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SKYLAB: Sensors and Remote Sensing in Support of the EREP Oceanographic Program

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ABSTRACT

The acquisition of numerous types of oceanographic data over broad areas of the globe from the orbiting of SKYLAB in mid-1973 heralds a new dimension in oceanography. Remote sensors aboard SKYLAB will be able to observe ocean-surface phenomena over spatial areas heretofore unobtainable by present techniques. This report describes the applications to oceanography of the various sensor systems aboard SKYLAB contained in the Earth Resources Experiment Package (EREP). Data from the EREP sensor systems will encompass a broad range of the electromagnetic spectrum. As a consequence, validation of the EREP data will require obtaining correlative data using airborne remote-sensing techniques. For this purpose a C-130 aircraft belonging to the National Oceanic and Atmospheric Administration, equipped with a multitude of environmental sensor systems, will be the primary platform used. The types of surface truth necessary to support the EREP program, as well as a flight program for the C-130, will also be discussed.

PROBLEM STATUS

A final report on one phase of a continuing NRL problem.

AUTHORIZATION

NRL Problem R07-20

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SKYLAB: SENSORS AND REMOTE SENSING IN SUPPORT OF THE EREP OCEANOGRAPHIC PROGRAM

INTRODUCTION

The year 1973 has great promise for the future of oceanography from space, for this year the National Aeronautics and Space Administration (NASA) will orbit a manned orbiting spacecraft called SKYLAB. For the first time, several experiments designed specifically for obtaining oceanographic information will be included in the scientific program to be performed aboard SKYLAB. In the past, oceanographic information in the form of sea-surface-temperature data has been obtained from NIMBUS or TIROS infrared (IR) imagery. APOLLO 9 photography has been used to study sedimentary plumes off the Carolina coast. Information on sea-state conditions has been inferred from satellite sun-glitter photographs. Unfortunately, the use of sun-glitter data is available only where relatively clear skies are present and thus infers calmer sea conditions.

Practically all of these studies have been either rudimentary or qualitative, since cloud cover has limited viewing the surface of the earth from TIROS, NIMBUS, ATS, and other satellites. The all-weather capability of radar and microwave radiometry from SKYLAB will practically eliminate the problem of cloud cover. Even with the constraints imposed by having SKYLAB view the earth for relatively short periods of time, significantly more oceanographic information on sea-surface winds, waves, and temperature will be obtained from the SKYLAB Earth Resources Experiment Package (EREP) sensors than from any other satellite, regardless of the weather conditions below. Moreover, SKYLAB will be the first satellite for which oceanographic experiments can be preplanned to obtain correlative information between satellite, aircraft, and surface vessels or buoys.

The sensor systems which make up the EREP program consist of:

- S-190: Multispectral Photographic Facility
- S-191: Infrared Spectrometer
- S-192: 13-Band Multispectral Scanner
- S-193: Combination Microwave Radiometer/Radar Scatterometer/Altimeter
- S-194: L-Band Microwave Radiometer

these systems will be discussed later in more detail.

The SKYLAB workshop will be inserted into a 235-naut-mi circular orbit with an orbital inclination of 50°. The first of three Command Service Modules (CSM), manned by three astronauts, will be targeted for rendezvous with the workshop within 5 to 8 revolutions after insertion into orbit. The first phase of experiments will last approximately 28 days. The second and third phases of the SKYLAB mission will each last for a period of up to 56 days.

Although the total SKYLAB mission encompasses a maximum of 140 days, there are constraints regarding the number of data-gathering orbits for obtaining oceanographic information. A maximum of 45 EREP passes has been programmed for the entire SKYLAB mission. For each EREP pass the workshop will be rotated so that the sensors are looking down at the earth.

The main emphasis in this report will center around the S-193 and S-194 experiments, because in recent years elaborate remote-sensing experiments were conducted in support of prototype instrumentation. Less elaborate experiments were performed in support of the S-190, S-191, and S-192 prototypes. Any inference that S-193 and S-194 are the more important experiments is not intended. A description of the type of surface-truth information necessary to support the SKYLAB EREP measurements, as well as a proposed aircraft under-flight program, will also be given.

