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EARTH RESOURCES PROGRAM GROUND TRUTH SESSION

Test and Operations Office
Manned Spacecraft Center
Houston, Texas

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

EARTH RESOURCES PROGRAM
GROUND TRUTH SESSION

FINAL REPORT

NOVEMBER 1967

PREPARED BY

TEST AND OPERATIONS OFFICE
SCIENCE AND
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INTERIM REPORT

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INTRODUCTION

The importance of ground truth to the success of the Earth Resources Aircraft Program (ERAP) is recognized by user agencies, instrument teams, and NASA. It is also recognized that documentation is needed of the role of ground truth in future orbital space missions, as well as present capabilitites and future requirements in the ERAP.

The initial ground truth working session was held at the Manned Spacecraft Center (MSC) on November 27, 1967, to discuss and document these capabilities and requirements. The ground truth activities discussed in the session primarily included the following topics:

1. Existing ground truth capabilities.
2. Measurements required and measurements currently being made.
3. Equipment now being used and future requirements.
4. Ground sites now supported and type of support.
5. Recommendations relative to the ERAP concerning ground truth.
6. Extrapolations of the above topics for short term (10-15 days) and long term (1-2 years) orbital missions.

This report is a compilation of papers presented at the session by various participants in the ERAP. This document is not intended to represent total ground truth capabilities and requirements, but should be used for information and as an aid in planning for development of ground truth capabilities in the future.

Table of Contents

Earth Resources Ground Truth

for Agriculture

By V. I. Myers, USDA

EARTH RESOURCES GROUND TRUTH FOR AGRICULTURE

Victor I. Myers, USDA *

Introduction

Agricultural ground truth can be defined as data concerning plants, soils, water, atmosphere, and energy balance, gathered for scientific interpretation of phenomena registered on a remote sensing detector or camera.

In selecting agricultural remote sensing sites or flight lines, the following criteria should be given consideration:

1. Sites should have representative soil and plant conditions.

2. Flight lines should be in straight lines insofar as possible to facilitate flying.

3. The same flight lines should be covered each time to provide repetitive seasonal and annual coverage of specific conditions.

4. In selecting sites, advantage should be taken of controlled experiments already being conducted for other purposes, whenever possible, such as statistically designed plot studies.

5. Calibration panels and instrumentation must be available along the flight lines.

The following report on ground truth for agriculture also includes brief material on techniques and instrumentation for forestry. Regular organized ground truth collection programs are underway by the U.S. Forest Service, the University of California, Purdue University, as well as U.S.D.A., Agricultural Research Service, Weslaco, Texas.

Figure 1 shows flight lines for the Agricultural Earth Resources Site 32 in the Lower Rio Grande Valley of Texas. The flight lines, selected according to the above criteria, cover ground truth site conditions described in Exhibit A.

Minimum Basic Equipment Required for a Fundamental Agricultural Test Site

Field fundamental and applied studies

Thermal hand-held radiometers - 2 required (ground truth temperatures)
Field spectrometer-short wave (0.3 to 2.5 microns)
Field spectrometer-long wave (2.5 to 14.0 microns)

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* Material contributed by Robert Heller, U.S.D.A. Forest Service, and Purdue University.

Seven-track magnetic tape recorder for each spectrometer - 2 required
Storage oscilloscope for instantaneous recording and viewing of spectra from field spectrometers - 2 required
Mobile instrumentation pickup truck with camper (for spectrometer instrumentation recording complex)
Infrared camera for detailed field thermal studies involving crop canopies
Infrared reference for IR calibration
Automatic data recording system (punch tape) for meteorological data - 20 channels
Mobile instrumentation trailer for data recording system and auxiliary equipment
Meteorological and micrometeorological instrumentation
Recorders - dual pen millivolt
Cameras

Fundamental laboratory studies

Microscope
Spectrophotometer

Photo laboratory and densitometry

Photographic film processing equipment for at least 70 mm
Combination isodensitracer and microdensitometer
Densichrons for optical density measurements

Communications

UHF Radio System (necessary for communications between aircraft and ground parties and between ground parties during remote sensing overflights)

Miscellaneous laboratory and field equipment

Crop and Soil Identification

The USDA remote sensing program at Weslaco is concerned primarily with recording, measuring, and identifying the energy in wavelengths between .3 and 14 microns reflected or emitted from the earth's surface, and the microwave frequencies. A working hypothesis is that each crop and soil condition reflects or emits energy typical of the specific condition. The problem is to determine which wavelengths are the most sensitive to changes in crop and soil conditions, to discover sensors sensitive to these wavelengths, and to develop methods of recording, measuring, and identifying the specific crop or soil condition represented by a specific reflected spectrum.

The attached Exhibit A describes the objectives and procedures for collecting ground truth and determining characteristic crop and soil signatures at NASA Earth Resources Site 32.

Data Collection

General

As is evident from the work plan, extensive ground truth data are collected in connection with NASA overflights. Figure 2 shows one of a number of ground parties making crop and soil measurements at the time of an overflight. Radios are considered essential during these overflights for maintaining mobility and communications.

Figure 3 shows a sample data sheet of the type filled in by ground parties.

Soil Moisture Measurement on Rangeland Site

Available soil moisture in the root zone affects the reflectance pattern from agricultural crops and rangeland vegetation. Also, surface soil moisture influences the intensity of monochromatic light reflected from soils. Careful measurement of soil moisture is essential as an element of ground truth.

Figure 4 shows a technician measuring soil moisture with a P-19 Nuclear Chicago neutron probe and portable scaler* in an area of rangeland vegetation. This equipment requires semi-permanent installation of an aluminum access tube at each ground truth site.

Automatic Recording of Field Data

Automatic recording of data is accomplished with the Howell Data Logger shown in Figure 5. The instrument, a 20-channel logger, records sequentially on command every 3 seconds, 6 seconds, or 8 seconds. Each channel reading is summed for 10 readings and the average is punched out on tape at the end of a 10 value recording cycle. The range of input signals the equipment is capable of handling extends from -2 to 18 mv.

Interpretation of Photographic and Scanner Transparencies

Interpretation of photographic and scanner transparencies is made with manual densitometers and with automatic equipment, the most important of which is the isodensitracer. The isodensitracer, shown in Figure 6, is a high-speed, direct reading isophotometer designed for the rapid presentation of two-dimensional photometric information. The instrument quickly and automatically scans and measures the optical density of all points in a film transparency and plots the values as a quantitative, two-dimensional density map of the scanned area.

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* Trade names and company names used in this paper are for information only and do not constitute endorsement by the U.S. Department of Agriculture.

The isodensitracer eliminates the tedious manual correlation of data from successive tracings. It can also be used as a microdensitometer to plot absolute optical density in graphical form. This equipment has recently been fitted with encoders which permit placing values of optical density and X-Y position of resolution elements on paper punched tape. Digitized data can then be processed in a computer. Figure 16 is an isodensitracing of thermal imagery shown in Figure 15, taken at 1900 hours.

Field Spectrometer Data Collection

Reflectance and transmittance measurements from a laboratory spectrophotometer (see Figure 7) are valuable for controlled studies of plants and soils and frequently indicate the portion of the spectrum where anomalies can be expected to occur in remote sensing measurements. The absolute energy value of spectrophotometer curves is difficult or impossible to determine, however, and the spectral distribution of the source differs from that of solar energy. Field spectra, which have a solar energy source, are influenced by such factors as reflectance from multiple leaf layers, soil background radiance, and atmospheric absorption and scattering of certain wavelengths.

An Instrumentation Specialties Company (ISCO) Spectroradiometer, shown in Figure 8, is used for gathering field spectra. Other field instruments also have been used for this purpose. In Figure 9 a Perkin-Elmer SG4 Spectrometer is elevated over field plots on a Truco Aerial Lift. The spectroradiometer has a wavelength range of 450 to 1550 mu with bandwidths of 15 and 30 mu, respectively, in the visible and infrared. Sensitivity is from 0.3 to 1000 uw $cm^{-2}mu^{-1}$ in eight ranges with accuracy of 7 to 10 percent. Two sensing heads, each having 180^{o} field of view, are provided with the spectroradiometer. One is a diffusing screen mounted directly on the instrument case for measuring incoming radiation, and the other is a six-foot fiber optics probe which is directed toward selected areas of plants and soils for measuring radiance. The fiber optics probe has been modified to decrease the field of view from 180^{o} to 10^{o} so that specific areas can be isolated for radiance measurements. A recorder-scanner is used in conjunction with the spectroradiometer which records spectral intensity versus wavelength in a continuous spectral distribution curve. It incorporates a 24-hour program timer which may be set to initiate a scanning cycle at any predetermined time during the day at intervals of fifteen minutes of longer.

A punched tape format, shown in Figure 10, has been prepared for automatic handling of spectroradiometer data. Field data are placed on punched tape according to the format.

Purdue University has developed a mobile laboratory for gathering field radiance data and for taking other auxiliary data. The equipment is described in Exhibit B.

Radiance spectra acquired in the field with a spectrometer or spectroradiometer have a general similarity to reflectance spectra measured from individual leaves on a spectrophotometer in a laboratory. There are important differences, however, which are due to the following: (a) absorption and scattering by gas molecules and dust reduce incoming solar radiation in certain wavelength bands; (b) illumination from the sun varies in intensity with numerous conditions; (c) the energy source in a spectrophotometer is of constant intensity whereas the solar energy source varies in intensity with wavelength; (d) radiance from crops in the field is affected by crop geometry, background soil reflectance and other factors; and (e) radiance from soils in the field is difficult to duplicate in the laboratory with disturbed soils.

Spectra from a cotton field, measured with an ISCO spectroradiometer, and from a cotton leaf using a laboratory spectrophotometer are shown in Figure 11.

Thermal Infrared Calibration Procedures

The NASA plane is not equipped with internal reference signal generation for the thermal infrared scanners. Therefore, it is necessary for thermal imagery to be calibrated by making ground truth measurements. These measurements are made during, immediately before, and immediately after the scanner-bearing plane is over the target area.

A Barnes PRT-5 radiometer sensitive in the 8-14 micron wavelength range is used for the ground measurements. It is calibrated over a wide range in its reference body temperature against a Leslie cube blackbody source. The temperatures for soil, plant, and other surfaces, then are equivalent blakcbody temperatures; i.e., the temperatures these objects would have if they had unit emissivity. This reporting form is used unless the necessary measurements for correction for reflected radiation from the surroundings (fuchs and Tanner, Agron. J. 58:597-601. 1966) are made. The care with which the radiometer is calibrated and the high emissivity of dry soil (about 0.92) and green leaves (0.97 to 0.98) minimize the departure from true temperature.

Interpretation of the imagery is made by making microdensitometer tracings across the film imagery at sites where the ground truth temperature is determined. Optical density of the film at these particular sites is then plotted against the ground truth temperature to produce a curve encompassing the range of film densities in the imagery.

Since it is not possible to integrate the temperature of plants, and exposed soil in furrows, in a ground based measurement, as the airborne sensor does, large areas of uniform surface are used. A highway, a 6 acre-foot water reservoir, and smooth bare fallow soil are the principal calibration sites. Temperature measurements are also made of plywood panels 25 feet by 50 feet recently painted with 3M optical white and optical grey (obtained by mixing optical white and optical black) paint.

Because the temperature of plant, soil, and other surfaces fluctuates readily with changes in insolation, the direct plus diffuse radiation indicated by an Eppley pyranometer is recorded at the same time the temperature measurements are made.

Figure 12 shows the relationship of film density (D) and equivalent blackbody temperature (T) established for a rangeland site. The relationship of T to D is linear. The bare soils were considerably warmer than the semi-desert vegetation and the water surfaces were cooler. The individual brush species vary approximately 1.5 C in temperature.

Thermal Infrared Thermograms as Ground Truth

In addition to using a Barnes PRT-5 radiometer for obtaining plant, soil, and water temperatures for ground truth, a Barnes Model T-5 infrared camera produces a thermogram of the target in the form of a Polaroid picture. Temperatures from the thermograms can be used to establish the accuracy of those obtained from the NASA IR scanner.

Plant canopy temperature patterns obtained with an infrared camera during a study of diurnal temperature changes in small, differentially irrigated cotton plots are presented in Figure 13. The figure is a composite of 4 thermograms taken at the time of day (CST) indicated below each thermogram. The first thermogram was obtained at 0540, well in advance of daybreak. The light areas from bottom to top on this thermogram - ignoring the one at the very bottom of the thermogram - are a man kneeling between the plot in the foreground and the center plot, an incandescent lamp in the far plot, and three side-by-side instrument shelters just beyond the plots. The other three thermograms depict the same target at later times during the day.

In all the thermograms presented, the lighter toned areas present warmer plant temperatures. Interpretation of the thermograms is made by matching the tone of a target within the field of view with one of the eight gray scale steps printed automatically at the top of each thermogram. From the electronic settings used to obtain the thermograms and a parameter corresponding to the gray scale step, the target radiance may be calculated and then converted to target temperature. It was necessary to vary the electronic settings as the crop surface warmed so that temperature differences could not be compared by visual inspection except relatively within individual thermograms.

The cotton plot in the foreground and the one in the background of each thermogram were at about the same moisture condition, and have the same tone. The middle plot was drier than the others. The calculated temperature difference between dry and wet plots was 0.1, 0.3, 2.0, and 0.2 C at the hours 0540, 0935, 1520, and 2210, respectively.

Thermal Infrared Detection of Soil Characteristics

Soils are unique in that subsurface soil characteristics influence the energy received by thermal infrared remote sensors. Investigations of thermal infrared detection of soil characteristics are being made in an area of alluvial floodplain soils shown in Figure 14. The bare soils shown in fields k, l, and m are those investigated in detail. A transect of 16 soil sampling sites was extended across the bare soil area, having a variation in surface and subsurface soil characteristics.

Diurnally-flown thermal imagery of the area is shown in Figure 15. Each of the transparencies was scanned with an isodensitracer to determine film densities. An isodensitracing of the 1900 hour thermogram is shown in Figure 16. Film densities (D) are directly related to equivalent blackbody temperatures. The temperature-film density relationship was established at a well instrumented site several miles away which was flown only a few minutes earlier, in each case, with the same scanner electronic gain settings. Data from the calibration site were used to plot a graph of ground truth temperature versus film density. The relation was linear in every case.

Temperatures at 30 selected sites were determined and are shown on the isodensitracing of Figure 16. The numerals beneath each point (23/26) mean point 23 which is at 26°C. The significance of these temperatures in relation to soil characteristics are discussed in the 1967 Weslaco, Texas, NASA report.

Data Processing

The amount of information being collected and the number of different forms of data being collected demands that there be a means of automatically summarizing all the different forms of signals and to convert all summaries to a common base.

The Weslaco remote sensing program at present has information in the form of photographic and scanner imagery from the NASA plane, analog signals on magnetic tape from the four scanners in the Michigan plane, photographs in conventional color, black and white infrared, and infrared color taken from the local Weslaco plane as well as information from laboratory instruments on punched paper tape, x-y recorder charts, and strip chart recordings. All these forms of data are compared to manually recorded ground truth conditions and to pictures from ground level.

Crop signatures will be developed for testing by recording reflected spectra from various crop and soil conditions by ground based spectrometers. Spectrophotometer curves of transmitted and reflected energy from individual leaves under controlled conditions are also used to suggest crop signatures.

Statistical analyses and summaries of data in the form of digitized spectrophotometer curves, data logger output of meteorological sensors, and other laboratory measurements are being made by Texas A&M University.

Efficient handling of data in many formats and originating in a number of different forms requires a data handling system specifically designed to take care of the unique characteristics of the system. Figure 17 is a flow sheet which shows sources of ground truth data; ground based instrumentation for gathering ground truth, as well as aerial equipment; and how the output from the instrumentation and equipment must be processed and analyzed by computer and then, in some cases, reconstituted into imagery.

Establishing Interpretation Keys

In phases of the agriculture and forestry programs which involve identification of crops and soils, forest and range species or plant communities, establishment of interpretation keys is found to be a valuable aid in establishing standards. Interpretation keys in current use consist of vertical photographs supplemented with obliques and ground photography. Interpretation keys serve three purposes; first, as a training aid for the new student; second, as indoctrination into new areas or items for trained personnel; and third, as a comprehensive library reference for the experienced interpreter.

Forestry Ground Truth

Investigations are underway by the U.S. Forest Service (R. C. Heller and associates*) to determine the ground instrumentation, aerial sensing equipment, and techniques required to detect vigor loss and previsual signs of tree mortality caused by bark beetles in coniferous timber stands. Ground and aerial studies are involved. Figure 18 shows the 1966-1967 USFS-NASA Black Hills Beetle Test Site near Lead, South Dakota. The following are examples of ground truth obtained in this study. Many other forestry projects are underway for which ground truth data are collected.

Establishment of Attractant Sites

It has been found that by placing laboratory reared beetles in screen cages on host trees (Figure 19) during the period of active beetle emergency in the summer, wild beetle populations could be induced to attack the tree with the caged beetles and many surrounding trees as well. In August 1965, a total of 11 sites were established in this manner within the study area.

Method for Determining Vigor Loss

Needle moisture tension is one additional parameter measured in 1967 that may help to determine early vigor loss. Briefly the method is as follows:

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* Pacific Southwest Forest and Range Experiment Station, USDA, Berkeley, California.

The twig end of a freshly-cut foliage sample (about 4 inches long) is inserted through a rubber "o" ring which is fitted into the top side of a pressurized container (Figure 20). The proximal end of the twig is exposed to atmospheric pressure. The needle portion of the sample is then placed inside the bottom part of the container and the two parts are screwed together. Nitrogen gas is introduced slowly to the container until free water begins to bubble from the tracheid cells in the cut end of the twig. Normal foliage required less pressure to force out the water than foliage from stressed trees. The absolute pressure values - but not comparative values - are affected by time-of-day, season, soil moisture availability, and sunlight conditions.

Preparation of Ground Resolution Target

A ground resolution target measuring 8x68 feet was constructed to determine spatial and thermal resolution capabilities of thermal infrared scanners. Twenty-seven fiberboardpanels, each 4x8 feet, were covered with 2 mil aluminum foil; the foil was pasted to the smooth side of the panels with wallpaper paste. Half of the panels in widths of 2, 4, and 8 feet were painted with 3M black velvet paint; the remaining panels were left aluminum. They were then laid out in alternating black and aluminum array (Figure 21).

This target array was designed to test whether the airborne scanners had a 1-, 2-, or 3-milliradian resolution capability.

Ground Truth Measurements - Short Term Orbital Mission

The following ground truth measurements (at time of overflights) would be required in relation to a 10-15 day orbital mission:

1. Simultaneous photography (aircraft and ground).

2. Plant and soil observations at all ground stations as recorded on standard form (Figure 3).

3. Short wave spectrometer spectra.

4. Meteorological measurements

   a. Barometric pressure
   b. Dew point
   c. Incoming total radiation
   d. Sky radiation
   e. Wind
   f. Ambient temperature

5. Specific fields with stressed plant conditions shall be established to determine if they can be detected from space.

6. A large bare field will be subdivided and prepared to include different soil conditions for detection from space.

7. Large areas of various range type plant communities will be delineated for sensing from space.

Ground Truth Measurements - One Year Orbital Mission

The same measurements made for a short orbital mission will be made for a one-year mission with the following additions:

1. Sequential measurements will be made to establish the validity of orbital sensing of plant and soil characteristics under a wide variety of conditions.

2. Yields of crops will be measured and correlated with orbital sensing data.

EXHIBIT A

Objectives:

1. To determine characteristic multiband signatures of various crops and soils in the Lower Rio Grande Valley of Texas.

2. To identify crops and crop conditions by remote spectral sensing techniques.

Variables:

1. Under investigation

a. Crop varieties

(1) Cotton

(2) Grain Sorghum

(3) Citrus

(4) Corn

(5) Vegetables

(6) Pasture

(7) Oats

(8) Alfalfa

(9) Native brushland

b. Stage of maturity

(1) Plant height

(2) Leaf area index

(3) Percent ground cover

(4) Number of nodes

(5) Row spacing

(6) Phenological development

c. Plant vigor and condition

(1) Stand (Plants per unit length of row)

(2) Weediness

(3) Crop color

(4) Nutrient deficiencies

(5) Insect and disease infestation

(6) Relative turgidity or absolute water content

(7) Yield or potential yield

d. Soil characteristics

(1) Soil series

(2) Moisture content

2. Not under investigation

a. Climatic variations

(1) But dates of irrigations, standard weather station data, and solar radiation information will be recorded or available.

b. Cultural practices

(1) Will be observed and recorded at test sites.

Procedure to be followed:

The ground truth will be that obtained in conjunction with overflights along 65 miles of ground test sites, and continuing periodic flights by NASA and locally chartered plane. On these flights multiband imagery is collected from airborne remote sensors such as multilens cameras, multichannel optical scanners, thermal pyrometers, microwave radiometers, radar scanners, and other appropriate instruments. Ground truth information describing completely the soil and crop conditions is collected simultaneously with the multiband signatures.

All imagery will be examined visually and electronically to detect obvious differences in the crop signatures. Characteristic signatures will be set in an electronic discriminator and into a digital computer to determine the uniqueness of the specified signature. Confidence levels of individual signatures will be determined through statistical calculations in a computer.

Signatures from individual fields will be correlated with ground truth observations through a covariance matrix calculation in a computer. Factors that are significantly correlated will be examined more closely to determine the interrelations among crop factors and signatures.

Data to be obtained:

Crop signatures, or portions of signatures, will be obtained as

a. Voltage signals on magnetic tape

b. Recorder trace on paper charts

c. Photographic imagery

d. Thermograms

e. Photographs of oscilloscope display

f. Isodensitracings of transparencies, and

g. Densichron readings of transparencies

All signals will represent intensity of reflection or emission in one or more wavelength bands.

Interpretation and Application of Results:

Signatures will be used to survey areas to determine the extent of the crop species or condition specified by the signature. Surveys may be used to determine the potential yield, to locate the outbreak of certain plant diseases, to assess the spread of an insect invasion, to follow the progress of harvesting, or to estimate the acreage planted, and to determine the need for soil moisture or plant nutrients.

EXHIBIT B

LABORATORY FOR AGRICULTURAL REMOTE SENSING

Truck Instrumentation and Capabilities

The basic field data instrumentation is designed to be mounted as a complete unit in the field van such that all field data can be collected in the natural environment of the sample to be measured with a minimum of external equipment and a minimum of set-up and take-down time. As a self-contained unit, the field van contains all the necessary measuring equipment and its own power source. Provisions are included for operating the data collecting instruments from either the field van roof or the cherry-picker bucket (up to 50 feet from the ground surface). The general instrument schematic is shown in Fig. 1.

This instrumentation includes the sensing instruments and the necessary recording equipment. The recording equipment consists of three basic types-- the Ampex SP-300 seven-channel (1/2 inch) FM or direct tape recorder, the Honeywell 24-channel strip recorder, and the operator's data sheet. The Ampex SP-300 seven-channel tape recorder is used to record the output signals (interferograms) and the digitizing signals (clock signals) from the Block interferometers. The output signals from the Block interferometers are recorded in the FM mode in order to eliminate the reproduced signal amplitude variations inherent in a direct mode tape recording device, while the clock signals are recorded in the direct mode because of the frequency limitations of the FM mode. Provisions are included for a voice channel for recording identification numbers and other pertinent information if it is desired. The Honeywell 24-channel strip recorder is used to record in a sampled form on paper the slowly-varying signals from thermocouples measuring the ground and/or ambient temperatures at various levels, the output signal from the Eppley pyrheliometer used for indicating the quantity of incident solar energy contained in four wide wavelength bands, the output of the Barnes PRT-4 radiometer for measuring

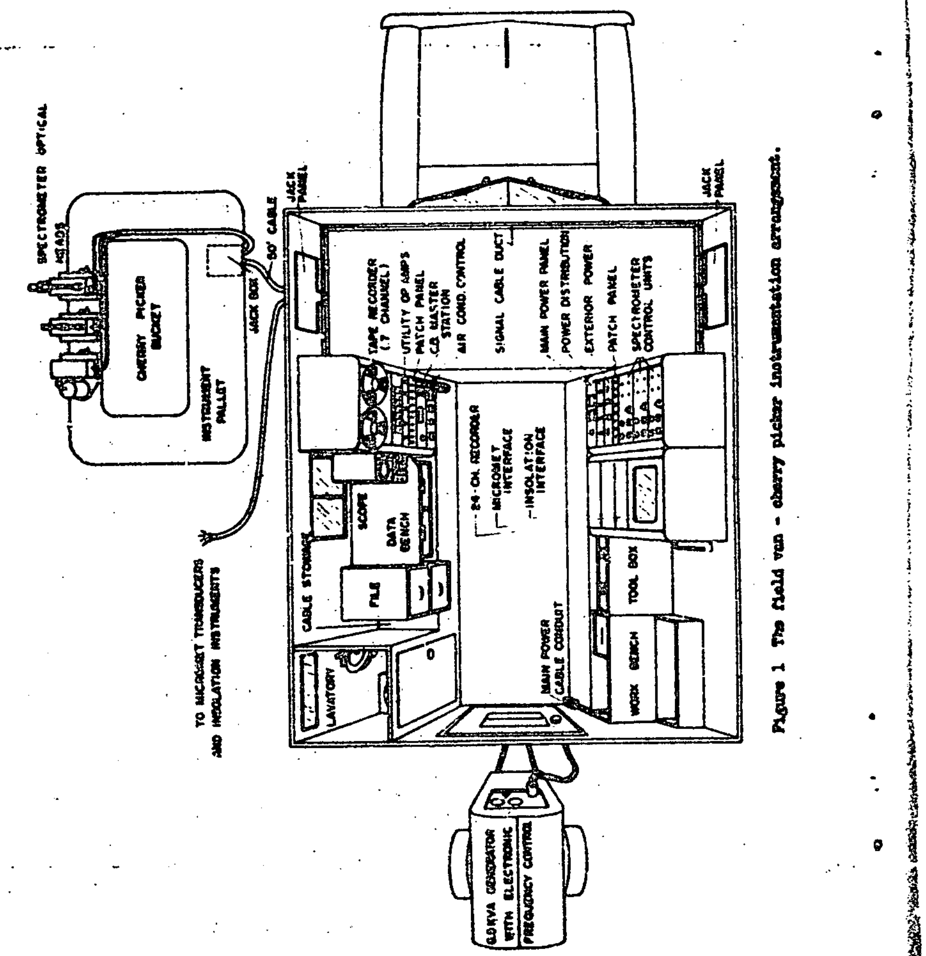

Figure 1 The field van - cherry picker instrumentation arrangement.

the apparent temperature of the scene examined, and the output of the ISCO spectroradiometer for indicating the spectral distribution of the incident solar energy. This recorder is a universal 5mv recorder for indicating sampled values of slowly varying conditions pertinent to the experiment. The operator data sheet indicates the information necessary for tying together the data recorded on the other recorders. This includes information such as the run identification numbers, the tape position indicator values for the stop and start of each run, the time of day, various instrument settings, and photograph number if photos were taken.

Other accessory equipment is required for operation as a self-contained unit. This includes the 6.5KW gasoline (or gaseous fuel) driven Kohler frequency stabilized MG set for supplying instrument and lighting power, the 3KW truck engine driven generator for supplying power to the air conditioner and tools which are apt to cause line transients that interfere with data collection, the tranceiver gear for communications between the operator of the sensing equipment and the recording equipment operator, and miscellaneous tools and instruction manuals for field maintenance.

At the present time most of the sensing and recording equipment and all of the accessory equipment has been installed and used on several data collecting missions. The remainder of the equipment is in the process of being installed and continued improvements are being made on the existing installation.

The installation of the accessory equipment is complete and in operational status. The frequency stabilized 6.5KW generator attaches as a trailer with connecting cables to the field van and has a frequency stabilization sufficient to maintain constant recorder speeds. The 3KW generator connects to the truck engine when needed and the voltage level and frequency are controlled from the van. The communications gear is rack mounted and is used both for data recording and for unloading the data from the truck to the analog-to-

digital converter. Tools and manuals are in permanently mounted cases and file cabinets in the van. Because of the weight distribution in the van it has been found necessary to equip the truck with heavy duty springs which are now being obtained.

The Ampex SP-300 tape recorder and the Block 195T and 195E interferometer electronics are rack mounted in the van. Figure 2 shows the recorder in its mount in a preliminary set-up. Cabling has been made with interface panels for operating the interferomatic optical heads either on top of the van as shown in Figure 3 or in the cherry-picker as shown in Figure 4 and Figure 5. At the time of these photos, the truck interface panels were not installed. The cabling and interface panels allow for simultaneous operation of the Block 195E and 195T interferometers. Operation from the van roof is made by mounting the optical heads on a tripod set on the aluminum grid platform and connecting cables from the optical heads to the interface panel. Operation from the cherry-picker is made using an instrument platform mounted on the bucket. The optical heads are mounted on geared pan heads fixed to this platform. A fifty foot cable connects the optical heads to the truck interface panel. The long cables have not noticeably affected the quality of the output signals. The output of instrument electronics in the van are connected via interface panels on the instrumentation rack and on the recorder rack to the respective recording channels. The input and recorded signals are monitored on an oscilloscope for instrument and recorder level adjustments.

The Honeywell 24-channel recorder is in the process of being mounted in its rack in the van. Connections will be made from the recorder to the outside of the van. The sensing equipment for this recorder are, for the most part, portable and are set up outside the van either on the ground, on the truck roof, or in the cherry-picker as the experiment requires.

In a typical data-collecting mission using the cherry-picker and the

Block 195E and 195T interferometers, three operators are required. About 15 minutes are required in order to set-up and adjust the recording levels, optical heads, and cabling. For the 195E interferometer, liquid nitrogen is transferred from the large dewar in the truck to the small vacuum bottle mounted with the optical head. A proper flow of liquid nitrogen must be obtained in order to assure cooling of the detector. The run procedure requires that one operator in the cherry-picker aims the optical heads at the desired scene of view while the other operator records the run number, description, etc., on the data sheet. A minimum of one minute of data and clock signals are recorded to separate the runs. The third operator installs micromet and insolation gear on location, and takes radiometer readings as required. When all the runs desired at one location are complete, the cable to the cherry-picker bucket platform is disconnected at the platform and the van and cherry-picker move separately to the new location. Take-down time at the end of the day is also on the order of 15 minutes since only the external equipment and cabling must be packed.

The data is transferred to the LARS A/D converter by means of the fifty foot cable and interface panels at the truck and the building. This allows the data to be reproduced from the SP-300 without removing the recorder from the van. The transceiver gear is used in this process for communication between the operator in the van and the operator of the A/D converter in the building.

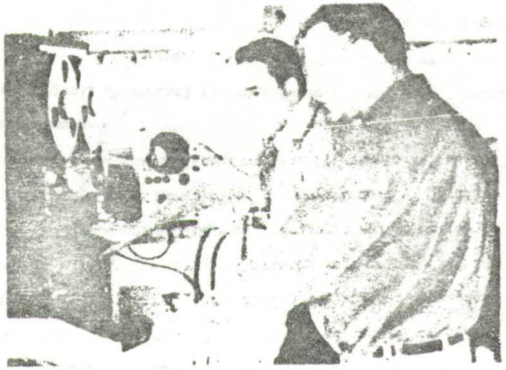

Figure 2 At the tape recorder inside the truck.

Figure 3 Measuring crop radiance in the 2 to 16μ band from the field van roof.

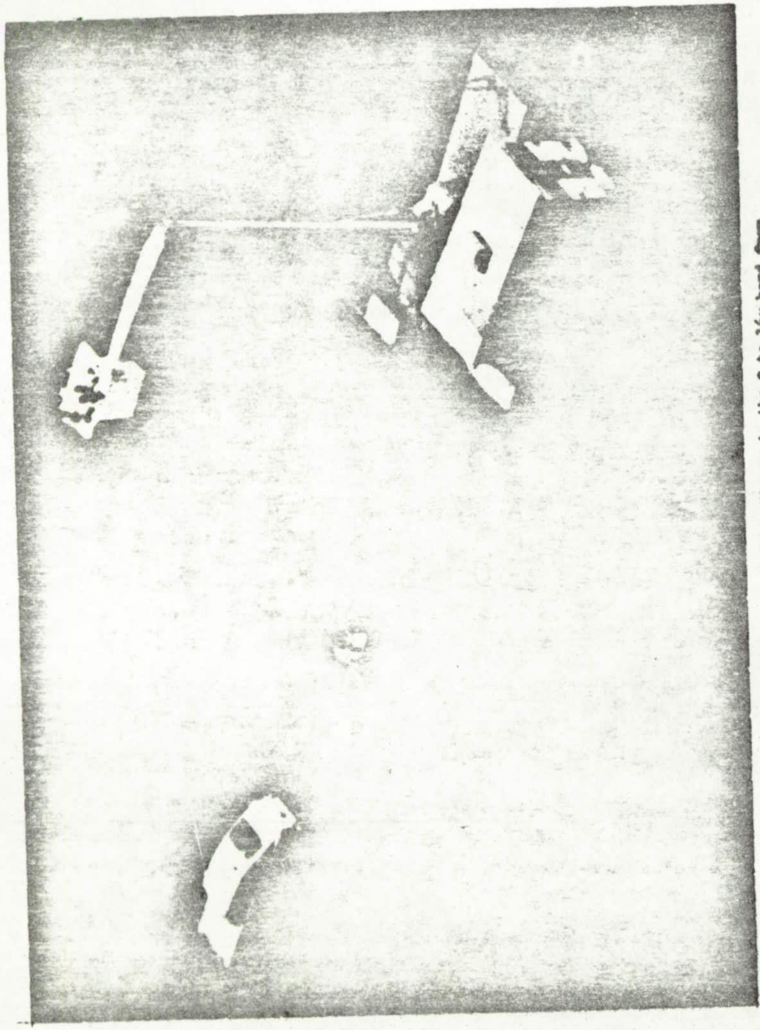

Figure 4 Measuring corn field radiance in the 2 to 16µ band from the cherry picker during a NASA flight mission.

