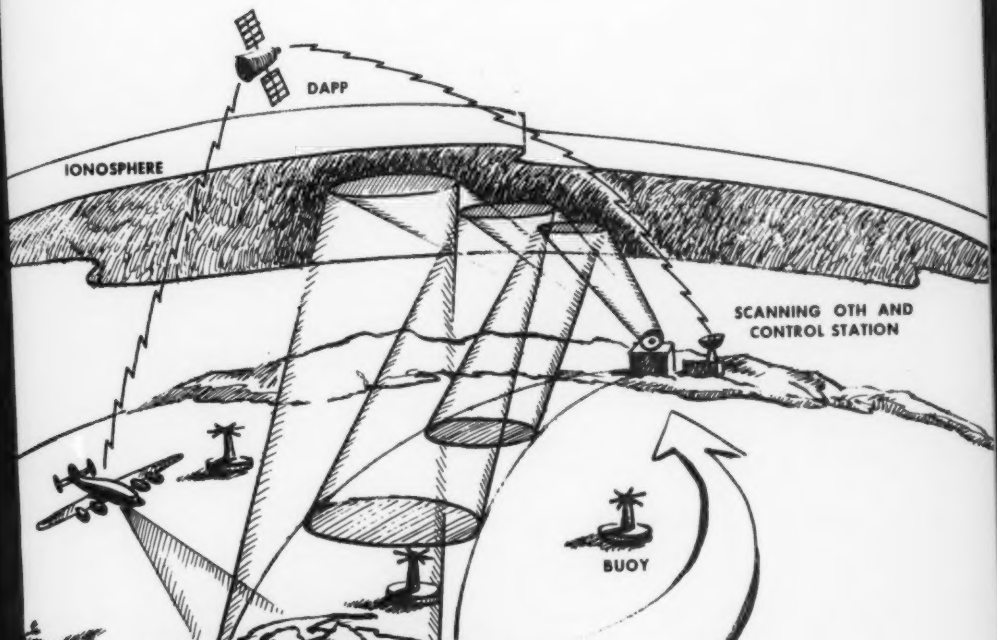
NAVAL RESEARCH

REVIEWS

JULY 1977



PROFILES IN SCIENCE

RADM Leonidas D. Coates

RADM Leonidas D. Coates, USN (Ret) is an aeronautical engineer, who is well known as a Naval Officer and Scientific Administrator. In 1964 he retired from the Navy as Chief of Naval Research, and in 1974 he retired from the Lockheed Ocean Laboratory as Head of Ocean Sciences.

Many of RADM Coates's assignments were at the Bureau of Aeronautics where he was Director of the Guided Missiles Division, Assistant Chief of the Bureau (Research and Development), and then Deputy Chief of the Bureau.

In 1961 the President appointed him Chief of Naval Research. Since he had been Deputy and Assistant Chief of Naval Research in 1954, he knew ONR and its programs. His good judgement guided the support ONR gave to important research in superconductivity, radio astronomy, and mathematics.

While at Lockheed RADM Coates was very active with the National Security Industrial Association, both on its Anti-Submarine Warfare Advisory Committee and on its Ocean Science and Technology Advisory Committee.

RADM Coates was awarded the American Defense Service Medal, the American Campaign Medal, the World War II Victory Medal, and the National Defense Service Medal.

Remote Sensing of Environment: Achievements and Prognosis for the Future

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Introduction

With the Nation's energetic quests to maintain military superiority, exploit aerospace technology, and cope with burgeoning environmental problems, an explosive growth in earth observations has taken place in the last 30 years. Methods of remote sensing of environment have played a major role. Remote sensing of environment is the detection of conditions of terrain, waters, and atmosphere of the earth by remotely positioned sensors that detect the properties of reflected, scattered, and emitted electromagnetic energy. Information on these conditions is obtained by interpretation of the acquired data arrays, using models, equations, simultaneous direct measurements, or a priori knowledge of the environment. Remotely positioned sensors, as discussed in this article, are predominantly cameras, photometers, radiometers, and radar receivers mounted on aerospace platforms. Underwater remote sensing by acoustical means is excluded from this discussion.

Remote sensing of environment is the application of this technology to environmental research or problems. But the data must be converted into information. The key to the utility and mission relevance of the technology lies in the capabilities of the environmental sciences to provide concepts and models for correct data interpretation.

Four major factors have contributed to this growth of remote sensing: (1) defense requirements for early warning reconnaissance and surveillance, (2) rapid expansion of aerospace technological capabilities,

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(3) rapid development of large-capacity computers and numerical methods, (4) and widespread political awareness of high-priority environmental problems. With the advent of nuclear stalemate and high speed weapons systems such as the ICBM or fractional orbital missile, priority was placed on surveillance of potential enemies. As a result, remote sensing systems were developed to monitor potentially hostile activities without violation of treaties or the sovereignty of nations. Motivated by the challenges of superiority in space, space exploration, and placing man on the moon, the technological capabilities of this industrial society made immense strides in aerospace technology. The National Aeronautics and Space Administration, founded in 1958, became the focus of the civilian effort in U.S. aerospace programs in response to the USSR launch of SPUTNIK in 1957. The first environmental products of this effort were instrumented aircraft and experimental and operational satellite systems. The Television Infrared Observational Satellite (TIROS I, 1960) was the first environmental satellite; it inaugurated the photography of cloud cover from unmanned spacecraft. The experimental TIROS, NIMBUS (1964), and Advanced Technolgoy Satellites (ATS-1, 1966) led to the presently operational NOAA LANDSAT and SMS/GOES series of environmental satellites. These systems have provided large quantities of remotely sensed data for experimentation, and various federal agencies funded investigators who had imaginative or utilitarian experimental concepts. Data became available, and at relatively low cost. Parallel with the aerospace developments was the development of large-capacity computers and numerical methods.