BACKGROUND

Since its inception in 1965, the Spacecraft Oceanography (SPOC) Group of NOAA (formerly with the Naval Oceanographic Office, NAVOCEANO, and the Naval Research Laboratory, NRL) has supported research, on behalf of NASA, in the application of space technology for oceanographic purposes. In directing the oceanography discipline under the Earth Resources Survey (ERS) program of NASA, SPOC helped to provide remotely sensed oceanographic data to its investigators. This was accomplished by planning and coordinating experiments using primarily an aircraft from the Manned Spacecraft Center of NASA equipped with a broad spectrum of remote sensors.

Where possible, remote sensors aboard other aircraft were used for the purpose of obtaining complementary or surface-truth information or both. On more than one occasion, a NAVOCEANO C-121 aircraft provided wave-height surface-truth information for radar sea-state experiments. On several occasions an NRL C-121, equipped with a four-frequency radar (4FR), flew jointly with a NASA aircraft to obtain, for correlative purposes, simultaneous radar-backscatter data from the sea surface.

The SPOC program has identified many oceanographic parameters and phenomena which should be observable from satellite altitudes using remote-sensing techniques. These include: water, land, and sea interfaces; biological indices; ocean-color discontinuities; sea-surface temperature; and sea-state conditions. All of these parameters are to be sensed in the SKYLAB EREP program.

The S-193 and S-194 experiments aboard SKYLAB represent the next step after airborne testing of ptototype systems in the development of a space system for monitoring and predicting ocean winds and waves on a global scale.

Airborne and tower experiments were conducted by NRL and NASA as a prelude to the S-193 experiment and to develop an understanding of the nature of microwave backscattering and emission from the sea surface as a function of wind and sea conditions. Table 1 is a chronological list of microwave sea-state experiments conducted by NRL and NASA, which were planned by or with SPOC assistance. Other passive microwave sea-state experiments have been conducted by: NASA/Goddard Space Flight Center (GSFC) (in 1968) over the Salton Sea; Aerojet General; RCA; North American Rockwell (under contract to NASA); Jet Propulsion Laboratory; Radiometric Technology Inc.; the University of Miami; NRL (in 1971 and 1972) under contract to

Table 1
Microwave Sea-State Experiments (SPOC Supported)

Agency	Date	Location	Primary Instrumentation	Type of Platform
NRL	7/65	Puerto Rico	Four-frequency radar (4FR)	C-121
NASA/MSC	3/66	Bermuda	13.3-GHz radar scatterometer	Convair 240
NASA/MSC	10/67	Newfoundland	13.3-GHz radar scatterometer	Convair 240
NASA/MSC	4/68	Iceland	13.3-GHz radar scatterometer	P-3A
NRL	2/69	Ireland	4FR	C-121
NASA/MSC	3/69	Ireland	0.4-, 1.6-, 13.3-GHz scatterometers	P-3A
NASA/GSFC	3/69	Ireland	19.35-GHz microwave radiometer	Convair 990
NRL	3/69	Bermuda	X- and K-band microwave radiometers	Argus Island
NRL	7/69	Bermuda	X- and K-band microwave radiometers	Argus Island
NRL	1/70	Bermuda	4FR	C-121
NRL	1/70	Bermuda	L-, X-, and K-band microwave radiometers	Argus Island
NASA/MSC	1/70	Bermuda	13.3-GHz radar scatterometer and a multifrequency microwave radiometer	P-3A
NRL	3/70	Bermuda	L-, X-, and K-band microwave radiometers	Argus Island
NRL	2/71	U.S. East Coast	4FR	C-121
NASA/MSC	2/71	U.S. East Coast	13.3-GHz radar scatterometer	C-130

NASA/Langley; and several others. Table 1 lists only the microwave instrumentation used in the experiments. Other instruments were used for secondary experiments and surface truth.

In June 1969 a meeting was held at NASA Headquarters where a review of microwave observations of the sea surface was conducted. The results of airborne, tower, and land-based passive microwave observations of the sea surface, incorporating the most recent data, were discussed in great detail. Hollinger (1), using X- and K-band microwave radiometers, showed that the K-band horizontally polarized antenna-brightness temperatures increase approximately 0.6°K/knot at a 50° incidence angle within the wind-speed range of 0 to 22 knots. Conaway (2) showed that the effect of large foam patches on antenna-brightness temperatures is an important contribution at wind speeds greater than 15 knots.