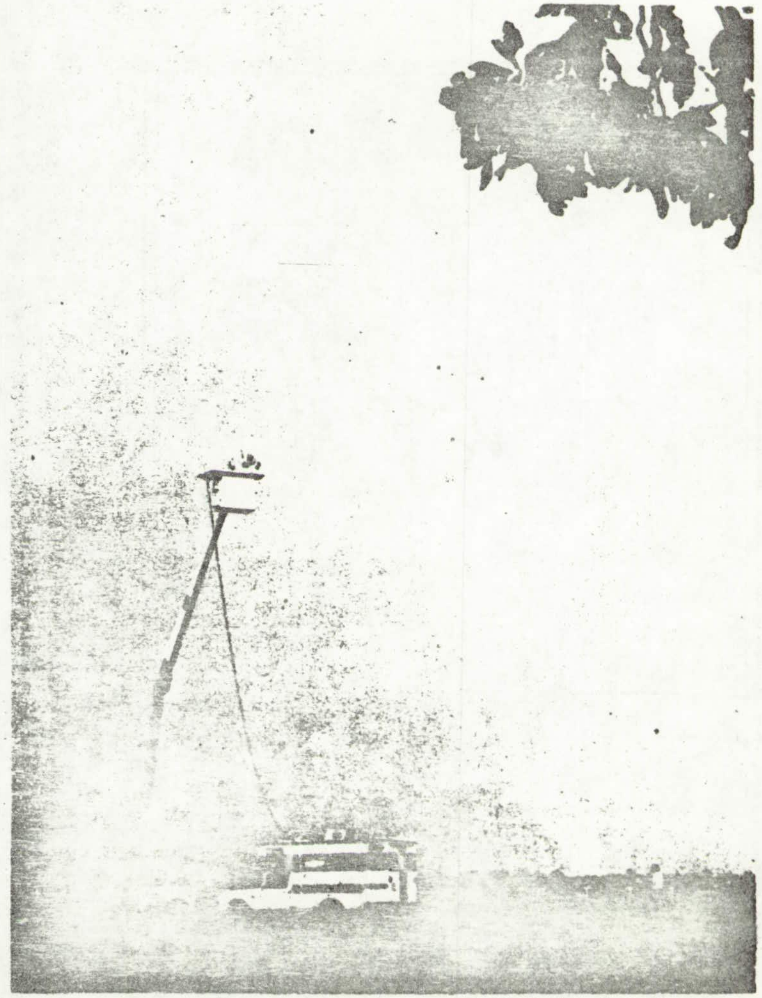

Figure 5 Measuring soybean radiance in both the 1 to 6µ band (195R) and the 2 to 16µ band (195T) from the cherry picker.

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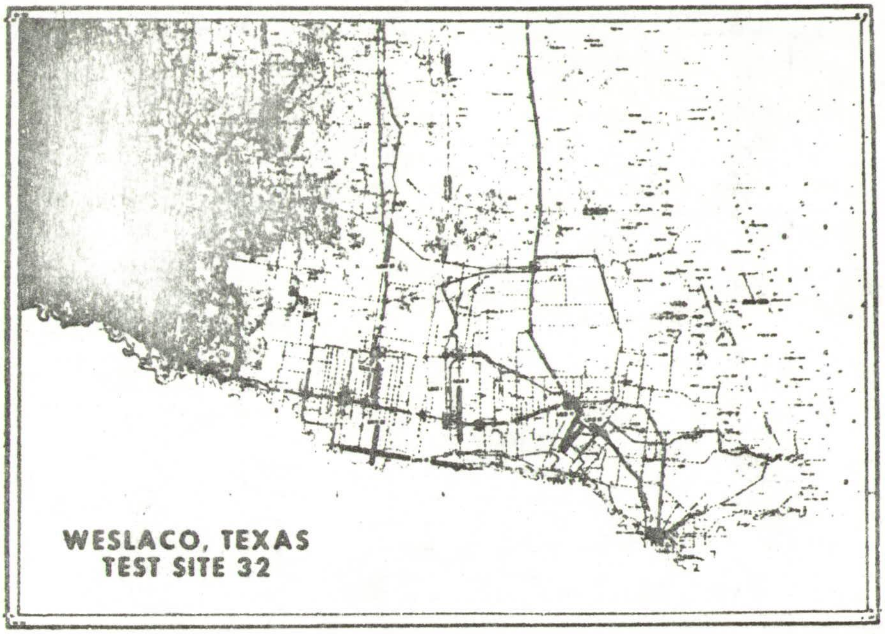
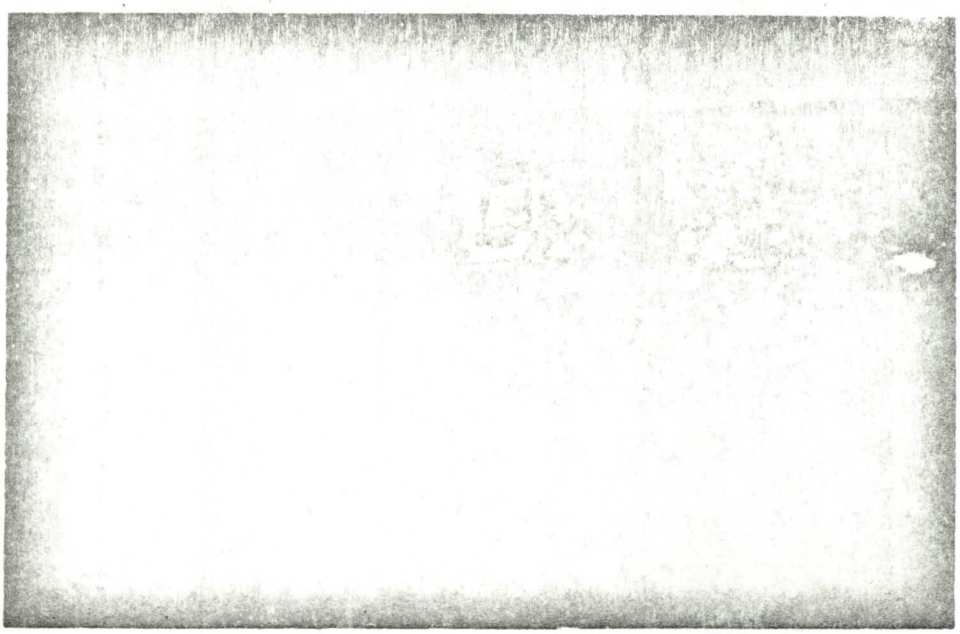
FLIGHT LINES
LOWER RIO GRANDE VALLEY



NASA-S-67-7730

MEASURING PLANT HEIGHTS
WESLACO



NASA-S-67-7727

FORM USED IN COLLECTING GROUND TRUTH INFORMATION

FLIGHT DATA SUMMARY SHEET

LOCATION: Transect ____ Site No. ____ Legal Descr. ____________

FLIGHT: Date ________ Time ________ Plane ____________

VEGETATION: Species ____________ % Ground Cover ____ % Weed Cover ____

PLANT: Height ______ Maturity ________ Row Width ______ Orientation ______

Appearance ____________ Nodes ________ Yield ________

Leaf Moisture, Oil ______ Grav. ______ Leaf Thickness ______ LAI ______

Color, Munsel ________ 540u ________ Chlorophyl ________

SOIL: Series ________ Color, Wet ________ Dry ________ Sat. % ______

Texture ________ Surface Cond. ________ Depth to Water Table ____

Moisture, Surface ______ 1st Ft. ______ 2nd Ft. ______ 3rd Ft. ______

Salinity ____________ Other ____________

TEMPERATURE. (PRT) Plant ________ Soil ________ Integrated ________

ENERGY: Incoming, Ground ________ Plane ________ Reflected ________

GROUND PHOTO: B&W No. ______ Color No. ______ IR No. ______ Other ______

AERIAL PHOTO: ______ ______ ______ ______ ______ ______

SPECTROPHOTOMETER CURVE NO. ____________ Book ____________

ISODENSITRACING: Channel ______ ______ ______

Rec. No. ______ ______ ______

DENSICHRON:

Channel ____ ____ ____ ____ ____ ____ ____ ____

Reading ____ ____ ____ ____ ____ ____ ____ ____

Channel ____ ____ ____ ____ ____ ____ ____ ____

Reading ____ ____ ____ ____ ____ ____ ____ ____

Channel ____ ____ ____ ____ ____ ____ ____ ____

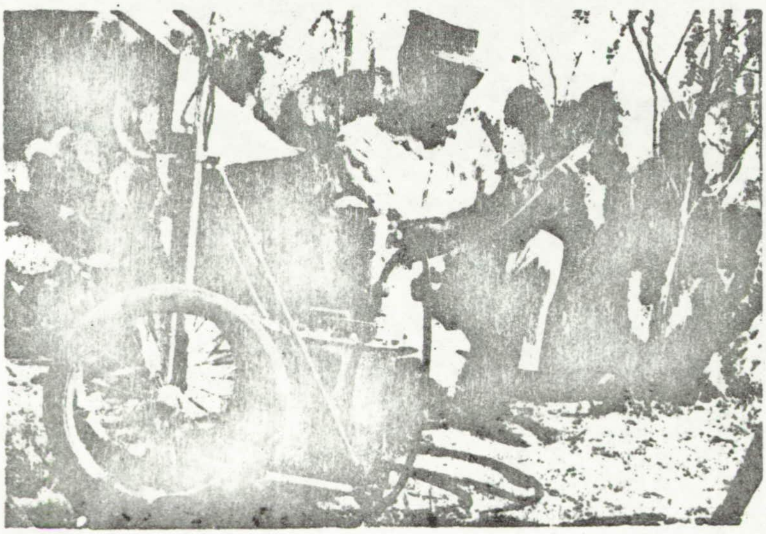
Reading ____ ____ ____ ____ ____ ____ ____ ____

NOTES:

NASA-S-67-7731

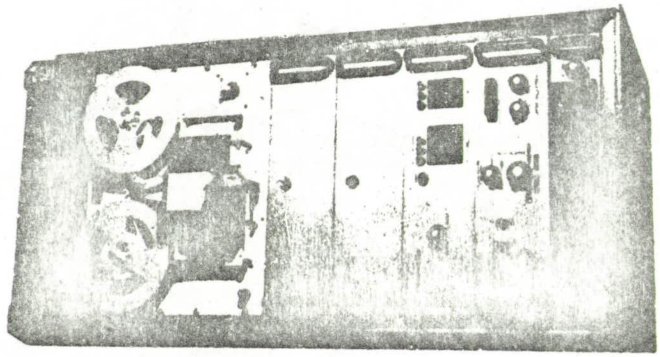
NEUTRON PROBE AND SCALER

USED TO MEASURE SOIL MOISTURE



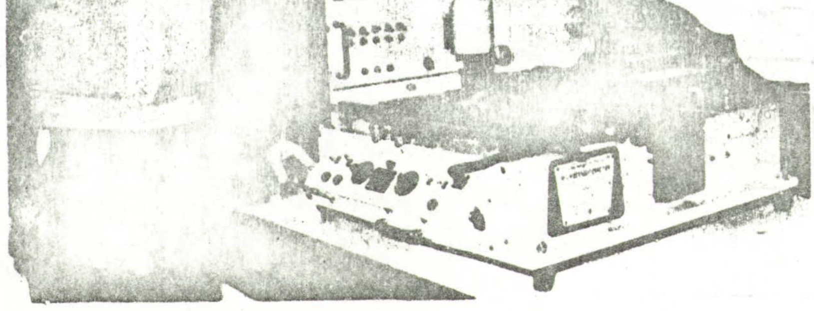
NASA-S-67-7748

DATA
LOGGING
SYSTEM
USED
IN MOBILE
LABORATORY



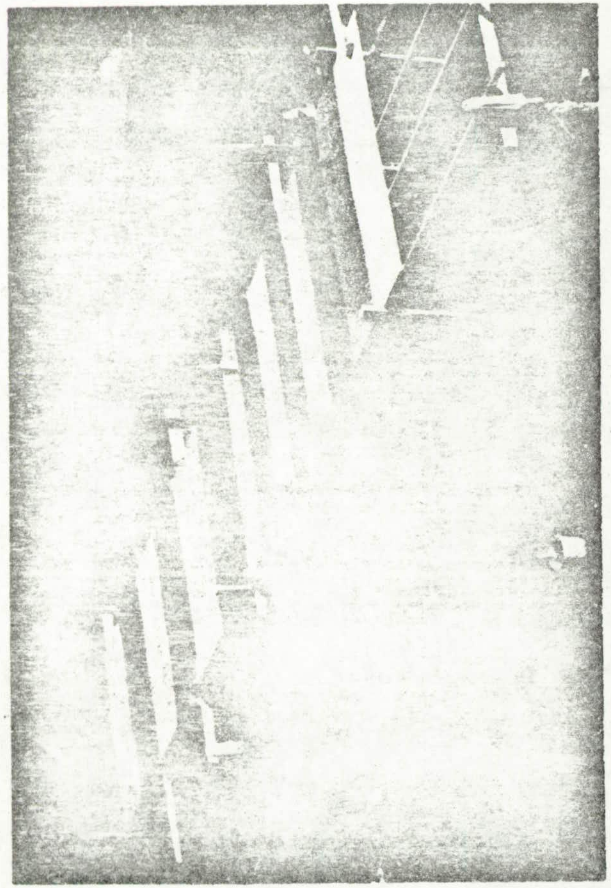
NASA-S-67-7734

ISODENSITRACER
AND MICRODENSITOMETER
FOR MEASURING PHOTOGRAPHIC FILM DENSITY



NASA-S-67-7732

RESOLUTION TARGET
AT BLACK HILLS SITE



Geologic Ground Truth for Earth Resources Survey Programs

Joseph Lintz, Jr., Jack G. Quade, Peter Chapman

University of Nevada

Present Capabilities of the University of Nevada Geology Ground Truth Team

The capabilities of the geology ground truth team of the University of Nevada are amenable to division into two classes - research and operations. Research includes those activities designed to analyze and identify those components that comprise ground truth, to determine the ranking or importance of each of them to the total sensed signature, to develop means and techniques for their measurement and determination. Implicit in this type of research is the ability to interpret remotely sensed data, since this provides the only feedback to indicate the degree of success in the analytical and identification procedures. Research field activity is a long term procedure requiring several weeks on the site collecting detailed data. In contrast to research activities, ground truth operations are herewith defined as the measurements of the various field parameters taken in association with remotely sensed data. It consists of field data collected in a, say, 24-hour period before, during, and after aircraft/spacecraft flights. To date, the majority of our operations activities have been included in the research phase, as we have been developing techniques and checklists of operational ground truth activities. A few of our operations have been in the nature of service work for other agencies which may have led to research analysis by others.

The distinction between research and operations is here emphasized because it is conceivable that in the future an operations unit could be established outside the research unit. Discussion of this point is not germane here and is reserved for some of the concluding paragraphs.

The research phase itself is again divisible into two aspects, each with its own specialized equipment: field research and laboratory research. Actually the laboratory work represents a continuation of the field collecting, and for this reason some of the activities appear twice. The equipment and techniques vary sufficiently, however, as well as the locale, so that the division is genuine.

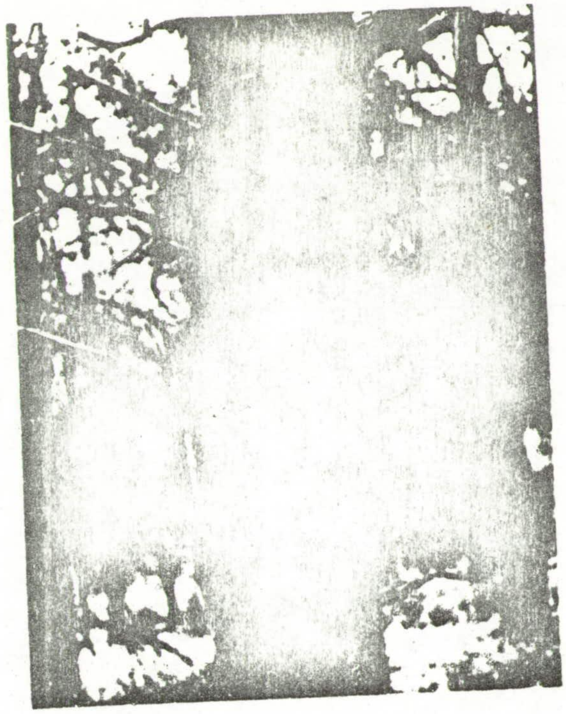
Laboratory capabilities of the present include:

1. Rock analysis - total, rapid
   a. Chemical
   b. Mineralogical
   c. Particle size

2. Moisture analysis

3. Microtexture analysis (surface roughness)

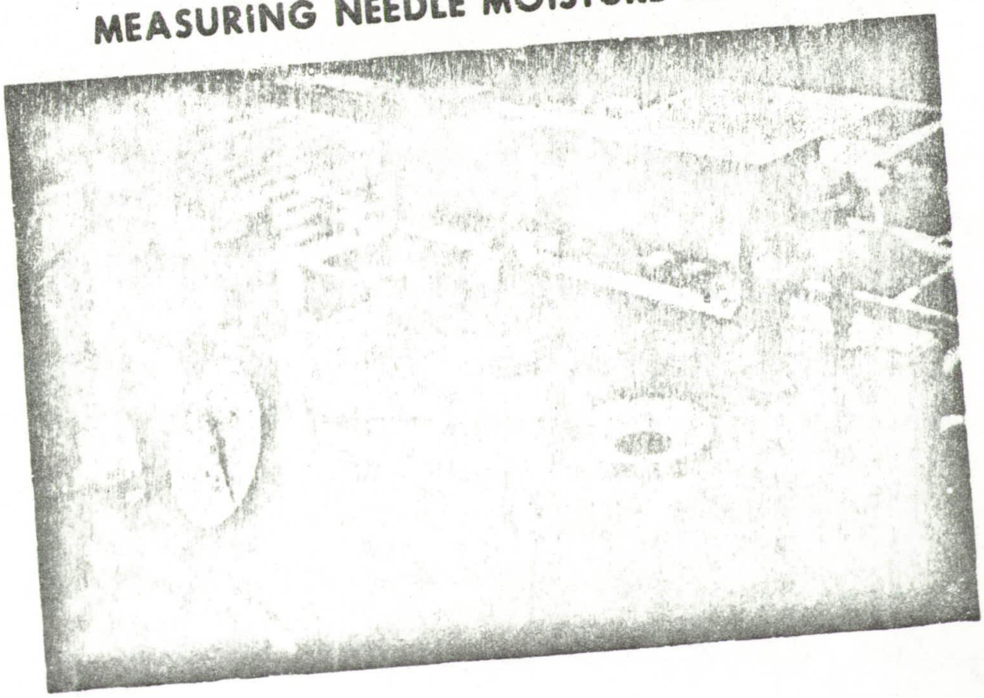
NASA-S-67-7718



SCREEN
WIRE CAGE
CHARGED WITH
LIVE BEETLES

NASA-S-67-7735

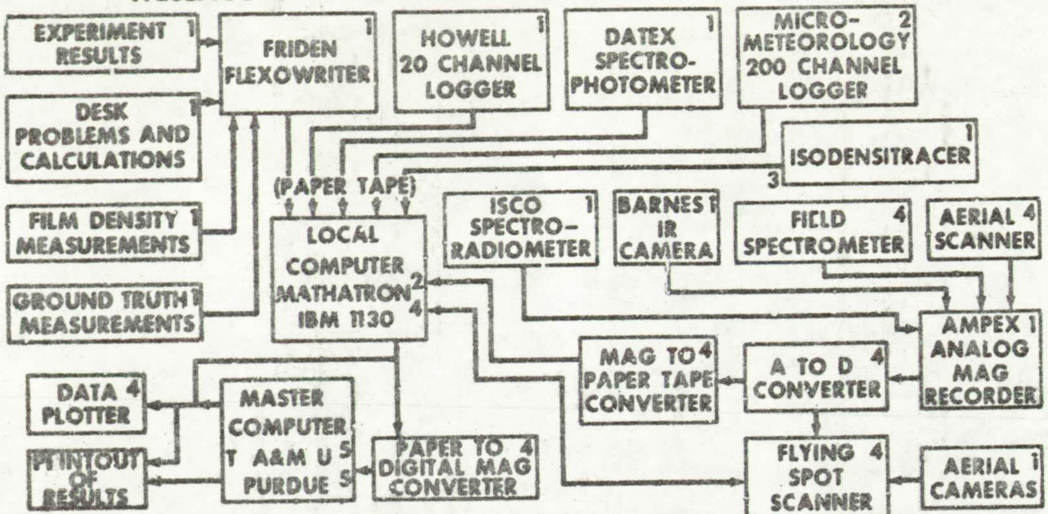
SCHOLANDER BOMB FOR
MEASURING NEEDLE MOISTURE TENSION



NASA-S-67-7729

FLOW SHEET

WESLACO SWC REMOTE SENSING HANDLING EQUIPMENT



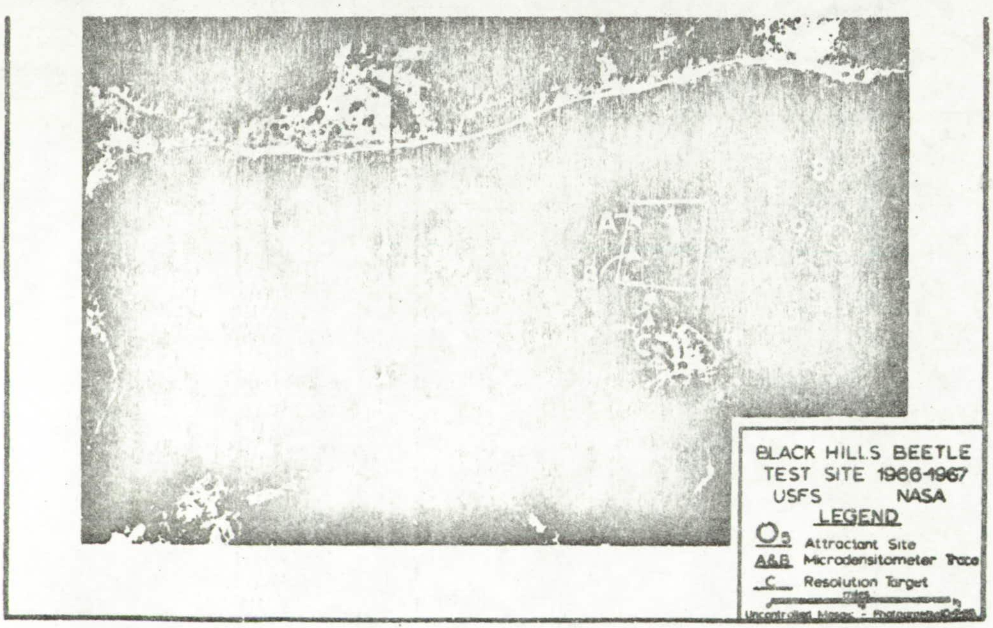
LEGEND:

STATUS OF COMPONENTS
1 ON HAND
2 ON ORDER
3 NEGOTIATION FOR TAPE READOUT ADAPTATION
4 PURCHASE ANTICIPATED
5 POSSIBILITIES

1 COMPUTER PROCESSED ANALOG SIGNALS FROM AERIAL SCANNERS
2 COMPUTER PROCESSED TRANSPARENCIES
3 RECONSTITUTED IMAGERY
4 STRIP CHARTS PROCESSING AND COMPUTATIONS

NASA-S-67-7725

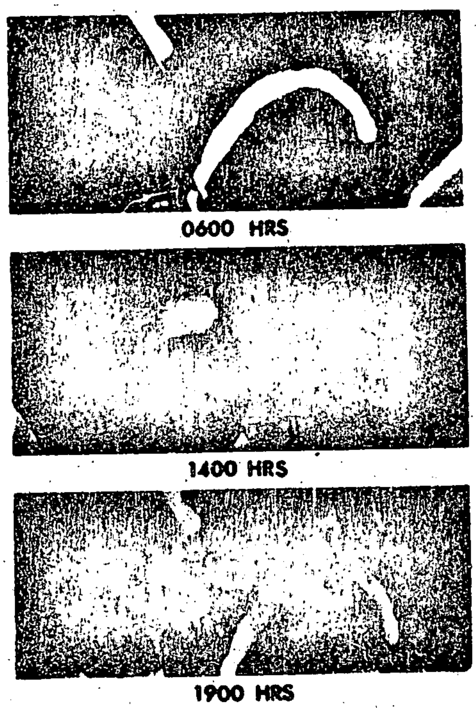
SIX ATTRACTANT SITES
NEAR LEAD, SOUTH DAKOTA



NASA-S-67-7723

DIURNALLY-FLOWN THERMAL IMAGERY (8 TO 14 MICRONS)

MOON LAKE AGRICULTURAL AREA



ISODENSITRACING, MOON LAKE AREA

8 TO 14 MICRONS, 1900 HOURS, 2000 FEET

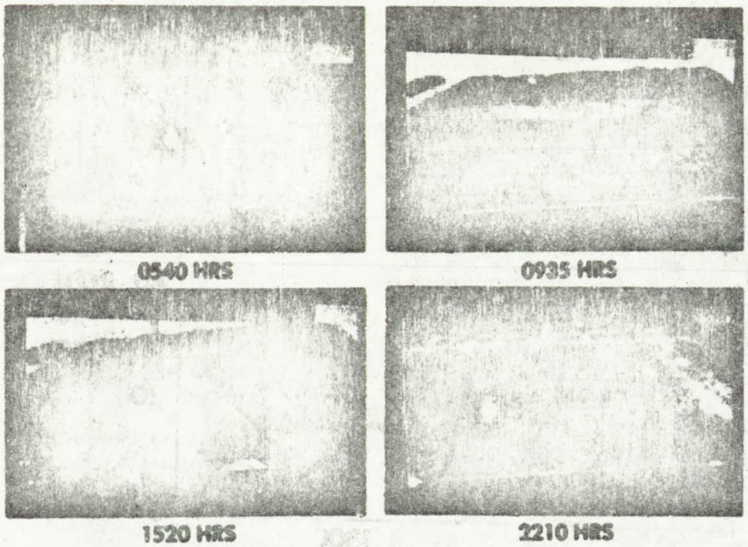
(LEGEND: 31/29 = SITE NUMBER/DEGREE CENTIGRADE)

