraft for a flight over the central and southern California coast. Ten flight lines along the California coast had the RS-14 infrared scanner and photographic data runs with altitudes flown from 500 to 1,000 feet. Seven flight lines of SLAR data offset roughly two nautical miles from the coast matched the photographic flight line and were flown at an altitude of 5,000 feet.

FLIGHT OPERATIONS

In flying this mission, the NASA 927 aircraft was staged out of Moffett Field, California. The predawn flight containing 14 flight lines extended from approximately Ano Nuevo, San Mateo County, to just north of San Clemente, Orange County, California. The flights were generally flown with an equal balance of land and water or to be fairly biased, toward a larger percentage of water than land, but generally strict tangent flight lines. A summary map is shown in Figures 2A and 2B. A listing of the precise location of imagery was generated from the onboard data processing system (ADIAZ) obtained from the automatic inertial guidance system on NASA 927. This system simultaneously logged physical parameters relating to the flight for subsequent printing.

REMOTE SENSING SYSTEMS

Remote Sensing Devices

For this particular flight, and to be described in the next sections, the following devices were installed:

a. Camera System:

Camera	Position	Type	Film	Filter	Lens	Forward overlap, percent
RC-8	1	Color	SO-397	Haze	6 in.	60
RC-8	2	Color IR	2443	12	6 in.	60
KA-62	1a	Color	SO-397	12	3 in.	60
KA-62	2	B&W	2402	25A	3 in.	60
KA-62	3	B&W	2402	58	3 in.	60
KA-62	4	B&W IR	SO-246	89B	3 in.	60
SLAR boresight		Color	2448			

1/ KA-62 camera #1 with color film was overexposed one f-stop over a normal land return exposure in order to achieve water penetration.