In addition to the passive microwave observations, studies of radar backscatter from the ocean surface were also discussed. Results of radar-backscatter data obtained by NRL and NASA were shown to be in disagreement. As a direct result of this conference, further experiments were planned. Results from these more recent studies narrowed the disagreement to the present state, which is

$$\sigma_0 \sim W_{\mathrm{NRL}}^{0.6}$$

$$\sigma_0 \sim W_{\mathrm{NASA}}^{1.5}$$

at X-band, where σ_0 is the normalized radar cross-section backscatter and W is the wind speed in knots.

EREP SENSOR SYSTEMS

The primary purpose of the S-190 Multispectral Photographic Facility for oceanography is to obtain multispectral photography of coastal areas. Mairs (3) used APOLLO 9 and high-altitude multispectral photography to determine coastal circulation patterns from sedimentary plumes off the Carolina coast. Multispectral photography has also been used to determine water depth penetration, as described by Ross (4).

The S-191 Infrared Spectrometer will be used for determining sea-surface temperature. Although IR systems have been used before for determining sea-surface temperature, the S-191 spectrometer has one main feature which makes it superior to other operational systems. The use of sea-surface-temperature information, as obtained from high-resolution infrared (HRIR) systems aboard (for example) NIMBUS satellites, is limited, due to a spatial resolution of about 5 naut mi. The S-191 spectrometer has a field of view of 1 milliradian at nadir, which is equivalent to a 0.25-naut mi-radius circle, thus offering much higher resolution. Although cloudiness remains a problem to be dealt with, much very-high-resolution sea-surface-temperature data should be obtained.

The S-192 Multispectral Scanner is another system which will yield high-resolution (spatial and spectral) information over coastal areas. This system will provide valuable information on coastal marine processes, longshore and offshore currents, sedimentary plumes, water pollution, bottom topography (possibly), shoal areas, etc. Based on multispectral data obtained over coastal areas from the Earth Resources Technology Satellite (ERTS), launched in 1972, S-192 together with S-190 will play a very important role in learning more about coastal ecology from space.

The S-193 microwave system is a combination of three sensors. The passive-microwave-radiometer and radar-scatterometer (RADSCAT) portions will be used for obtaining information on sea-surface winds and waves. Over the ocean the altimeter mode of S-193 could provide information on the shape of the earth's geoid. The all-weather capabilities of microwave radiometry and radar, viewing practically the same patch of water at essentially the same time, are complementary. In due time, space-acquired active and passive microwave data will be a direct input into a global program for forecasting surface winds and waves.

Although geodesy is by no means a new science, the application to geodesy of pulsed radar altimetry from satellites is now practical. Although airborne radar systems have been used to obtain profiles of ocean wave height, radar systems have been used only recently for geodetic purposes. The S-193 microwave system, in many ways represents a major "first."

The S-194 L-Band Radiometer, with a center frequency of 1.4135 GHz, is complementary to the 13.9 GHz S-193 microwave system. Although the S-194 radiometer looks at a much larger surface area than the S-193 system, sea-surface-roughness data and salinity information will be obtained.

Tables 2 - 5, extracted from Ref. 5, provide some description and specifications of each sensor system.

SURFACE TRUTH

In past years, two Joint Ocean Survey Study (JOSS I and II) experiments have used several aircraft for obtaining microwave backscattering and emission information from the sea surface. These experiments included other instrumentation for the purpose of relating the passive- and active-microwave data to observed sea-state conditions, i.e., surface truth. For the most part, these experiments attempted to have the participating aircraft from several U.S. agencies fly over the same test site nearly simultaneously. For the SKYLAB support experiments (JOSS III), the participating investigators have different surface-truth requirements and plan to use various aircraft. In addition, experiments involving the RADSCAT and altimetry modes of the S-193 package are incompatible, because S-193 can operate in only one of these modes at a time. Therefore, the altimetry experiments will be separate from the RADSCAT experiments and will be planned by the individual investigators. Aircraft for the altimetry experiments are planned to be under the control of NASA/Wallops Island. Assuming the altimetry experiments will be coordinated with a SKYLAB pass off the east coast of the U.S. (preferably northbound), surface-truth information could be obtained from (a) the Chesapeake Light Station, (b) Ocean Station "Hotel" (38N, 71W), (c) XERBI (a Coast Guard buoy at 36.53N, 73.53W, (d) coastal weather stations, and (e) supporting spacecraft data. Table 6 lists much of the available synoptic weather information provided by these sites.