NASA-S-67-7749

THERMOGRAMS

COTTON PLOTS VARYING IN SOIL MOISTURE CONDITIONS

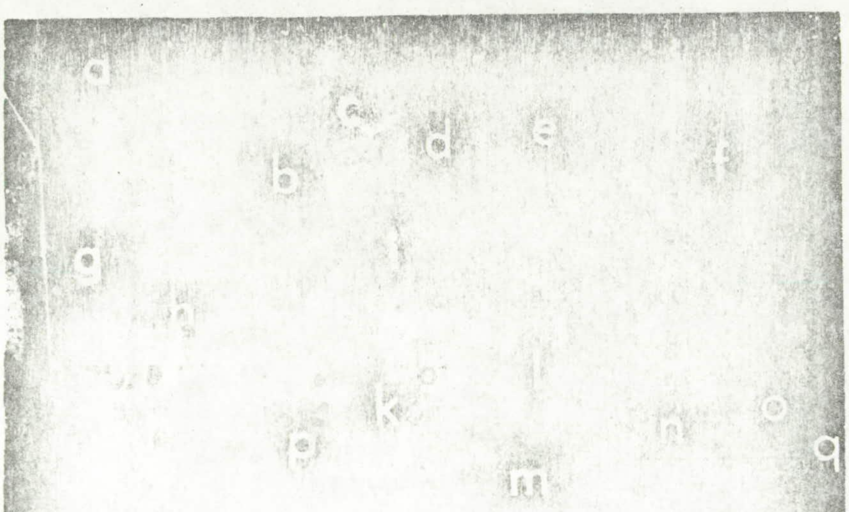
JUNE 10, 1965



NASA-S-67-7717

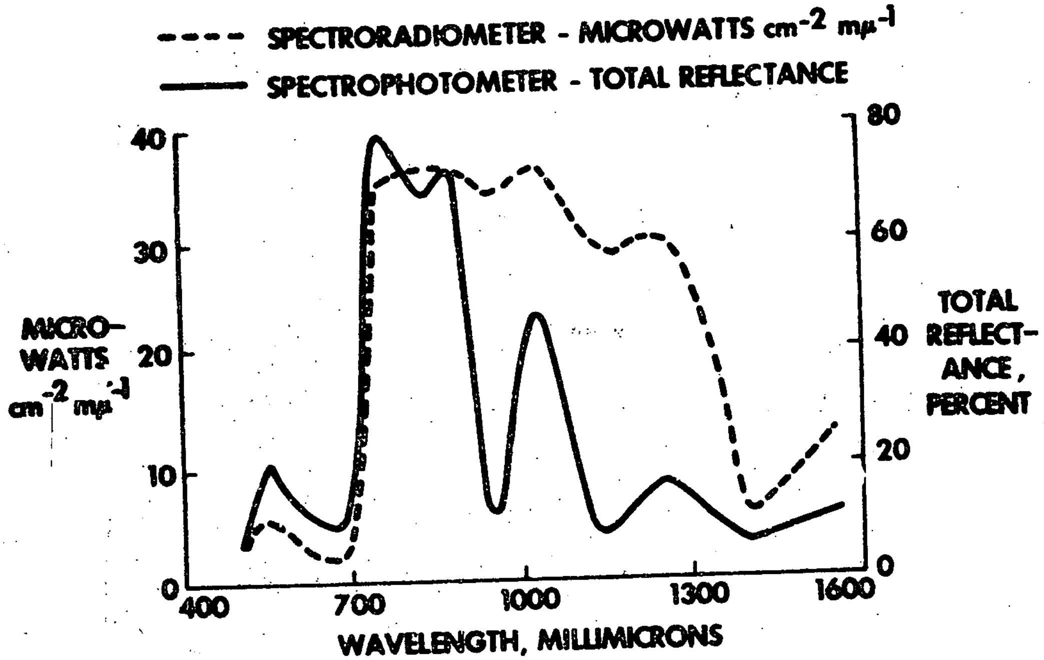
MOON LAKE AGRICULTURAL AREA

LOWER RIO GRANDE VALLEY



NASA-S-67-7715

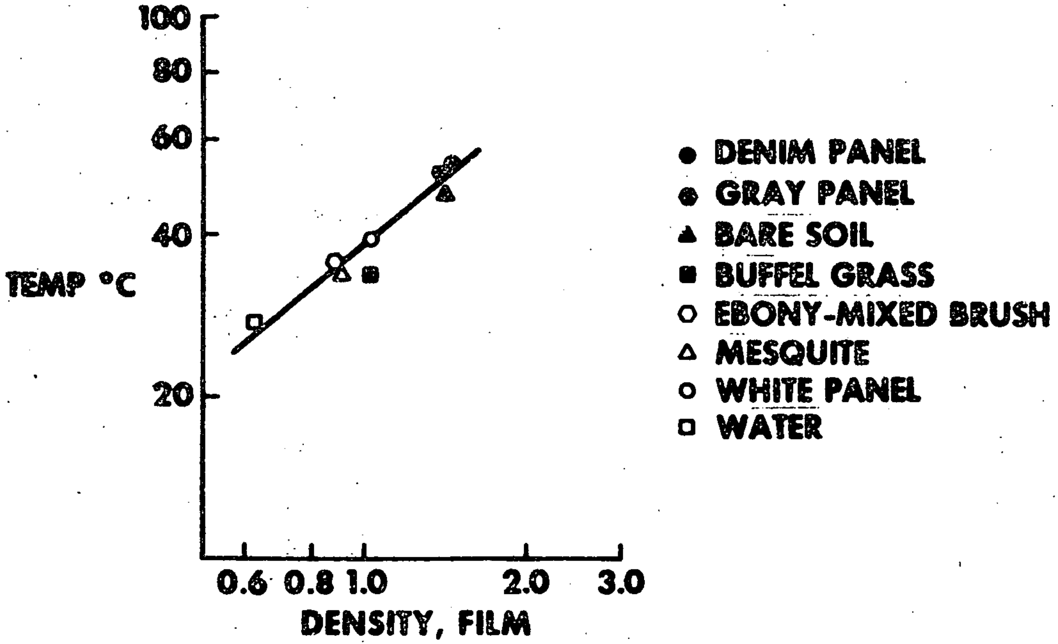
COTTON



NASA-S-67-7722

FILM DENSITY FROM 8 TO 14 MICRON REGION

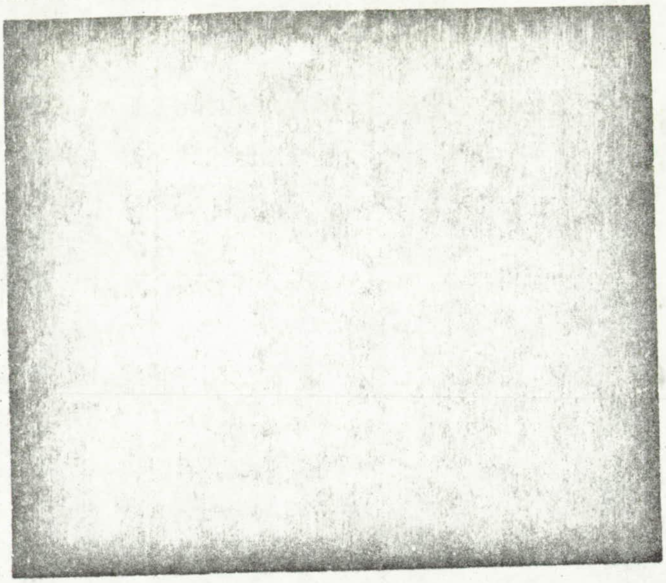
GROUND TEMPERATURES



NASA-S-67-7733

HIGH RANGER

RECORDING INSTRUMENTS MOUNTED IN BUCKET



NASA-S-67-7726

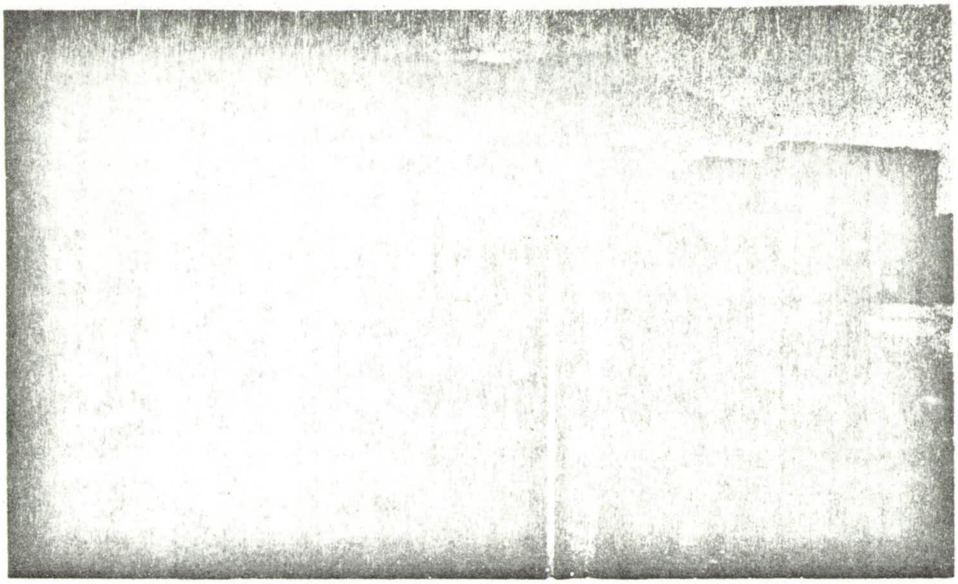
PUNCHED TAPE FORMAT

SPECTRORADIOMETER DATA

		PI	
01	Observation Number 000-999	‡	Space
02	Date (Month, day, 2 digits of year) 010167 to 123199	‡	
03	Location (NASA flight line numbers) 00 to 99	‡	
04	Site Number 000 to 999	‡	
05	Crop and Variety 00 to 99 for crop 0 to 9 for variety	‡	
06	Crop Condition 00 to 99	‡	
07	Ground Cover, Percent 000 to 100	‡	
08	Plant Height, cm. 000 to 999	‡	
09	Plant Maturity 0 to 9	‡	
10	Plant Spacing Rows, cm. 00 to 99	‡	
11	Row Spacing, cm. 000 to 999	‡	
12	Row Direction, Degrees 000 to 180	‡	
13	Leaf Area Index 0.00 to 9.99	‡	
14	Leaf Thickness, mm. 0.000 to 9.999	‡	
15	Soil Mechanical Analysis, percent - Sand 00 Silt 00 Clay 00	‡	
16	Soil Condition 0 to 9	‡	
17	Soil Surface Moisture, Percent 00.0 to 99.9	‡	
18	Date of Last Irrigation (Day, month, year)	‡	
19	Wind Speed, m. per hour 000 to 999	‡	
20	Wind Direction, coming from 0 to 360	‡	
21	Ambient Temperature, °C -00 to 99	‡	
22	Humidity, °C 00 to 99	‡	
23	Barometric Pressure, mm Hg. 000 to 999	‡	
24	Haze Condition 0 - 9	‡	
25	Cloud Condition 0 - 9	‡	
26	Spectrophotometer Curves 10 digits followed by PI & followed by 3 digits of reflectance or transmittance, a space and five digits of wavelength followed by PI 23457 space. Ten digit parameter assigned as follows: First 3 Observation Number Fourth Measurement Code At end of set of curves type in	‡	
27	Spectroradiometer Number 1 or 2	‡	
28	Scan Number 00 to 99	‡	
29	Time (Military) 0000 to 2359	‡	
30	Scale Range 0 to 9	‡	
31	Sun Azimuth 000 to 98x	‡	
32	Sun Vertical Angle 00 to 90	‡	
33	Radiation, cal cm^{-2} min^{-1} 0.00 to 9.99	‡	
34	Probe Used (0 for none, 1 for 3 feet, 2 for 6 feet)	‡	
35	Probe Angle from Horizontal 00 to 90	‡	
36	Height of Sensor above Ground, cm. 000 to 999	‡	
37	Height of Sensor above Canopy, cm. 000 to 999	‡	
38	Direction of View of Probe 000 to 360	‡	
39	Spectroradiometer Curves Coordinates of each point indicated by 4 digits for wavelength, space, five digits for reading. Points in visible range followed by PI/ and space. Points in infrared range followed by PI' and space. At end of set of curves, type in	µ	

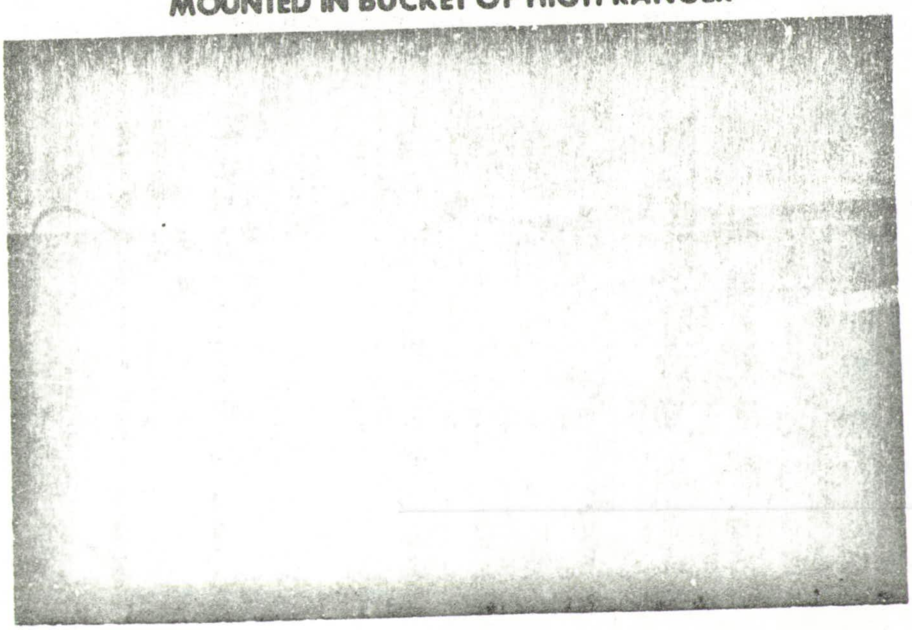
NASA-S-67-7724

SPECTROPHOTOMETER AND PAPER TAPE PUNCH SYSTEM



NASA-S-67-7719

SPECTRORADIOMETER MOUNTED IN BUCKET OF HIGH RANGER



4. Soil analysis

5. Emissivity analysis

6. Meteorologic analysis

7. Density - specific gravity

8. Photogrammetric constructions

9. Drafting and illustrations

10. Documentation and reports

11. Test site selection analysis

Field capabilities include:

1. Geologic mapping

2. Soils mapping

3. Rock and soil moisture data

4. Emissivity data

5. Meteorologic data, including ground to sensor profiles

6. Thermal data collection (8-14u)

7. Thermal diffusion

8. Vehicular and transportation

9. Communications
   a. Intraparty
   b. Ground-aircraft
   c. Single side band

10. Beacons for sensors
    a. Microwave
    b. Radar

11. Flight line marking

12. Biosphere data collecting micro to mega sphere

While it is well enough to know one's strengths and abilities, the wise will have full knowledge of their limitations as well. Thus, the following capabilities have not been activitated and may be worthy of future consideration:

a. Depth studies in rocks. The majority of our research has been at the surface. Recently, we began measuring atmospheric profiles between the surface and the sensors. We have still to commence studies of rock data down to the penetration limit of the NASA suite of sensors, a depth of 10-12 feet. The microwave team has expressed an interest in our undertaking research in this area.

b. Ground based sensors in the microwave region. Because of the tightly constrained aircraft schedule and the general lack of microwave data, ground based microwave sensors (radiometer and/or scatterometer) would yield meaningful data and shorten the time span required to evaluate ground truth parameters at these wavelengths.

c. Telemetering. The ability to telemeter data to any direction is totally lacking. Possible points of transmission include (1) up to an aircraft or spacecraft, (2) laterally to a van, (3) direct to the Manned Spacecraft Center (MSC) data bank.

Ground Operations

n a very broad sense, the Ground Operations Flow Chart (Plate 3) escribes a systematic method in which ground and airborne sensor ata are accumulated and shows how the resulting information, the orm of a final evaluation of remotely sensed data, is produced.

ince the ultimate objective of the program is to remote-sense specific argets from space and airborne sensors, it follows quite logically hat in the initial stages of the program a clear understanding of what ontributes to the total signal of any sensor must be defined and easured if we are ever to make sense out of the data.

nstrument teams must understand the limitations and capabilities f their own instruments before user groups can intelligently designate heir use for any specific target. The need for calibrating the nstruments by building a backlog of data generated over carefully tudied targets has been a common objective of the instrument and ground ruth teams.

e have a description of the varied parameters that affect the total ignal of the microwave, infrared, multispec, and radar. It now becomes n charge of the ground team to collect the data on the ground that n be used to describe quantitatively the percentage contribution of ch of the varied parameters affecting the total signal on the aircraft nstrumentation. The next logical step would be to superimpose on the nstrument data measurements taken on the ground from which some under- anding of instrument capability should evolve as well as new and better erating parameters for specific targets.

geologic target provides some of the most complex problems in remote nsing; however, even though the targets vary, the same instruments are volved and the parameters, if any, remain constant. It is the applied chniques that change.

Parameters Affecting the Infrared Signal

Three types of sensors in the infrared portion of the spectra are currently being flown in the Earth Resources Program - an infrared radiometer, an infrared imager, and a spectrometer. For the sake of simplicity the parameters affecting the total signal of these three instruments are combined on plates 7 and 8. Each instrument's mode of operation controls the order of significance of the individual environmental variables.

The heating property of a material is controlled by two variables, the albedo and the thermal conductivity. For example, a dark substance such as basalt will heat more rapidly under solar radiation than a lighter material such as granite. However, a soil may heat with even greater rapidity due to its slow downward conduction of energy. During the nightly cooling period of these units, a complete inversion of surface temperature is likely to occur. The soil material will quickly equilibrate with the air and in the case of evaporative cooling may even drop below the air temperature. The granite which has a comparatively high thermal diffusion will now be heated by a subsurface temperature and become the warmest material.

The amount of energy radiated at the surface of a material is dependent on its emissivity (E_λ). For example, a substance at 70°F with an emissivity of .80 will radiate only 80% of that energy and appears to an infrared radiometer to have a temperature of 56°F. The other 20% of the energy is reflected from the sky and neighboring material. The total signal can be expressed by the equation $T_R = T_M (E_\lambda) + T_E (1-E_\lambda)$, where T_E is the temperature of the environment (i.e. sky), $(1-E_\lambda)$ is the reflectance, T_M is the temperature of the material and T_R the temperature received at the radiometer.

The energy attenuated by the atmosphere is extremely frequency-sensitive. A slight change in ozone or water vapor content may absorb one wave length's energy and have little or no affect on another wave length. For this reason close attention should be taken to the atmospheric column between the aircraft and ground. Without proper correction for atmospheric content, data recorded at different altitudes should not be compared. Likewise, data taken at various times during a seasonal period should be compared with caution.

Data interpretation is complicated by vegetation on the geologic test sites. A multisensor package is very useful in removing this variable from the signal. Near infrared camouflage detection film may aid in identifying the type and distribution of vegetation, and the vigor of individual types. Plant life is very helpful in spotting chemical changes in soil content and defining a climatic zone. The latter is significant when interpreting the weathering characteristics of various rock types and the soils they are forming. Moisture content and percolation, which affect vegetation distibution and vigor, is dependent on rock type, porosity, and soil sorting.

Proper interpretation of the environmental variables is necessary in defining and interpreting thermal anomalies. In predicting volcanic eruption, the type of material, the thermal diffusion, and emissivity will determine whether a large transfer in subsurface temperature will be reflected at the surface. In the case of sulfide oxidation, climatic features and the weathering characteristics of the sulfide bearing rock will determine the size and extent of this anomaly.

Parameters Affecting the Radar and Microwave System

In the microwave portion of the spectra many of the parameters affecting the signal are similar to those in the infrared. The major difference between infrared and microwave is the depth of penetration of the radiant energy. The penetration power is controlled by the dielectric properties of the material. In particulate matter, three variables must be considered - the dielectric constant of the solid matter, the contained water, and the porosity. In areas of high moisture content even the pH of the moisture can affect the conductivity - resistivity balance. In solid rock, dielectric constant measurements can be made directly on small samples.

The emissivity at microwave frequencies is lower than that of the infrared. This makes the reflectance of considerable importance in the signal received at the instrument. Slope, surface geometry, and the temperature of the sky, contribute a larger portion of the radiant energy received.

All subsurface features such as layered bedding, depth of water table, and subsurface temperature directly affect the emitted radiation. Plate 11 shows the diurnal heating and cooling curve of soil at depth. Note that lag in heating produced by poor thermal conduction. Subsurface temperature measurements are necessary in data interpretation in materials which cannot be easily removed for laboratory analysis of their dielectric properties.

Equipment List

A list of measurements and the equipment used by the University of Nevada are indicated on Plates 12 and 13. While not meant to contain all the minor supporting gear, these Plates indicate some of the major equipment and the measurements made by these instruments.

There should be a standardization in the aircraft overflight monitoring gear, to make possible the comparison of data from different test sites.

Recommendations for the Future

Aircraft Program

Recommendations for the aircraft program have arisen over a period of two and one-half years and represent a synthesis of discussion with many people who have varying degrees of familiarity with the program.

1. Ground Based Sensors - For spectra longer than the visual region, much more surface work with sensors on the ground should be accomplished in IR, both imaging and spectral, in microwave, and in scatterometry. In a multispectral approach these sensors might be tied together with a field van, although several independent vans would be superior in that they would offer greater flexibility and the van would not be useless to the other sensors if one sensor were inoperable. There is an intense need for field work basic to the understanding of ground truth which can be best accomplished with this technique.

2. Telemetering - MSC should be entering telemetering procedures as rapidly as possible in the aircraft segment of the Earth Resources Survey Program. Experience prior to spacecraft flights is required. Data can be telemetered upward to aircraft or spacecraft, downward to field vans, or directly to MSC data bank. RECOMMENDED: A conference to decide how telemetering is to be accomplished and when it can commence.

3. Automated Data Processing - MSC needs to move toward any system likely to lead to automated data processing. Each possibility needs to be explored and evaluated with the idea of determining which is best suited for the Earth Resources Survey Program. The optimum would appear to be a single system which would handle data from all parts of the spectrum. Automation must start immediately with the Aircraft Program; to wait for the spacecraft is to invite disaster.

4. Sensor Integration - New sensors have special problems of their own; they require severe time frames and intensive usage until they become calibrated and useful for their feasibility studies. RECOMMENDED: Acquisition of a light aircraft for getting the bugs out of new prototype sensors. The larger multisensor aircraft should not be tied up with this type of activity, and should carry only those sensors which have proven themselves in the air on an isolated basis.

5. Additional Sensors - Additional sensors should be sought for consideration. Most likely sorts of things to be desired: additional wavelengths, especially longer wavelengths in infrared and microwave than currently being studied. This approach would also give better multispectral capability.

6. Ground Truth Squads - Full consideration should be given to the establishment of ground truth collection teams within MSC or via contractors. These teams would function to collect data on operational missions, collecting according to specific instructions for each site as established by the research teams. Thus, there would be research teams for geology, oceanography, agriculture, etc., operating at the scientific level, including planning of missions and continued research in improved techniques. Ground truth squads would be primarily technicians with the capability of collecting ground truth data for every discipline. This type of activity will become much more important in the future when the larger aircraft operate outside the country and when spacecraft fly.

7. Communications - There needs to be a greater number of meetings of the various components of the Earth Resources Survey Program for the full exchange of ideas and progress among the various contractors and grantees. Prior to 1966, meetings of this type were relatively rare and the majority of workers in the program did not have a clear view of the overall program. The commencement of aircraft scheduling meetings in Houston in the fall of 1966 afforded the representatives of the instrument and discipline groups the opportunity to gather every three months for informal discussions and markedly aided communications. RECOMMENDED: This type of program be continued.

8. Boresight Camera for MR 62-64 Radiometers - A boresight camera depicting the field of view for the MR 62-64 microwave radiometers is required for the interpretation of microwave data. These sensors are tied to the tracking devices of the present photographic systems indirectly. Locating the field of view of the existing microwave data is cumbersome at best, and impossible at worst. The microwave radiometers are hard mounted and the camera systems are flexmounted. The cameras look at the nadir, the radiometers look a minimum of 10° from the nadir, and as high as 45°.

9. Fast Film for Night Missions - We recommend experimentation with films of 3,000 and 6,000 ASA for night missions at 2,000' absolute to see if visual data can be gathered to permit interpretation of the non-imaging data such as microwave radiometers and scatterometry.

10. AAP-1A Test Sites - Test sites for instrument calibration for AAP-1A should be defined as early as possible and should be overflown with the aircraft in the near future for preliminary studies.

11. The time is approaching when ground truth determinations should be standardized as to equipment and technique. We are not at this point today, but it is on the horizon. Ground truth squads (#6 above) will, of course, bring increased emphasis on this requirement.

Spacecraft Program 14-Day Mission at 125n.m. 50° Inclination

Recommendations made in this section are the result of inquiries commenced by Frank Casey in October 1966 and represent an evolutionary continuum of thought since that time, rather than ideas generated in the past two weeks.

1. Well-known Test Sites - For geology we believe that the test sites should have adequate conventional geology available, so that the field teams need only perform the specialized studies required for ground truth calibration work.

2. Ground Truth Research Teams - A two to three man ground truth research team will be needed on the ground for 90-100 days, any time in advance of the overflight. Their role will be to plan the operational aspects of the ground truth data collection and to obtain advanced field data for research purposes. This group would subsequently write and make available to the operational ground truth squad a manual of operations.

3. Ground Truth Operational Squads - A squad of 15-20 men, suitably equipped, will be needed for each geologic test site. Their time in the area should be approximately two weeks, during which time they establish themselves, support an aircraft overflight in preparation for the spacecraft overflight and finally support the spacecraft overflight. Their work will be laid out in prepared manuals which will become available prior to their departure from MSC or other base.

4. Simultaneous Aircraft Overflights - In conjunction with the spacecraft flights there need to be aircraft operations to permit the build-up of remotely sensed data in three dimensions: on the ground, at aircraft altitudes, and at space altitudes. Simultaneous aircraft overflights are of prime importance in the early spacecraft missions to provide a standard of comparison of data, so that the quality of the space sensors can be more accurately gauged. Ideally, identical sensors would be on the aircraft and spacecraft.

5. Eight to Ten Test Sites - Eight to ten test sites should be sufficient to calibrate the sensors for a variety of geological features. The majority should be in the United States for reasons of economy and efficiency, but a few will need to be outside the country to meet conditions which are not found within the United States. The test sites recommended here have been under consideration for more than a year, and appear to offer a most meaningful experiment calibration system. They are numbered in random order and no priority is intended by any of the numbers.

5.1 McDonald Range, Alice Springs, Australia. This is the locale of a great sequence of sedimentary rock very simply arranged. Detailed geologic reports are available and the area is ideal for the minimal soil and vegetation encountered.

Also the weather is exceptionally favorable, with clouds a rarity.

5.2 Volcanos, Hawaii. The volcano complex on the island of Hawaii, especially the Mona Loa-Kilauea complex is of especial interest. The United States Volcanologic Observatory has an extensive background of data, and could cooperate with the ground truth teams and squads. This represents an outstanding opportunity to see what can be accomplished by remote sensors in the area of volcanologic study.

5.3 Southern California. This very large test site, extending across the southern margin of California, includes a variety of diverse geologic and other features. It is in an area of low cloud cover which makes it a high interest site for all sensors. Included within this test site are: (a) Metropolitan San Diego (geography), (b) intrusive igneous rock complexes (geology), (c) desert terrain (geology and geography), (d) Salton Sea (hydrology), (e) Imperial Valley (agriculture), (f) Extrusive and sedimentary rocks (geology), (g) the Colorado River on the eastern boundary for sensor blackbody calibration. The Pacific Ocean off the coast is also of interest to oceanographers and serves for blackbody calibration.

5.4 Sumatran-Javanese Volcanoes. On Gemini photography all of Java and most of Sumatra are obscured by clouds. These island chains have a vertebrae of volcanoes, many of which are classified as "dangerous" to the dense population. This would make an exceedingly fine site for volcano study by the cloud penetrating sensors; microwave and radar. Good ground support is available locally.

5.5 Yellowstone National Park. The U.S. Geological Survey has had a program of research going in this locality for many years and has built up an impressive number of man-months of field and laboratory research effort. This body of data deserves to be augmented by spacecraft data. Clouds and the biosphere are likely to be deleterious to a few of the sensors.

5.6 Pinacati Hill, Mexico. This circular, well-known feature immediately south of the American border is of geologic interest as an extensive lava field. It is readily located by its proximity to the Gulf of California, and showed up well on Gemini photography.

5.7 Sheep Mountain, Wyoming. A sequence of folded sedimentary rocks in simple pattern, this breached anticline serves as an excellent structural target with a wide variety of sedimentary rocks which are well exposed. Much of the basic geologic work is already complete for this target providing an excellent base to apply remote sensed techniques.

5.8 Quadrilatero Ferrifero, Brazil. This is an area of important metallic ores and would serve to provide an area of study where vegetation is not dense and where rock exposures are good. A huge background in conventional geology is available for this test site.

5.9 Continental Margins. Continental margins should be scrutinized always for possible water resources entering the sea, usually visible by temperature contrasts and should appear on infrared and microwave radiometry data.

In closing, a table of events is postulated for geologic ground truth, showing the sequence of events anticipated and the probable amount of time required for each event (Figure 19).

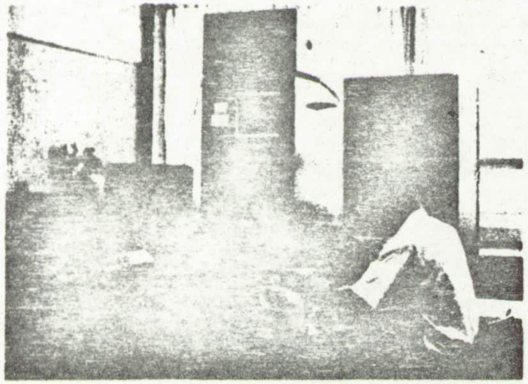
Spacecraft Program - One Year Mission at 270-300 n.m. 50° Inclination

A one year mission might very well be run in four two-week segments to take advantage of the seasonal changes for the non-geologic disciplines. For the geologic test sites, we recommend that the basic two-week ground truth regimen of the previous section be followed.

We cannot help but wonder what level of resolution NASA anticipates receiving at this altitude with the present generation of sensors. We ask also if it might be possible to schedule a remote sensing operation during the decay phase of the mission when the spacecraft would be orbiting at 125-150 n.m.?

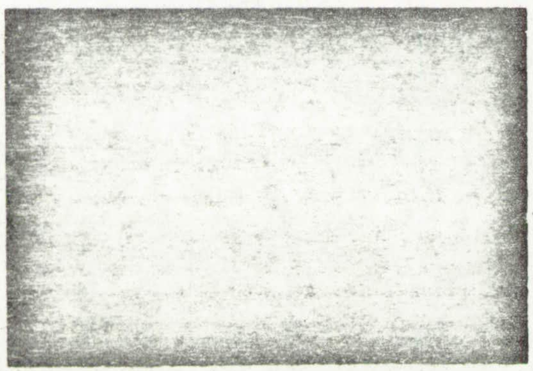
NASA S-67-7743

SIEMENS UNIVERSAL X-RAY SPECTROMETER

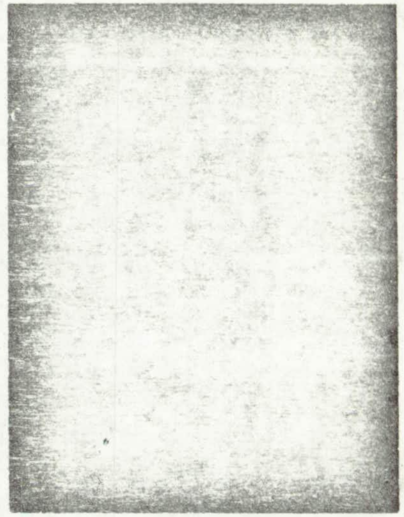


NASA S-67-7744

MICROWAVE BEACON



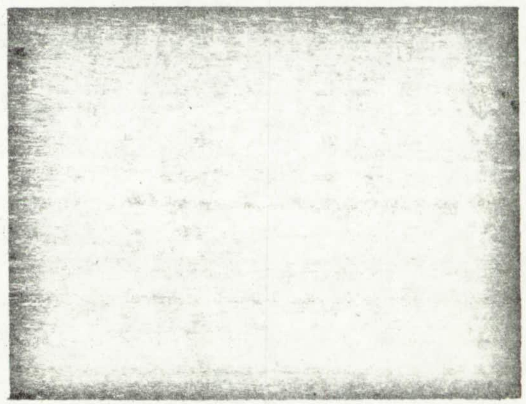
NASA S-67-7747



LAUNCHING A
RADIOSONDE
BALLOON

NASA S-67-7746

BARNES INFRARED
RADIATION THERMOMETER



NASA-S-67-7718

GEOLOGIC GROUND TRUTH

LABORATORY CAPABILITIES

- TEST SITE SELECTION
- ROCK ANALYSIS
  - CHEMICAL
  - MINERALOGICAL
  - PARTICLE SIZE
- MOISTURE ANALYSIS
- SOIL ANALYSIS
- EMISSIVITY ANALYSIS
- SURFACE ROUGHNESS (MICROTEXTURE)
- DENSITY - SPECIFIC GRAVITY
- DRAFTING
- PHOTOGRAMMETRY
- DOCUMENTATION
- ELECTRONICS SHOP
- METEOROLOGIC ANALYSIS

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NASA-S-67-7714

DEFINITION OF GROUND TRUTH

- GROUND TRUTH
  - MEASUREMENTS TAKEN BEFORE, AFTER AND DURING AN OVERFLIGHT THAT CAN BE USED TO QUANTITATIVELY DESCRIBE THE VARIOUS PARAMETERS CONTRIBUTING TO THE TOTAL SIGNAL OF A REMOTE SENSING INSTRUMENT

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NASA-S-67-7709

GEOLOGIC GROUND TRUTH (CONT)

FIELD CAPABILITIES

- GEOLOGIC MAPPING
- SURFACE ROUGHNESS DATA
- ROCK AND SOIL MOISTURE DATA
- SOILS MAPPING
- EMISSIVITY DATA
- METEOROLOGIC DATA (PROFILE GROUND TO SENSOR HEIGHT)
- THERMAL DATA (8 - 14 μ)
- THERMAL DIFFUSIVITY
- VEHICULAR AND TRANSPORTATION
- COMMUNICATIONS
  - INTRAPARTY
  - GROUND TO A/C
  - TRUTH SITE TO UNIVERSITY
- MICROWAVE AND RADAR BEACONS
- FLIGHT LINE MARKERS
- BOTANIC DATA (MICRO TO MEGA SIZE)

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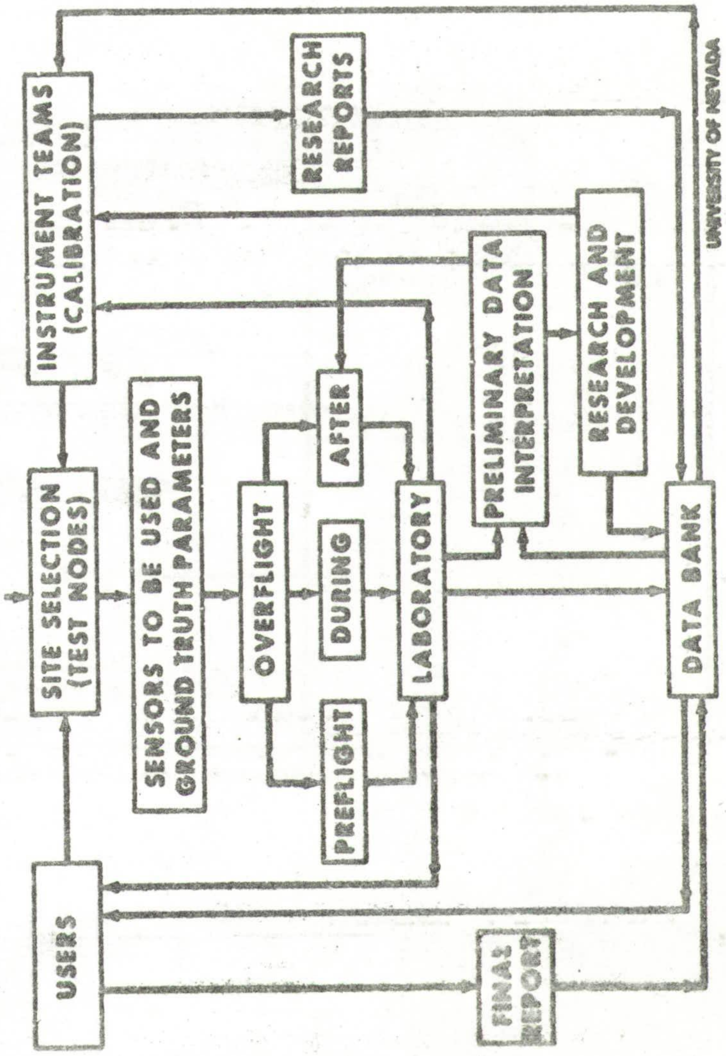
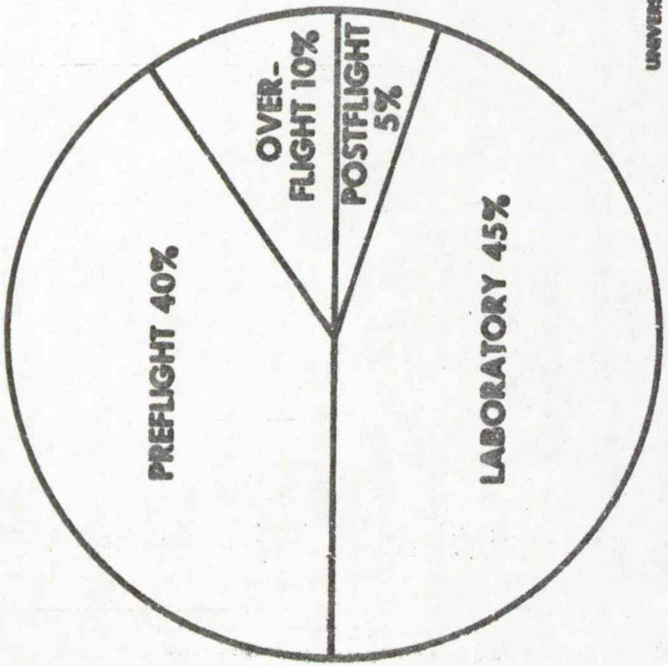
NASA-S-67-7721

GROUND OPERATIONS



NASA-S-67-7707

MANHOURS EXPERIENCED ON GEOLOGIC SITES



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TEST SITES SUPPORTED

	SITE NO.	PRE-FLIGHT	OVER-FLIGHT	LAB	SPECIAL STUDIES	INSTRUMENTATION PRIME	SECONDARY
SONORA PASS	19	XXX	XX	XX	XX	RSC IV, MR 62 & 64 IR SPEC	RC 8
ARIZONA SED	31	XX	XXX	XX	XX	RSC IV, MR 62 & 64, SCATTER	RC 8 AAS-5
MT LASSEN	36	X	X	X	X	RSC IV, MR 62 & 64	RC 8 T-11
BUCKS LAKE	20	X		X	X	RSC IV, MULTIBAND	RC 8
MONO CRATERS	3	X	XXX	XX	X	RSC IV, IR SPEC	RC 8 AAS-5
PISGAH	2		XX	X	X	RSC IV, SCATTER	RC 8
PADRE ISLAND	-	X		X	X	IR SPEC	
MISSISSIPPI DELTA	120		X			RSC IV, MR 62 & 64	
MONO (STANFORD)	3	XX	XX	XX	XX	IR IMAGER BENDIX, MULTIBAND	
STANFORD LINE	-		X	X	X	IR IMAGER BENDIX, MULTIBAND	
TOTAL		11	13	13	12		