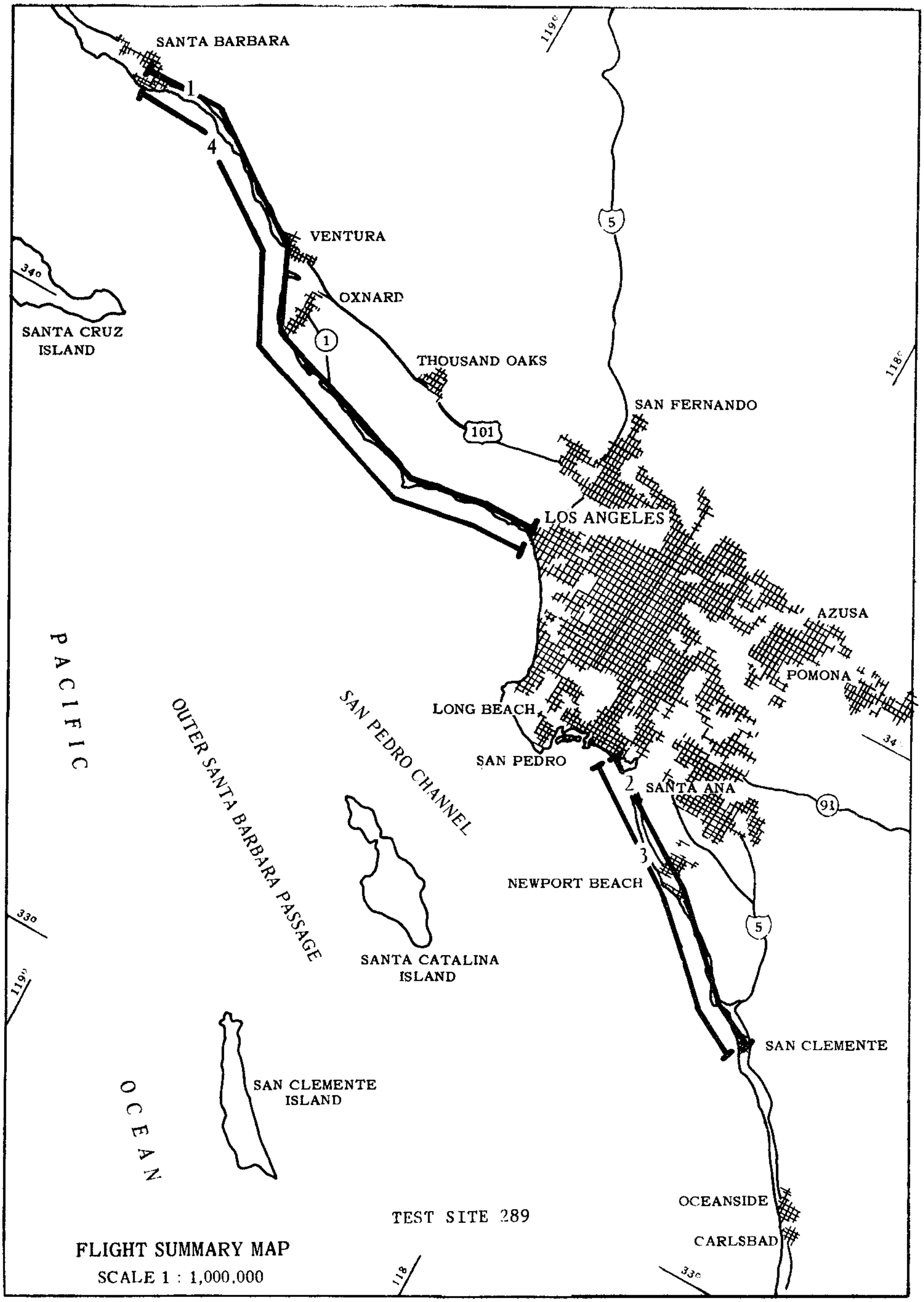

SANTA BARBARA
1
4
VENTURA
OXNARD
THOUSAND OAKS
SANTA CRUZ ISLAND
5
101
1
SAN FERNANDO
LOS ANGELES
AZUSA
POMONA
PACIFIC
OUTER SANTA BARBARA PASSAGE
SAN PEDRO CHANNEL
LONG BEACH
SAN PEDRO
2
SANTA ANA
91
3
NEWPORT BEACH
SANTA CATALINA ISLAND
SAN CLEMENTE
SAN CLEMENTE ISLAND
OCEAN
OCEANSIDE
CARLSBAD
TEST SITE 289
FLIGHT SUMMARY MAP
SCALE 1 : 1,000,000