The birth and growth of modern remote sensing of environment has received major impetus from the Office of Naval Research (ONR). The very term "remote sensing" originated with the Geography Programs of this agency about 1961. It was created in the redesignation of a project entitled "Interpretation of Aerial Photographs" to "Remote Sensing of Environment." It was a natural and appropriate change in view of the development of sensors to make observations in regions of the electromagnetic spectrum, beyond the ranges of human vision and photographic sensitivity. It was recognized that a new term was needed to encompass the total of observational processes from remote platforms.

In February 1962, ONR sponsored the first symposium on remote sensing of environment at the University of Michigan's Willow Run Laboratories. By the seventh symposium, in 1971, these meetings had become international and attendance had expanded from 70 U.S. scientists in 1962 to more than 800 from 27 countries. In October 1975 more than 165 papers were presented at the 10th International Symposium on Remote Sensing of Environment, at which there were 646 attendees. Sponsors included 13 U.S. government agencies, a government agency of the Republic of China, a Japanese corporation, and a

Spanish university. A professional journal (*Remote Sensing of Environment*, née 1972) and trade journals, along with numerous special education programs, have come into existence. ONR leadership provided an important start here and continues to fund selected areas of research with potential for Navy missions.

Achievements and Status

The achievements and status of the field of remote sensing of environment are most vividly illustrated by today's operational systems. The existing systems include the Defense Meteorological Satellite Program (DMSP Block 5-C satellites), the NOAA Improved TIROS Operational Satellites (ITOS), the NOAA Stationary Meteorological Satellites (SMS/GOES), the LANDSAT series (ERTS A and B), and the NASA NIMBUS series and Skylab experimental satellites. The systems under development include the DMSP Block 5-D satellites, the TIROS-N, the NIMBUS-G, SEASAT-A, LANDSAT-C,STORMSAT-A, Applications Explorer Mission (AEM-A), Remote Ocean Measurement System (ROMS), and Synchronous Earth Observatory Satellite (SEOS). Each of these latter systems is built upon the concepts and technological advancements conceived or developed in the earlier aircraft or satellite experiments. They will expand our environmental remote sensing capabilities both in a qualitative and a quantitative sense. SEASAT-A represents a new thrust, the first dedicated oceanographic satellite and the first incorporating passive and active microwave primary mission sensors. The TIROS-N satellite marks a new age of cooperation in space between the Department of Defense, Department of Commerce, NASA, and several NATO Allies. This system will be based on the spacecraft of the DMSP, with sensors developed by NASA, United Kingdom, and France. The Department of Defense will launch these satellites (two operational) into space and NOAA will conduct the remote sensing operations and distribute data.

In the following paragraphs a review of selected concepts is presented within a framework of results from operational systems. These concepts are: (1) the Defense Meteorological Satellite Program, (2) sea-surface temperature measurements, (3) vertical temperature and humidity profiling of the atmosphere, (4) uses of reflected visual and near-infrared radiation, (5) remote sensing by active and passive microwave sensors, (6) the tracking of balloons, buoys, floats, and satellite data collection platforms, (7) laser sounding of the ocean, (8) and detecting and measuring properties of soil and rock.

The Defense Meteorological Satellite Program

The Defense Meteorological Satellite Program is a premium system for military use, having been originated and developed by the Air Force in response to real-life problems of Southeast Asia operations. It is now a joint services program managed by the Air Force and a paradigm for environmental information support systems.

The DMSP provides a near real-time, readily assimilated imagery on weather conditions to the analyst, providing a quantum jump in the quality of environmental support. Input of satellite data into weather forecasts by analysts and digital processing for use in numerical prediction models has also made important improvements in these services.

The Defense Meteorological Satellite Program (DMSP) will soon launch a new advanced series of satellites designated the Block 5-D. which is a unique integrated spacecraft into which functions of the uppermost state of the launch vehicle are incorporated. It guides itself into orbit from liftoff. This system is designed for longer spacecraft lifetime and to incorporate major improvements in data.

ONR took an important role here in the early 1970's by sponsoring a study of the coastal oceanographic processes with the imagery at the U.S. Naval Oceanographic Office and a post-operations analysis of the tactical data obtained from the carrier USS *Constellation*. The former study, a combined ONR/7th Fleet/NAVOCEANO operation, crowded the system capabilities far beyond normal meteorological requirements and achieved some surprising and useful results. Data from the VR (0.6 km resolution) visual sensors were used to detect sea ice and turbid river discharge plumes in coastal waters. Thermal infrared data (3.7-km resolution) were used to detect sea-surface temperature gradient features and measure their movements and changes with time. Despite the coarse 1.6° C temperature quantization interval of the data, the high resolution infrared (0.6 km) sensor acquired an excellent series of images in the Sea of Japan, the Yellow Sea, and East China Sea in the fall and winter of 1972 (1). This unique electro-optically contoured imagery provided near real-time information on the position and structure of sea-surface temperature gradients as well as a means of quantitatively estimating temperature differences between water masses (2). Examples of sea-surface data, including surface temperature gradients, albedo of turbid coastal waters and sea ice, are shown in Figures 1-3.