MICROWAVE VAN SUPPORT (JPL) CALIBRATION STUDIES

	FIELD	LABORATORY
PIXLEY	X	X
DEATH VALLEY	X	X
BRAWLEY DUNES	X	X

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NASA-S-67-7708

REPORTS
TECHNICAL REPORTS

- GEOLOGY OF SONORA PASS-EMIGRANT BASIN, TEST SITE NO. 19
- GEOLOGIC MAP OF SONORA PASS
- GEOLOGY OF THE ARIZONA SEDIMENTARY TEST SITE NO. 31 AND GEOLOGIC MAP
- CENOZOIC VOLCANISM OF THE CENTRAL SIERRA NEVADA
- GEOLOGY OF THE BUCKS LAKE TEST SITE NO. 120 AND GEOLOGIC MAP
  - RADAR EVALUATION OF NASA SEDIMENTARY TEST SITE
  - CO-AUTHORSHIP WITH CRES

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NASA-S-67-7709

REPORTS (CONT)
TECHNICAL LETTERS

- SUPPORTING MEASUREMENTS OF PASSIVE MICROWAVE RADIOMETER DATA
- VARIATIONS OF EMISSIVITY IN THE INFRARED RANGE (8 TO 14μ)
- CONFIDENCE OF GROUND MEASUREMENTS FOR THE INSTRUMENT AND GEOLOGIC TEAMS
- SOIL STUDY OF SONORA PASS TEST SITE
- SURFACE ROUGHNESS 1/10 TO 100 mm
- GROUND MONITORING OF OVERFLIGHTS MISSIONS NO. 28, NO. 36, NO. 46
- SONORA PASS STANDARDS
- PRELIMINARY GROUND TRUTH REPORT OF THE MT LASSEN TEST SITE NO. 36
- GROUND TRUTH PARAMETERS FOR PADRE ISLAND, TEXAS
- GROUND TRUTH DATA MISSIONS NO. 50 AND NO. 56
  - SITE NO. 36 MT LASSEN, SITE NO. 19 SONORA PASS
  - SITE NO. 3 MONO CRATERS

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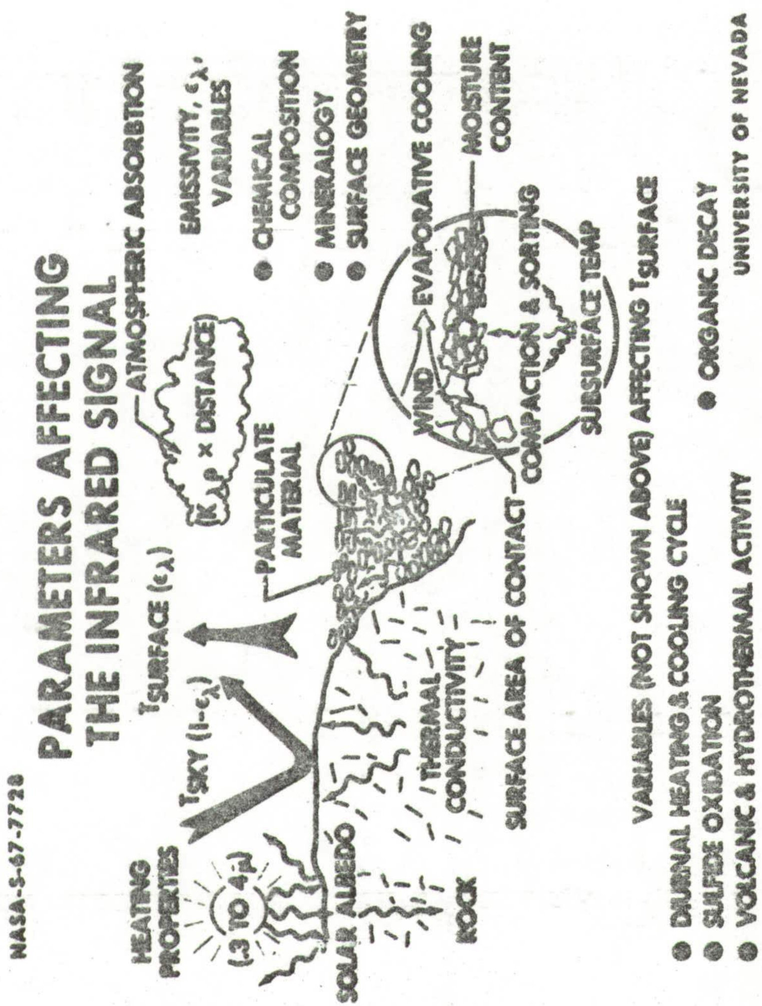

INFRARED SYSTEMS

PARAMETERS EFFECTING TOTAL SIGNAL	ENVIRONMENTAL VARIABLES
THERMAL DIFFUSIVITY	• MOISTURE CONTENT • GRAIN SIZE AND SHAPE • SUBSURFACE TEMPERATURE • 'THERMAL CONDUCTIVITY' • COMPOSITION • BULK DENSITY
EMISSIVITY, E_λ	• SURFACE GEOMETRY • MINERAL CONTENT*
SOLAR ALBEDO	• COLOR AND SURFACE GEOMETRY • DIURNAL HEATING CYCLE
METEOROLOGY	• AIR TEMPERATURE • SKY TEMPERATURE • WIND • AIR WATER CONTENT*
BIOSPHERE	• VEGETATION TYPE AND DISTRIBUTION • VEGETATION VIGOR • ORGANIC DECAY
ANOMALOUS FACTORS	• VOLCANIC & HYDROTHERMAL ACTIVITIES • SULFIDE OXIDATION

*VERY IMPORTANT IN INFRARED SPECTROMETRY

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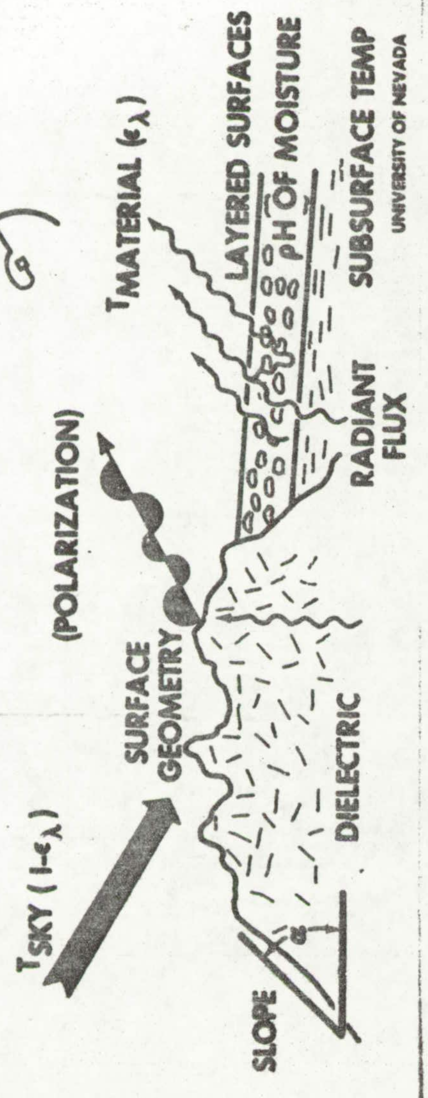
NASA-S-67-7736

PARAMETERS AFFECTING MICROWAVE SIGNAL

(NOT INCLUDING THOSE SHOWN ON INFRARED ILLUSTRATION)

$$T_R = T_{MATERIAL}(\epsilon_\lambda) + T_{SKY}(1-\epsilon_\lambda)$$



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NASA-S-68-448

RADAR AND MICROWAVE SYSTEMS

PARAMETERS AFFECTING [illegible]	ENVIRONMENTAL VARIABLES
EMISSIVITY, ϵ_λ	• COMPOSITION • CHEMICAL • MINERALOGICAL • SURFACE GEOMETRY
CONDUCTION AND RESISTIVITY	• DIELECTRIC CONSTANT • CONTAIN MOISTURE • pH OF ELECTROLYTE • BULK DENSITY • POROSITY
SCATTERING AND POLARIZATION EFFECTS	• SURFACE ROUGHNESS • LINEATIONS AND BEDDING
METEOROLOGY	• AIR MOISTURE • SKY TEMPERATURE* • WIND*
BIOSPHERE	• VEGETATION TYPE AND DISTRIBUTION • VEGETATION VIGOR
SLOPE	• SLOPE ANGLE AND TOPOGRAPHY
TEMPERATURE	• SURFACE AND SUBSURFACE TEMPERATURE

* IMPORTANT MOSTLY IN PASSIVE SYSTEMS

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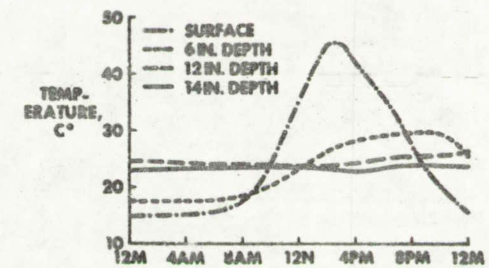
NASA-S-67-7728

DIURNAL HEATING-COOLING CURVE FOR BASALT CINDER



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MEASUREMENTS MADE AND EQUIPMENT USED

MEASUREMENT	EQUIPMENT
THERMAL RADIATION (8-14μ)	• BARNES RADIOMETERS
BULK DENSITY & BULK MOISTURE	• GAMMA-GAMMA, NEUTRON PROBE
TOPOGRAPHIC	• PAULIN ALTIMETERS STEREO PHOTO-EQUIPMENT • MICROBARAGRAPH
SUBSURFACE TEMP	• DIGITECS & THERMISTOR PROBES
CHEMICAL COMPOSITION	• SIEMENS X-RAY SPECTROMETER-INTERFACED TO PDP-8 COMPUTER
MINERALOGY	• NORELCO X-RAY DIFRACTION UNIT • RESEARCH MICROSCOPE • (MODAL ANALYSIS EQUIPMENT)
SOIL SAMPLING & ANALYSIS	• MOISTURE TINS • SIEVE ANALYSIS EQUIPMENT • MOISTURE BALANCE
SURFACE ROUGHNESS	• [illegible] (SEE TEC LETTER NO. 3)
EMISSIVITY (8-14μ)	• EMISSIVITY CHAMBER
THERMAL DIFFUSIVITY	• THERMAL DIFFUSION TEST SET
ATMOSPHERIC	• COMPLETE WEATHER STATION INCLUDING RADIOSONDE EQUIP

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NASA-S-67-7708

SUPPORTING EQUIPMENT

- FIELD
  - AIR TO GROUND RADIOS
  - GROUND TO GROUND WALKIE-TALKIES
  - LONG RANGE SHORTWAVE RADIO (900 MILES +)
  - FOUR WHEEL DRIVES
  - TOTE-GOTES
  - FIELD EQUIPMENT-CAMPING GEAR, ETC
  - SIXTY CYCLE GENERATORS AND INVERTER BATTERY PACKS
- LAB
  - DRAFTING SUPPLIES
  - KAIL PLOTTER AND MAP PREPARATION EQUIPMENT
  - PHOTOGRAPHIC LAB

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NASA-S-67-7712

RECOMMENDATIONS

AIRCRAFT PROGRAM

- GROUND BASED SENSORS (VAN)
- TELEMETERING EQUIPMENT FOR DATA GATHERING
- PRIORITIZATION A/C OPERATIONAL TIME
- USE OF 3000, 6000 ASA FILM, NIGHT MISSIONS
- DEVELOPMENT OPERATIONAL GROUND TRUTH TEAMS (AS DISTINCT FROM RESEARCH)
- AUTOMATED PROCESSING OF DATA
- ADDITIONAL SENSORS - ADDITIONAL WAVELENGTHS
- PERIODIC MEETINGS - INSTRUMENT, USER TEAMS
- BORESIGHT CAMERA FOR MICROWAVE RADIOMETERS

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NASA-S-67-7713

GEOLOGY GROUND TRUTH TEST SITES

SPACECRAFT AT 125 N MI - 14 DAY MISSION 50° INCLINATION

- APPROXIMATELY 10 TEST SITES REQUIRED
- 90 - 120 DAYS FIELD-WORK
- TWO MAN PARTY PRIOR TO OVERFLIGHT. PRELIMINARY DATA GATHERING AND PLANNING
- 10 - 20 MAN TEAM DURING OVERFLIGHT
- AIRCRAFT OVERFLIGHTS PENESIMULTANEOUSLY

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GEOLOGY GROUND TRUTH TEST SITES

50° INCLINATION SPACECRAFT AT 125 N MI 14 DAY MISSION

TEST SITE	FEATURE TO BE CALIBRATED	PRIME SENSORS
• MC DONALD RANGE ALICE SPRINGS, AUSTRALIA	SEDIMENTARY ROCK PATTERNS AND IDENTIFICATION	ALL I R SYSTEMS
• KILAUEA, HAWAII	VOLCANOLOGIC	ALL RADIOMETERS
• SOUTHERN CALIFORNIA	INTRUSIVE & EXTRUSIVE ROCKS SALTON SEA HYDROLOGY SAN ANDREAS FAULT SYS	ALL SYSTEMS
• JAVA-SUMATRA	VOLCANOLOGIC CLOUD COVER	MICROWAVE & RADAR
• YELLOWSTONE NAT'L PARK	THERMAL ACTIVITY	ALL I R SYSTEMS
• PINACATE HILLS, MEXICO	EXTRUSIVE ROCKS	ALL SYSTEMS
• SHEEP MT, WYOMING	FOLDED SEDIMENTARY ROCKS	ALL SYSTEMS
• BRAZIL, QUADRILATERO FERRIFERO	ECONOMIC GEOLOGY	ALL SYSTEMS

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NASA-S-67-7711

CALIBRATION SITE ACTIVITIES

MONTHS	EVENTS
-5	LOGISTICS AND PLANNING
-4	ON-SITE RESEARCH AND PLANNING
-3	
-2	OPERATIONS MANUAL TO MSC ON-SITE RESEARCH CONTINUES
-1	
-1/2	OPERATIONS TEAM TO TEST SITE
-1/4	AIRCRAFT OVERFLIGHT
0	ORBITAL FLIGHT AND AIRCRAFT RUN
+1	DATA AVAILABLE FOR PROCESSING QUICK LOOK REPORT
+2	DATA REDUCTION AND ANALYSIS
+12	REPORTS ISSUED

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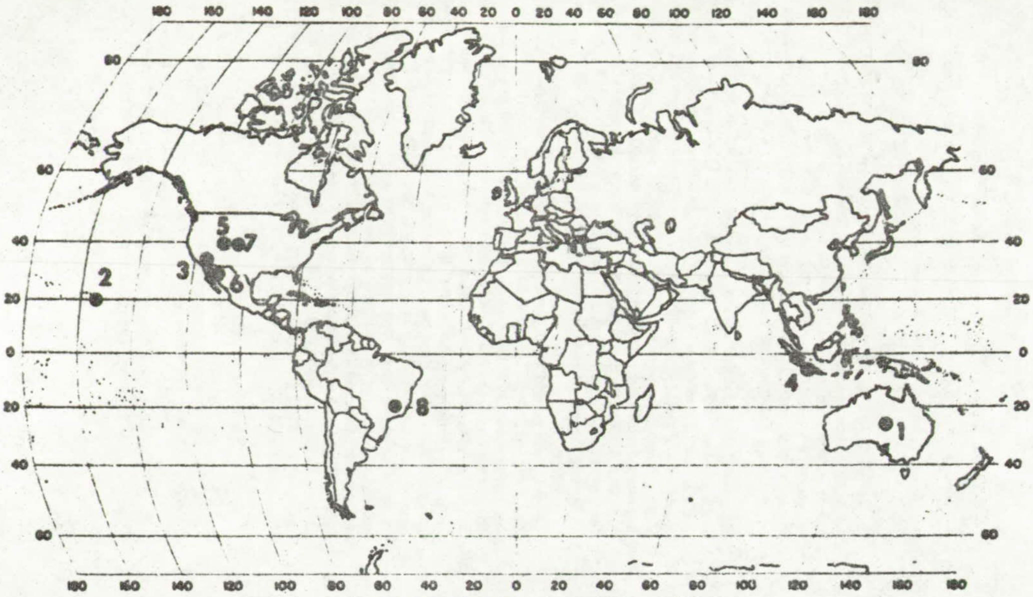
NASA-S-67-7737

GEOLOGY GROUND TRUTH TEST SITES
SPACECRAFT AT 125 N MI - 14 DAY MISSION 50° INCLINATION



INTERNATIONAL TEST SITES

EQUATORIAL SCALE

5000 0 5000

MILES

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NASA-S-67-7738

GEOLOGY GROUND TRUTH TEST SITES
SPACECRAFT AT 125 N MI - 14 DAY MISSION 50° INCLINATION

DOMESTIC TEST SITES

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Presentation by Jules Friedman, USGS

(Text not available for printing

in final document)

Ground Truth Measurements to Support Radar Studies

Dr. D. S. Simonett

University of Kansas

Introduction

The atmosphere is not a pressing problem in the collection of radar data as it is with other sensors. Air temperature is unimportant, so are ground temperatures except when dealing with frozen ground, snow and ice, for which object temperature measurements need to be obtained. Atmospheric particles (dust, water vapor, etc.) including clouds have virtually no effect, nor is the level of natural background radiation of significance.

However, with X-band radar (wavelengths of about 3 cm) light to moderate rainfall of the order of .2 cm per hour will produce attenuation in the range 1 to 3 db which is of the order of the inherent uncertainty even in fully calibrated systems. Finally, interference from ground and airborne radars and some UHF and VHF systems may occur. Thus, with the exception of chance occurrences of interference and for the relatively rare occasions when rainfall rates exceed approximately 3 db attenuation, ground truth observations regarding the weather may be confined to brief visual reports of conditions. Data on attenuation by rainfall may be obtained from Moore and Simonett (1967).

In evaluating multifrequency, polypolarized radar it is essential that both carefully-controlled ground sites and extended sites be available. Detailed measurements have been made by Cosgriff, Peake and Taylor (1960) and Peake, Riegler, and Schultz (1966) using truck-mounted radar equipment. These and similar studies by Lundien (1965) and others at the U.S. Waterways Experiment Station, Vicksburg, Mississippi, are among the most carefully controlled studies concerning radar return from crops and other materials. However, these measurements are essentially microscale, the illuminated area being only about a foot square. Hence they are not necessarily representative of data obtained from aircraft or orbital radars of very different resolutions. Present studies at selected test sites attempt to achieve comparable results, but on a macro or aircraft scale, by considering the nature of the radar return in relatively large areas as obtained with aircraft radars. As an example, the ground truth data collected at Garden City, Kansas (NASA-MSC Test Site No. 76) may briefly be described through the factors which most influence the radar returns:

1. Surface roughness to the order of 1/10 of the radar wavelength
2. Geometry of the surface of the objects illuminated
3. Dielectric properties, including conductivity, permitivity, and resistivity of the illuminated surface
4. Polarization characteristics of the surface
5. Radar incidence angle on the surface being illuminated (for this factor, it is very important to acquire boresighted oblique and/or vertical

aerial photograph concurrently with the radar data)

Surfaces with a roughness less than 1/10 of the radar wavelength generally appear smooth (dark areas on positive imagery) to that wavelength. However, such surfaces are relatively rare for most radar frequencies, being represented only by placid water or smooth highways. In an area of gentle slopes (as at the agricultural test site at Garden City), we may anticipate that the soil surface and plant geometry will contribute substantially to differences in radar return.

Other factors affecting radar return, such as surface penetration and radar polarization are not yet fully understood and are contributing factors not easily identified. Relatively little soil-surface penetration is achieved with high frequency radar such as K-band radar.

Variation in the electrical properties of imaged objects such as dielectric constant, conductivity, etc., will also affect the return signal strength. Although a smooth water surface tends to act as a specular reflector, returning little energy to the antenna, rougher land areas which are moist (such as soils which have been recently wetted by irrigation) may provide a stronger return than adjacent dry soils if all other things are unchanged. This stronger return is theoretically attributable to differences in dielectric properties, arising from the moisture in the soil. However, all other things are not unchanged, and the smoothing of the surface which accompanies irrigation may actually lower the radar return. Consequently ground condition should also be monitored.

Radar signal incidence angle and look-direction are other variables influencing radar return. More experiments are needed to accurately describe their influence.

<u>Ground Truth Measurements to Support Radar/Agriculture Studies</u> - Measurements on a large scale of micro-roughness, crop geometry, and dielectric constant in agricultural crops are infeasible in our present state of understanding. It is necessary, therefore, to select measures which are both related to or are partial surrogates for the actual parameters which influence the radar return and would be relatively simple to obtain in the field at the time of a radar overflight. For example:

1. Crop type, height, moisture content, and stage of growth.
2. Moisture content of the soil at several depths.
3. Method of land preparations, including cloddiness, row directions, etc.
4. Percent of ground covered by vegetation, measured at the radar incidence angle.

The relative importance of each of the selected parameters may then be statistically determined through an analysis of co-variance.

To simplify the analysis of the effect of only these selected variables on radar return signal strength, it has been desirable to reduce certain unnecessarily complicating factors for the early studies. This has been accomplished by selection of a test site which minimized soil type differences and effects of slope, and maximizes the range of other variables. Such is the case of the agricultural test site at Garden City, Kansas. In this area there are over 400 fields for which data are collected at the time of radar overflights. The area was chosen because fields are generally large, slopes are extremely gentle, soils are uniform, both dryland and irrigated cropping is practiced, and there is some diversity of crop types, agricultural techniques, and moisture conditions.

Other sites chosen by the University of Kansas to provide additional environmental data include (all data collected by CRES personnel):

1. Horsefly Mountain, Oregon (NASA-MSC Test Site No. 159) - This test site chosen in order to examine forestry and natural vegetation conditions. Landform (geomorphic) analysis also important.

2. Lawrence, Kansas (NASA-MSC Test Site No. 85) - Chosen because of its proximity to the University of Kansas. This site includes examination of urban and rural settlement patterns, agricultural, and broadleaf woodland conditions. A geology subsite is located near Lawrence. The geology subsite has been mapped in detail by the Kansas Geological Survey both for the geology and for various environmental factors (soils, vegetation, land-use, etc.)

3. Wichita, Kansas Soil Strip (NASA-MSC Test Site No. 35) - Chosen because it is an area of diverse soil types and is covered with a number of recent soil surveys.

Ground truth of these sites consists simply of documenting the cultural and natural land-use patterns. In some cases radar corner reflectors would be valuable as markers to establish key locations, and in uniquely flat areas or recently ploughed fields stereo ground photographs or microrelief profiles may be obtained (the latter with a simple profile sampler).

Ground truth currently collected at Garden City, Kansas (NASA-MSC Test Site No. 76) by CRES personnel:

1. Maps of field boundaries have been made from ASCS 1:20,000 scale aerial photos. These field maps have been checked in the field and modified to fit current conditions.

2. All field data is plotted on the field maps.

a. All field data is collected on either side of three N-S county roads located one mile apart. The length of each of the three test strips is 16 miles. An additional flight line is located diagonal to the N-S roads. A short flight line located over the main runway of the Garden City, Kansas Municipal Airport provides calibration data for the scatterometer.

b. Crop type is recorded; its height measured and noted. The height recorded is an average of at least three independent measurements recorded at least 60 feet from the adjacent roadway.

c. Percent ground covered by vegetation is estimated and noted. Visual estimation of percent ground coverage is based on previous studies which involved taking 35mm ground photography of crops in each field during several NASA sponsored side-looking radar (SLR) missions. During these missions, ground photographs were taken of the crop in each field with the camera elevated about twelve feet and aimed at the same angle as the mean incident radar beam. A grid was then placed over the resultant enlarged photography and percent of ground covered was calculated. After a large file of photographs representing small incremental steps in percent cover of various crops was obtained, the photographs were taken into the field during later missions and estimates accurate to a few percent could readily be made.

d. Average crop moisture percent is calculated for the crop in each field. The procedure for obtaining this information is as follows:

(1) Sorghum: Ten or more leaves randomly selected from several plants are taken, along with a sorghum head and portion of a stalk. All samples are placed in a single plastic bag and sealed, and the sample location noted.

(2) Corn: The sampling procedure is similar to that of sorghum - ears and tassels are sampled if the crop is at that stage of growth.

(3) Sugar Beets: This plant is essentially leaf and root. Samples of ten or more leaves in the early stages of growth, and five or six at maturity are randomly taken and included as one sample for that field. The samples are sealed in a plastic bag.

(4) Wheat, Sudangrass and Alfalfa: Approximately ten random cuttings of these are taken. If wheat and Sudangrass are headed, several heads are included with the stalks. All are sealed in a plastic bag.

(5) Pasture, stubble, or weeds: Representative samples of the vegetative cover was taken for each field and included as a single sample of that field.

e. All samples are collected at least 60 feet into the field to eliminate extraneous effects on the field margins or near the road. If fields of crops are at least 33% weedy, representative samples of the weeds

are collected and included in the crop sample. The percent of moisture in each sample is calculated at the Kansas State University Agricultural Experiment Station at Garden City by oven-drying the samples and using the following formula to obtain a percentage:

$$\frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100 = M\%$$

f. Soil samples are taken of nearly all bare fields and in most fields under the crops. Standard soil sampling cans are filled, not packed, with soil taken at the surface (0 to 3 1/2 inches). To date, only the higher frequency radar systems have successfully acquired data at Garden City and relatively little soil-surface penetration is achieved, hence, moisture data has been limited to the range 0 in. to about 3 1/2 inches. However, when longer wavelength systems successfully acquire data at Garden City, it is anticipated that soil moisture data will be acquired at three-inch increments up to 12 1/2 inches.

Oven dry weight was determined by placing the soil samples in an oven at a temperature of 105°C until they lost no more water. A volumetric technique is used to establish a measure of soil moisture, since a value obtained from percent by weight varies as the bulk density of the soil varies. The volume of the cans used are 475 cc, and the formula for computing the volumetric measures of percent moisture is:

$$\frac{\text{wet weight} - \text{dry weight}}{475\ \text{cc}} \times 100 = MV\%$$

g. Additional field data are noted such as:

(1) Stage of crop growth (maturity)
(2) State of the crop (parched, diseased, weedy, well-cultivated, etc.)
(3) Irrigated or non-irrigated (with approximate irrigation date of recently-irrigated fields)
(4) Crop row direction
(5) Other significant lineations
(6) Cloddiness of the surface, estimated and photographed for establishing subsets of cloddiness.

<u>Ground Truth Measurements to Support Radar Geologic Studies</u>

<u>Topographic Characteristics - Gross Topography</u> - Existing contour maps with a 10-foot contour interval are normally adequate for this purpose. A 20-foot contour interval is barely acceptable.

<u>Surface Roughness</u> - In general, average roughness less than λ/10 (1/10 wavelength) is not significant in affecting the radar return. Roughness greater than this affects the scattering of the transmitted pulse and hence the magnitude of the return signal, depending on the degree of organization of this roughness.

The radar wavelengths which are being or will be used in our studies are given below.

		λ	$\lambda/10$	
Wright-Patterson (Avionics Aircraft)	35,000mc	8.6mm	1mm	Radar Imagers
Naval Research Laboratory	8,910mc	3.4cm	3mm	Radar Imagers
	4,450mc	6.7cm	1cm	Radar Imagers
	1,225mc	24 cm	2cm	Radar Imagers
	428mc	70 cm	7cm	Radar Imagers
NASA-MSC	16,500mc	.18cm	.01cm	
NASA-MSC	400mc	75 cm	7.5cm	Radar Scatterometer

Extremely rough surfaces, presenting many faces to the transmitted pulse within the confines of a single range resolution patch, act in some degree (weak or strong) as Lambert Law scatterers. However, to our knowledge, only dense evergreen forests act as strong Lambert Law scatterers, though gravel bajadas and aa lava at Pisgah Crater, California approach this. Most surfaces, it will be appreciated, are essentially rough surfaces for the short-wavelength systems. Even a pond lightly stirred by the breeze is rough. An absolutely still pond at dawn may be smooth enough to be a specular reflector to all frequencies normally in use.

Requirements - In areas which are totally or almost completely vegetation free, oblique and vertical ground stereo photographs should be obtained which indicate the nature of the micro-relief. Scales should be included on all photographs. In addition random microrelief profiles using a device comparable to that used by Dr. Timothy Whitten and associates or that by Dr. L. F. Dellwig of the University of Kansas should be used. The Dellwig device is designed so that microrelief at 1cm intervals may be obtained at a series of randomly designated sites on each lithology. The bases for randomization should follow standard statistical design, of the type employed by Dr. Timothy Whitten at Pisgah Crater.

The operation of the Profilometer is simple. It is loosened over the sample site. Thin metal rods drop and make contact with the ground. All are then clamped with butterfly nuts at both ends, laid flat on white paper and the ends lightly sprayed with spray paint to give a microrelief shadow. The shadow is then a permanent record of the microrelief at the given site.

Profilometers may be made also with 0.5cm centers as well as 1.0cm centers for the thin (1.5mm diameter) rods. Our present Profilometer is on 1cm centers. Our next one would be on 0.5cm centers and we recommend the closer spacing as giving a better control on microrelief.

The micro-roughness problem is exceedingly difficult to handle in the field. Our solution, of using stereo ground photographs (with scale), together with the Profilometer, falls far short of the requirements for

proper theoretical treatment of the data. It is a counsel of desperation, not the ideal. However, we cannot ask geologists to obtain measurements of microrelief accurate to 1mm on X-Y-Z coordinates over distances of meters in the field.

Ground vertical and ground oblique photographs should be taken where any vegetation occurs so that an estimate of the total percent of ground cover may be made. Oblique photographs should be taken at an angle of 45° if possible as in the photography below. Color slides or Polaroids are appropriate to accompany black and white (35mm). It is most important that a copy of the best available recent air photos accompany the geologic map when sent to other investigators.

Structural Characteristics - A geologic map with structural symbols is essential background information as are geologic cross-sections. Sub-surface contour maps as a geologist ordinarily thinks of them are unnecessary, though materials very shallowly buried (a foot or so) may be sampled by shallow augering. If isopach maps are required by other investigators we would not ignore them, for we can make use of them. More desirable would be a measured section. Since much of our interpretation will hinge on the quality of the geologic mapping it is essential that the best talent available be used for field mapping and reporting.

Weathered Layer (Overburden) Characteristics - It is appropriate to delineate the thickness and extent of an overburden and to note the composition of soil types found in an area as part of the normal routine of geologic mapping. No special effort at accurate measurements of depths, etc., need be made.

If field study coincides with the time of a radar flight, the moisture content in the surface half-inch and the layer 3 to 3 1/2 inches from the surface should be determined on a percent by VOLUME (NOT by weight) basis at least in random triplicate for each soil type. If no radar flight occurs this information may be ignored. Where information is available on the clay minerology this will be valuable but is not essential. The texture of the soil as given by percent sand, silt and clay would be desirable but is not vital. A normal soil field texture determination (e.g. silty clay loam) is adequate. The direction and angle of slope at any point sampled should be noted together with notes on superficial coverings of alien material (i.e., sand etc.).

Hydrologic Characteristics - If data is collected at the time of a radar flight the presence and depth of dry or wet snow should be noted. The temperature of the snow at the time of the study should be obtained. (Radar penetrates dry snow very well.)

Vegetation - The type, size, life-form, height, and life-stage should be noted even when vegetation is very sparse. Even our so-called lunar analogs on earth are by no means vegetation free. With high resolution some of the effects of vegetation can be filtered out, but inspection of ground photographs of Pisgah Crater, for example, shows small vegetation of sprawling habit which will be included willy-nilly with rocks with most sensors, including radar.

Lithologic Characteristics - Physical properties - Notes on the density, porosity, permeability and texture, and preferred orientation of grains, jointing, shattering, are appropriate. If the rocks are free of vegetation and the overburden is less than 6 inches thick, a full megascopic description should be made. It is assumed that a suite of rocks will be collected for later study, and that detailed laboratory study will be carried out as proven necessary.

Some of the radar systems we are studying have the property of recording polarized and cross-polarized return signals. Polarization and cross-polarization may be sensitive to anistropy in minerals, layering in rocks, slikensliding, etc., as well as being sensitive to the direction of a dielectric slab (such as trees versus a sprawling crop).

Dielectric Properties - Permittivity and conductivity both affect the radar return signal. Permittivity is dependent at least in part on transmitted wavelength and strongly influences the reflecting properties of a surface in the wavelengths we are using. Conductivity in these same frequencies affects mostly attenuation of the signal.

Permittivity and conductivity are closely related to the contained water content of rocks and their mineralogy. Published values of the dielectric for rocks indicate much overlap within the igneous and metamorphic groups and even some sedimentaries overlap the former in value.

However, as a general rule sedimentary rocks have higher conductivity than low-water igneous types, usually well outside the extreme range of the latter. It is worth noting also, that much of the variation in dielectric within a single igneous rock type probably relates substantially to slight variations in contained (including telluric) water.