FIGURE 2A

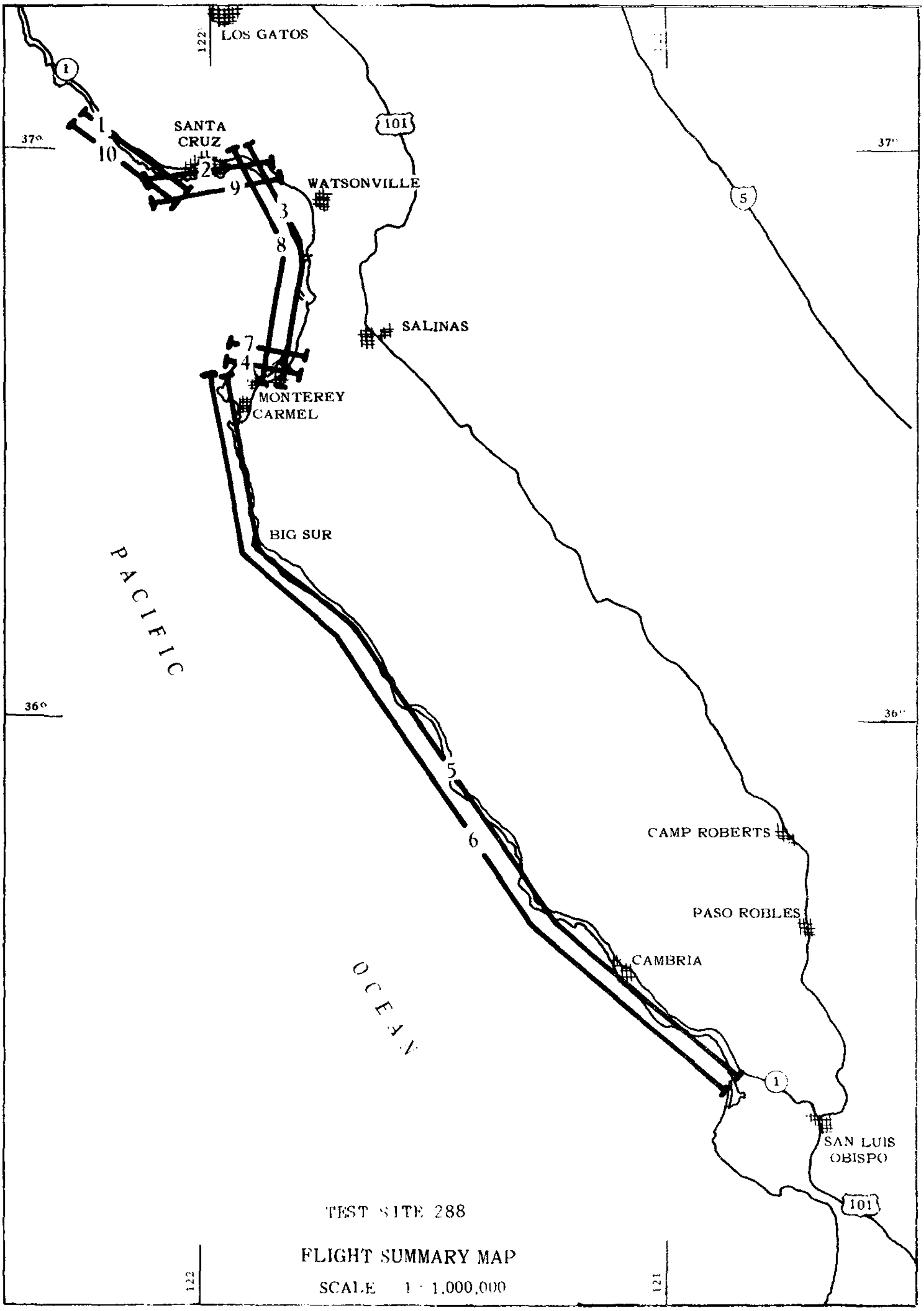

LOS GATOS
122
1
101
SANTA
CRUZ
37°
37°
5
WATSONVILLE
SALINAS
MONTEREY
CARMEL
BIG SUR
PACIFIC
36°
36°
OCEAN
CAMP ROBERTS
PASO ROBLES
CAMBRIA
SAN LUIS
OBISPO
101
TEST SITE 288
FLIGHT SUMMARY MAP
SCALE 1 : 1,000,000
122
121