Sea-Surface Temperature Measurements from Space

The surface of the sea radiates thermal infrared energy with an intensity proportional to its temperature. The capability of the satellites to detect and measure this radiation provides a potentially vital environmental data bonus for receiver-equipped aircraft carriers to task forces. Many regions of the globe have horizontal sea-surface temperature gradients that delineate tactically significant changes in the conditions for sound propagation. A wide range of very common water column

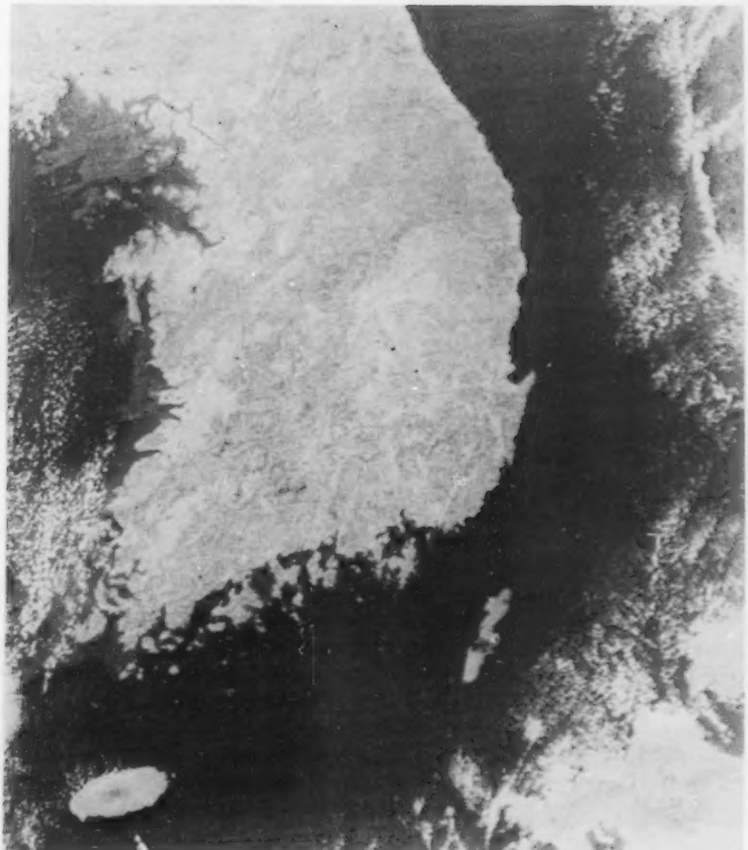

Figure 1 — Direct readout visual and infrared imagery from the Defense Meteorological Satellites. a) VHR visual (0.6 km spatial resolution) image, a small portion of the full swath showing the Korean Peninsula and surrounding oceanic areas.

Figure 1 (Continued) — Direct readout visual and infrared imagery from the Defense Meteorological Satellites. b) HRIR infrared (3.7 km spatial resolution) image, a small portion of the swath showing the Korean Peninsula and electro-optically contoured surface temperatures in surrounding seas. A special enhancement not obtained simultaneously with a.

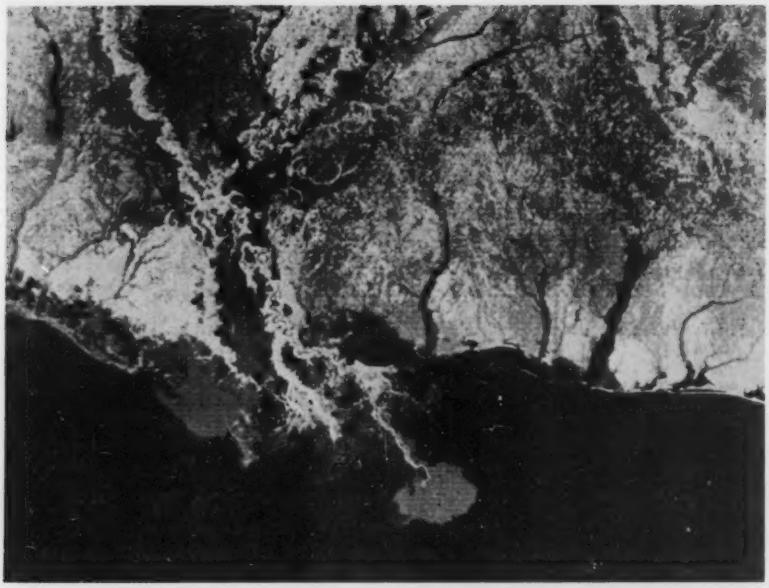

Figure 2 — DMSP VHR albedo patterns along the Louisiana-Mississippi-Alabama coast. This image shows the turbid plumes of suspended sediment-laden coastal waters at the mouth of the Mississippi River, Atchafalaya Basin, Mississippi Sound, Mobile Bay, and west Louisiana continental shelf area.

features, both transient and permanent, vary significantly from climatological mean locations of conditions of temperature and salinity (i.e., sound velocity) for any given area. Some examples are ocean eddies (5-500 km scales) that thicken or thin the warmer surface layer of the sea by hundreds of meters, convergence zones between major currents, water mass boundaries on local or regional scales, and transient upwelling of deep waters (Figures 4-6).