In short, differences in dielectric properties are not likely to be a reasonable basis for specifically distinguishing between say, aa or pahoehoe lavas with radar. Their variations may be significant at some wavelengths.

If data is being collected at the time of a radar flight it would be appropriate for field geologists to obtain in triplicate on each lithology some conductivity measurements for the surface rock or soil, following a standard procedure. At other times judgement should be used. At Pisgah Crater, for example, to determine conductivity soon after a rain would be a waste of time.

Permittivity cannot reasonably be determined in the field and is exceedingly difficult on soils. Consequently only solid rock samples 6" x 2" x 2" should be collected and packed in plastic bags in air-tight metal boxes for laboratory dielectric measurements.

Laboratory dielectric measurements are not made as a routine service (with appropriate fee) by any individual or agency as yet.

Reflective Characteristics - Albedo - We would like information on albedo in all wavelengths available as a function of angle of incidence. This information is not a significant parameter in evaluation of the radar per se, but because we wish to build up data on the relations between albedo and radar return for experience in working with comparable lunar relations.

Ground Truth for Scatterometer/Sea State Experiments - Recently NASA-MSC Mission 60 was flown off southern Newfoundland to gather 13.3 GHz scatterometer/sea-state data. Prior to the mission, a meeting was held at MSC to establish among other things what kind of ground truth measurements are required for this kind of experiment. At the meeting it was decided that the method of wave and wind speed and direction hindcasting employed by Dr. Willard Pierson of New York University is appropriate for ground truth at a wave study site. "Hindcasting" gives estimates of wave height of the desired accuracy and repeatibility for scatterometer/sea-state experiments. However, adequate hindcasting depends on inputs from many vessels at sea.

Suggested alternatives for the inputs are:

1. Wave staff measurements such as those at Argus Island, Bermuda. The wave staff could be of the continual recording type or visual observations could be noted during the time of a mission.

2. Shipborne wave height recordings either of the continual recording variety or by a trained observer. Ship location would be preferably at end of flight line but if not feasible, somewhere along the wind fetch.

3. Airborne profiles such as that currently mounted in a Navy ASWEPS aircraft. Profiler equipped aircraft should fly side-by-side with the NASA-MSC remote sensor aircraft. Ideal situation would be to have a profiler mounted in the NASA-MSC P3 aircraft along with the 13.3 GHz and .4 GHz scatterometers. Frequency of the profiler must be different than that of the scatterometer so as not to create RFI (interference). Profilers cannot be used at the low altitudes needed to obtain the wave spectrum for high winds and seas, because of safety considerations.

The acquisition of single camera stereo photography for ground truth purposes appears to be infeasible for the following reasons:

1. Since the ocean is continually moving the maximum cycle times for stereo photography would need to be on the order of 4 seconds (i.e., it takes approximately 4 seconds for a wave to form and break so that two stereo photos taken more than 3 or 4 seconds apart would not indicate

the true geometries of the waves). For an ordinary metric mapping camera with a 6-inch lens and 60% overlap, cycle times on this order of magnitude would be most difficult to achieve unless the aircraft flew at very low altitudes (approximately 1000 feet). At this low altitude in high winds and seas the scatterometer data is degraded and severe turbulence would partially or fully exceed the stabilization limits of the camera system; hence, distortion problems. Such distortions are expensive to remove during photogrammetric processing, but the resulting processed photography is of questionable value without it. Then there would be the question of time and money involved with transforming and stereo plotting a large mass of stereo photo data, almost regardless of altitude.

Another factor should be considered in regard to stereo photo acquisition. Scatterometer/sea-state data acquisition experiments are designed to fly at the highest altitudes practical for the aircraft involved in order to average over a large enough area to encompass the full spectrum of the waves. This means aircraft altitudes, according to present MSC aircraft capabilities, in the range 12,000 - 35,000 feet. At these altitudes it is almost certain that undercast conditions would prohibit acquisition of stereo-photography. And the cycle rates are prohibitive.

Bi-static or side-lap stereo photos in which two aircraft, each carrying a single mapping camera and flying side-by-side could provide the necessary stereo photos. The ramifications of mission planning in this regard are almost without end.

In summary, there is no single simple accurate solution to obtaining ground truth for the wave spectrum of the ocean. Any decision is a compromise and the location of the site in relation to available ASWEPS and NASA aircraft, shipping lanes and so on are factors to be considered.

<u>Ground Truth for Sea or Lake Ice Studies</u> - The following data is required to support either imaging or scatterometer studies:

1. Vertical pan minus blue air photography, 60% and lap
2. Ice and snow temperature measurements at several depths (surface, 1 foot, 2 feet, etc.)
3. Ice and snow contained moisture measurements at same depths
4. Borings to determine depth of ice and snow. For scatterometer studies at least three borings should be made in each ice type studied, preferably up to 10 borings in each ice type.

<u>Ground Truth for Snow Depth Studies with Radar</u> - The following data is required to support snow depth and moisture content studies with multi-frequency multi-polarization radar scatterometer and imaging systems:

1. Vertical pan minus blue air photography, 60% end lap
2. Snow moisture content temperature, and depth measurements at depths of 0", 6", 12", 18", 24", 36", 48", 60" etc.
3. Where feasible multi-frequency transponder systems may be employed in some cases at remote sites. However, such a system is warranted only for experimental evaluation of snow depth penetration.

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Oceanographic Ground Truth Requirements

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Spacecraft Oceanography Project

U.S. Naval Oceanographic Office

This report discusses the status and requirements for oceanographic test sites involved in the Spacecraft Oceanographic Project, United States Oceanographic Office.

In consonance with the NASA Earth Resources Survey Program Plan, a series of experiments are being conducted employing various remote sensors. The current effort of the Spacecraft Oceanography Project under the NASA Program is directed toward program and instrument definition and the use of aircraft for determining sensor feasibility and instrument development and also spacecraft experiments leading to eventual operational systems in earth orbit.

The Earth Resources Survey Program is utilizing a number of test sites as a means of calibrating sensors and providing "ground truth" for assessment of airborne or spacecraft sensors. Matters pertaining to test sites are governed by the Test Site and Aircraft Committee of the Natural Resources Program.

Several test sites have been selected for oceanographic purposes. The general locations of these sites are shown in Figure 1. The selection of sites has been based on oceanographic phenomenon desired to be measured and the availability of the critical requirements needed to provide adequate ground truth data. The oceanographic test sites are categorized as: (1) calibration sites, (2) overflight sites, (3) special purpose sites.

(1) Calibration Sites - Sites with climatic/historical oceanographic data available. These sites are instrumented and manned to provide correlative environmental ground truth. They provide multi-purpose environmental sensor test facilities.

Three calibration test sites have been selected by the Naval Oceanographic Office (NAVOCEANO) for their diversity of oceanographic properties, which are considered suitable for evaluating the various airborne sensors under know surface conditions. These sites are: (a) Argus Island (Bermuda), (b) Point Barrow (Alaska), and (c) Scripps Area (Southern California). It is intended that calibration site overflights will help evaluate the aircraft remote sensors under known environmental conditions and not just to gather large amount of oceanographic data.

(2) Overflight Sites - Sites containing one or more special oceanographic features. Surface data will be obtained on an opportunity basis. Some historical/climatic data of atlas type are available.

A larger number of oceanographic overflight sites have been selected by NAVOCEANO to extend the sensor feasibility investigations to a greater variety of oceanographic conditions. Overflight sites selected to date are: (a) Goose Bay (Labrador), (b) Columbia River Mouth (Oregon), (c) Mississippi Delta Region (Louisiana), (d) Florida Straits (Florida), (e) Navy Acre (31°-32°N and 71°-72°W), (f) Gulf Stream (off Nova Scotia), (g) Grand Banks (off Newfoundland), and (h) Baffin Bay (west of Greenland). For the overflight sites, surface data acquisition is arranged with oceanographic ships-of-opportunity operating in the area and capable of being correlated with the planned aircraft or spacecraft overflight.

(3) Special Purpose Sites - Sites which contain one particular feature, usually in a remote area.

The availability of concurrent surface data is improbable over the Special Purpose Sites, and interpretative techniques are the primary means of evaluating the data. Little or no historical/climatic data is available. These sites are selected as required or determined as the opportunity arises to coordinate aircraft flights over particular dynamic oceanographic features such as various sea state conditions.

Because of the necessary requirement of relating surface parameters to remote sensor "signatures" calibration site functions will be the basic content of this report.

The surface equipment recommended for support of various areas of investigation is outlined in Table 1 for each of the Calibration Sites. Calibration Site descriptions, functions, and requirements are discussed below.

Site Descriptions

Argus Island (Bermuda) - Argus Island is a Texas tower-type structure. The tower is located approximately 22 miles southwest of Bermuda atop Plantagent Bank, which is a large sea mount to the southwest of the Bermuda Islands. This oceanographic platform has been used by the U.S. Naval Oceanographic Office since late 1961 for data collection and instrumentation development purposes.

An area around the tower has been designated as one of the fundamental test sites for testing remote sensing instruments for the purpose of determining their applicability in measuring and investigating gross oceanographic parameters from overflying aircraft. The parameters which have been and can be investigated at Argus Island are those which are directly or indirectly related to the following areas of interest:

1. Sea state
2. Surface temperature
3. Volcanic activity
4. Air-sea interaction

Because of the water depths present, deep water wave calibrations can be performed at Argus Island with comparative ease. Considerable wave height/tidal/power spectrum data has been collected at this site. The site, however, lacks for the most part, the wide variety of sea-state conditions desired for a more extensive sensor evaluation such as might be obtained over the rougher North Atlantic waters. The Argus Island site provides sea-state conditions, primarily swells, ranging from low to moderate. The site also offers suitable temperature variations for calibration as the waters pass across the shoals. The deeper colder waters, during such passage, are forced up and mix across the bank to present a cold area anomaly ideal for surface temperature calibrations. The utility of the site for investigation of volcanic activity by the remote sensor is questionable. The area has been quiescent for a long period of time and both temperature anomalies and out-gassing traces are not anticipated for future calibration overflights.

Argus Island Instrumentation

The types of equipment currently available and utilized at Argus Island for purposes of the remote sensor calibration program are outlined below.

Instrument	Parameters Measured
1. Wave staff	Waves
2. Anemometer	Wind speed and direction
3. Thermistor	Sea and air temperature
4. Tide gauge	Tides
5. Current meter	Current speed
6. Current direction sensor	Current direction
7. Eppley Pyrheliometers	Solar radiation
8. Thornthwaite net radiometer	Net total radiation
9. Data acquisition system	-
10. Hurricane recording system	-

In addition to the above principal instruments, the site can provide: (a) a gravity meter, (b) depth sounder, (c) buoy markers, and (d) dye markers. A significant addition to the listed equipments is a flux meter which can make measurements to determine the exchange of energy between the air and sea due to windfields. Coordination between ground and aircraft personnel is provided by a ground-air radio communication system at the Tower.

The following are data presently available at Argus Island:

1. Wave height measurements
2. Current measurements
3. Tidal ranges
4. Wind speed and direction
5. Sea and air temperatures
6. Solar radiation
7. Magnetic intensity

Pt. Barrow, Alaska - This site offers an optimum location for the calibration study of airborne instrumentation directed toward sensing and mapping sea-ice distributions and associated surface characteristics. In addition to the wide variety of ice/water/snow land interfaces, that are present in this area, considerable scientific/technical/labor personnel as well as facilities are provided by the Arctic Research Laboratory (ARL) under contract with the Office of Naval Research (ONR).

Two general areas of investigation are considered at this site. These are:

1. Ice Mapping and Thickness Measurements - The geographical areas established for these investigations include (a) the off-shore area about the Laboratory which is located at 71° 20' N Lat., and 156° 46' W. Long., (b) a narrow strip of 30-60 miles long from Pt. Barrow at a course of 045° true, (c) an equivalent strip at 315° true, and (d) the floating ice-island, T-3 (Fletcher's Island).

2. Thermal Mapping and Land/Water/Ice/Snow Interface Studies - The geographical areas established for these investigations include (a) and (b) above.

Research Facilities - Scientific, technological, and labor support for Arctic research is provided by ARL. The Laboratory is located about four miles north of Barrow, Alaska, and about six miles south of Pt. Barrow.

The principal role of ARL is to provide all facilities and services for research in scientific fields related to the Arctic environment. This includes both support of laboratory studies per se and logistic services to field parties.

At sea, ARL operates one major drifting research station: Fletcher's Ice Island, or T-3. On the island are emplaced semi-permanent, well-equipped laboratory and housing facilities, and an airstrip, upon which landings may be made year-around, weather permitting. The station is manned continuously.

Scripps Area - This Southern California site offers a large variety of oceanographic conditions, facilities, and favorable weather conditions for evaluating the airborne (and spaceborne) remote sensors.

The calibration site encompasses an extended area which includes specific locations for site calibration efforts. The calibration areas that are included in this site are:

a. The near-shore area extending northward some ten miles or so parallel to the coastline from the Naval Electronics Laboratory Tower off Mission Beach to the Scripps Beach area north of Pt. LaJolla. This includes both shallow and fairly deep waters. The following experimental areas are applicable to this area:

1. Surface Temperature Measurement
2. Location and Mapping of Longshore Currents
3. Shoreline and Beach Studies
4. Bottom Detection by Wave Refraction and Color Tones
5. Laser Altimetry Calibration

b. An area which is some 30-100 miles off-shore, lying east of San Clemente Island and south of Santa Catalina Island. This area is suitable study in the following areas:

1. Surface Temperature Measurement Involving the Japan Current
2. Biological Studies

The off-shore waters and coastal beaches of this area have been the object of intensive research for fifty years. The Scripps Institution maintains continuous observations of many types, including tides, water temperatures, salinity, and weather, and has the capacity to undertake comprehensive inshore and beach surveys when desirable.

The site is optimumly situated to provide the maximum control (ground truth) in oceanographic and littoral processes. The large scale features, as coastal embayments and a headland such as Pt. LaJolla might provide readily identifiable landmarks at orbital altitudes.

The Scripps area site offers a large number of facilities for the acquisition of ground truth data, including the Oceanographic Data Archive (approximately 500,000 BT observations), a 1000' x 20' pier, a number of research vessels, and smaller boats.

Some of the significant data available at this site are the following:

Scripps Pier

Tidal variations
Temperature
  surface
  bottom
  bathythermograph
  dual-wavelength IR radiometry (3.5 - 4.5 microns; 2.0 - 2.4 microns)
Salinity
  surface
  bottom
Air temperature
Wet and dry bulb thermometer readings
Maximum and minimum daily temperature readings
Wind velocity and direction
Multiple bathythermograph readings
Continuous wave recording for short periods of time
Inshore bathemetry and beach surveys

Navy Electronics Laboratory Oceanographic Tower

Wind direction and velocity
Water temperature
  surface
  bottom
  bathythermograph
Water acoustical properties
Tide measurements

For the deeper water areas off San Clemente, the research vessel facilities are exemplified by the Ellen B. Scripps. Some of the equipment onboard for ground truth measurements include:

Hytech. STD
8-13 micron radiometer on prow of boat
Single element towed thermistor
Anemometer
Physchrometer
Ship-air communications (4415.8 kc)

Site Requirements

Argus Island Site

Sea State Measurement - The primary surface measurements required for sea state measurement are wave height and tidal range measurements, wind speed and direction, surface photography and surface current flow.

The wave height and tidal range measurements at the surface can be satisfactorily made by instruments available at the site with the possible exception of a small radar to perform scatterometry measurements, albeit at low gazing angles.

The Navy boat (MAC III), manned by technicians, is available to obtain data over any greater area or deeper waters near the site; it is noted that a shipboard wave staff can be available which has an accuracy of about ± 6 inches; the method of adequately recording data from this mobile installation needs further determination.

The anemometer installation at the Tower is sufficient for wind and direction measurement. In anticipation of future requests by investigators for a more extensive gathering of local wind data, several secondary sources of meteorological data can be made available. First, data from the weather station at Kinley AFB can be obtained despite the relatively long distance from Argus (approximately 40 miles). Second, a shipboard mount on the MAC III can be used to make measurements about the Island; this requires procurement of a portable anemometer for shipboard use. Third, a sparse array of moored, telemetering buoys could perform such measurement at, say, three to five different locations about the site waters with recording completed at the Tower.

Some form of surface-based photography is possible to correlate with the airborne sensors. A 35mm motion or small, hand-held framing camera, while deemed to have a medium significance factor in this calibration, could provide imagery to supplement the visual observations expected to be recorded in the surface logbook which should be maintained throughout the calibration effort.

The measurement of surface current flow is included, primarily because of its availability at the site, but its value to the sea-state calibration remains to be clearly determined.

Surface Temperature Measurements - Argus Island offers some useful surface temperature distributions for calibration and evaluation for some of the remote sensors considered by the Project. Surface measurement requirements include reflectivity and emissivity, wind speed and direction measurements, surface temperature, current speed and direction, air temperature and relative humidity measurements.

The surface calibration measurements emphasize obtaining atmospheric conditions. Air temperature and humidity measurements at low level can be adequately handled by the equipment installed at the Tower; this can be supplemented by data taken by the weather station at Kinley AFB, some 40 miles away. In addition, a hygrometer is available onboard the NASA P3A which, by making level runs at various fixed altitudes supplies vertical distribution data on air temperature, water vapor and liquid moisture content. The Manned Spacecraft Center at Houston (per L. Childs/H. Toy) may be able to offer the use of radiosondes dropped from the P3A. Two types are being investigated: (a) a small radiosonde which provides temperature profiles by telemetry to the aircraft and (b) a larger radiosonde which telemeters both temperature and pressure during descent and after surface contact releases a thermistor giving water temperature data that is telemetered to the aircraft; the latter offer considerable more needed data, and is preferred.

A significant calibration measurement that is extremely complex is that of emissivity/reflectivity of the perturbed ocean surfaces, as it applies to both the remote sensing infrared and passive microwave equipments. The smooth surface case which can be more easily handled is not too informative. For this reason, a broad band IR radiometer with appropriate filters mounted on the Tower is suggested as a useful piece of surface equipment which may be utilized. An equivalent Tower mount of a passive microwave radiometer should be noted that at the short ranges involved, the errors introduced by slide-lobes may be extremely troublesome in data interpretation.

An interesting surface technique for helping evaluate passive microwave equipments would utilize some floating reflector sheets on relatively smooth water. The metal reflector with its microwave emissivity close to zero essentially masks any thermal contribution beneath it and the observed anomaly may serve as a cold landmark calibration reference during overflight. At 1000-foot altitudes, the airborne passive microwave equipments can resolve less than a 17-foot patch. This technique does not lend itself to source depth measurement because of the small penetration at the X and K bands involved.

With the use of the MAC III (and a technician), surface temperature measurements away from the Tower and especially over the shoal where the deeper colder waters come up and mix can be made; a simple resistance or expansion thermometer would be used. Additionally, the boat crew could use the bucket approach to obtain water samples which might show significant oil slick or other properties affecting emissivity/reflectivity interpretation.

Air-Sea Interactions - The study of air-sea interactions at Argus includes fog, clouds and water vapor distributions. Surface measurement requirements for this study are sea temperature profile measurements, air temperature and humidity profiles, wind speed and direction, current speed and direction, wave heights, solar influx measurements, IR surface temperatures, and surface volatiles.

Associated with surface measurements is the need for weather charts and other meteorological records to provide interfaces between the data collected and weather conditions over the larger entire area which preceded and followed each overflight period; hourly records of such data are indicated. It is noted that air-sea interaction investigations, as in many of the others discussed in this report, require surface environmental information such as sea temperature profiles, near-surface air temperatures, current speeds, etc., which are amenable to common buoy mounts having distributions which allow a realistic description of the site areas. Since the Argus site is sufficiently small, the use of perhaps five moored, non-expendable buoys may be an important addition to this calibration site.

For the gathering of higher-level meteorological data it is recommended that the current NASA aircraft plans for implementing the P3A to drop radiosondes as previously mentioned be continued.

Point Barrow, Alaska

Ice Mapping and Thickness Measurements - In order to evaluate the airborne remote sensors for their capability in ice mapping and thickness measurement, a wedge-shaped area extending north of the Point and the ice-island T-3 is utilized for the variety of ice forms encountered there. This includes: (a) the shore-fast ice area in the vicinity of Pt. Barrow extending six to eight miles offshore, (b) an offshore polar-ice area on a course of 045 degrees true and 30-60 miles from the Point, and (c) an offshore, seasonal-ice area on a course of 315 degrees true and 30-60 miles from the Point, and (d) the thick, floating, manned ice-island, T-3. Surface requirements measured for airborne remote sensor data evaluation are: physical and chemical properties of snow and ice, ice and/or snow surface temperatures, ice and/or snow thicknesses, wind speed and direction, ice stress-strain measurements, ice ages, surface roughness, solar influx, air temperature, and relative humidity profile measurements.

Since ice thicknesses vary considerably during the entire year, the "all weather" capability sensors can be effectively evaluated during all four seasons. On the other hand, because of the extensive fog conditions which are prevalent during the third quarter, airborne remote sensors as photographic, infrared, laser will be denied effective operation during this season.

Arctic operations pose a severe limitation on surface equipment requirements because of logistics and extreme cold effects on components. For this reason, all surface equipments/techniques used for this calibration effort are primarily at Point Barrow. With some possible assistance from gathering higher-level meteorological data from the NASA P3A via hygrometer and the currently-planned radiosonde drops, a weather vane implant is also in area (b) above.

The off-shore areas, (b) and (c) above, offer a relatively simple means of performing mapping of ice movements. A large number of black, empty oil drums can be made available by the Arctic Research Laboratory (ARL-Under ONR Contract) for this purpose. These drums can be dropped from the ARL aircraft, on almost straight-line references along the 045 and 315 degree courses from 30 to 60 miles from the Point. These lines of drop will be approximately perpendicular to current flow for these floating-ice waters. Experience (per Max Brewer, Director of ARL) indicates that such markers have proven to be among the most effective for photographic or visual sensing at remote distances. Drops less than a mile apart will form an identifiable reference line whose distortion with time will relate to the ice movements in these areas. Emphasis is placed on the airborne panoramic camera(s) which should reveal ice movements (normal to the drop line) of 50-60 miles, under relatively clear atmospheric conditions. Stero photography also provides information on vertical displacement.

<u>Thermal Mapping and Surface Interfaces</u> - These investigations can be performed over two of the four areas used for ice-mapping/thickness measurements, using the immediate vicinity of Pt. Barrow, and the occupied ice island, T-3.

These two areas are able to provide adequate voice communications and homing beacons for control/navigation. In addition, NASA plans for dropping radiosondes might be modified to include telemetering temperature sensors that could be dropped onto ice floes or into open leads or polynas to provide extended temperature references for calibration, recorded onboard the aircraft. Both Barrow and T-3 facilities include the capability for such measurements which are very local in extent and recorded at these sites. The radiosonde technique can simultaneously provide air temperature profiles (and the very low humidities expected). The hygrometer onboard the P3A can also be used for this purpose by flying at a series of fixed altitudes; this instrument can also measure liquid water content.

<u>Scripps Area</u>

<u>Surface Temperature Measurements</u> - Surface temperature measurements for the Scripps area have been divided into two areas of operation. The most accessible area for surface measurements is a near-shore area extending some ten miles parallel to the coastline from the Naval Electronics Laboratory (NEL) Tower to the south at Mission Beach, up to and just north of Scripps Pier. Off-shore the strip will extend out to about 1-3 miles offering both a shallow and deep water facility including the sloping continental shelf, the Scripps Canyon and the San Diego Trough (approximately 6000 feet); the second area of interest lies southeast of San Clemente Island and includes those waters about 50-60 miles off-shore where Japan currents come in from the north creating eddy distributions that offer some realistic temperature patterns for adequate testing of spatial/temperature resolution of the airborne sensors. Research vessel facilities for obtaining ground truth data are available from the Scripps Institution of Oceanography (SIO).

The near-shore area described previously can be adequately handled. The facilities at the NEL Tower and off of Scripps Pier will essentially satisfy requirements for ground truth acquisition. If measurements are to be expanded about these local points, a number of small motor craft (on the Pier) can be utilized using a hand-held or portable thermometer, psychrometer, anemometer or shipboard wave staff with a crew of two technicians. A dual-wavelength radiometer is also available at the Pier for making temperature gradient measurements at the surface. The latter requires a new detector system to improve its sensitivity.

The off-shore area southeast of San Clemente requires a ship operation. The SIO research vessel, such as the Ellen B. Scripps, can satisfactorily provide surface requirements.

<u>Location and Mapping of Longshore Currents</u> - This calibration effort can be suitably performed at the near shore strip between the NEL Tower and Scripps Beach area, extending one to three miles off the shoreline. This area is easily accessible to instrumentation, especially for current measurement which is the most critical calibration involved in the surface effort.

Surface equipments, for surface requirements, i.e., current tracking, sea temperature profiles, air temperature profiles, relative humidity, and wind speed and directions, are available through the Naval Electronics Laboratory and Scripps Institute of Oceanography. It is noted, however, that a careful review of available equipment is required concerning the accuracy of measuring slowly-moving longshore currents which are present at the site. Dye marking offers semi-quantitative data. J. Cairns (NEL) has suggested the floating crossed-vane drogue as an intermediary device subject to some improvement in accuracy; the crossed vanes present an almost uniform drag surface regardless of current direction. Motion with the current can be sensed at the aircraft by identifiable float markers above the water line, and observing the displacement with time, providing <u>wind effects</u> are minimized in the flotation design. Selection of this or other available current-measuring techniques, i.e., Eulerian current meter, Roberts meter, hot-wire anemometer, etc., or a new development may have to be considered for this particular problem.

Shoreline and Beach Studies - The shoreline utilized for this investigation runs from the Mission Bay Split to the south up to the Torrey Pines-Del Mar Area. This provides a variety of coastline features of long, straight beaches, small pocket beaches, rocky coastlines and cliff structures.

Surface requirements for shoreline and beach studies include sample analysis (sand, rock, vegetation), water content of beach sands and rock units, sea state measurements, surface temperature mapping, offshore current measurements, and meteorological data. These requirements are adequately provided for by existing facilities at the Scripps Institute of Oceanography.

Bottom Detection by Wave Diffraction and Color Tones - This calibration effort can be suitably performed in the Scripps area over a longshore strip from the NEL Tower on the south to the Scripps Pier area on the north, extending off-shore some one to three miles. This beach area provides both shallow and deep waters in a relatively small area which is conveniently accessible to surface facilities and personnel.

Among the various surface measurement requirements for this investigation, the need for bottom contour data and optical-transparency of the sea water is paramount for this investigation. In view of the ongoing extensive efforts by such organizations as NEL, SIO, and the U.S. Coast and Geodetic Survey, the bottom contour problem is minimal. To supplement or verify the data which is already available, a portable meter-wheel fathometer, sonar depth finder, or pressure gauge (Bourdon, Vibratron) can be manned from one of the boats available to make spot check measurements.

Underwater photometers and equipment necessary for the measurement of sea water transparency are available.

Equipment at the NEL Tower and Scripps Pier are adequate for collecting meteorological data during overflight periods. This can be supplemented for higher-altitude data by the P3A hygrometer and contemplated radiosonde drops from the NASA aircraft, or data procurable from North Island/Lindberg Airport Weather Stations.

Biological Phenomena - Calibration data related to remote sensing of biological phenomena in the Scripps area is best handled by a research vessel operation. The desired biological phenomena are not generally available close to the shore areas proposed for the other investigations at the Scripps site. Surface ship calibration efforts can be conducted in waters some 30-100 miles off-shore in the vicinity of the Santa Catalina-San Clemente Islands which offer considerable varieties of biological species, i.e., fish, plankton, etc.

Biological surface measurement requirements include site temperature measurements, transparency/luminescence observations, solar influx or sky record, bioluminescence measurements, atmospheric trace spectrometry determinations, chlorophyll concentrations, and population density measurements.

Most surface measurement requirements can be effected with the available instrumentation on the Scripps Institute of Oceanography vessel "Ellen B. Scripps" except for a photometer used for obtaining transparency/liminescence data, though can be obtained from SIO facilities under agreement with NAVOCEANO.

Altimetry by Laser - Estimated surface calibration requirements necessary to help evaluate laser altimetry for oceanographic purposes consist of altimetry calibration, penetration calibration, stability calibration, and accuracy calibration. The Scripps Beach area presents an adequate range of wave heights, period and direction approach, usually during October-February. Average breaker heights of about 5 feet are indicated in this period with occasional winter storms causing heights of 12 feet or more for short periods of time.

Critical areas in the calibration of the laser technique as applied to oceanography are (a) errors inherent in the technique due to penetration of the sea surface by the light beam with the resulting volume scatter at appreciable (order of feet) depth beneath the surface, and (b) errors in ranging that result from flight platform instabilities inasmuch as beam widths of 10^{-4} to 10^{-5} radians will be involved.

Absolute range calibration can be performed on the ground, using horizontal paths against target reflectors whose distances must be surveyed to an accuracy that is better than the projected for the laser (0.1 - 0.2 feet) against nonpenetrable surfaces. Having established the ranging accuracy by ground tests, one can now measure the degradation in accuracy using the aircraft platform at various altitudes, to examine the effects of known atmospheric paths and platform instabilities.

A wooden platform exposing 6 steps (5 x 20") to the laser beam can provide calibration data on the accuracy of contouring for an idealized non-penetrating surface. The actual step heights require accurate measurement to ± 0.25". The critical difficulty is in precise navigation over such a small target, approximately 30 by 20 feet, for the pilot at a suggested altitude of 1000 feet. By orienting the conspicuous, white beaded-urethane painted steps so that the required ground track is parallel to the shoreline, a coarse visual navigation guide is conveniently provided. By adding a number of markers/lights along the desired track through the target, the desired precision can be obtained, especially after a few passes aided by communication from ground observers. If possible, procurement of a surplus Norden bombsight would also be a significant aid in this problem. The overall technique has been favorably checked with several pilots.

A floating flat top barge (20 x 20") can provide a non-penetrable target whose small height (one foot) is accurately known above the penetrable water. Comparison of the altimetry data taken just before, during, and immediately following the target overpass should provide data on the errors introduced in altimetry over adjoining sea surfaces. Calm waters offer the least introduction of error in this measurement; the problem of foamy, aerated surfaces is questionable for the proposed technique.

For stability calibrations the use of the wooden steps previously mentioned can be utilized to make some determination of short-period instability (.12 second at 150 knot ground speed). By mounting a wide angle camera (tilted down) above the step structure, a time exposure, should provide a track of the diffusely reflected beam as it moves across the step structure. Appropriate filtering on the camera should allow the laser track emission to stand out against the background (moonlight reflection, beacon sources used for guidance, etc.). The proposed measurement is limited to a few samples of short-term beam deviations, but is easily implemented.

Summarized below are generalized measurements and equipments necessary for ground truth requirements at the oceanographic calibration and overflight sites.

MEASUREMENTS REQUIRED AND BEING MADE

The following lists those oceanographic variables which are measured at the surface to properly assess the feasibility of remote sensing for oceanography. Not all measurements are required for every experiment. Those measurements being made generally apply to the calibration site; the surface data for overflight sites depends on the type of surface or near-surface platform employed.

	OCEAN VARIABLES	MADE
1.	Sea Surface Temperature	Yes
2.	Surface Salinity	Yes
3.	Wave Height/Direction	Yes
4.	Current Speed/Direction	Yes
5.	Water Depth (Shoal area)	Yes
6.	Water Clarity/Color	Yes
7.	Water Samples (Sediments/Biological content)	Yes
8.	Air Temperature	Yes
9.	Wind speed/direction	Yes
10.	Cloud cover	Yes
11.	Moisture in Air Column	Sometimes
12.	Percent Foam/Spray	No
13.	Reflectivity/Emissivity	No
14.	Thermometric Temperature	No
15.	Solar radiation	Yes
16.	IR Measurements	Yes
17.	Detection and Description Fish Schools	Yes
18.	Sea Ice Distribution	Yes
19.	Sea Ice Thickness	Sometimes
20.	Sea Ice Temperature	Sometimes
21.	Detail Sea Ice Topography/Water Features	Sometimes

EQUIPMENT REQUIRED AND USED

As in the previous section, this listing is general and not specifically tied to any given experiment. Not all instruments are required for every experiment. Insofar as the use of ships and buoys is concerned, the requirement is for greater use specifically for remote sensor experiments. Except for a few cases, this has not been possible up to now because of the long lead-time required to program for ship time and the basic lack of funds to pay for this time and furnish the staff to obtain the required observations.

	REQUIRED	USED
1.	Bucket thermometers/thermistors	Yes
2.	Water samplers	Yes
3.	Surface salinograph	No
4.	Expendable BT	No
5.	IRT/ART	Yes/No
6.	Wave staff	Yes
7.	Current meters	Yes
8.	Met. Instruments (air temp, wind speed/direction, humidity, etc.)	Yes
9.	Dropsondes or radiosondes	No
10.	Transmissometer	No
11.	Photo systems	No
12.	Buoys (moored, free floating, arctic)	Rarely
13.	Ships	Sometimes
14.	Small boats	Sometimes
15.	PDR	No
16.	Microwave (19 GHz, 6 GHz, etc.)	No
17.	Ice measuring equipment	Partially
18.	Sonar	No
19.	Surface to air communications	Sometimes

DETAILED RECOMMENDATIONS RELATIVE TO THE AIRCRAFT PROGRAM CONCERNING OCEAN TRUTH

Comment - Some of the concepts derived through the geological phase of the program do not lend well to "ocean" truth. The "calibration site" concept, for example, does not apply. For, although permanently located and well instrumented, the fact that the ocean is dynamic and variable weakens the reason for having a special static site where long term observations are obtained to "understand" the area. It is also difficult, if not impossible, to select a permanent site and wait for all the ocean variables of interest to come by.