FIGURE 2B

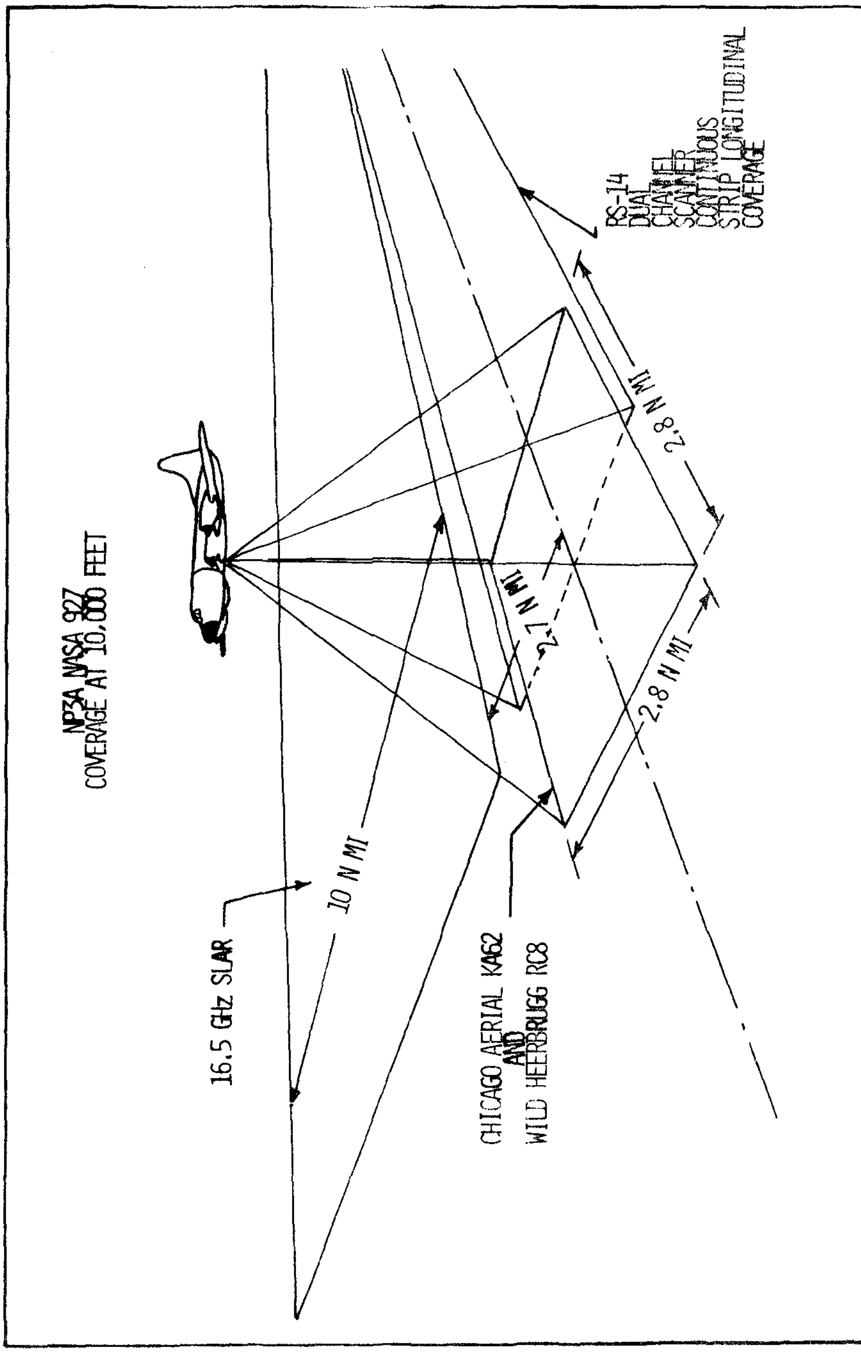

NP3A NASA 927
COVERAGE AT 10,000 FEET
16.5 GHz SLAR
10 N MI
CHICAGO AERIAL KA62
AND
WILD HEERBRUGG RC8
2.7 N MI
2.8 N MI
2.8 N MI
RS-14
DUAL
CHANNEL
SCANNER
CONTINUOUS
STRIP LONGITUDINAL
COVERAGE

FIGURE 3

b. RS-14 Scanner:

(1) Channel 1 - 3 to 5.5 μm
(2) Channel 2 - 8 to 14 μm

c. 16.5 GHz SLAR:

(1) Optimized settings to enhance water and wave action return.
(2) Full polarization matrix.

d. PRT-5: Recorded on onboard strip chart and magnetic tape.

e. Atmospheric sensors: Temperature, dew point, and liquid water content.

f. LTN-51

Cameras:

RC-8 Metric Camera. The Wild-Heerbrugg RC-8 metric, general mapping cameras employ a 6-inch focal-length, Universal Aviogon lens capable of color, color infrared, or conventional black and white on 9-inch format photo film. The camera is primarily employed as a high resolution terrain correlation and indexing device as described in the NASA MSC publication, "Earth Observation Aircraft Facility of the Manned Spacecraft Center, Vol. I."

The camera incorporates two separate data systems: an electromechanical events counter and a data recording cathode ray tube (CRT). The CRT displays encoded auxiliary data (ADAS) pertinent to camera operation and aircraft flight. The events counter registers the frame number and fixed data consisting of lens serial number and focal length. The events counter and fixed data is displayed on the edge of the film and CRT data is displayed on a corner of each frame.

The RC-8 cameras were mounted in T-28A-6 stabilized camera platform which increase camera steadiness and vertical accuracy under all conditions of flight within the range of the platform's freedom of movement. The platform is electronically controlled and gyroscopically stabilized to:

Provide a stabilized platform to support the RC-8 aerial camera in the aircraft

Maintain the optical axis of the camera fized with respect to vertical

Increase image resolution by reducing the effects of aircraft vibration and roll and pitch motion

Provide remote positioning of the camera azimuth to correct for the "crab" of the aircraft.

The maximum limits of correction for the T-28A-6 stabilized platform are as follows:

Azimuth	±15°
Roll	± 8°
Pitch	± 8°

KA-62 Camera System. The KA-62 is a serial frame camera employing spectral bandpass filters, a 3-inch focal length lens, and a 4.5-inch square image format. Depending on the filters installed, the camera may be used for broadband photography or for photographs sensitized to a selected portion of the spectrum.

A multiband camera system is formed by boresighting the cameras in the aircraft and using a different spectral bandpass filter with each camera. In the multiband application, the cameras are operated synchronously; photographs obtained show differences in tone density because of differential reflectance, thus accurately representing characteristics of the terrain.

The KA-62 camera incorporates two separate data systems: a 4-digit, cumulative, resettable, electromechanical events counter, and a data recording cathode ray tube (CRT) with their respective optical projection systems. The CRT displays encoded auxiliary data on camera operation and aircraft flight. The events counter registers the frame number and fixed data consisting of lens serial number and focal length. The events counter display is recorded on the edge of the film and the CRT data is recorded on a corner of each frame.