Vertical Temperature and Humidity Profiling of the Atmosphere from Space

In addition to mapping earth scenes with scanning radiation sensors, recent developments are providing data in the third dimension and remote sounding of temperature and humidity profiles of the atmosphere. The Vertical Temperature Profiling Radiometers (VTPR) are multiple wavelength, infrared (and now microwave) radiometers that provide temperature and humidity soundings. This capability will eventually help correct sea-surface radiation temperatures for atmospheric effects. Quantitative measurements of temperature and humidity at various pressure levels in the atmosphere are among the most fundamental

Figure 3 — Direct readout VHR visual data, 600 m spatial resolution, showing the sea ice canopy over the northwestern two-thirds of the Sea of Okhotsk. Note: The shore leads around Sakhalin, the northern coast, leads in the ice pack outlining the granular meso-scale structure of the ice, the frozen Tatar Strait, volcanic mountains on Kamchatka Peninsula, and the cumulus cloud streets where the cold, dry winds blow off the ice canopy over the open water.

observations required for weather forecasting. These atmospheric sounders thus contribute to atmospheric forecasts, sea-surface temperature measurement, and weather forecast capabilities of the Navy.

Reflected Visual and Near-Infrared Radiation

The spectral composition of visual and near-infrared energy reflected skyward from the earth's surface has been altered by differential absorption, scattering, and attenuation by terrain features, ocean, and atmosphere. The visual and near-infrared scanners of the operational and planned satellite systems are superseding the more costly aerial

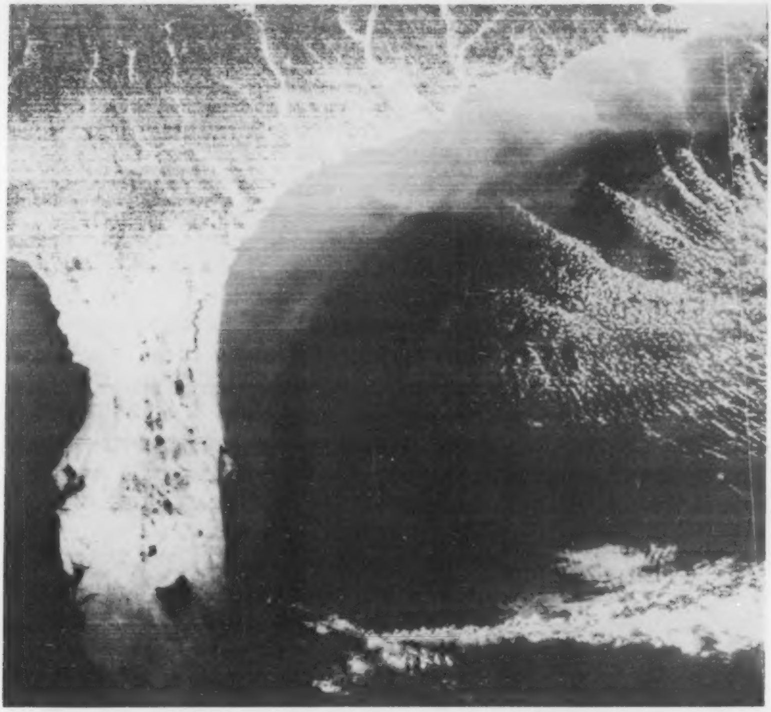

Figure 4 — NOAA satellite Very High Resolution Radiometer, infrared image, 4 April 1975. Note the suppression of thermal gradients along an east-west line crossing Florida at about the latitude of Lake Okechobee. The Gulf Stream seems to disappear and the Florida Peninsula nearly fades from view through the humid marine air mass. This is an atmospheric humidity front separating polar continental air to the north and warm, moist, but clear sky marine air to the south.

photography for larger scale environmental monitoring, resource exploitation, crop inventory, soil mapping, and hydrological-limnological-oceanological applications. The operational visual sensors in the LANDSAT series satellites provide opportunities for detecting a wider dynamic range of signal intensities and electronically calibrating the measured intensities of reflected light. It provides an electronic output on computer-compatible tapes that are amenable to computer processing of the imagery.

The most stringent requirements arise from military needs to describe the offshore shoals, surf zone width, beach slope, tidal ranges, and trafficability from the standpoint of soil bearing strength, roads, creeks, and other advantages or impediments to maneuvers.

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Figure 5 – NOAA satellite Very High Resolution Radiometer, infrared image, 4 April 1975. Image shows portions of Honshu and Hokkaido, Japan, and the Kuroshio-Oyashio currents in the northwest Pacific. Strong outbreak of polar continental air from Siberia reveals spectacular sea-surface temperature patterns outlining the convergence of these major currents and the array of eddies at their juncture. Note the build-up of cumulus cloud streets offshore, obscuring the seaward extension of the gradient features.