Recommendation - That specific sites not be designated, but that, within aircraft range constraints, test sites be selected where "the action is."

For example, in order to get desired wave conditions, it appears necessary to select a period when the probability for the conditions is high, then fly sufficiently long legs over the area to increase the chances of obtaining the desired data.

Comment - Attempting to forecast the event of an ocean variable six months in advance is a very costly exercise. Waiting until the probability of the event can be predicted more accurately can increase the chances of success.

Recommnedation - That greater flexibility be allowed in scheduling the aircraft for ocean sensing, particularly waves. Some phases, such as river effluent studies, bathythemetric studies, sea ice, etc., may continue to be scheduled well in advance.

Comment - The range limitations of the Convair 240 minimize its usefulness as an oceanographic data collector.

Recommendation - Except for coastal experiments, the P-3 be scheduled for ocean work. The increased range and duration will permit greater opportunity for acquiring data on most ocean variables.

Comment - In most cases, engineering factors in remote sensing far exceed the oceanographers ability to use the instruments. Most ocean investigators are just beginning to define the problem and develop an experiment program for a solution.

Recommendation - That haste in requiring quick results and answers from the oceanographers may not be in order. More communications between investigators and those obtaining the data will lead to mutual understanding of requirements, problems, etc., enhancing chance for success.

Comment - A successful ocean truth program must make provision for those resources (people, ships, instruments) which will permit programming experiments specifically for SPOC.

Recommendation - Funding for this purpose be provided.

Comment - The staggering number of test sites and investigators in the Earth Resources Survey Program deters effective aircraft scheduling for ocean experiments.

Recommendation - Consideration be given to obtaining an aircraft especially for oceanography, and/or permit for contracting of specialized aircraft, and/or make available NASA Sensors for temporary or permanent installation on other aircraft such as ASWEPS.

Comment - Some sensor techniques being developed (WISP system for example) require testing on, and in fact may be more economical to test on, special aircraft.

Recommendation - The program consider funding for aircraft time in cases where warranted.

Comment - Data for data's sake usually serves no purpose but to fill file drawers. Frequently, if not always, only very little data are required to advance feasibility studies, providing the data are of the type and quality required by the investigator. Often, massive amounts of data do more than fill massive numbers of file drawers; they may actually retard or deter effective analysis. These statements pertain to surface as well as aircraft and orbital data.

Recommendation - The specifications of the investigator should be understood and closely adhered to in acquiring aircraft, space and ocean truth data. On the other hand, Investigators must be required to define in better terms their environmental and sensor data requirements, and then maintain communications with the data collectors and even participate actively in the data collection process.

Comment - A wealth of ocean truth sites (platforms) are available through existing oceanographic programs. This generally entails going where the ships (platforms) are at the proper time, since it usually has not been possible to program ship time specifically for SPOC projects. Some of these platforms include the survey ships of BCF, ESSA, Coast Guard, Navy, Woods Hole Oceanographic Institute, etc. as well as the Coast Guard Light Towers, and the Ocean Station Vessels. Resources (money and people) are required to implement a successful ocean truth program.

Recommendation - Funding be provided for ship time personnel and special instrumentation for ships (microwave, IR, etc.).

Preliminary Spacecraft Test Site Requirements - Phases of sensor testing preceeding the spacecraft utilization phase which are devoted to program and instrument definition and use of aircraft for determining sensor feasibility include extensive testing of basically identical sensors aboard airborne platforms. This testing provides experience with results of airborne sensors to establish a comparative base for analysis of test results from spacecraft-borne equipment in the later time frame.

It will be useful to correlate results of simultaneous operations of both types of platforms to determine the comparative utility of spacecraft-borne instruments, especially during those experiments where the physical phenomena of the sea vary markedly with time. For this reason plans for simultaneous aircraft utilization with spacecraft schedules should be established when spacecraft overflight information becomes available.

While much of the ground truth data will have to be gathered at the time of the spacecraft overflight, some of it can be taken in advance, by aircraft flights, to provide panoramic and topographic mapping of coastal features.

Documentation should cover an area large enough to be useful for calibration of the spacecraft data. Minimum size of useful calibration areas should be determined, since current experimental flights could be extended to provide the initial coverage of these areas.

Particular areas of the Gulf of Mexico are of special oceanographic interest. The Yucatan Current and Gulf Loop and areas of upwelling north of Yucatan Peninsula are significant oceanographic features. Large thermal gradients should be associated with these phenomena. Aircraft missions over areas such as this with concurrent ground truth acquisition will contribute to understanding oceanographic phenomena in the Gulf of Mexico which has been designated as an area of interest for the AAP-1A Mission. It is perhaps not premature to explore the feasibility or concept of designating the Gulf of Mexico as the "NASA Acre." This concept would utilize the Gulf of Mexico as the spacecraft test site and use the many resources for a surface observational network. The idea has merit and should be considered, although some ocean features (ice, high sea state) will still require observations outside the area.

The Spacecraft Oceanography Project has selected five basic oceanographic experimental areas for the AAP-1A Mission contingent on the availability of the primary instrumentation identified in Tables 2-6. These are:

a. Food from the Sea
b. Ocean Dynamics
c. Coastal Features
d. Environmental Prediction
e. Selected Photography

The above areas are further delineated in specific experiments as shown in Tables 2-6.

The geographical experimental areas were selected based on oceanographic phenomena and the availability of surface or near surface platforms during the proposed period of the AAP-1A Mission. The platforms will include ships, aircraft, and/or towers as identified in Tables 2-6. These experimental areas are outlined in Figure 2. The larger areas will be narrowed in coverage when the exact times of spacecraft coverage are known to coincide with the planned positions of the ships operating in the area.

It is anticipated that missile tracking vessels possessing some ground truth capabilities will be utilized as additional sources of data collection systems during orbital missions.

Photographic areas will not necessarily have ground truth but cover areas which possess features of oceanographic interest.

A surface observational program will be developed when details of the spacecraft instruments and orbit parameters are determined.

TABLE I SURFACE EQUIPMENT

SURFACE REQUIREMENT	INSTRUMENT	FUNCTION	PLACEMENT	ACCURACY	MEASUREMENT RATE	DATA RECOVERY	COMMENTS
A. PROBLEM INVESTIGATED: SEA STATE MEASUREMENTS				SITE: ARGUS ISLAND			
1. Wave Heights and Tidal Range Measurements	Wave Staff	To provide sea-state data for comparison to remote data.	1-5 units distributed over site area to account for shallow and deep changes	1.5%	Continuous during overflight	Marine Cable or Telemetry	Deep water measurements may require ship or other platform.
2. Wind Speed and Direction	Anemometer	To provide local wind data for correcting aircraft measurements.	Shipborne, or buoy mount(s) to correlate with wave staff measurements	Speed: 3 knots Direction: 5 deg.	Continuous during overflight	Shipboard recording, cable or telemetry	
3. Ship Based Photography	35 mm motion or widefield hand-held camera	To obtain information on sea-state, and imagery of sea emplacements.	Ship based or shore based (tower)	Not critical	Once per 1/2 hour during overflight period		Simple addition in terms of equipment. Provides corroborative data.
4. Surface Current Flow	Rotor current meter (speed), movable vane (direction)	To correlate surface current flow with sea-state measurements.	Moored-buoys (1-5 units)	Speed: 1-2% Direction: 5 deg	Continuous during overflight	Marine cable or telemetry	Dye markings offer semi-quantitative data.
Note: A 1-5 distribution of moored buoys within a 1 square mile test site for obtaining environmental data, as above, can also provide fixed "landmarks" for spatial references recorded by the multiband (metric) cameras during any single run over the site at altitudes ≤ 1000 feet.							
B. PROBLEM INVESTIGATED: SURFACE TEMPERATURE MEASUREMENTS				SITES: ARGUS ISLAND AND SCRIPPS BEACH			
1. Surface Temperature Measurement	Thermistor recording system	To provide temperature calibration references of the actual sea and air boundary being sensed by A1, 2, 3, 4, and 5 above.	Vertical: 1-3' above surface, vertical array with 1' spacings down to 10' (thermoclines). Horizontal: 1-5 units distributed over site.	System: 0.1°C (0.1°K)	Before and after overflight (timing not critical)	Marine cable to land, buoy telemetry	See "Argus I Instrumentation" table ([illegible])
2. Reflectivity and Emissivity Measurement	Laboratory reflectometer or night flight over smooth water	To help provide absolute temperature calibration for smooth surface.	Not critical	3 significant figures	Prior to, during or following overflight (timing not critical)		Moon-less night run would eliminate any contributions.
3. Wind Speed and Direction Measurement	Anemometer	To correlate local wind effects with aircraft measurements	Use weather station at Kinley AFB-Radiosonde or a few moored installations	Speed: 3 knots, Direction: 5 deg.	Continuous during overflight		
4. Wave Height Measurement	Wave Staff	To correlate wave structures with emissivity effects on aircraft temperature measurements	Unless wave structure varies radically over site area, a single staff installation is satisfactory	1.5%	Continuous during overflight		
5. Current Speed and Direction Measurement	Rotor current meter and movable vane	To correlate current flow with aircraft measurements.	1-5 units distributed over site area	Speed: 1-2% Direction: 5 deg.	Continuous during overflight		
6. Solar Radiation or Sky Radiance Measurements	Bolometer or bolometer	To obtain knowledge of incident sky radiation, this coupled with surface reflectivity allows separation of reflected and emitted components of aircraft measurements.	At island or shipborne	1% (?)	Continuous during overflight		
7. Air Temperature and Relative Humidity Measurement	Wet and dry bulb thermometers and air pressure gauge	To obtain calibration of weighting factors used in passive microwave and IR spectrometer analysis to correct for atmospheric contributions to surface emissions.	Kinley AFB weather station Radiosondes and Argus Tower for low-level measurements	Temperature: 0.1°C. Humidity: 1 percent	Before and after overflight		

TABLE I SURFACE EQUIPMENT (Continued)

SURFACE MEASUREMENT	INSTRUMENT	FUNCTION	PLACEMENT	ACCURACY	MEASUREMENT RATE	DATA RECOVERY	COMMENTS
C. PROBLEM INVESTIGATED: AIR-SEA INTERACTIONS, FOG, CLOUD, WATER VAPOR — SITE: ARGUS ISLAND							
1. Sea Temperature Profile Measurements	Thermistor recording system	To provide adequate ground truth temperature information leading to estimates of radiative, convective and conductive heat transfers from the ocean surface; includes loss by evaporation.	Vertical: 1-3' above surface; vertical array in water with 1' spacings down to ~ 10'. Horizontal: 1-5 units distributed over site.	System 0.1°K	Before and after overflight (timing not critical)	Marine cable, buoy telemetry	Salinity, [illegible], data or measurement would be valuable accessory.
2. Air Temperature and Humidity Profile Measurements	Wet and dry bulb thermometer, pressure gauges	To establish water vapor content at the sea-air interface leading to heat transfer estimates.	Near surface location coupled with radiosonde profiling up to several thousand feet (See Kinley AFB facilities and NRL Tower)	Temperature: ~0.1°K Humidity: ~1%	Before and after overflight		
3. Wind Speed and Direction Measurements	Anemometer	To relate air motion effects over the sea surface with heat loss, evaporation rates, surface wave and turbulence, etc.	Use weather station facilities at Kinley AFB and/or a few moored installations	Speed: 3 knots, Direction: ~5°	Continuous		
4. Current Speed and Direction Measurements	[illegible] current meter and [illegible]	To examine effects of surface currents, eddies, or turbulence in their relationship to temperature and other environmental variables.	1-5 units distributed over site area	Speed: 1-2%, Direction: ~3°	Continuous		
5. Biological Environment Observations	[illegible] survey, ship photography, [illegible], absorption spectrometer	To provide surface data on seasonal chlorophyll concentration, plankton and fish concentrations to correlate their effects in this problem area.	Ship survey over 1 square mile area, including water bottle sample analysis.		Before, during or after overflight (once per day)		
6. Wave Height Measurements		See Items C.4 and C.6					
7. Solar Influx Measurements		See Items C.4 and C.6					
D. PROBLEM INVESTIGATED: ICE MAPPING AND THICKNESS MEASUREMENTS — SITE: PT. BARROW, ALASKA							
1. Ice Sampling and Analysis	Core drills, core and lab instrumentation	To determine the physical and chemical properties of the ice including conductivity/resistivity measurements, transparency, salinity distributions, etc.	Field samples removed to the laboratory for examination	Not available	Not critical	By written report or available literature	Much of this information is already available ([illegible]).
2. Surface Temperature Measurements	Thermistor Recording System	To provide a temperature calibration reference of the actual ice/air interface.	Environmental difficulty coupled with logistics problems may deny these approaches (per conversation with [illegible]). However, this Phase I effort offers these as idealized desirables. Actual placement will be subject to Phase II results. Expendable aircraft drops, small aircraft or helicopter landings, etc., will be required.				See PLACEMENT
3. Wind Speed and Direction	Anemometer	To determine effects of local winds upon aircraft measurements.					
4. Acoustic/Seismic Soundings	Refraction Seismometer	To determine ice thickness at sample locations to provide calibration for aircraft data.					
5. Solar Influx on Sky [illegible] Measurements	Radiometer or Pyranometer	To provide knowledge of incident sky radiation coupled with surface reflectivity, to allow separation of reflected and emitted components of aircraft measurements.					
6. Air Temperature and Relative Humidity Profile Measurements	Wet/dry bulb thermometers and barometers	To provide data for the calibration of [illegible] sensors used in aircraft infrared data interpretation.					

TABLE I SURFACE EQUIPMENT (Continued)

SURFACE REQUIREMENT	INSTRUMENT	FUNCTION	PLACEMENT	ACCURACY	MEASUREMENT RATE	DATA RECOVERY	COMMENTS
E. PROBLEM INVESTIGATED: THERMAL MAPPING AND LAND/WATER/ICE/SNOW INTERFACES — SITE: PT. BARROW, ALASKA							
1. Sea Temperature Profiles	Expendable Bathythermographs	To measure vertical sea temperature profiles as a function of time and at times of overflight.	Several polynas and leads among the ice floes to be overflown; at ? foot intervals of depth down to ? feet.	1° K (?)	On command from overflying aircraft once per minute (?)	Telemetry to overflying aircraft	These instruments are standard equipment aboard the ASWEPS Super Constellation.
2. Ice Temperature Profiles	Recording thermograph	To measure vertical and horizontal temperature profiles as a function of time and at times of overflight.	Horizontal and vertical spatial arrays at various depths in ice floes to be overflown.	1°K (?)	On command from overflying aircraft once per minute	Telemetry to overflying aircraft	Difficulty may be encountered in implanting sub-ice surface sensors.
3. Air Temperature and Relative Humidity	Recording wet/dry bulb thermometer-hygrometer	To measure near-surface air temperature and relative humidity.	On floes or aircraft (See COMMENTS)	Temp: 1°K Humidity: 1%	On command from overflying aircraft continuously	Telemetry or direct readout in aircraft	If aircraft can make a low altitude approach to floe (~ 50') hygrometer-thermometer and barometer may be mounted in the aircraft.
4. Air Pressure	Recording barometer	To measure near-surface barometric pressures.	On floes or aircraft (See COMMENTS)	1 mm of Hg 0.02 psi	On command from overflying aircraft continuously	Telemetry or direct readout in aircraft	See COMMENT E.3 above.
5. Wind Parameters	Anemometer	To measure wind speed and direction.	On floes to be overflown or in near vicinity	Speed: 1 knot Direction: 5°	On command from overflying aircraft continuously	Telemetry to overflying aircraft	One anemometer for a 25 mile area may be sufficient.

Note: An icebreaker calibration platform can also serve as a navigation reference.

SURFACE REQUIREMENT	INSTRUMENT	FUNCTION	PLACEMENT	ACCURACY	MEASUREMENT RATE	DATA RECOVERY	COMMENTS
F. PROBLEM INVESTIGATED: LOCATION AND MAPPING OF LONGSHORE CURRENTS — SITE: SCRIPPS BEACH							
1. Current Tracking	Dye markers and/or floating corner reflectors and/or visual buoy markers	To track progression of current (direction, cross-current speed distribution) over long periods of time.	One or more lines of markers placed across current at 1000' intervals extending several thousand feet either side of current boundaries	Speed: 1 knot Direction: 1°	Stereo time-lapse photography (or microwave imagery with corner reflector/emitters) every hour.	Remote sensing	Will provide large-area information on current movements with time.
2. Sea temperature profiles	Expendable bathythermographs	To measure vertical sea temperature profiles to great depth as a function of time and at time of overflight.	Initially deployed every 1000' across current direction, extending for several thousand feet either side of current interfaces.	10° K (?)	On command from over flying aircraft once per minute (?)	Telemetry to overflying aircraft.	These instruments are standard equipment aboard the ASWEPS Super Constellation.
3. Air temperature profiles and relative humidity	Recording wet/dry bulb thermometer-hygrometer	To measure near-surface (0-100') vertical temperature profiles, and relative humidity.	Radiosonde equipment deployed on balloons or parachutes over the site at various locations to sample vertical profiles.	Temp: 1°K Humidity: 1%	On command from overflying aircraft or boat, continuously.	Telemetry	Parachutes will enable retrieval of equipment for re-use.
4. Wind speed and direction	Recording anemometer	To measure the speed and direction of the wind at the site (air/water interface).	On buoys or at nearby ground station (?)	Speed: 1 knot Direction: 5°	On command from overflying aircraft, continuously.	Telemetry	One anemometer for entire site may be sufficient.

Note: Since these measurements will be made considerably off-shore, the availability of an SOI research vessel is indicated.

TABLE I SURFACE EQUIPMENT (Continued)

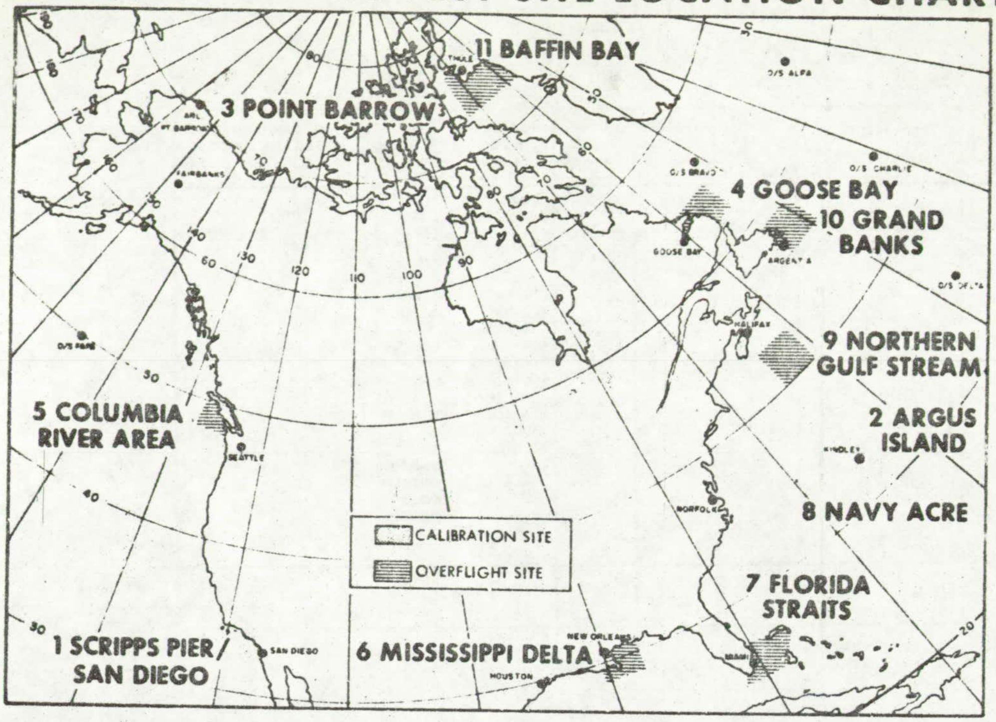
SURFACE EQUIPMENT	INSTRUMENT	FUNCTION	PLACEMENT	ACCURACY	MEASUREMENT RATE	DATA RECOVERY	COMMENTS
G. PROBLEM INVESTIGATED: SHORELINE AND BEACH STUDIES					SITE: SCRIPPS BEACH		
1. Sample analysis	Sand, rock and vegetation sampling	To determine the actual mineral and vegetation composition of surface rocks and beach sands.	Samples to be taken randomly within area of observation and specifically from locations of particular interest.	Not Applicable	Not critical	Laboratory analysis	Can be anytime prior to or after aircraft flight.
2. Water content, beach sands and major rock units	Sand and rock analysis	To determine the effect of water content on beach sands and shoreline rock formations.	Samples to be taken randomly within area of observation and specifically from locations of particular interest.	Not Applicable	Not critical		Should be done just prior to aircraft flight.
3. Sea-state measurements	Wave staff	To provide basic information on the relationship between sea states and beach and shoreline morphology.	A single representative location should be adequate for entire site.	1-Ft	Continuous during overflight	(?)	
4. Surface temperature mapping	Recording thermometers	To provide surface correlation for remote IR data	3 representative locations, and at areas of specific interest.	1°K	Continuous during overflight	Data retrieved manually from recorders	
Note: Shoreline/beach erosion and littoral-fill data is anticipated to be available from other SIO studies.							
H. PROBLEM INVESTIGATED: BOTTOM DETECTION BY WAVE DIFFRACTION AND COLOR TONES					SITE: SCRIPPS BEACH		
1. Sounding	Sonar or mechanical sounding device	To provide thorough and detailed maps of the ocean bottom over the active site to be used for this experiment	Sounding should be taken every 500 feet, and at closer intervals in areas of gross discontinuities in bottom elevation	Vertical: 10'	Not applicable	Direct readout on ship	This may be done at any time prior to overflights.
2. Sampling	Retrievable container	To provide samples of bottom material in areas of interest	Samples should be taken where color tone differences are noted (see COMMENTS) on both sides of color discontinuity	Not applicable	Not applicable	Ship	Color tone differences may be caused by a difference in bottom material, vegetation, etc., rather than by elevation differences.

TABLE I SURFACE EQUIPMENT (Continued)

Surface Equipment	Instrument	Function	Placement	Accuracy	Measurement Rate	Data Recovery	Comments
I. PROBLEM INVESTIGATED: BIOLOGICAL PHENOMENA					SITE: SCRIPPS BEACH		
1. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Continuous during runs	[illegible]	[illegible]
5. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Continuous during runs	[illegible]	[illegible]
6. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Continuous during runs	[illegible]	[illegible]
7. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Continuous during runs	?	[illegible]
Note: [illegible]							
J. PROBLEM INVESTIGATED: ALTIMETRY BY LASER					SITE: SCRIPPS BEACH		
1. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	None	[illegible]
2. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	None	[illegible]
3. [illegible]	[illegible]	[illegible]	[illegible]	Not applicable	[illegible]	Film	[illegible]
4. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

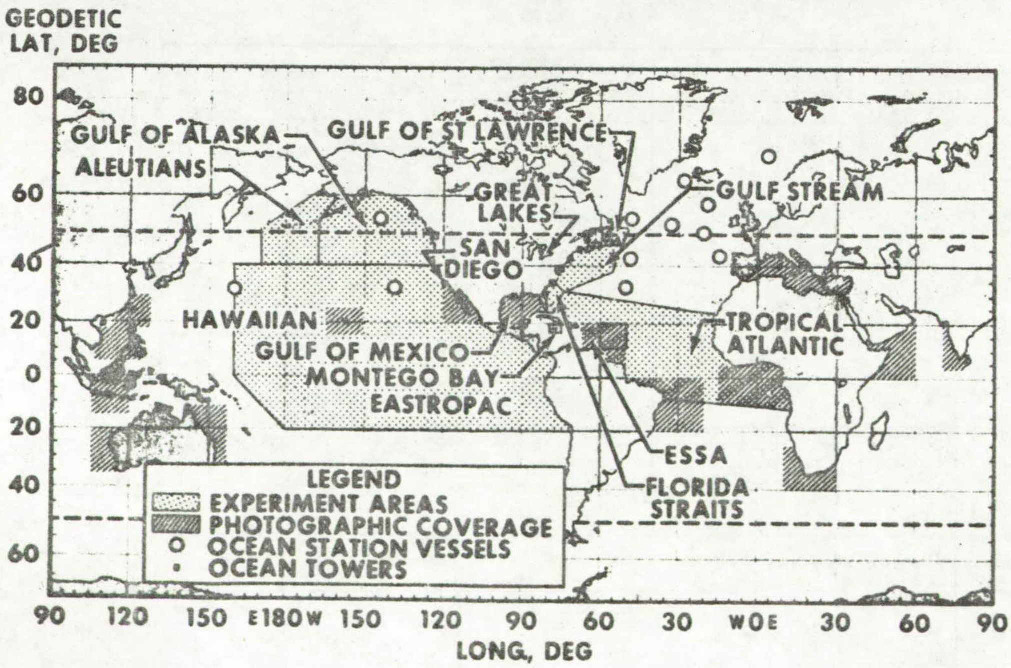
NASA-S-67-7826

OCEANOGRAPHIC TEST SITE LOCATION CHART



NASA-S-67-7825

OCEANOGRAPHIC EXPERIMENT AREAS



OCEANOGRAPHIC FEATURES

FOOD-FROM-THE-SEA

	6'' METRIC CAMERA	MULTI-BAND CAMERA	INFRARED SCANNER	MICRO-WAVE RADI-OMETERS	INFRARED RADI-OMETER	DAY-NIGHT CAMERA	EXPERI-MENT AREA	SURFACE DATA SOURCE	USER OR ANALYSIS GROUP	OBSERVA-TIONAL REQ
FISH SCHOOLING	P*	P	S*				GULF OF MEXICO	BOWERS, GERONIMO	BCF	**
THERMAL DATA			P	P	P		GULF STREAM	DELAWARE II ALBATROSS IV AGOR IV, VI ASWEPS A/C	BCF	**
							FLORIDA STRAITS	OREGON		
							HAWAIIAN ISLANDS	GILBERT, CROMWELL		
							TROPICAL ATLANTIC	UNDAUNTED		
							EASTROPAC PACIFIC	JORDAN		
							ALEUTIANS	KELER		
							GULF OF ALASKA	MANNING PRIBILOF COBB		
							ESSA (BARBADOS)	OREGON II		
BIOLUMINESCENCE	S	S	S			P	MONTEGO BAY	JOHNS HOPKINS/ NAVY	NAVY	**

* P = PRIMARY REQUIREMENT S = SECONDARY REQUIREMENT
** OPERATE PRIMARY AND SECONDARY SENSORS ±3 MINUTES OVER TEST SITE

OCEANOGRAPHIC FEATURES (CONT)

OCEAN DYNAMICS

	6'' METRIC CAMERA	MULTI-BAND CAMERA	RADAR SCATTER-OMETER	MICRO-WAVE IMAGER	INFRARED SCANNER	MICRO-WAVE RADI-OMETERS	IMAG-ING RADAR	INFRARED RADI-OMETER	EXPERI-MENT AREA	SURFACE DATA SOURCE	USER OR ANALYSIS GROUP	OBSERVA-TIONAL REQ
SEA STATE	S		P	P		S	S		BERMUDA	ARGUS ISLAND TOWER	NAVY/ESSA	**
									NOVEMBER	OSV SHIP		
									PAPA	OSV SHIP		
									DELTA	OSV SHIP		
									ECHO	OSV SHIP		
									GULF STREAM	AGOR IV, VI; ASWEPS A/C		
									GULF OF MEXICO	MINE DEFENSE LAB TOWERS		
									ESSA (BARBADOS)	OREGON II, ESSA SHIP		
UPWELLING	P	P		S	P	S		P	SAN DIEGO	AGOR V, SIO, NEL	NAVY/BCF	**
									EASTROPAC	JORDAN		
									TROPICAL ATLANTIC	UNDAUNTED		
CURRENTS	P	P		S	P	S	S	P	GULF STREAM	AGOR IV, VI; ASWEPS A/C ALBATROSS III	NAVY/BCF	** ***
									EASTROPAC	JORDAN		
									FLORIDA STRAITS	OREGON		

** OPERATE PRIMARY AND SECONDARY SENSORS ±3 MINUTES OVER TEST SITE
*** TIME SERIES DATA DESIRED VIA SUBSEQUENT ORBITS

OCEANOGRAPHIC FEATURES (CONT)
COASTAL FEATURES

	6" METRIC CAMERA	MULTI-BAND CAMERA	INFRARED SPECTROM-ETER	INFRARED SCANNER	MICRO-WAVE RADI-OMETERS	INFRARED RADI-OMETER	DAY-NIGHT CAMERA	EXPERI-MENT AREA	SURFACE DATA SOURCE	USER OR ANALYSIS GROUP	OBSERVA-TIONAL REQ
HYDROGRAPHY	P	P	S	S		P	P	ESSA (BARBADOS) FLORIDA STRAIGHTS BURMUDA	OREGON II, ESSA OREGON, U OF MICH MASS. INST OF TECH AGOR XI, ARGUS IS. TOWER	NAVY/ESSA	**
ESTURAINE DISCHARGE	P	P		P	S	P	S	GULF OF MEXICO	ALAMINOS	TEXAS A&M	** ***

** OPERATE PRIMARY AND SECONDARY SENSORS ±3 MINUTES OVER TEST SITE
*** TIME SERIES DATA DESIRED VIA SUBSEQUENT ORBITS

OCEANOGRAPHIC FEATURES (CONT)
ENVIRONMENTAL PREDICTION

	6" METRIC CAMERA	MULTI-BAND CAMERA	RADAR SCATTER-OMETER	MICRO-WAVE IMAGER	INFRARED SPECTROM-ETER	INFRARED SCANNER	MICRO-WAVE RADI-OMETER	IMAG-ING RADAR	INFRARED RADI-OMETER	DAY-NIGHT CAMERA	EXPERI-MENT AREA	SURFACE DATA SOURCE	USER OR ANALYSIS GROUP	OBSERVA-TIONAL REQ
SEA ICE	P	P	S	P	S	P	P	P	P	S	GREAT LAKES GULF OF ST LAWRENCE	ESSA SHIPS NAVY/COAST GUARD A/C & SHIPS	ESSA/NAVY/CG	** ***
SEA SURFACE TEMP				S	S	P	P		P		GULF STREAM ESSA (BARBADOS)	AGOR IX, XI OREGON DELAWARE II ALBATROSS IV ESSA SHIPS	ESSA	**
SEA STATE	S	S	P	P	S		P	S			BERMUDA NOVEMBER PAPA DELTA ECHO	ARGUS ISLAND TOWER OSV SHIP OSV SHIP OSV SHIP OSV SHIP	ESSA/NAVY	**

** OPERATE PRIMARY AND SECONDARY SENSORS ±3 MINUTES OVER TEST SITE
*** TIME SERIES DATA DESIRED VIA SUBSEQUENT ORBITS

OCEANOGRAPHIC FEATURES (CONCLUDED)

• CLOUD PATTERNS

	6" METRIC CAMERA	MULTI-BAND CAMERA	MICRO-WAVE IMAGER	INFRARED SPECTROMETER	INFRARED SCANNER	INFRARED RADIOMETER	DAY-NIGHT CAMERA	EXPERIMENT AREA	SURFACE DATA SOURCE	USER OR ANALYSIS GROUP	OBSERVATIONAL REQ
	P	P	P	P	P	P	P	SAN DIEGO NOVEMBER PAPA DELTA ECHO ESSA (BARBADOS) GULF STREAM	NEL, SIO, AGOR V OSV SHIP OSV SHIP OSV SHIP OSV SHIP ESSA SHIPS OREGON II ALBATROSS IV DELAWARE II AGOR IV, VI	ESSA	** ***

** OPERATE PRIMARY AND SECONDARY SENSORS ±3 MINUTES OVER TEST SITE
*** TIME SERIES DATA DESIRED VIA SUBSEQUENT ORBITS

Ground Truth Working Session

Dr. R. J. P. Lyon

A conference on ground measurements for the instrument and geologic teams was held on the Reno campus of the University of Nevada March 14-15, 1966. This was an attempt to establish certain test requirements before the field summer season commenced at Sonora Pass.

This two-day meeting was designed to identify the basic needs of each instrument group and how these needs might be accomplished. The reader is referred to Technical Letter No. 3 of the University of Nevada group in which these requirements are fully detailed. Requirements for the infrared (IR) spectrometer/radiometer experiment have been copied and included in this document as Table I.

Since that time attempts have been made by Stanford and by the University of Nevada to implement many of these measurements, particularly those dealing with the atmosphere. We have delegated the responsibility to the Nevada group to provide most of the ground truth measurements for the P3A IR spectrometer/radiometer experiment when this experiment has been used in the airborne mode. At test sites other than Sonora Pass and Mt. Lassen the ground truth measurements have been made by the Stanford group themselves.