Image motion compensation (IMC) capability is provided to allow operation within a wide range of aircraft altitude and ground speeds. The KA-62 camera may be operated using either modified pulse mode or modified IMC pulse mode, controlled by remote switching in the Aircraft Camera Control System (ACCS).

An 89B filter is used with infrared aerographic film when operating only one camera with IR film; if two cameras are used with IR film, a 25A filter is used with the second camera.

Infrared

RS-14 Dual Channel Infrared Imaging Scanner. The Texas Instruments RS-14 Scanner detects infrared or ultraviolet radiation and processes the detected signals as video, displays the video as an intensity-modulated CRT trace, and projects the CRT trace on traveling photographic film. Infrared energy received is reflected through the scanner optical system and is focused upon a detector enclosed in the vacuum chamber of a closed-cycle refrigerator or cooler. Either two or four infrared detectors are available, depending upon preflight selection and installation of detectors for the particular mission. A fifth sensor, a photomultiplier tube that may be installed before flight in place of two of the four IR detectors, detects ultraviolet and visual radiation.

While recording during flight, the selected detector converts received infrared or ultraviolet visual energy variations into electrical signals. The sensor output is processed into video and displayed as an intensity-modulated trace on a 5-inch CRT in the recorder unit. The CRT trace image is optically coupled to the film magazine unit, exposing the film to produce a rectilinear map.

Figure 4 is a simplified operating diagram of an IR scanner. In addition to the video calibration sources, a 10-step calibration scale and auxiliary data are displayed on the film. The system compensates for aircraft roll by use of inputs from a vertical gyro in the scanner.

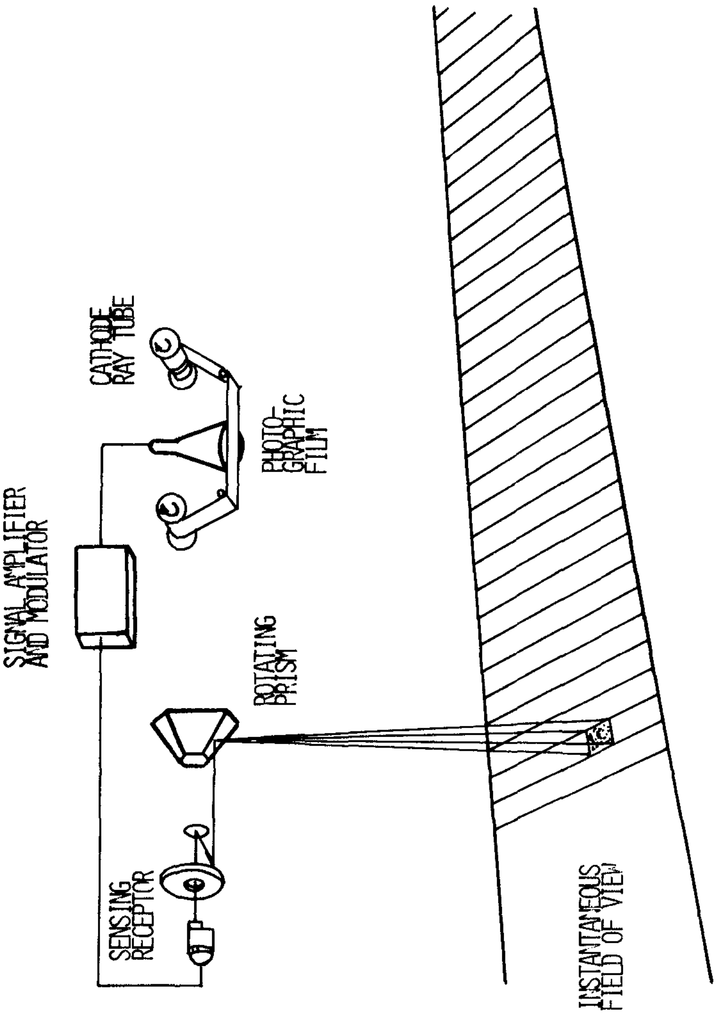
Principles of Operation. The RS-14 IR Scanner is a passive, airborne, infrared and ultraviolet imaging system. The instrument scans the ground surface along the aircraft flight path and produces a rectilinear photographic image of the terrain. The system is passive in that it detects and records variations in the radiant energy emanating from earth terrain. Information received by the scanner is converted to video intelligence and processed through the scanner. The video intelligence is converted to visible energy via a CRT for recording on photographic film within a film magazine. A heat exchanger, part of the cryogenic cooling system, maintains the low temperature necessary to operate the infrared detectors located within the scanner. A power supply provides system operating voltages.