The visual-range sensors of the meteorological satellites, NOAA, DMSP, and SMS/GOES have important applications (beyond meteorological), even with their low spatial and spectral resolutions. Most important is the detection of ice and snow fields on the basis of the extreme reflectivity differences against water and terrain. Detection of sea ice, the marginal ice zone, and leads of open water in sea ice are of direct operational importance. Studies of ice dynamics benefit directly from the high repetition rates of the polar orbiting satellites, providing imagery every couple of hours. Poor solar illumination levels and cloud cover are the present encumbrances to this capability. NOAA has successfully monitored the snow fields of the U.S., measuring

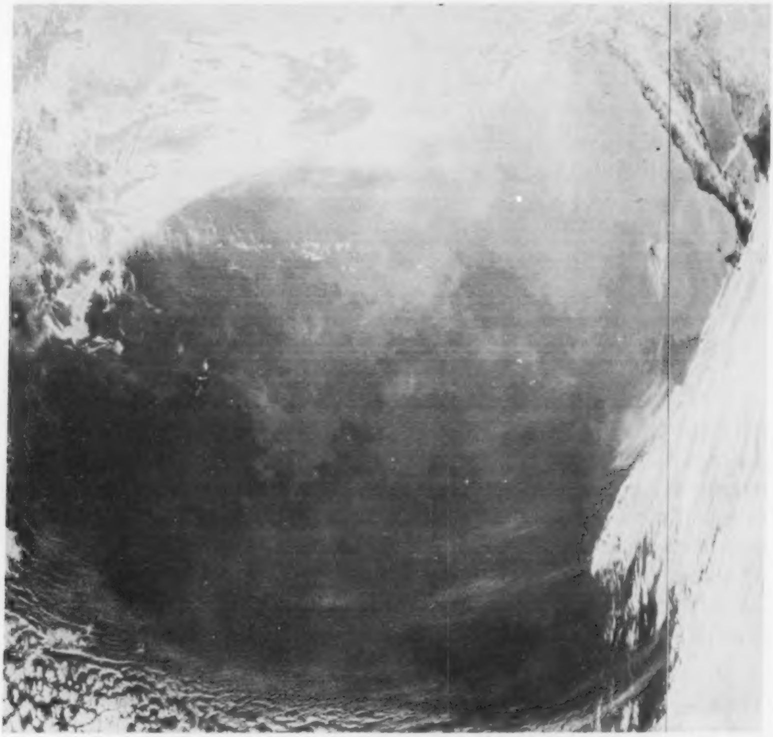

Figure 6 — NOAA satellite Very High Resolution Radiometer, infrared image, 14 December 1974. Central Pacific region. A large outbreak of continental air moved west from Southern California/Baja California (to the far east in the image) to provide good imaging condition for detection of mesoscale temperature gradients featured on the sea surface, the subtropical convergence of the North Pacific.

changes in snow field area and using these to predict meltwater production and thus river stages downstream.

Remote Sensing of Environment of Active and Passive Microwave Sensors

Microwave remote measurement systems promise to elimate one of the major disadvantages or limitations of present systems, weather dependence. Detection of environmental conditions during periods of cloud cover, extreme atmospheric humidity (tropic and temperate summer seasons), as well as nighttime is a major requirement, particularly for the military, whose operations often must continue during periods of inclement or severe weather, closely following the limiting conditions of feasibility for mission accomplishment. Microwavelengths are actually long in comparison to visible and infrared wavelength, ranging between 1 mm and 1 meter. Polarization is often used as a parameter of feature discrimination in the microwave region of the spectrum inasmuch as the transmitting and receiving antennas are readily built with single polarization directions. In comparison to visual and infrared systems, the geometry of radar range measurement facilitates the use of observational angles well away from the vertical. By comparison, the visual and infrared sensors are most effectively used in the near vertical mode. Active microwave sensors provide their own illumination, whereas passive systems measure radiation originating elsewhere.

Remote sensing of environment with active and passive microwave sensors is clearly an important area requiring further research and development. The potential for measuring sea state, geographic patterns of sea-surface salinities, ocean dynamic topography, soil moisture, terrain roughness, foliage density, and sea ice properties in all-weather daytime or nighttime conditions is being aggressively pursued. Development of data interpretation and use capabilities is severely hampered by difficulty of access to sensor systems and data. More widespread availability of aircraft missions in support of oceanographic, coastal, geologic, geographic, and meteorological research programs is essential (Figure 7).

Tracking of Balloons, Buoys, Floats, and Satellite Data Collection Platforms

A series of advances in the print-2-point displacement measurements of winds and ocean currents has taken place. These advances have been made possible by new telemetry and data-link technology that has been combined with remote sensing platforms. The first spacecraft experiment was the Interrogation Recording and Location System (IRLS) operated from NIMBUS 3 and 4 satellites which were used to track about 30 stratospheric balloons (3).

For smaller scale studies, ONR-sponsored research produced the over-the-horizon radio direction-finding system for tracking coastal and shelf currents (4). This system, using simple, inexpensive, lightweight, and portable equipment, requires only one operator at each of two shorebased tracking stations. With it one can track the movements of as many as 15 drogues within 450 km of the shore stations. These are similar achievements to the development of the neutral-buoyance acoustically tracked subsurface oceanic floats such as Swallow Floats (5) and SOFAR Floats (6). Review of these programs demonstrates capabilities of making measurements of atmospheric, sea-surface, and subsurface ocean circulation from planetary scales to microscales. These experiments rather impressively demonstrate the new tools available