In a recent study effort at Woods Hole considerable time was spent delineating the basic problems in remote sensing for geology, and methods by which these could best be solved in a research and development effort. Figure 1 is taken from this report and indicates that considerable effort should be devoted to the understanding of the geology of the outermost surface (or "optical depth", "skin depth", or "depth to opacity"). It is this surface skin layer which ultimately determines the response of the rocks to the remote sensors. Detailed study of Figure 1 indicates that the maximum effort should be devoted to the surficial geology, with only minor effort devoted to classical geological mapping. A similar minimum effort only should be devoted to the development of new remote sensing hardware. Over 80% of the total R&D effort is recommended be placed in understanding the ground truth data.

In order to relate these concepts to the operational aspects of the P3A aircraft, Figure 2 has been drawn. In this flow diagram the relationships between Stanford, University of Nevada and the Manned Spacecraft Center (MSC) on the IR spectrometer/radiometer experiment are clearly indicated. The stippled areas in the center of the diagram are those in which much more research and many more measurements are required.

the top left-hand corner of Figure 2 in the hachured area is shown the
rea of responsibility of MSC, for operational use of the combined
ckage (the Rapid Scan spectrometer, the radiometer (or PRT-5), the
resight camera, the aircraft hygrometer, and the aircraft data recording
stem). The next block indicates that the data from such an aircraft
eration flow through the MSC formatting computer to produce blocked
gital tapes immediately compatible with the Stanford IBM 360 computer
stem. The boresight and RC8 camera data are sent to Stanford to
tablish the precise ground position of the aircraft at any given time
eeded to ± 10 feet at 2000 feet). These data are used in an inter-
lation program in the Stanford computer to establish the aircraft
sition on an arbitrary ground grid, which is drawn on a base map
epared from high altitude photographs of the locality, taken (hopefully)
e same day. From these two outputs it is possible to relate any given time
s from the ASQ90 or from the various aircraft clock syctems in use at
e moment) to a portion of the map grid, and hence (through the relation-
ip shown as a vertical line) with the mapping and ground truth parameters
termined by the University of Nevada.

e identification of aircraft location on high altitude photographs and
the map grid, as well as the production of the computer reduced aircraft
ectra and all data analysis are the responsibilities of Stanford University.
the lower section in the left-hand and bottom edge of Figure 2, the
sponsibility areas of the University of Nevada are indicated.

the center of the diagram the attenuation of the emitted infrared
diation by the atmospheric column is measured, by the use of weather
ations and, when used together with the aircraft hygrometer, provide
profile of the water vapor in the airpath between ground and aircraft for
e computers at Stanford. The field data collection is well in hand but
e aircraft systems need improvement. The second block (Surface Skin
mpositions) is determined by measurements of soil moisture, vegetation
unt and particle size. These surface skin compositions are then related
hrough the aircraft time system) to surface geology (along the aircraft
ack) integrated over the field of view of the equipment (0.3°) at any one
stant of time. This is one of the major ground truth measurements which
st be made in greater detail than is in present practice.

e lower section of Figure 2 shows how determination of rock type and
e pattern (or structure) and distribution of rock types ar. lated
rough field geology mapping to a basic geological map. A t. al
ological map is a subsurface map and generally does not show, for example,
e position of snow banks, sand dunes, and other surficial cover. These
l affect the "target", which is the surface integrated over a field of
ew of the instruments. The vertical time-linkage between the University
Nevada operations and the MSC operations of the aircraft is essential
nd will be brought out in a later chart) as ground truth is only useful
ere the aircraft passed in its flight pattern.

more detailed analysis and flow chart of the operation is shown in
gure 3. This rather complicated diagram starts in the center left-hand

side with an Experiment Definition, a Site Selection and a specific Target Selection, which were confirmed at the preflight Mission Briefing approximately 14 days before the flight. The P3A flight then occurs and starts the flow diagram into operation.

In the center of the diagram one sees the boresight camera being triggered by output from the spectrometer and their mutual relationship with the radiometer (presently the PRT-5). The aerial cameras give the aircraft location. These locations are compared then with the target selections and the ground truth measurements made by the University of Nevada. The area of responsibility for the Nevada group is shown in the upper hachured segment. Laboratory work, following the aircraft flight, will enable the University of Nevada to prepare Rock Type analyses using thin section and point counting and to provide Stanford with a modal (or mineralogical) analysis.

The x-ray fluorescence unit yields a chemical composition of the rocks from which one can determine a "normative" or theoretical mineral composition. Both of these analyses are fed into the block labeled "Data Analysis". Again it is most important that the samples used in the determination of the rock type and chemical composition be those which are exactly (or at least adequately represented) along the flight lines actually flown.

In the center panel we see the relationships between the aircraft operation at MSC and the data handling design responsibilities of Stanford (under Dr. Roger Vickers). The center hachured and stippled area shows the detailed experimental design (which originated at Stanford) and its execution in an aircraft flight and subsequent data reduction performed at MSC. Digital recording is still not installed in the aircraft although we are already installing it for our ground operations. The digital radiometer and spectrometer outputs are sampled in the computer by the signal from the edge coding around the periphery of the filterwheel in the spectrometer. This pulsed signal is used to trigger the digital sampler in the computer. This in turn produces an IBM 360 tape formatted to the Stanford pattern. This tape is then sent to Stanford wherein spectra are produced from programs operating on the Stanford computer.

These spectra are the single most important product of the entire flight. An on-line program called CORRCO (a correlation coefficient program, see SRSL Technical Report 67-1) is used, and this produces a ranked, rock-type analysis as seen on the right-hand side. Other Stanford programs are used by Switzer in a step-wise discriminant function (or adaptive learning) program which learns from standard spectra and identifies rock classes on a probability basis. The correct class is assigned to each incoming aircraft spectra. Another rock-type listing is produced and this, in turn, is compared with the CORRCO rock-type ranking, in the Data Analysis block. A further program is utilized by Switzer at Stanford in the mineral analysis program to produce a "modal" (or mineralogical) analysis as its end product. This also is compared through the Data Analysis block with that derived by rock-type analysis by the University of Nevada.

This is the program design diagram. At present few of the cycles have been completed for Mission 56 as considerable portions of the data are not yet available. Modal analyses of thin section material have not yet been prepared but a number of useful chemical compositions and normative analyses have been received. These however are percentages of theoretical minerals and not the actual minerals occurring in the rock. In addition, most of the samples which have been so far analyzed are not from this year's flight lines. This is not meant as a negative statement, but to indicate work yet to be done on one mission. We are all in a learning situation with "ground truth", and working responsibilities and tasks are continually becoming more clearly defined.

In the area represented by the center block called "Aircraft Location" we have also had many problems due to the malfunction of the boresight camera. We have had to revert to an aircraft location method which utilizes the RC8 cameras which trigger every five seconds. These cameras carry their own clocks and it is possible with a fair degree of precision* to interpolate spectral start times between individual RC8 frames to locate the 300 spectra which occur between each RC8 photograph. The RC8 cameras were locked in position to the aircraft frame and were not corrected for drift in order to have them record as accurately as possible the nadir beneath the line of sight of the spectrometer.

In summary some points to be made are shown in Table II as a listing of axioms for ground truth operations. These are:

a. Ground truth data are only useful along the aircraft ground track.
b. Weather data are only useful at flight time.
c. Water content in the air and on the ground is the single most important parameter to be measured.
d. Ground truth data are only useful if they can be used in subsequent statistical analysis of the data.

In conclusion, it is still necessary at present to make a considerable number of ground truth measurements. It is perhaps debatable how many should be made prior to aircraft flight, during aircraft flight, or following the aircraft flight. In some cases the seasonal conditions preclude making these measurements after aircraft flight, particularly when one considers the time required between the aircraft flight and receipt of the photographic data by which aircraft tracking must be determined. One must then add time for a considerable amount of work involved in transferring camera center points from the RC8 camera and in locating these on the ground. It can be estimated that approximately 2-4 weeks effort would be required after an aircraft flight and prior to accurate ground location being obtained along the aircraft track.

* ($\pm$ 25 feet) 180 Kts. = 300 feet/sec. FOV of spectrometer is 0.3° or 5 m radians, or 10 feet at 2000' clearance. A/C smear is 50 feet in the 150 msec between spectra totalling 10 x 60 feet/spectrum.

We must more fully understand the total system, how the ground truth parameters and the subsurface geology (as shown on a typical geological map) interact in the surficial skin geology, and in turn how the atmosphere between the aircraft modifies these signals. We must not neglect the effects of the aircraft data system and how final output from the computers further changes the data. After all, "success" is the right relationship between the output from the computers and the final output from the ground truth measurements. Before this becomes possible we are going to have to face up to the collection of a considerable amount of possibly redundant data. In addition a strong plea must be made for a more sophisticated ground measurement system. It is already fairly clear that even measurement of water vapor content between an aircraft and the ground is an extremely difficult and quite sophisticated meteorological experiment, not yet performed by meteorologists with a degree of local and temporal precision requested by this experiment.

APPENDIX

Computer Analysis of Ground Truth Data

Analysis of Stanford 1965 meteorological data has been made by cross correlation methods. Several attempts have been made previously to search for meaningful patterns in our 1700 sets of ground truth data, which would relate directly to the results of the infrared spectral matching process. One such report appeared in our first semi-annual report a year ago (May 10, 1966, p. 15) and another was summarised in the First Annual Report (November 1, 1966) on page 4 and in detail on pages 54-56 of that report. At the latter time we felt that we could see no effect on the outcome of the spectral matching process which would be directly related to meteorological conditions present at the time the spectra were taken.

Intuitively, this seems to be the wrong conclusion, and so we have made a further, more detailed analysis of these field data. One answer to which we attribute some credence is that the spectra are themselves so noisy, due to the microphonic condition of the Cu:Ge detector (See SRSL Tech Report 67-3) that any further perturbations introduced by "noise" in the weather variables cannot be seen. In this manner one can truthfully say that...."the use of the....[weather]... variables did not lead to a significantly better classification into rock types." (1st Annual Report, p. 4)

The present study was to all intents and purposes a "shot-gun" approach. We collected all the available data and found we had 2 groups.

Group I Those with data for 17 variables (275 samples)

Group II Those with data for 23 variables (252 samples)

A cross correlation program was run in the computer with these groups of data and a triangular coefficient matrix prepared for each group (pages A3 and A4). Suitable stippled patterns indicate the 0.25, 0.4, and 0.6 coefficient levels. No confidence level was run by

this program so we are not sure which numbers are significant at the 95% level, for example. A quick glance will show that for 250 samples of 17 or 23 variables each, the stippled levels are conservative.

Of more significance is the analysis following in Tables X A & B, where we have tried to segregate relationships which have obvious character (even redundancy in some cases) from those which might have experimental significance. Many associations can be explained by the temporal pattern of daily or yearly activity (geographical locations or altitudes for example) as we moved from test site to test site.

Sequence of Test Sites - 1965 Field Period

Date (Day) (1965)	Location (California)		Altitude/S.L.	Rock Type	Tape No.
8/12 (224)	Pacific Coast	(PGLHO1)	30	Granite	1
8/13 (225)	Pacific Coast	(PGLPO1)	30	Granite	2
8/18 (230)	Donner Pass	(DPGCO1	6825	Granite	2
9/25 (268)	Mono Lake	(MCABO1)	7310	Granite	3
9/26 (269)	Mono Lake	(MCSCO1)	8680	Rhy. Pumice	3
9/27 (270)	Mono Lake	(MCSCO5)	8680	Rhy. Pumice	4
9/28 (271)	Mono Lake	(MCNCO1)	6800	Rhy. flows	4
10/1 (274)	Mono Lake	(MCNCO1)	6800	Rhy. flows	4
10/2 (275)	Mono Lake	(MCCCO1)	7629	Bas. Cinder	5
10/3 (276)	Mono Lake	(MCSCO5) (MCSC10)	8680	Rhy. Pumice	6
10/4 (277)	Mono Lake	(MCSBO1)	6440	Pum. Beach	6
10/14 (287)	Tioga Pass	(TPOPO1) (TPLDO1)	8500	Granite	7
10/15 (288)	Mono Lake	(MCBPO1)	6520	Basalt Cone	8
10/23 (296)	Pisgah Crater	(PCWRO1,02,03)	2515	Basalt Cone	8,9
10/24 (297)	Pisgah Crater	(PCTPO1) (PCERO1,02)	2543	Basalt Cone	9,10
10/25 (298)	Pisgah Crater	(PCLL12,13,14)	1888	Basalt flows	10
10/26 (299)	Pisgah Crater	(PCLL15)	1888	Basalt flows	10

WEATHER DATA, INSTRUMENT VARIABLES, MODEL ANALYSIS AND CROSS-CORRELATION RESULTS

GROUP I - 17 VARIABLES

DAY	LAPSE	RANGE	ALT	ROCK T	BB	SAND T	AIR T	RH	WIND V	PRD	CS	BP	QTZ	VOID	TAPE	SPEC	
	-.02	.19	.007	.15	.20	.15	.28	-.78	-.01	-.34	.60	.03	-.35	.04	.89	.20	DAY
		.25	.21	-.20	-.20	-.28	-.26	-.04	-.21	-.12	.12	-.14	-.10	-.14	-.15	.38	LAPSE
			.12	-.16	-.16	-.10	-.14	-.03	-.14	-.04	-.03	-.04	-.10	-.12	.10	-.0	RANGE
				-.42	-.67	-.59	-.62	-.20	-.16	-.25	.30	-.32	-.02	.23	.32	.05	ALT
					.76	.81	.73	-.14	.19	-.01	-.02	.27	.04	.29	.21	-.02	ROCK T
						.84	.85	-.06	.13	.10	-.10	.35	.00	.24	.36	.03	BB
							.84	-.09	.18	.08	-.20	.21	.09	.32	.49	-.10	SAND T
								-.16	.10	.06	-.04	.25	.03	.24	.44	.10	AIR T
									-.01	.30	-.49	.20	.28	-.02	.60	-.24	RH
										.05	-.13	-.24	.05	.04	.03	-.19	WIND V
											-.19	-.22	.10	.09	-.27	-.16	PERIOD
												-.18	-.19	-.10	.36	.12	GAIN
													-.01	.00	.23	-.16	BND PASS
														-.14	-.33	-.12	QTZ
															.07	-.19	VOID
																.08	TAPE
																	SPEC

WEATHER DATA, INSTRUMENT VARIABLES, MODEL ANALYSIS, COMPUTER OUTPUT AND CROSS-CORRELATION RESULTS

GROUP II - 20 VARIABLES

DAY	LAPSE	RANGE	ALT	ROCK T	BB T	SAND T	AIR T	RH	WIND VEL	SG-4 PRD	SG-4 GAIN	SG-4 BP	QTZ	VOIDS	E	E var	CORRCO	TAPE	SPECTR	
	.02	.15	.04	.1	.19	.18	.27	-.79	-.02	-.34	.61	.02	-.35	.05	.01	.10	-.27	.90	.22	DAY
		.22	.20	-.17	-.19	-.27	-.26	-.05	-.10	-.14	.14	-.13	-.11	[illegible]	-.20	-.09	.15	-.11	[illegible]	LAPSE
			.10	-.11	-.09	-.05	-.10	.01	-.11	-.05	.10	-.01	-.10	-.13	-.18	-.05	-.12	.14	.03	RANGE
				-.61	-.67	-.60	-.62	-.21	-.16	-.26	-.32	-.32	-.02	-.23	.06	.05	.03	-.30	.03	ALT.
					.76	.81	.73	-.14	.18	-.01	-.03	.27	.04	.11	-.04	-.07	-.08	.10	.005	ROCK T
						.86	.86	-.08	.13	.10	-.13	.35	-.005	.24	.01	-.09	-.07	.36	.08	BB T
							.84	-.09	.18	.08	-.22	.21	.09	.34	.04	-.01	-.12	.29	-.08	SAND T
								-.16	.10	.06	-.06	.25	.03	.25	-.06	.04	-.13	.43	.13	AIR T
									-.003	-.31	-.53	.20	.28	-.04	-.18	-.17	.10	.63	-.25	RH
										.02	-.16	-.26	.06	.05	.10	-.07	-.06	.02	-.21	WIND VEL
											-.22	-.22	.10	.10	.17	-.01	.003	-.27	-.16	PERIOD SG-4
												-.20	-.20	-.10	-.03	.14	-.13	.39	.36	GAIN SG-4
													-.02	-.01	-.29	-.19	-.03	.22	-.17	BP SG-4
														-.16	[illegible]	-.07	.18	-.35	-.13	QTZ
															.29	.14	-.17	.08	-.20	VOID
																.23	-.24	.08	-.37	E Bar
																	-.17	.08	-.05	E var
																		-.34	.16	CORRCO
																			.10	TAPE
																				SPECTR

The tables A-K which have been prepared from this analysis are as follows. Experimentally significant tables are indicated by an asterisk(*).

A. Logically explainable by parameter involved
B. Explainable by relationships between meteorological and rock temperature.
C.* Experimentally significant relationships not immediately explainable.
D Directly related to the yearly sequence of site chosen for field work.
E. Related to daily work pattern at sites.
F. Related to sequential breakdown of detector in SG-4.
G.* Instrumental Relationship
H. Modal Quartz percentage
I. Emissivity average (E Bar)
J. LMSC correlation coefficient (CORRCO)
K. Correlations ranked by value (over 0.24).

The following notes are important to the analysis of tables A-K:

1. Tape No. - Serially from Tape 1 to Tape 10
2. Day - day of the year, see sequence table above
3. Temperatures - all contract, using DIGITEC thermistor probes in °C
   (Sand)
   (BB)
   (Rock)
4. Air Temperature - 6 inches off ground in shade, DIGITEC thermistor
5. Relative Humidity - Percentage, Honeywell RH Indicator meter, type W611A used with 5 ranges of probes
6. Altitude - taken from topographic maps
7. SG-4 parameters - electronic settings off unit, period in seconds
   (Gain)
   (Period)
   (Bandpass)
8. Spectrum No. - sequential spectral group along any one tape
9. Lapse Time - time in minutes since last filling of liquid helium cryogenics (appeared to be directly related to noise increases in the field)

10. Quartz - modal analysis, prepared by counting 1500 grains in a thin section under the microscope, can be considered to be an approximation of rock type
11. CORRCO - See footnote table K, correct answer for that rock type target was used, not the highest value
12. VOIDS - modal analysis as for quartz. Both Pisgah basalts and Mono Crater pumice had high void values which may have acted to cut down "spectral contrast".
13. E BAR - average emittance ratio values in LMSC program
14. E Var - variance of emittance ratio in LMSC program
15. Wind velocity - in miles per hour, hand held "venturi" gauge
16. Range - in feet, if over 1000, taken from maps.

TABLE X
CORRELATION STUDIES ON 1965 FIELD DATA

A. LOGICALLY EXPLAINABLE BY PARAMETER INVOLVED

Simply Explainable	Correlation Coefficient
1. Tape No. vs. Day of Year	(.90)
2. Sand Temperature vs. BB Temp.	(.86)
3. Sand Temperature vs. Rock Temp.	(.81)
4. BB Temperature vs. Rock Temp.	(.76)
5. Sand Temperature vs. Void %	(.34)
6. Rock Temperature vs. Void %	(.31)
Not so obviously related	
1. Sequential spectrum no. vs. lapse time	(.43) (should be higher but lapse Time returns often to zero)

B. EXPLAINABLE BY RELATIONSHIPS BETWEEN METEOROLOGICAL & ROCK TEMPERATURES

Simply Explainable	
1. Air Temperature vs. BB Temp.	(.86)
2. Air Temperature vs. Sand Temp.	(.84)
3. Air Temperature vs. Rock Temp.	(.73)
4. Air Temperature vs. Altitude Temp.	(- .62)
5. Average Emissivity ($\bar{E}$) vs. Void %	(.29)
6. Lapse time vs. BB, rock, air, Temp.	(-.17 to -.27)
Not so obviously related	
1. BB Temperature vs. Altitude	(- .67)
2. Sand Temperature vs. Altitude	(- .60)
3. Rock Temperature vs. Altitude	(- .41)
4. SG-4 Gain vs. Altitude	(.32)
5. Air Temperature vs. Day	(.27)
6. SG-4 Bandpass vs. Altitude	(- .32)

C. EXPERIMENTALLY SIGNIFICANT RELATIONSHIPS NOT IMMEDIATELY EXPLAINABLE

	Correlation Coefficient
1. LMSC Correlation Coefficient vs. Tape No.	(-.34) (Why?)
2. SG-4 Gain vs. BB Temperature	(.35) (Why not negative?)
3. Average Emissivity ($\bar{E}$) vs. SG-4 Bandpass	(-.29)
4. Average Emissivity ($\bar{E}$) vs. Void %	(-.29)
5. Quartz % vs. RH	(.28)
6. Quartz % vs. Day of Year	(-.35)
7. Average Emissivity ($\bar{E}$) vs. Lapse Time	(-.28)

D. RELATED TO THE YEARLY SEQUENCE OF SITES CHOSEN FOR FIELD WORK

1. Day No. vs. Relative Humidity	(-.79)
2. Tape No. vs. Relative Humidity	(-.63)
3. Tape No. vs. Air Temp.	(.43)
4. Tape No. vs. BB Temp.	(.36)
5. Quartz content vs. Day of Year	(-.35)
6. Tape No. vs. Altitude	(-.30)
7. Tape No. vs. Sand Temp.	(.29)

E. RELATED TO THE DAILY WORK PATTERN AT SITES

1. SG-4 gain vs. Sequential Spectrum No.	(.36) (not clear)
2. SG-4 period vs. Day of Year	(-.34)

F. RELATED TO SEQUENTIAL BREAKDOWN OF DETECTOR IN SG-4

1. SG-4 gain vs. Day of Year (whereas BBT vs. day is (.19))	(.63)
2. SG-4 gain vs. Tape No.	(.39)
3. SG-4 gain vs. Sequential Spectrum No.	(.36)
Uncertain Why Relationship Exists	
1. SG-4 gain vs. Relative Humidity (Day vs. RH is -.79) (Day vs. SG-4 gain is .63)	(-.53)

Uncertain Why Relationship Exists	Correlation Coefficient
2. SO-4 Period vs. Day of Year	(-.34)
3. SO-4 Period vs. Rel. Humidity	(.31)

G. INSTRUMENTAL RELATIONSHIPS

Clearly Related	
1. SO-4 Bandpass vs. BB Temp.	(.35) (not so clear)
2. SO-4 Period vs. SO-4 Bandpass	(-.22)
3. SO-4 Gain vs. SO-4 Bandpass	(-.20)
Clearly related and should be of other sign	
1. SO-4 Gain vs. BB Temperature	(-.13) (why negative?)
Unclear but probably should be of other sign	
1. SO-4 Gain vs. SO-4 Period	(-.22)

H. MODAL QUARTZ PERCENTAGE

Relationship Found	Correl. Coeff	Reason
1. Quartz vs. Day	(-.35)	Day vs. Tape (.90)
2. Quartz vs. Tape	(-.35)	
3. Quartz vs. RH	(.28)	Day vs. R.H. (-.79)
4. Quartz vs. E Average	(-.25)	

I. EMISSIVITY AVERAGE ($\bar{E}$)

$\bar{E}$ vs. Voids	(.29)
$\bar{E}$ vs. SO-4 Bandpass	(-.29)
$\bar{E}$ vs. Time Lapse	(-.28)
$\bar{E}$ vs. Quartz	(-.25)
$\bar{E}$ vs. LMSC CORRCO	(-.24)
$\bar{E}$ vs. E variance	(.23)
$\bar{E}$ vs. Range	(-.18)

J. LMSC CORRELATION COEFFICIENT (CORRCO)

	Correl. Coeff.
CORRCO vs. Tape No	(-.34)
CORRCO vs. Day	(-.27)
CORRCO vs. E	(-.24)
CORRCO vs. Quartz	(.18)
CORRCO vs. Voids	(-.17)
CORRCO vs. E variance	(-.17)
CORRCO vs. Spectral Sequence	(.16)

CORRELATIONS RANKED BY VALUES	Group II (23 variables includes LMSC output)	Group I (17 variables)
Tape number vs. Day	.90	.89
Sand T vs. BB Temp	.86	.84
Air T. vs. BB Temp	.86	.85
Air T. vs. Sand Temp	.84	.84
Sand T. vs. Rock Temp	.81	.81
RH vs. Day	-.79	-.78
BB Temp vs. Rock Temp	.76	.76
Air Temp. vs. Rock Temp	.73	.73
BB Temp vs. Altitude	-.67	-.67
SG-4 Gain vs. Day	.63	.60
Tape No. vs. R.H.	-.63	-.60
Air Temp vs. Altitude	-.62	-.62
Sand Temp vs. Altitude	-.60	-.59
SG-4 Gain vs. R.H.	-.53	-.49
Tape No. vs. Air Temp	.43	.44
Spectrum no. vs. Lapse Time	.43	.38
Rock Temp vs. Altitude	-.41	-.42
Tape No. vs. SG-4 Gain	.39	.36
Tape No. vs. BB Temp	.36	.36
Spectrum No. vs. SG-4 Gain	.36	.32
SG-4 Bandpass vs. BB Temp	.35	.35
Quartz vs. Day	-.35	-.35
Voids vs. Sand Temp	.34	.32
SG-4 Period vs. Day	-.34	-.34
Tape No. vs. CORRCO(*)	-.34	(not used in Group I)
SG-4 Gain vs. Altitude	.32	.30
SG-4 Bandpass vs. Altitude	-.32	-.32
Voids vs. Rock Temp	.31	.29
SG-4 Period vs. R.H.	.31	.30
Tape vs. Altitude	-.30	-.32
Tape vs. Sand Temp	.29	.29
Ē vs. SG-4 Bandpass	-.29	
Ē vs. Voids	.29	
Quartz vs. R.H.	.28	.28
Ē vs. Lapse Time	-.28	
Air vs. Day	.27	.28
SG-4 Bandpass vs. Rock Temp	.27	.27
CORRCO(*) vs. Day	-.27	
Sand Temp vs. Lapse	-.27	-.28
Tape No. vs. SG-4 period	-.27	-.27
SG-4 Period vs. Altitude	-.26	-.25
SG-4 Bandpass vs. Wind Vel.	-.26	-.24
SG-4 Bandpass vs. Air Temp.	.25	.25
Voids vs. Air Temp	.25	.24
Spectral No. vs. R.H.	-.25	-.24
Ē vs. Quartz	-.25	

*CORRCO - Correlation coefficient used was from the LMSC output. The value used was that which correctly matched the target rock type, for the same rock type in the library, and not necessarily the maximum value of CORRCO.

TABLE I

PRELIMINARY BASIC REQUIREMENTS AS DEFINED BY DR. R. J. P. LYON FOR THE INFRARED TEAM

March 14, 1966

A. Field Solid or Loose Material - Surface Only

1. Roughness using Form Tool-NS and EW profiles. Make profile and then record to $\pm$ 0.5 mm, by:

   a. Spray paint (not pencil).
   b. Photo sensitive paper (visicorder rolls) on a sheet of rolled chart paper for late reduction by curve follower methods.
   c. Fabric or texture - describe, draw, and also photograph.

2. Surface sample down to 1 cm depth

   a. If rock, cut 3" x 3" slab and place in cotton in box (mail to Lyon).
   b. If loose, pour black plastic mold for vertical sectioning. Send half to Lyon for modal analysis of polished slab.
   c. Note color, weathering degree, glacial polish, desert varnish, etc., in field.

3. Photometric backscattering in field

   Produce graph at least in N-S and E-W planes. If continuous trace is not available, then position lamp source at +60° and take readings with PE cell at 0, 30, 60, 90, 120, 150, and 180°. (May have to be done after dark if instrument is not adequate.)

4. Emissivity box measurements in field. Two at each grid point. (Need values to $\pm$ 0.05)

5. Color photos vertical. Two each (with original set for Lyon) of:

   a. Kodachrome II or Ektachrome
   b. Aero Infrared Ektachrome (CD)

   If possible:

   c. From 2 feet and 10 feet
   d. Stereo-shifted 3" at 2 feet
   e. Stereo-shifted 12" at 10 feet

   Use "b" for Lichen and vegetative counts.

TABLE I (contd)

6. Moisture - if possible in field (especially on flight days)

   a. Surface to 1 mm.
   b. Other layer at 1-2 cm depth.
   (Accuracy needed ± 5% of amount present)

7. Atmospheric - and micro - meteorology (especially on flight days).

   Wind velocity to 1 mph, RH to ± 0.5%. Air temperature (°C) at 1 1/2 meter/ground (to ± 0.2°C), Barometric pressure (to ± 0.5 inches), all taken at a single base-camp with respect to time of day in a 24-hour cycle. Repeated once a week, but specifically performed on flight days 12 hours before to 12 hours after flight. (For colors, use GSA Standard Rock Color Chart.)

B. Laboratory

1. Modal analysis, major minerals - 1500 point count. If fine grained, use thin section(s), if coarser, use a polished slab (+ a thin section to identify the ground mass). Bring piece back for slab polishing.

   Identify:

   a. To ± 1% of amount present - quartz, K-spar, plagioclase (with An% to ± 5%) pyroxene, amphibole, olivine, mica, glass and voids. Determine bulk rock S.G.
   b. To ± 5% of amount present - opaques, color index. (Identify opaques if practical.)
   c. Fabric texture, note, preferred orientation of grain pattern in soil using:

      (1) Bulk "parent" rock at some small depth below weathering rind and/or soil
      (2) Actual surface chip (or layer of soil) to ± 1 mm depth.

2. Chemical analysis (X-ray, spec. or emission spec.). Record as oxides to ± 0.5% of amount present. Si, Al, K, Na, Ca, Mg, Fe(T), (± Fe_2O_3 and FeO if possible) Ti etc. to ± 5% of amount present. Use 1 lb. specimen, pulverise and mix thoroughly. Send 10 grams in bottle to Lyon. Get powder SG as well as bulk rock SG.