Precision Radiation Thermometer. In order to determine precise temperatures directly below the aircraft and to appropriately adjust the RS-14 radiometer, a Barnes Precision Radiation Thermometer (PRT-5) was operated during the times that the RS-14 was in operation.

The Barnes PRT-4 has a 2° field of view. The detector is an immersed thermistor bolometer. The absolute system accuracy of ±0.5°C (claimed) is achieved by controlling the temperature of a heated in-line reference cavity within the optical head of the PRT-5. Incoming target radiation (8 to 14 microns) is compared continuously with the known radiation of the internal reference. The difference is converted into a proportional electrical signal that is equivalent to the target radiation temperature. The output of the PRT-5 is proportional to the fourth power of the absolute radiation temperature; thus, a correction should be made to any linear interpolation between the high and low range marks.

SIDE LOOKING AIRBORNE RADAR (SLAR)

In an attempt to determine the applicability of side looking airborne radar (SLAR), a 16.5 GHz SLAR was operated on 14 flight lines of the 4 October 1971 NASA flight.



RS-14 Operating Diagram

Figure 4.

The SLAR is an unfocused, synthetic aperature, airborne, radar mapping device which scans the terrain on the starboard side of the aircraft's ground track. The AN/DPD-2 radar was modified by Philco-Ford to provide a dual polarization capability, with the radar data formatted into four separate polarization information channels for film recording.

The microwave energy scattering characteristics of physical objects provide a wide range of identifiable radar backscatter, or return. The differences between these returns enables use of radar to map a given area. The results may be interpreted through an understanding of the characteristic returns as more data is obtained on these characteristic returns. The 16.5 GHz SLAR provides high resolution ground mapping by utilizing a short pulse-width for range resolution (across-track) and a long, synthetically obtained antenna aperture for azimuth resolution (along-track).

The SLAR generates four 10-nautical mile-wide strip map images of the area on the right side of the aircraft. The strip map images (one parallel and one cross polarization for both horizontally and vertically polarized transmissions) are recorded on film during flight. All radar data processing needed to produce a map image is completed before recording on film.

The radar operator may select one of five slant-range swath positions (0 to 10 n.mi., 1.4 to 11.4 n.mi., 2.7 to 12.7 n.mi., 4.0 to 14.0 n.mi., or 5.4 to 15.4 n.mi.) to map the desired area.

As the aircraft flies over the selected terrain, a pulse generator circuit produces a continuous train of pulses. The pulses are used to drive the transmitter and to initiate the sweep on the CRTs which expose the film. The transmitter converts each pulse received into a burst of radio frequency (RF) energy. The duplexer, a switching device used to connect or disconnect the antenna to or from the transmitter or the receiver, connects the antenna to the transmitter during the brief pulse period when RF energy is generated. The antenna radiates the energy toward the terrain below in a narrow, shaped beam. Because of the depression angle (the angle below horizontal at which the energy is directed), the wave front contacts the ground at a point Q (see Figure 9 on the following page) and continues to sweep outward to point T. The antenna receives the backscatter, and because it is connected by the duplexer to the superheterodyne receiver, feeds the microwave energy into the electronic network. The backscattered energy is converted into voltage variations which in turn modulate the intensity of two CRTs. The recording film is transported across the face of the CRTs at a rate proportional to the aircraft's ground speed. The CRTs expose the film in "sweeps" or lines in synchronism with the RF energy wave front "sweep" over the terrain (see Figure 10). The transmitter utilizes a ferrite switch to control polarization of transmissions.

16.5 GHz SLAR Antenna Pattern Diagram

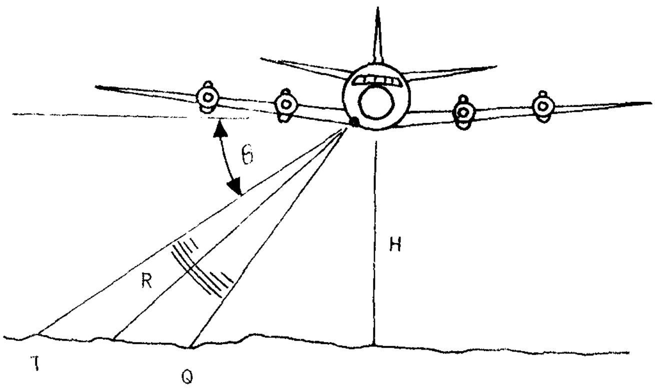


Figure 9

GENERAL CONFIGURATION OF A MAPPING SIDE-LOOKING RADAR (16.5 GHz)