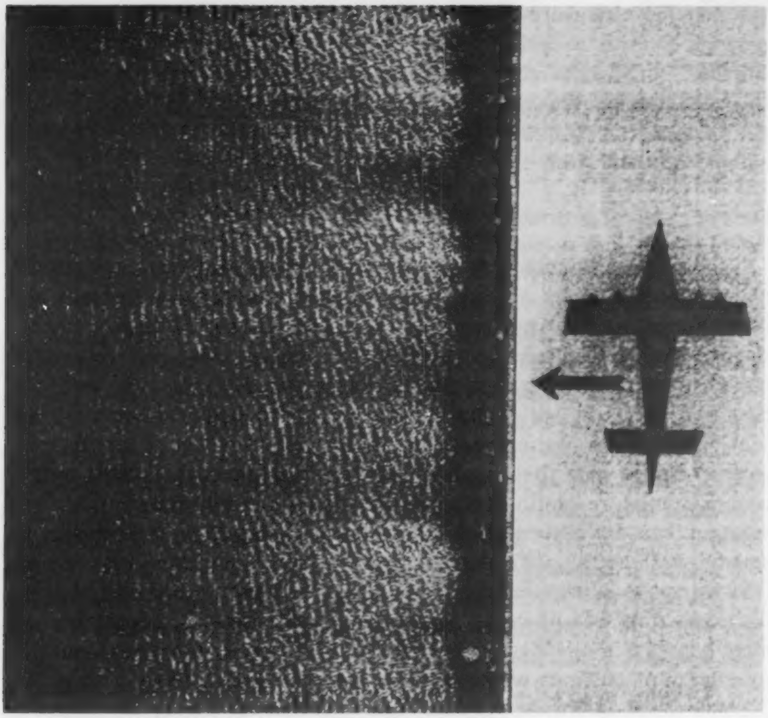

Figure 7 — L-band radar image of the ocean surface obtained from the NRL four-frequency radar system.

for environmental data support for military operations (1) from a real-time readout of measurements critical to operations or (2) from numerical modeling of circulation with increased data base and new understanding of the kinematics of flow.

Laser Sounding of the Ocean

Vertical laser sounding for temperature structure, thermocline depths, depth to bottom, or particulate concentration using pulsed lasers may be a most powerful capability for future development. Operating in the blue-green portion of the spectrum, lasers can provide maximum capability for penetration of the water column. Airborne utilization of lasers in this portion of the visible spectrum provides the capability for simultaneous measurement of the sea-surface wave profile and of bathymetry in the coastal regions. Further, analysis of the laser signal return as a function of depth within the water column will provide a measure of the turbidity within the column. This turbidity may be related to optical visibility and to littoral sediment transport. Further, coupling of the laser beam with the molecular resonance of the water molecules can stimulate Raman frequency shifts and polarization changes in the received energy which can provide temperature and salinity profiles within the water column.

Detecting and Measuring Properties of Soil and Rock

Studies are underway to develop a technique for rapid assessment of surface soil types and conditions (including moisture content and temperature) over large areas of the globe. Satellite-based remote sensing techniques have been shown to satisfy the requirement for rapid global monitoring, but the particular approach that will yield the best soil data has yet to be determined. Microwave radiometers are sensitive to soil water content over depths on the order of a few centimeters, but to date their applicability has been severely limited by the coarse spatial resolution. By using visible and infrared sensors, resolution can be improved, though depth of detection is reduced (to several millimters) and weather conditions are limiting. Idso et. al. (1975) have demonstrated that albedo (a measure of reflectivity) is useful for characterizing surface soil water content of bare soils. Measurem nts after heavy rain or irrigation show that soil water content from surface to a depth of 10 cm is well correlated with surface albedo (7).

In retrospect, it is essential to recall that all the systems provide only numbers, i.e., variations in voltage. There is no interpretation of these spatial or time variations in sensor readings without concepts: concepts of the earth scene and its changes; concepts of electromagnetic radiation interacting with solid liquid and gaseous components of the scene; and concepts of how the sensor data distort the scene appearance. Over the past 20-30 years data interpretation concepts have changed dramatically from the subjective classification and identification of features in aerial photographs to the use of precisely formulated quantitative concepts, numerical models, and statistical classification techniques for correcting, classifying, analyzing, and interpreting the data. Experience shows one fact to be clear; in research, the full range of approaches will co-exist. Contemplative study of mapped data by specialists is the concept development stage and in many cases is the necessary forerunner of automated processing.

Prognosis for the Future

The questions for the future are, what scientific and technological directions must be pursued, and what can the Navy expect from this field?

Technology must improve platforms, sensors, and data links. Needed are greater spatial resolution, increased repetition rates, narrower spectral bands and more of them, changeable sensor gain, and all-weather/day/night capabilities. In meteorology and oceanography a major thrust is coming in microwave sensors for all-weather and day/night sensing. *Increased control* of sensors is needed to point, to change resolution ("zoom"), to change look angle, to vary the mix of spectral bands according to special user needs, and to escape the vagaries of natural illumination. Active sensors will play a major role in the future, but power limitations and antenna sizes demand new technological developments. Control of remote sensing systems is presently by telemetry of commands and by man-in-space Skylab-type projects. With the space shuttle and orbiting space stations proliferating in the coming several decades, teams of scientists and engineers will jointly perform "field" work, operating sensors and conducting work from space. It is interesting to note that they can also make simultaneous ground-truth measurements, interrogating in situ sensors that record, store, and telemeter direct measurements for analysis and comparison in space or at far-away ground stations. The results of discoveries will be nearly immediate inasmuch as near real-time data acquisition and processing allows the experiments and thought processes to continue without interruption. Tests of concepts in some cases will be continued in a series of different earth locations with remotely sensed data acquired farther along orbit or on a later orbit.