Table 2
S-191 Infrared Spectrometer

DESCRIPTION

Filterwheel spectrometer using circularly variable interference filters

Viewfinder/tracker for astronaut target acquisition and tracking

Internal wavelength and radiance calibration

At orbital altitude, it records radiance from the surface of the earth

Solar radiance in the 0.4- to 2.4-μm region
Emitted thermal radiance in the 6.2- to 15.5-μm region

OBJECTIVE

Perform controlled experiments in which the applicability of the 0.4- to 2.4-μm and 6.2- to 15.5-μm regions of the spectrum is quantitatively evaluated from space

Ground sites are actively acquired and tracked by the flight crew using the spectrometer viewfinder/tracking system

PHYSICAL CHARACTERISTICS

Dimensions:	19- by 20- by 51-in. external envelope (max)
Volume:	$\approx$ 11.2 ft^3
Weight:	$\approx$ 402 lb (total)
Power:	$\approx$ 200 W (avg)

Table 3
S-192 Multispectral Scanner

DESCRIPTION

Radiometer that optically scans successive contiguous lines across the flight path

Records simultaneously, in 13 discrete spectral intervals, the energy reflected and emitted by earth features

Visible
Infrared

Records reflected energy with a sensitivity better than 1% noise equivalent reflectance

Records emitted energy to a sensitivity of 0.4°K

OBJECTIVE

Gather quantitative high-spatial-resolution line-scan imagery data on radiation reflected and emitted by selected ground sites in the U.S.

PHYSICAL CHARACTERISTICS

Dimensions (preliminary)

Scanner: 29 by 34.5 by 23.2 in.
Spectrometer: 22 by 24.5 by 15 in.
Electronic assembly: 17.32 by 16.5 by 10 in.

Volume (preliminary)

Scanner: 13.5 ft^3
Spectrometer: 4.7 ft^3
Electronics assembly: 1.2 ft^3

Weight

Scanner: 125 lb
Spectrometer: 110 lb
Electronics assembly: 75 lb

Power

226 W (peak)

Table 4
S-193 Microwave System

DESCRIPTION

Combination active and passive microwave system

- Radiometer
- Scatterometer
- Altimeter

Parabolic antenna transmits and receives dual-polarized radiation

- Cross-track scan
- Along-track scan

Measures simultaneously radar scattering cross section and microwave-emissivity and signal-correlation properties

OBJECTIVE

Provide simultaneous evaluations of radar backscattering cross section and passive microwave emissivity of the land and sea

Compare surface-brightness-temperature measurements at two microwave frequencies (by correlation with the S-194 data)

Provide engineering data for use in designing an optimum radar altimeter for space use

PHYSICAL CHARACTERISTICS

Dimensions

- Electronics Package: 83 by 63 by 8 in.
- Antenna: 48-in. diameter

Weight

- Electronics Package and antenna: 250 lb

Power

- 153 W, 28 V dc, average
- 300 W, 28 V dc, peak

Table 5
S-194 L-Band Radiometer

DESCRIPTION

Absolute microwave radiometric sensor using a fixed planar-array antenna oriented toward nadir

Records thermal radiation in the microwave (L-band) range

Digital data output gives the absolute antenna temperature to an accuracy of 1°K

PHYSICAL CHARACTERISTICS

Dimensions

Antenna: 40 by 40 by 10.5 in.
Electronics package: 20 by 10.5 by 5.25 in.

Volume

Antenna: 9.7 ft^3
Electronics package: 0.6 ft^3

Weight

Antenna: 31.5 lb
Electronics package: 16.0 lb

Power

Operate: 15.0 W, 28 V dc
Survival: 20.4 W, continuous
Total operating power: 35.4 W

DESIGN FEATURES

Radiometer using a calibration scheme referenced to a fixed hot- and cold-load input

SPECTRAL CHARACTERISTICS

Center frequency: 1.4135 GHz
Wavelength: 21 cm
Bandwidth: 27 MHz

SPATIAL CHARACTERISTICS

Beamwidth (half power): 15°
Beamwidth (first null): 36° (90% of power)
Resolution (half power): Circle with a diameter of 60 naut mi

Table 6
Surface Truth available from U.S. East Coast

Chesapeake Light Station
Synoptic weather reports
Ocean wave statistics
XERBI
Synoptic weather reports
Current speed and direction
Average wave height
Ocean Station "Hotel"
Synoptic weather reports
Visual wave conditions
Twice daily radiosonde observations
Coastal Weather Stations
Synoptic weather reports
Radiosonde observations
Radar observations on precipitation
Supporting Spacecraft Data
Photography and IR imagery