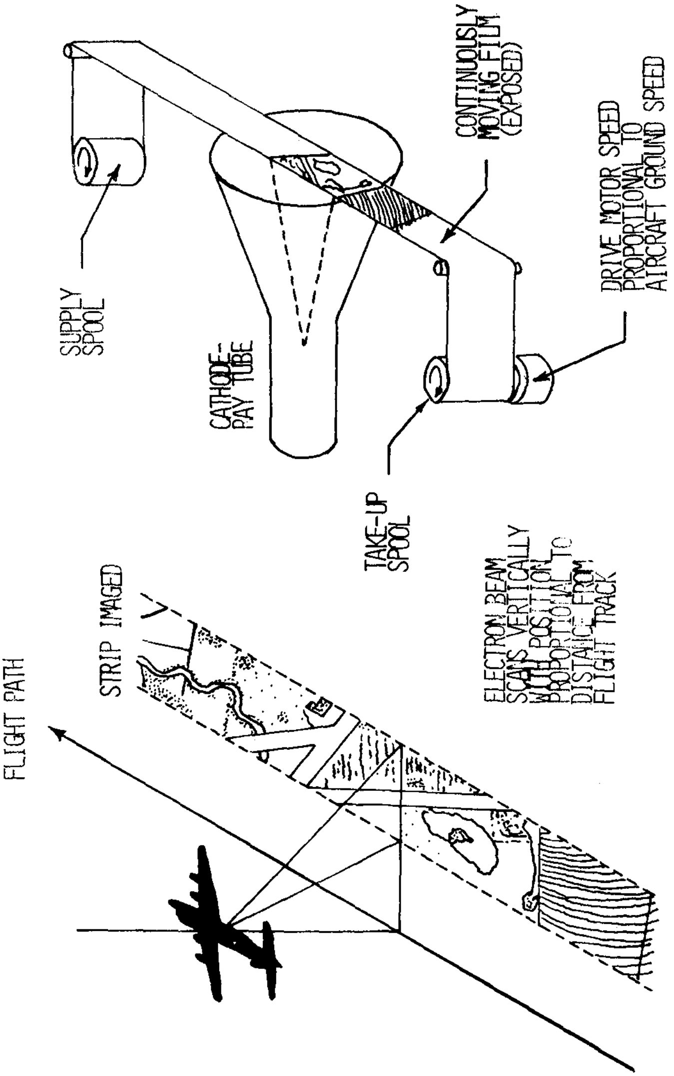


FIGURE 10.

ENHANCEMENT AND IMAGE PROCESSORS

In the process of obtaining coastal information from imagery generated during this flight, a number of optical and electronic devices were used in an attempt to obtain maximum information from the available imagery. In cooperation with the NASA Manned Spacecraft Center, the Corps of Engineers personnel processed imagery on various devices at the MSC Earth Resources Systems in the Agena Building, Clear Lake City, Texas. The basic equipment used in this effort consisted of three systems, as follows:

The Multiband Camera Film Viewer (MCFV)
The Additive Color Viewer Printer
The Datacolor System

Multiband Camera Film Viewer (MCFV). The Multiband Camera Film Viewer, developed by I^2S, is a three-channel electronic system, capable of converting image data, stored on 70 mm or 5 x 5-inch format film, into electronic form, and digitally processing these data, in a high speed real time mode, into a special form for presentation on a high resolution 1,000-line color display. The three key elements of the MCFV system are the scanner, control, and display subsystems.

The scanner subsystem is housed in a console which provides an isolated, stabilized structure to support the various components. These components include a high resolution (1,000-line) CRT, beam splitters, lens, film transports, film holders, film gate drives, condenser lenses, the photomultiplier assembly and the associated drive electronics. The support provided for these components consists of a rigid optical bench assembly, supported and stabilized by three automatically leveled pneumatic struts.

The video signals generated by the scanner are processed by the components of the control subsystem housed in the display console. The two major components of the control subsystem are the Analog Signal Processor (ASP), and the Digital Image Processor (DIP).