Further control of remote sensing is available through the use of remotely piloted vehicles. Here the sensor package can be moved closer or farther from the target phenomenon. This allows maneuvering with respect to cloud decks and use of active sensors of lower power. Drone aircraft or aerostats can loiter for days at high altitudes, awaiting conditions or commands to acquire the desired data. Artificial illumination of the earth scene with varying portions of the electromagnetic spectrum multiplies enormously the measurements possible.

Of major importance is the development of automated in situ measurement technology, coupled with telemetry. The concept here is that automated sensors and data links create an artificial "nervous system" extending man's perception capabilities to the remotest, most inclement, and most inhospitable regions of the earth. New measurements and information on extreme conditions and on the earth will be increasingly possible. Improved sampling and on-scene processing and telemetry can increase capabilities by transmitting required information rather than raw data.

An expansion of application of remote sensing technology awaits the low-cost distribution of high-quality data to operational decision makers. The DMSP remote vans and the NOAA APT capabilities have demonstrated the appetite that field groups have for high-quality data. Necessary are improved capacity of portable remote receivers, antennas, minicomputers, and display devices. Required is low-cost access to a large variety of data for small military field units, university field camps, commercial operators, etc.—all who make important practical decisions on the basis of environmental prognoses and conditions.

The environmental disciplines are evolving rapidly, experiencing expansion of problems to solve, information available, and technological power. Far more knowledge is needed on the reflective and emissive characteristics of the ocean atmosphere and terrain, through an increasingly wider range of the electromagnetic spectrum. A shift from measurement of parameters to measurement of fluxes is underway. It will include measurement of fluxes of energy and matter through complex ecosystems with interactions at many levels of scale. Research with the increasing array of tools will uncover new information on the temporal and spatial structure of processes, revealing regularities of pattern extending over large geographic domains. Already studies of the relationships of ocean and atmospheric events over long distances, called *teleconnections*, have been investigated by several workers. Examples include research on the influence of northern hemisphere circulation on droughts in Brazil, (8) the influence of strong flow in the equatorial countercurrent on the occurrence of El Nino, (9) and the teleconnections between the Aleutian Low, the westerlies, the trade winds, and convective activity near the equator. These examples are environmental events structured in time and space, expansive cause and effect chains. The study and modeling of these system interactions will add new strength to environmental prediction. Other teleconnections can be envisioned, and remote sensing is a key to detection and forecasting. For example, early snowmelt seen by satellite can be used to initiate a model run duplicating the rate of movement of spring runoff and its impact on the entire hydrologic basin, river mouth, and coastal oceanic region.

Much inference is necessary to deduce environmental conditions. Researchers must work intensely to improve interpretation capabilities. One optimum use of remotely sensed data is for tuning, correction, and monitoring the divergence of numerical models from reality. Models are mandatory to provide quantitative interpretation of conditions detected, and are needed for quantitative extrapolation and interpolation between observation periods and spaces. Improved models of four classes are needed:

1. Atmospheric transmission and attenuation models for the increasingly greater range of spectral regions of interest.

2. Models of variations in reflected and emitted brightness temperatures and surface scattering processes.

3. Numerical fluid dynamical models of atmospheric and hydrospheric processes.

4. Models of morphodynamic processes that shape the sediment accumulations and bedrock surfaces of the solid earth.

Vital to the success of the modeling in remote sensing is keeping the efforts very closely linked to the field investigations, from inception to testing. Increased or optimized realism requires that these efforts occur within environmental research programs rather than in programs strictly oriented toward numerical methods.

Future research directions call for combined multidisciplinary studies using multitechnological approaches—for instance, meteorological-oceanographic studies, meteorological-hydrogrological studies, surface reflectivity-emissivity with soils and geology, or heat capacity-thermal inertia with geology and soils. Imaginative and unprecedented aggregates of technology will appear spontaneously, such as electro-optical remote sensing combined with acoustic surveillance, or in situ sensor telemetry with seismic monitoring of environment. These are, of course, high-cost efforts, and increased competition and more stringent cost-benefit analyses will be necessary.

In the future, military analysts will receive much more accurate, extensive, and responsive environmental intelligence than ever in the past. Near real-time inputs on conditions of the sea, atmosphere, and terrain will rapidly increase user confidence in the information, and it will play an increasingly important role in the strategic and tactical decision-making process. For example, task forces will receive detailed information on the surface temperature structure, sea surface roughness, water levels, currents, boundaries, sea ice, and atmospheric conditions of a target objective region. From these, models will generate specific sonar conditions, optimum ship transit speeds and tracks and radar detection conditions. Amphibious and special forces will receive near real-time instead of historical information on nearshore conditions such as surf zone width, wave height, locations of bars and shoals, beach trafficability, and conditions on the route to the amphibious objective area. Detailed environmental data of adequate resolution will come in large quantities and will need automatic reduction and, most critically, some measure of reliability. Military commanders will not weigh environmental data of spotty reliability in the face of hard military intelligence in the making of important decisions.

For more than a third of a century, the Navy has been a driving force and technological leader in environmental research in the United States. In the last 15 years the Office of Naval Research has consistently supported basic research stressing utilization of remote sensing systems. Navy requirements for measurement, analysis, and prediction capabilities needed to support military missions demand that high-resolution, high-accuracy, and high-reliability environmental prediction products be available to field units operating anywhere on the globe. Knowledge of the physics of oceanographic, atmospheric, and geomorphic processes is necessary to the construction of reliable operational prediction models. High-accuracy measurement technology is necessary to support research efforts that define the basic environmental physics and that sustain subsequent prediction models. For the Navy, remote sensing of environment will play an increasingly vital supporting role. Of all the services, it is the Navy that launches operations in all environments of the globe – in the air, on the sea, under the sea, on coastal regions, and across the ice and snow of the poles.