SURFACE-TRUTH OBJECTIVES

Introduction

With regard to the microwave (S-193 and S-194) and IR (S-191) systems aboard SKYLAB, the various experiments will attempt to detect and quantize the physical phenomena of: sea conditions (wave spectra); whitecap and foam coverage; surface wind speed; microwave brightness temperature of the sea surface; radar sea return; and sea-surface temperature. From the standpoint of understanding the environment during the S-193 and S-194 experiments, the S-191 IR system should be operated concurrently. Sea-surface-temperature data would be useful in understanding the ocean and atmospheric contribution to the attenuation of microwave emission from the sea surface.

The overall objectives of the JOSS III remote-sensing experiments in support of the SKYLAB S-191, S-193, and S-194 programs are to obtain concurrent data along the SKYLAB subsatellite track on:

- Sea-state conditions
- Surface wind velocity
- Percentage foam and whitecap coverage
- Atmospheric soundings
- General synoptic weather
- Multifrequency microwave radiometric measurements
- Radar-backscatter measurements
- Sea-surface temperature

Each of these are broad items which now will be discussed in more detail.

Sea-State Conditions

Primarily, sea-state conditions refer to the wave spectrum present at the place and time of the experiment. For SKYLAB, wave spectral information should be obtained along the subsatellite track. Laser wave profiles should be obtained as a minimum means of describing the sea surface. Oblique, still, and strip-camera photography affords a better method for describing the sea-surface directional wave spectrum and can also be used for correlation with the laser profilometer. An analog wave recorder on the Chesapeake Light Station and Ocean Station "Juliett" (at 52.5N, 20W) would be further useful in describing observed sea-state conditions. Analysis of all these types of wave data will yield spectral information on waves with wavelengths ranging from a few cm to wavelengths in excess of 100 m.

Surface Wind Velocity

The predominant factor affecting the sea state is the surface wind velocity. If accurate synoptic wind-velocity data were available routinely, numerical techniques for global wave forecasting would become an operational reality. Future satellite determination of wind velocity would be critical for global wave forecasts. As dense a network as is possible of surface wind velocity should be used in the SKYLAB support experiments. This network includes coastal, ship, buoy and tower reports and estimates (extrapolated) from aircraft. Wind velocities from aircraft can be obtained via LORAN, OMEGA, or Doppler navigation fixes, but data from inertial navigation systems (such as an LTN-51) are preferable. The accuracy of individual anemometers is not as important as having a great areal density of surface-wind measurements. The accuracy of wind observations becomes more important when the areal density of the observations is diminished.

Percentage Foam and Whitecap Coverage

In addition to being another technique for surface wind-speed determination, observations of these phenomena are important for correlation with and interpretation of the observed microwave temperature of the sea. The percentage foam and whitecap data can be obtained from analysis of vertical still or oblique strip-camera photography.

Atmospheric Soundings

The structure of the atmosphere as a function of altitude is an important factor in determining the attenuation of microwave energy from the sea surface. Information on the vertical structure of the atmosphere with regard to temperature, moisture content, etc., such as can be obtained via radiosondes taken from coastal weather stations and weather ships, is readily obtainable from the National Weather Service.

General Synoptic Weather

The minimum amount of information an airborne remote-sensing experiment requires for meaningful correlations to be made is a general knowledge of the weather conditions experienced at the test site. For the SKYLAB support experiments, a description of sky conditions, clouds (type, altitude, and thickness), and precipitation (type and rate) is required for a better understanding of the attenuation of microwave energy from the sea surface. This information can be obtained from a careful analysis of all available ship and coastal-weather-station reports and (if needed) from interpretation of weather maps.

Multifrequency Microwave Radiometric Measurements

Aircraft-obtained radiometric data at L and Ku Bands will be compared with the satellite-obtained radiometric data from S-193 and S-194. Further, radiometric data at about 22 GHz should be obtained from an upward-looking system to gain insight on the contribution of the sky, clouds, and precipitation to the apparent microwave temperature of the sea surface. The concept of understanding the physics involved is more than just comparing aircraft- and satellite-obtained radiometric measurements. Therefore, the aircraft program should include data at various frequencies, polarizations, and incidence angles over a broad range of sea conditions.