The display subsystem consists of a triniscope, housed in the display console. The components of the system include three CRTs, one for each primary color, and an optical assembly. Associated with the CRTs are their electronic chassis, and adjustable CRT/Monitor mounts. The optical assembly is also supported by an adjustable mount. Inputs to the display subsystem are the analog outputs of the Digital Image Processor. These video signals are converted by the triniscope into monochrome or color displays for viewing or photo recording. This device is described in "An Electronic Viewer for Multiband Imagery" by Howard M. Roberts, American Society of Photogrammetry, Washington, D.C. meeting, March 12-17 1972.

SUMMARY OF RESULTS

Color views and enhancements presented during the Vancouver conference cannot be presented in this paper, however, summaries of the resulting image analysis are given below:

a. RC-8 position 1 (color) produced excellent presentation of land features, and limited information from sea and subsurface features.

b. RC-8 position 2 (color IR) produced presentation of the size and quality of marine kelp beds, but provided no way of determining whether the kelp is on the surface.

c. KA-62 position 1a (color). The yellow wratten 12 filter on overexposed color film was found to give the most useful information for the analysis of current and sediment patterns. Material from sewer outfalls is clearly seen on this imagery. It also provided good water penetration.

d. KA-62 position 2 (red). With normal exposure, this camera produces primarily water surface information and is thus useful in enhancement combinations. If this combination is overexposed 1 "f" stop, considerable additional sedimentary information is obtained.

e. KA-62 position 3 (green). Provides good information for the analysis of current and sediment patterns, but with normal exposure, does not produce as good results as KA-62 position 1a. Better results would probably be produced with overexposure.

f. KA-62 position 4 (B&W IR). The infrared (IR) energy can only penetrate a short distance into seawater and is highly reflected by vegetation including algae. Therefore, only the surface canopy of nearshore kelp is seen in this photograph. The near IR film is excellent for use in the analysis of waves breaking upon a beach. Since the IR film is not sensitive to a response by sediments and bottom colors, a good photograph can be obtained of coastal waves, beach cusps, and refraction patterns. It was unfortunate that at the time of this flight, there were only small waves in the central California area; however, other imagery seen by the authors has shown that the use of near IR black and white or false color IR techniques are invaluable in the analysis of ocean wave phenomena.

g. SLAR Boresight Camera. Of little value due to inability to depress at same coverage angle as SLAR on this mission.

h. RS-14 IR Scanner. This device provided detailed information from which current and/or sediment movement may be implied. Man-made discharges produced good sources for tracing current movements.

i. 16.5 GHz SLAR. Due to low wave heights and frequency, only limited information is obtained and that is in the zone of breaking waves. In order to obtain information on sea and swell waves lower frequencies would probably be required.

j. Enhancements. Image enhancements produced by the various devices tested yielded impressive results. Of the devices tested, the MCFV produces the best opportunity to synergistically combine various images to display a typical desired parameter (such as offshore kelp beds) with the ultimate view of producing automatic processing of imagery.

CONCLUSION

Based on the summary of the results of the coastal remote sensing flight described in this paper, it is concluded that remote sensing provides valuable tools in the study of coastal processes. It is further concluded that remote sensing combined with appropriate enhancement and automatic data processing will lead toward the development of remote sensing/analysis systems that will not only record the phenomena under study but will also produce the desired numerical values of the appropriate parameters describing the phenomena.

ACKNOWLEDGMENTS

This work was jointly sponsored by the U. S. Army Coastal Engineering Research Center, Washington, D.C., and Earth Observations Aircraft Program of the National Aeronautics and Space Administration (NASA). Acknowledgment is gratefully made to NASA for the aircraft mission support, and subsequent image processing and enhancement assistance. Financial support of the Coastal Engineering Research Center for data analysis and report preparation are also gratefully acknowledged. The views presented are those of the authors and do not purport to reflect the position of the National Aeronautics and Space Administration or the Corps of Engineers, Department of the Army, or Department of Defense.

In the work reported on in this paper, Mr. Orville T. Magoon was the Principal Investigator (PI) and Mr. Douglas M. Pirie was a Co-Principal Investigator (COPI) and Mr. Allan Williams of the Los Angeles District was responsible for the image analysis of the southern California coast. The authors also gratefully acknowledge the friendly cooperation of the NASA personnel both in NASA headquarters, Washington, D.C.; and in the Manned Spacecraft Center, Houston, Texas, and especially to Mr. Gordon Hrabal, the NASA Mission Manager.

The authors also gratefully acknowledge the extensive Sea/Ground Truth support provided by the Department of Parks & Recreation, State of California, Dr. Ed Thornton, USN Postgraduate School, Monterey, California, and supporting personnel at CERC.