NASA-S-67-7768

TABLE II

AXIOMS FOR GROUND TRUTH

- GROUND DATA ONLY USEFUL WHERE THE AIRCRAFT ACTUALLY WENT. THIS MAY NECESSITATE POSTFLIGHT GEOLOGY AND SAMPLING. THIS IS PARTICULARLY SIGNIFICANT FOR NON-IMAGING LINE-TRACE EQUIPMENT LIKE IR SPECTROMETER, RADIOMETER AND MICROWAVE RADIOMETERS
- WEATHER DATA IS ONLY USEFUL AT FLIGHT TIME AND FOR 24 HOURS PRIOR TO FLIGHT IF GROUND IS WET
- WATER CONTENT IS THE SINGLE MOST IMPORTANT PARAMETER TO BE MEASURED BECAUSE OF ITS HIGH ABSORPTION COEFFICIENT AND EFFECT IN THE DIELECTRIC CONSTANT
  - MOISTURE ON GROUND
  - MOISTURE DOWN TO SKIN DEPTH, f (λ)
  - WATER VAPOR IN TOTAL AIR PATH FOR IR, AND ITS DISTRIBUTION WITH TIME
  - LIQUID WATER DROPLET SIZE AND FREQUENCY IN AIR PATH FOR MICROWAVE AND RADAR WAVELENGTHS
- GROUND TRUTH DATA ARE ONLY USEFUL IF THEY CAN BE USED

NASA-S-67-7767

R & D EFFORT MIX
RECOMMENDED FOR REMOTE SENSING IN GEOLOGY

		EFFORT IN LAB	EFFORT IN FIELD	DATA FROM AEROSPACE	%
INTERPRETATION	CLASSICAL GEOLOGY	2%	2%	2%	6
	SURFICIAL GEOLOGY*	6%	15% (A)	12% (B)	33
	INTER-RELATING REMOTE SENSING DATA TO SURFICIAL GEOLOGY	15% (A)	15% (A)	12% (B)	42
HARDWARE	REMOTE SENSING TECHNOLOGY AND HARDWARE	4%	8%	7%	19
		27	40	33	100

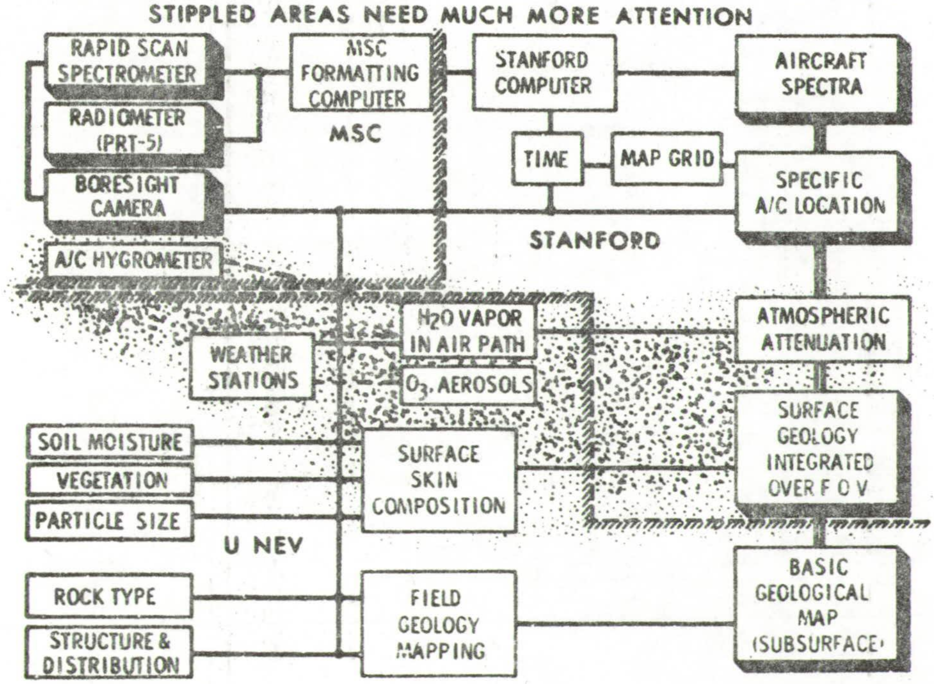
A, B IMPLIES A TIME-STEP SEQUENCE

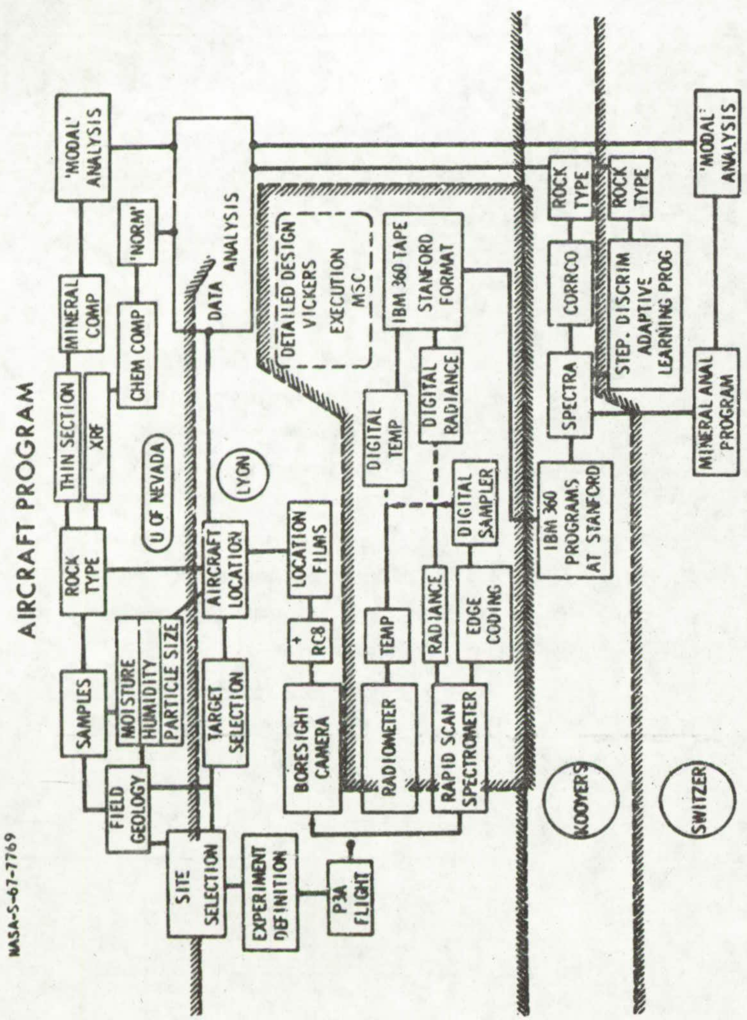
* SURFICIAL GEOLOGY = 'OPTICAL DEPTH', 'DEPTH TO OPACITY', 'SKIN DEPTH', GENERALLY $\frac{\lambda}{10}$, TO 10 λ

NASA-S-67-7766

STANFORD / U NEVADA / MSC RELATIONSHIP ON INFRARED SPECTROMETER EXPERIMENT -- P 3A AIRCRAFT

STIPPLED AREAS NEED MUCH MORE ATTENTION





Texas A&M University

Department of

OCEANOGRAPHY

GROUND TRUTH REQUIREMENTS FOR REMOTE SENSING OF OCEANOGRAPHIC FEATURES

By

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TABLE OF CONTENTS

Research conducted through the
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A&M Project 286-13

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Report prepared
22 November 1967

ABSTRACT

For almost two years the Spacecraft Oceanography Project (SPOC) at Texas A&M University has been studying the use of remotely sensed data from aircraft to determine oceanographic features in the Mississippi Delta region of the Gulf of Mexico. Past experience has shown that the present ground truth program is inadequate due to the nonavailability of research ships and other sophisticated instrument platforms. All the important physical parameters on the sea surface and in the atmosphere above should be measured. Recommendations: The Earth Resources Survey Program (ERSP) should lease or purchase additional research ships. Steps should be taken to secure international cooperation in making surface surveys of test site areas. Portable instrument packages should be made that may be placed on non-research ships. ERSP should standardize the calibration of the sensors being used on ship and aircraft.

GROUND TRUTH REQUIREMENTS FOR REMOTE SENSING OF OCEANOGRAPHIC FEATURES

BACKGROUND

The Spacecraft Oceanography Project (SPOC) at Texas A&M University was initiated in early 1966 under the Department of Oceanography. Its goals are to determine the utility of using remote sensors in studying the features of the Gulf of Mexico and specifically the Mississippi Delta area from airborne and Earth orbital heights, to develop techniques whereby these studies might be conducted, to nominate a group of remote sensors that have optimum use for oceanography and to design experiments to be conducted using satellite based sensors. The Department of Oceanography at Texas A&M University has been interested in the Gulf of Mexico and its features for some time. The region of the outflow of the Mississippi River (the second largest in the world) was selected as a test site for the Earth Resources Aircraft Survey Program due to many reasons. Firstly, it is an area where large spatial and temporal variations occur in the important parameters measurable by classical oceanographic techniques. Secondly, it is near Texas A&M University and MSC/NASA Houston where the aircraft are based. Lastly, it is an area in which a fair amount of classical oceanographic research had been conducted in the past.

To date seven flights by NASA aircraft have been made over the Mississippi Delta, Site #128. Only two of these flights have been supported by surface ships collecting data, and in only one of these flights was the data obtained anywhere near the amount and extent to satisfy the requirements of a ground truth program.

There are several areas of study under SPOC at Texas A&M University that are not concerned with the Mississippi Delta test site. One is a study aimed at correlating cloud patterns with oceanic features in the Gulf of Mexico. NIMBUS and ESSA data are being used in these studies using ground truth data from the various cruises of Alaminos for ground truth. Other studies are concerned with the heat and water budgets at the air-sea interface and periphery of the Gulf of Mexico.

PURPOSE AND SCOPE OF THIS PAPER

The purpose of this paper is to present a summary of our past experiences in gathering ground truth data from an operational point of view in support of the Earth Resources Aircraft Survey Program in oceanography. The material herein is intended to be supplementary in nature. Bearing in mind our limited viewpoint as regards the total Spacecraft Oceanography project's needs, the recommendations and comments contained in this paper apply only to our experiences in the Gulf of Mexico and specifically the Mississippi Delta region. It is not intended to be a comprehensive survey of the overall ground truth requirements of the Earth Resources Survey Program in oceanography.

GENERAL REQUIREMENTS OF GROUND TRUTH PROGRAM

The primary requirement for any ground truth program is that sufficiently accurate measurements be made of all the important parameters at the surface and in the subsurface under study and of all other parameters affecting the readings of the various sensors. In this way one may be able to show a correlation (positive or negative) between what is happening or present in the area of interest and what the remote sensors see from above.

Ideally, these determinations should be made synoptically--all at the same time. An exception of this principle could be taken if none of the parameters had changed during the period between the collection of remote sensed data and ground truth data.

In the case of oceanic surveys by remote sensors, only the temporal and spatial distribution of surface parameters such as temperature, salinity, roughness (sea state), biological activity, oils, etc. need be determined. The task of correlating these surface parameters to subsurface oceanographic phenomena is given to classical oceanographic survey.

It is possible that ground truth may be obtained by using measurements from remote sensor systems that are, or become reliable as the program develops. The IRT is an example of such a sensor. Another example is that it is possible to obtain ground truth on the roughness of the sea surface from the sun's glitter patterns as seen photographically. Low altitude flights may be able to provide ground truth for high altitude measurements.

EXISTING GROUND TRUTH CAPABILITIES

Under the present procedures, gr und truth is obtained by ships or fixed platforms in the Mississippi Delta. Since our SPOC project has no control over the scheduling of oceanographic research vessels except the Alaminos (Texas A&M University oceanographic research vessel) which is scheduled on a yearly basis in advance, it has been difficult to obtain simultaneo surveys of the test site by airplane and ship.

Due to the fluid nature of the oceans, ground truth measurements must be made synoptically or quasi-synoptically with the aircraft measurements or else their value is lost. This is the most significant difference between the requirements of a ground truth program supporting oceanographical studies and for one supporting land studies.

In the past, the problem of coordinating aircraft flights and ships cruises plus occasional inclement weather or equipment malfunction has resulted in a small percentage of successful ventures.

When the Alaminos is in the test site, the following types of data are collected:

1. Temperature of the skin of the ocean's surface is measured continuously by a Barnes IRT at a height of approximately five meters and recorded on a strip chart. A backup IRT is available in case of malfunction.

2. Total cloud cover is recorded by a time-lapse hemispheric (fisheye) camera.

3. Air temperature and dew-point temperature are recorded continuously at a height of ten meters.

4. Surface wind speed and direction is observed by personnel on-board and recorded in a log.

5. Standard meteorological surface observations are recorded in a log.

6. The temperature of the top layer (subsurface) of the water is monitored continuously by a resistance thermometer and recorded on a strip chart.

7. Sea surface salinities are continuously measured by a salinity cell and recorded on a strip chart.

8. Vertical distributions of salinity and temperature are measured by salinity, temperature and depth devices (STD's).

9. Additional vertical distributions of temperature are obtained by bathythermographs (BT's) which are rugged and reliable but not as accurate as the STD's.

Oceanographic research vessels can survey only a few lines in a few days so that synoptic coverage cannot be obtained by the one ship alone neither can one ship satisfactorily survey even an area as small as the Mississippi Delta region.

The other aircraft missions have been supported feebly by small boats and fixed oil platforms.

To illustrate the past problem of obtaining ground truth, the

following summaries of missions in the past are included:

1. July 1966 - Ground truth was collected in a very limited part of the test site area by a commercial charter boat, the Playboy, which had a graduate student on board to obtain some BT's and bucket-temperature measurements.

2. October 1966 - Personnel from MIT and the University of Nevada were on hand to make colorimetric and IR temperature measurements of the Mississippi River outflow. Unfortunately the aircraft mission was rained out after only a brief flight.

3. December 1966 - A partially successful aircraft flight coupled with no ground truth made this mission of questionable value.

4. February 1967 - A completely successful mission was flown by the aircraft; but, no ground survey of the area was possible due to the non-availability of ships.

5. April 1967 - Ground truth teams were prepared to survey the test site area, but the aircraft could not fly due to equipment malfunction.

6. June 1967 - This mission was similar to the February mission.

7. August 1967 - For the first time quasi-simultaneously surveys were made of the test site by both the NASA P3A and the Alaminos. To point out the differences between aircraft survey and ship survey, it took the Alaminos two days to survey the three lines surveyed by the NASA P3A in a period of two hours.

MEASUREMENTS REQUIRED

One of the goals of SPOC at Texas A&M University is to develop techniques whereby meaningful oceanographic measurements can be made from satellite based sensors. To accomplish this, the effects of the atmosphere in attenuating and redistributing the radiations from the ocean's surface must be considered. Thus, detailed knowledge about the temperature structure and composition of the atmosphere over the test site area must be obtained by the ground truth program. This implies the use of various atmospheric sounding devices such as radiosondes, rawinsonde, tethered balloons, wire sondes and rockets.

The sheer size and number of required measurements and instrument systems dictates the use of large platforms on which these instruments are to be based. The most logical platform is the ship. These vessels cost from two to six thousand dollars per day to operate. Also, the number of research vessels in the United States is quite limited.

In some cases, fixed platforms such as oil platforms may be used to hold ground truth instruments; however, these would be inflexible and necessarily located close to shore lines.

Aircraft may be used to provide ground truth in a number of ways in addition to those already mentioned. Dropsondes (atmospheric profiles) and expendable BT's may be dropped from ground truth aircraft along with buoys to monitor automatically water temperature, salinity and meteorological conditions at the air-sea interface.

With the above comments in mind, the following is a list of the measurements required (*indicates that these measurements are currently being made satisfactorily in our present ground truth program).

1. Amount and spectral distribution of direct and indirect solar radiation impinging upon the ocean's surface.

2. Net terrestial radiation near the ocean's surface.

3. Downward radiation from the sky in the microwave bands used by the passive microwave radiometers.

4. Vertical distributions of temperature and water vapor in the atmosphere over the test site from surface to 50,000 feet.

*5. Cloud coverage.

*6. Horizontal distribution of water-surface temperature and salinity in the test site area.

7. Magnitude and direction of water vapor flux and sensible heat flux at the air-sea interface.

8. Complete surface meteorological observations.

9. Accurate navigational equipment.

10. Colorimetric analysis of surface waters.

11. Amount of suspended material (sediments) in the surface water.

12. Unified data management system on board the ship using a common time base to enable correlation of ground truth data. This system should include analog-to-digital conversion and digital storage on magnetic tapes. All the measurements should be stored in digital format to provide easy reduction and use.

13. A system to allow real time comparison of ship and aircraft data at points of coincidence.

14. Development of portable or suitcase instrumentation adaptable to many different types of vessels.

Although the above requirements have been given in brief outline form, their importance to a remote sensing program cannot be over emphasized. Remote sensing itself consists of measuring a large area of the ocean surface on a very short-time scale. Although this has the obvious advantage of surveying large areas we must also know how representative our "instantaneous" picture is.

In the infrared or temperature picture a representative view requires that we must know the time change of heat flux from or toward the ocean surface (items 1, 2, 4, 5, 6, 7) in addition to vertical mixing at the surface. Without such information on both a spatial and temporal basis the temperature structure we describe by a remote sensor survey will have little meaning in any representative or scientific sense.

In addition to change at the ocean surface affecting the remote sensing approach to sampling the ocean surface, there is always the problem of looking through a sea of air. It is imperative that we know how the vertical temperature and moisture structure affects remote sensing equipment. The atmospheric pollutants can also play an important role in the "observed" surface temperature structure through selection, absorbtion and transmission. It is also possible that pollutants affect the representativeness of the surface temperature value on a time scale as well

as the actual measured value.

Similar problems exist for photographic interpretation. Factors such as water contaminants, surface roughness and even atmospheric pollutants can directly affect the apparent color of the water. In this aspect then, it is imperative to know the factor which lead to the color hues observed on the ocean surface (items 10, 11).

Microwave measurements are as sensitive, if not more so, to the same factors that must be considered for infrared measurements. In this aspect surface roughness is particularly important to signal return. Surface temperature and surface salinity effects microwave emission so that they also must be determined accurately before microwave data acquisition is realistic. An additional factor which must be considered, as in the case of the infrared measurements, is the sky radiation.

All the considerations stated above require adequate ground truth coverage.

The question might be raised as to why it is considered important to be able to determine the horizontal distribution of temperature, salinity and roughness on the ocean's surface. Studies at Texas A&M University have shown correlation between sea surface temperature patterns and currents. Most of the physical properties of sea water such as density, conductivity, dielectric constant, heat capacity and others can be obtained knowing its temperature and salinity. Roughness distribution can imply evaporation distribution. Finally, these parameters all enable estimates of the heat and water vapor flux into the atmosphere to be measured. This in turn affects long period weather forecasting.

SUPPORT OF MISSISSIPPI DELTA TEST SITE

Ground truth in the Mississippi Delta test site has been obtained in the past due to a combination of luck and persuasion. Research vessels are scheduled a year in advance; whereas, aircraft missions are scheduled quarterly. Since the principle investigators in Space Oceanography are not funded specifically for the maintenance of a fleet of vessels for use in the test site, vessels must be requested from the institutions under which they are controlled and many times the press of other research precludes their use at any given time and place. Apparently, the only solution is for funding to be made available for the leasing or purchasing of research ships specifically to be used to support the ground truth program of the Earth Resources Survey Program. Purchase of a fleet would involve a high initial capital investment; however, since the business of studying Earth from space is probably here to stay, the long-term economics of such a move fully justifies the initial investment. This needed fleet is not in existence today, and it is unreasonable to expect that the current fleet of oceanographic research vessels could do much to relieve the situation.

It appears that our ground truth problems lie not in the inadequacy of the instruments but in the nonavailability of the vessels on which to carry these instruments.

SPECIFIC RECOMMENDATIONS

Ship support

Since the major deficiency in ground truth support is simply lack of ship support it is recommended that NASA acquire the use of at least five support vessels to be used specifically for ground truth support during the next 5 to 10 years in this program. Furthermore it is recommended that these vessels be of the type used by the offshore oil platforms for logistic support. These ships are relatively inexpensive and available for either purchase or lease and lend themselves to the module concept of instrumentation. "Module" refers to the construction of instrumented vans which can be used in a manner to provide great flexibility. This concept has been successfully used by the Westinghouse Corporation on board their ship which supports their deep submergence program. Discussions with personnel from this ship revealed that the van system is very seaworthy and flexible. We estimate that each vessel with a basic suite of instrumented modules will cost about two million dollars initially. Annual operating costs will be in the range of three quarters of a million dollars. If the ship is leased the initial costs will be much lower though on a prolonged operational basis it may be cheaper to purchase them outright.

The five ships should be stationed where they can give the maximum flexibility in support of oceanic requirements for ground truth. It is recommended that Woods Hole, Miami, Texas A&M, Scripps, and Washington each have the management responsibility for one ship. In this way when the ships are not actually supporting a mission they could be out investigating oceanic features.

International cooperation

NASA cannot afford to meet all ground truth requirements throughout the world ocean. Negotiations should begin now on a program of international cooperation in ground truth and space oceanographic data sharing. By using international oceanographic vessels with some specialized instrumentation furnished by NASA the ground truth requirements for extensive world wide oceanic areas could be met.

The current planning for this type of program for the governments of Mexico and Brazil by NASA indicates steps in the right direction. Due to the closeness of the first Earth Resources Survey space mission, a rapid acceleration of this effort is necessary to insure that several nations will be able to support this program.

Suitcase instrumentation

It is recommended that NASA let a contract to develop a portable ground truth instrumentation package. Such units will be very effective in meeting requirements where several data points are required or where research vessels are not available.

Calibration standards

NASA should establish uniform calibration standards for all ground truth instrumentation developed under this program. This will insure that all instrumentation systems are compatible and checked against the same standard. Systems' specification and procurement should be under the supervision of a select group of environmental sensor experts. Total integration of all systems can be developed by applying the systems analysis approach to this effort.

SUMMARY

The lack of research vessels available for specific support of ground truth requirements of remote sensor studies of the ocean is the principal limiting factor in the Spacecraft Oceanography Program. The current fleet of research vessels cannot support the extra demands of this program nor are they readily available for the addition of the sophisticated instrumentation systems necessary to support this work. The only satisfactory answer is to add new ships to the U.S. research vessel fleet that are specifically earmarked for support of SPOC. In addition, provisions should be made for a simplified instrumentation package that could be placed on existing ships, ships of opportunity and other platforms when the regular ground truth vessels were not available or where more data points were required.

The soundest procedure is to consider the ship procurement and instrumentation installation as a ground truth support system. This should insure full compatability between instrumentation systems and the other ships in this class.

Even with these ships the requirements for ground truth support world-wide will exceed any reasonable NASA capabilities. Therefore it is important that NASA rapidly develop an international cooperative space oceanography program using our remote sensor platforms and the research vessels of foreign nations for ground truth support. The current Mexican-Brazilian program seems to be headed in this direction but it represents only a fraction of the effort required to enlist the aid of the world's oceanographic community.

There is no inexpensive way to obtain ground truth over and on the ocean environment. If space oceanography is to be part of the future space missions then there is no choice but to develop the ground truth support now. Each year that this decision is delayed will result in higher start up costs when it is finally implemented.

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A COMPARISON OF RADAR SCATTEROMETRY FOR 28 TO 30-KNOT WINDS OBTAINED OFF NEWFOUNDLAND WITH DATA FOR 16 TO 20-KNOT WINDS OBTAINED AT ARGUS ISLAND AND OVER THE GULF STREAM

(Preliminary Analysis)

Dr. W. J. Pierson, New York University

Data

Thirty-two plots of radar scattering cross section versus incidence angle in degrees were obtained with the NASA-MSC 13.3 GHz (2 cm wavelength) scatterometer during two flights on the CV240 based at Argentia, Newfoundland, (Mission 60). The flights were on 31 October 1967. Flight I was from 1551Z to 1823Z with a target area at 45°N 55°W, and Flight II was from 2059Z to 2320Z with a target area at 45°30'N and 50°30'W. These data are compared with data obtained by the same radar with the same aircraft near Bermuda on 7 March 1966 over the Gulf Stream on 12 October 1966.

Comparison of the 32 plots with wind data and wave hindcasts for region overflown

The winds over the area of interest shifted from a southerly direction to a northeasterly direction after 18Z 30 October, and were northeasterly from 00Z 31 October to 00Z 1 November. Graphs of the estimated wind speed at the two target areas for the 24-hour period encompassing the two flights are shown in Figure 1. The wind speed over the two target areas was essentially the same at the time of the overflight (shown by the arrows) and was somewhere between 28 to 30 knots.

The weather and wind patterns during the flight were rather confused compared to the more fully developed patterns that can occur, and it would be difficult to state precisely the overall nature of the wind field over the complete tracks of the aircraft. An appendix by Mr. Lionel Moskowitz describes the weather pattern and operational decisions.

Plots numbered 1 to 18 correspond to Flight I Target I. The essential feature of these plots is that the crosswind plots, no matter where taken, are all essentially equal throughout the entire flight. These plots are numbered as follows: 1, 2, 5, and 14 to 17. Plot No. 18 is close to the coast and runs from 2 to 3 db lower than the others. The upwind-downwind plots are again almost all essentially equal and run about 4 db higher than the crosswind plots. These correspond to plots 3, 4, and 7 through 13.

Plots 19 to 34 correspond to Flight II Target II. Plots 19, 20, 21, and 24 to 29 in the crosswind direction are all alike and essentially the same as 1, 2, 5, and 14 to 17. Plot 23 in the upwind-downwind direction is the same as plots 3, 4, and 7 through 13. Plot 19 is for nearly the same point as plot 18 and suggests that plot 18 may be anomalous.

Plots 30 to 34 all show a 2 to 3 db drop when compared to all other crosswind plots and suggest that the waves and winds may have decreased during the last part of the last flight; that is, around 2200 to 2300 on 31 October.

The wind data from the area suggest that the wind was essentially the same over each target area at the time of the respective overflights and that it was northeasterly at a speed of about 28 to 30 knots. The significant wave height was about 13 feet.

Figure 2 shows plot no. 4 for fore-aft scatter and plot no. 5 for crosswind scatter as being the closest to Target 1.

Comparison with Gulf Stream and Argus Island data

Mission 34 over the Gulf Stream and the flights near Argus Island (Mission 20) provided the same kind of plots for lower wind speeds and lower waves. The plots for both situations are essentially the same for incidence angles from 5 to 20 degrees, and the Argus Island data extend to 55 degrees. The waves measured over the Gulf Stream were somewhere between 4.8 and 5.4 feet, which corresponds to a wind from 16.2 to 17.2 knots. The waves measured at Argus Island were 7.4 feet, which corresponds to a wind of 20.2 knots. However, the spectrum at Argus Island suggests some swell, and if this is removed to recover the wind sea spectrum, the winds near Argus Island could have been as low as 19 knots. The data for both missions have been combined in one single plot in Figure 2.

We are thus able to compare the two sets of data, one for waves from 5 to 7 feet high, (more probably from 5 to 6 feet), and winds from 16 to 20 knots, (more probably 17 to 19 knots), and one for waves about 13 feet high and winds from 28 to 30 knots as shown in Figure 2.

For all incidence angles greater than 10°, the curves for higher winds and waves lie above the curves for lower winds and waves. The separation is 6 db at 15° and as much as 12 db at 55°. There is every indication that the trend could continue were these plots obtained for even higher winds and waves.

Comparisons of other available sea backscattered data

To show the changes in the normalized backscattering cross section as a function of incidence angle $\sigma_o(\theta)$ for sea return, certain available and appropriate published data were plotted for comparison in Figure 3.

The data used for comparison with the Mission 60 data were taken by the Naval Research Laboratory (NRL) with a vertically polarized X-band radar at 8.91 GHz. The NRL sea return data were taken roughly two years ago at Sea States 2, 3, and 4, where most of the $\sigma_o(\theta)$ information presented was in the range $30^o \leq \theta \leq 85^o$. This range, however, is of vital interest since it can be correlated to wave height or sea roughness. It must be noted that the NRL radar is at a slightly lower frequency than the NASA 13.3 GHz scatterometer.

All of the Sea State 4 data were taken on Mission 60, 31 October 1967, with the 13.3 GHz scatterometer. The Sea State 5 σ_o plots show upwind UW (or forward antenna beam), downwind DW (or aft antenna beam), and crosswind CW (forward and aft-beam) information in the angular range 5 to 60 degrees. The NRL σ_o data are shown for Sea State 2 for $0 \leq \theta \leq 30^o$; for Sea State 3 for $30^o \leq \theta \leq 70^o$; Sea State 4, CW, $30^o \leq \theta \leq 85^o$; and Sea State 4, UW and DW, $72^o \leq \theta \leq 85^o$. The Sea State 4 data were roughly interpolated in the region $30^o \leq \theta \leq 70^o$ for comparative purposes.

Mission 20, Bermuda, March 1966, sea return data taken by NASA with the 13.3 GHz scatterometer, (waves around 7 feet), are shown by the heavy black dots.

Of considerable analytical significance is the large difference in the value of σ_o (db) between Sea States 3 and 4. This difference is around 14 db at $\theta = 30^o$, and around 20 db at $\theta = 60^o$ when one considers only the upwind plots. This difference certainly is sufficient to allow good resolution of wave heights for the various sea states.

It is also important to note that both the NASA scatterometer and the NRL radar transmitted vertically polarized waves and received in the vertical mode VV. Additional information can be obtained in the horizontally polarized transmit-receive mode HH as well as the cross-polarized modes VH or HV.

As a final consideration, even though the data were taken from different sources and experiments, the plots and trends are clear and consistent particularly for angles greater than 30 degrees.

Conclusions and recommendations

The measurements for higher winds and waves follow the trend predicted by previous observations. Whether the plots are more nearly representative of wave height or local wind, speed cannot be decided on the basis of this one experiment. More observations for even higher winds and waves and for situations where strong winds blow directly offshore instead of parallel to the coast are needed to resolve these difficulties.

PPENDIX

Forecast and hindcast data

At 1200Z on 31 October, the southern coast of Newfoundland was under the influence of a pressure gradient yielding winds of 20 knots from 040 degrees. Offshore wind speeds were significantly greater (approximately 30 knots). The USCGC CASCO (45.8N, 53.9W) reported 29-knot winds and 14-foot seas. On the basis of the synoptic situation and the CASCO's report as an impetus, a "go" condition was decided upon. The target point 45N, 55W was selected, this point being chosen because it would remain under the influence of the prevailing synoptic conditions and it would afford a leeway in the flight time should the wind system collapse rapidly. A preliminary forecast of 28-knot winds from 060 degrees associated with 13-foot seas (significant wave height) was initially forecast. These forecasted values at the target were concurred by the duty forecaster of the Fleet Weather Facility, Naval Station Argentia.

After a "go" situation was determined and after flight plans had already been scheduled by the flight operations people, a phone call was received from L. Grabham of NAVOCEANO. From this call it was determined that the forecasters of ESSA concur on a "go" situation. The aircraft, airborne at 1552Z, proceeded with its mission and arrived over the target at about 1700Z and returned at 1825Z.

Prior to the return of the aircraft, it was decided to run a second mission, although the synoptic pattern was rapidly breaking down and seas did not apear to be as high nor wind speeds as strong as during the first mission. The second target, approximately 25 miles SE of Cape Race, was at 45.5N, 50.5W. The sea state was forecasted to be 9-10 feet.

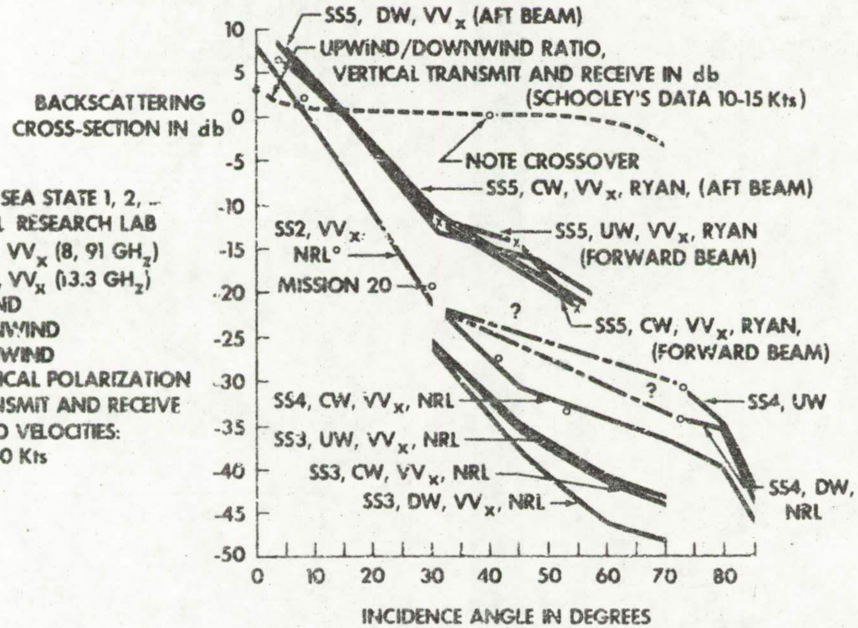
Winds were approximately 24 knots from 060 degrees. The second mission attempted to gather continuous scatterometer data from the coast to the target. The aircraft flew out and back at an altitude of 8000 feet. For the first mission, the aircraft flew out at 8000 feet and back at 15,000 feet. The aircraft was over the second target at about 2200Z. The cloud cover was overcast thin stratus with bases at 1500 feet and tops at about 3500 feet for both flights.

Hindcasts were prepared upon return to Washington, D.C., using more complete data. The results for Target I: $\bar{H}_{1/3}$ = 12-13 feet from 060 degrees. The results for Target II; $\bar{H}_{1/3}$ = 12-13 feet also from 060 degrees. Water temperatures were approximately 50°F for both missions. Air and dew point temperatures were, also, approximately 50°F. Water depth at Target I was over 400 fathoms and at Target II was approximately 40 fathoms. It should be pointed out that the water depth at Target I is non-representative of the general area only a few miles away. The contours off the south, southeast, and east coasts of Newfoundland are rather flat (approximately 40-50 fathoms) for at least 150 miles. The first target falls just outside the flat area.

NASA-S-68-75

COMPARISON OF OTHER SCATTEROMETRY DATA WITH MISSION 60 DATA

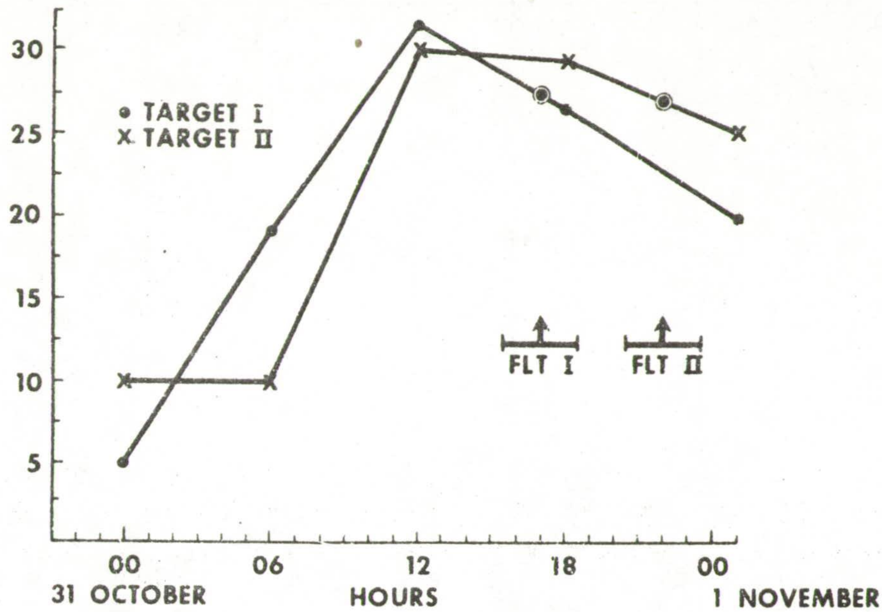
MISSION 60, SITE 160, FLIGHT 1, LINE 91, RUN 2



SS1, SS2, ... = SEA STATE 1, 2, ...
NRL = NAVAL RESEARCH LAB DATA, VV_x (8, 91 GH_z)
RYAN, VV_x (13.3 GH_z)
UW = UPWIND
DW = DOWNWIND
CW = CROSSWIND
VV_x = VERTICAL POLARIZATION TRANSMIT AND RECEIVE
WIND VELOCITIES: 28-30 Kts
FORE = x
AFT = °

NASA-S-68-76

GRAPH OF WIND SPEED VERSUS TIME OVER TARGETS I AND II. ARROWS SHOW TIME WHEN PLANE WAS OVER TARGET



NASA-S-68-77

COMBINED SCATTEROMETRY DATA FROM MISSION 34 (GULF STREAM), MISSION 20 (GULF STREAM), AND ARGENTINA (MISSION 60)