Radar-Backscatter Measurements

As above, aircraft-obtained radar-backscatter data should be compared with the S-193 radar data. Ideally, a RADSCAT system similar to the S-193 RADSCAT should be mounted aboard an aircraft. In addition, multifrequency radar measurements should be obtained to describe better the backscattering effects from the sea surface. This would have inferred using the NRL four-frequency radar. Unfortunately, this capability will not be available for this mission.

Sea-Surface Temperature

As a means of providing verification of the S-191 sea-surface-temperature (SST) data, surface truth can be obtained from ship, buoy and Coast Guard light-tower reports. An airborne IR radiometer such as the Barnes PRT-5 could provide SST information along the subsatellite track. The SST surface truth would also add valuable information in the analysis of the radiometric data from S-193 and S-194.

MISSION CONDUCT

Until now discussion has centered on observation of phenomena from numerous platforms in support of the oceanographic SKYLAB EREP experiments. Little has been said of the platforms and where and how the experiments should be conducted. The objectives of the experiments go beyond the need of correlating surface truth with SKYLAB data. Since SKYLAB data will cover many hundreds of square miles of the ocean surface, it is necessary to understand as best as possible the physical processes occurring at the sea-air interface. Therefore, there exists the requirement for obtaining the types of data discussed in the previous sections.

The primary platform to be used in the support experiments should and will be a NOAA C-130 aircraft. This airplane is uniquely equipped with many of the sensors discussed previously and could provide much of the necessary surface truth. At low altitudes the C-130 can obtain sea-air interface data and then can climb to higher altitudes to obtain cloud and atmospheric data. During these airborne remote-sensing experiments, the C-130 will be under the control of the Sea-Air Interaction Laboratory of NOAA. The C-130 has the desired capabilities of short ferry time and reasonably long-term on-station endurance. Although it may be possible for other aircraft to participate on any given day with the NOAA C-130, it is foreseen that the C-130 will be the essential "workhorse" of the SKYLAB oceanographic support experiments. This is advantageous, for it eliminates necessary coordination when more than one aircraft is used and allows for simplification of the supporting experiments. There are many environmental sensing systems aboard the NOAA C-130 that are necessary for the SKYLAB support experiments. The most pertinent data to be obtained from the NOAA C-130 are: sea-state conditions; surface and flight-level wind velocity; percentage foam and whitecap coverage; multifrequency microwave radiometric measurements; sea-surface temperature; atmospheric humidity; precipitation; and radar backscatter, if a suitable instrument could be installed aboard the aircraft.

For the conduct of a NOAA C-130 support experiment for SKYLAB, the assumption is made that there are no problems arising from the astronauts' living schedule aboard

SKYLAB, daylight conditions over the North Atlantic, and any problems not pertinent to the joint SKYLAB/C-130 experiment.

Prior to the commencement of a mission, a forecast of the SKYLAB orbits would be obtained. Each day there should be a northbound pass crossing the equator between 85W and 110W. The more easterly orbits will pass to the east of Cuba; the more westerly ones will pass over the east coast of the U.S. Both types of passes will proceed to 50N and then to points south and southwest respectively of Ireland.* The most logical candidates for a combined SKYLAB/NOAA C-130 mission are those northbound orbits that cross the equator between 95W and 110W. They will occur on about 17 of the 28 days during the first manned period and on about 34 of the 56 days of the third manned period. For numerous unspecified reasons, it is recommended that the NOAA oceanographic support experiments be conducted only during the first (SL2) and third (SL4) manned periods, assuming there is no major change in the launch date of SKYLAB.

During the first manned period (SL2), a northbound orbit will be selected. The most interesting area along the subsatellite track with the best wind and cloud conditions will be forecast in advance of the satellite pass over this area. If possible, this track should pass over or near those locations where surface platforms discussed previously are situated. The NOAA C-130 would depart at a convenient time and proceed to the subsatellite track such that data would be obtained before, during, and after passage of SKYLAB overhead. A data-taking flight by the NOAA C-130 would require approximately five hours along the subsatellite track. The aircraft could proceed to, say, Bermuda or return to the East Coast where, after a day or so, it might repeat the experiment an a southbound pass off the East Coast. On the northbound passes off the East Coast, the aircraft could continue taking data across the Atlantic Ocean, gathering open-ocean information using Shannon, Ireland, as a destination. The return flight from Shannon could make use of surface-truth information available from Ocean Station "Juliett" (52.5N, 20W) and then return to a refueling station, such as Argentia, Newfoundland, Halifax, Nova Scotia, Maine, etc., along some appropriate subsatellite track. Whether or not the aircraft flies in the direction of travel of SKYLAB is insignificant. The orbit pass takes only a few minutes, and either way the aircraft data will only be within plus or minus several hours of the spacecraft data except for that period of time chosen for near simultaneity.

For the purpose of this report it is unimportant how many support experiments/flights are conducted. This is a function of aircraft availability and funding. What is important is that data should be obtained in the near coastal zone off the U.S. east coast and over the open ocean for as broad a range in surface wind speeds and overall synoptic weather conditions as can be obtained.

During the northbound flights across the Atlantic Ocean, the S-193 data would be obtained in the along-track noncontiguous mode and scanned either to the left or right or alternately, depending on synoptic weather conditions. The NOAA C-130 would then fly a search pattern over a predetermined grid network for a period of a few hours

*Most of this information is extracted from the amended proposal to NASA "A Joint Meteorological, Oceanographic, and Sensor Evaluation Program for Experiment S-193 on SKYLAB" by E.P. McLain, R.K. Moore, and W.J. Pierson.

before and after passage of SKYLAB. The grid network should be located near areas where observed synoptic weather information can be readily obtained. Ocean Station "Hotel" (38N, 71W) would be one of the recommended areas. This type of experiment would be for the purpose of correlating S-193 data with surface truth as the system scans across the subsatellite track. At least two missions of this type of experiment should be performed to validate the results.

For correlation with the radiometric data to be obtained from S-193, airborne-microwave-radiometer measurements at L and Ku bands, coincident with the SKYLAB ground track, are most important. The measurements should be made for both horizontal and vertical polarization and over angles from nadir to at least 55 degrees. A zenith-looking radiometer should be mounted in the NOAA C-130 to calibrate atmospheric loss.

Although only briefly mentioned earlier, the S-190 Multispectral Photographic Facility and the S-192 Multispectral Scanner should be operated when SKYLAB is in the proximity of coastal crossings. It is expected that much more valuable information can be obtained from S-190 and S-192 over coastal areas rather than over the deep ocean. This is due mainly to the rapidly changing contrast between land and water. Surface-truth requirements for S-190 and S-192 are different from those for S-191, S-193, and S-194 in that water-depth measurements, high-altitude photography, and possibly water samples are also necessary.

CONCLUSION

In summary, the EREP program aboard SKYLAB, in conjunction with supporting aircraft remote-sensing flights, offers the oceanographic community a unique opportunity for obtaining large-scale information on various ocean phenomena. Certainly, correlation of the SKYLAB data with surface truth cannot be emphasized enough. For this purpose a NOAA C-130 will be the main platform for gathering surface truth. If the SKYLAB EREP program is to provide a basis for orbiting operational systems in the future (in support of the overall Earth Resources Survey Program of NASA), a better understanding is necessary of the physical processes occurring at the sea-air interface and in the atmosphere.

The NOAA C-130 is well suited for obtaining the types of surface-truth information required for the SKYLAB EREP program. It is unfortunate, however, that such heavy reliance is to be placed on this one platform. Hopefully, much use will be made of data obtained from other aircraft and surface platforms. Since SKYLAB's ground track differs from pass to pass, only properly coordinated aircraft-obtained surface truth can be relied on. There should always be a readily available aircraft suitably equipped for providing surface truth for future satellite experiments in support of the EREP program.

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13. ABSTRACT

The acquisition of numerous types of oceanographic data over broad areas of the globe from the orbiting of SKYLAB in mid-1973 heralds a new dimension in oceanography. Remote sensors aboard SKYLAB will be able to observe ocean-surface phenomena over spatial areas heretofore unobtainable by present techniques. This report describes the applications to oceanography of the various sensor systems aboard SKYLAB contained in the Earth Resources Experiment Package (EREP). Data from the EREP sensor systems will encompass a broad range of the electromagnetic spectrum. As a consequence, validation of the EREP data will require obtaining correlative data using airborne remote-sensing techniques. For this purpose a C-130 aircraft belonging to the National Oceanic and Atmospheric Administration, equipped with a multitude of environmental sensor systems, will be the primary platform used. The types of surface truth necessary to support the EREP program, as well as a flight program for the C-130, will also be discussed.

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Multispectral scanner						
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