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Infrared Information Sources

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Office of Naval Research, Chicago

The Navy has been interested in infrared (IR) technology since the military aspects of this portion of the electromagnetic spectrum became evident. ONR since its beginning had a strong interest in infrared research. In 1951 Mr. Frank B. Isakson of ONR Physics Program brought together a group of distinquished scientists for a summer study program on the military use of infrared technology. This became known as Project Metcalf, since it was held at the Metcalf Laboratory at Brown University. The committee thought highly of the series of meetings started in 1949 by ONR Pasadena that brought together government IR Contractors on the west coast and recommended that these meetings be expanded. This was the beginning of what is now called the IRIS (Infrared Information Symposia) Meetings. In the early days of IRIS, Dr. Arthur R. Laufer, of ONR Pasadena organized the west coast meetings while Mr. Thomas B. Dowd of ONR Boston organized those on the east coast. After a few years it was decided to merge the two meetings into a National IRIS Meeting to be held annually in various parts of the USA. About that time ONR Boston assumed the responsibility for these meetings and Mr. Dowd succeeded Dr. Laufer as National Chairman of IRIS. Mr. Jay Froman (ONR San Francisco) accepted the post of Deputy Chairman, a position that he still holds.

The Metcalf committee made strong recommendation for an information and analysis center specializing in IR technology. ONR then established the IRIA (Infrared Information and Analysis) Center at the Willow Run Laboratories of the University of Michigan. This facility was selected because of the size and expertise of the laboratories' staff and its commitment to military infrared programs. In 1973 the Willow Run Laboratories separated from the University to become the not-for-profit Environmental Research Institute of Michigan (ERIM) and the operation of the Center was transferred to ERIM. A vast amount of information (classified and unclassified) on military infrared technology is collected by the IRIA Center.

The IRIA Center is responsible for collecting all published information in the field of electrooptics with emphasis on the area of military infrared research and development. The staff of the center consists of a small core who can call upon the services of the engineers and scientists in the IR and Optics Division at ERIM to review and

*Dr. Ivory is Chairman, National IRIS. He is Physical Science Coordinator at the Office of Naval Research, Chicago. His field of interest is solid state physics.

categorize all incoming publications. These reviews are the basis of an annotated bibliography which is published and distributed to subscribers of the Center. This group of experts also provides support in producing critical reviews, data books, state-of-the-art reports and handbooks. The most recent state-of-the-art report, issued in 1975, was by A. J. LaRocca and R. E. Turner on "Atmosphere Transmittance and Radiance: Methods of Calculation". A replacement for "Handbook of Military Infrared Technology", produced by the Center in 1965, is now being prepared. Authors from the Center as well as various laboratories around the country are contributing to this unclassified volume. Publication is expected late in 1977 and will be sold to anyone interested.

The IRIS Meetings provide an opportunity for workers in the IR field to exchange ideas and information about on-going programs with emphasis on the classified projects which have military relevance. In addition to the National IRIS Meeting which covers all aspects of IR Technology, a number of meetings on special areas are held annually also. These specialty Groups cover the following areas:

1) Infrared Imaging;
2) Infrared Detectors;
3) Infrared Countermeasures and Targets;
4) Infrared Backgrounds and Atmospheric Physics.

The last two groups usually hold their meetings during the National IRIS Meeting. They are usually unclassified. The other two hold separate annual classified meetings. All of the meetings are organized by ONR with the assistance of the IRIA staff.

After the death of Mr. Dowd in 1975, Dr. John E. Ivory of ONR Chicago was appointed by Dr. William J. Condell, Jr., of ONRs' Physics Program, National Chairman of IRIS and Technical Monitor of the IRIA Center. Direction for the IRIS Meetings is provided by the National Executive IRIS Committee. Representatives of DOD and industry make up this committee. The Program Chairman for each of the National Meetings is recommended by this committee. Each of the Specialty Groups has a chairman who is responsible for the program of its annual meeting The Executive Committee as well as the Program Chairman of the Specialty Group meet at the time of the National IRIS Meeting.

The funding has gone through several changes since its establishment. It is now funded through an ONR Contract by contributions from the Defense Logistics Agency (DLA), formerly the Defense Supply Agency, the Army, Navy Air Force, DARPA, some federal agencies outside of the DOD and about 164 industries, with the largest support coming from DLA. These contributors are then eligible to use the services of the Center and attend IRIS Meetings. DOD personnel have unlimited use of these services and can send an unlimited number of representatives to the meeting of IRIS.

For others, both the services-provided and the number of representatives eligible to attend meetings is determined by their level of contribution. Organizations with cleared facilities and personnel with a need-to-know are invited to subscribe, but foreign groups are excluded. To-non-subscribers many of the publications and services are available individually on a service charge basis.

Information on the schedule of meetings, products available from the Center as well as other items of interest to the IR community are contained in the IRIA IR Newsletter which is sent to subscribers several times a year, but not on a fixed schedule. Additional information about the operation of the Center and the history of IRIA/IRIS can be found in the references given below. Interested readers may also contact the Center or ONR at the Addresses below for further details.

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Research Notes

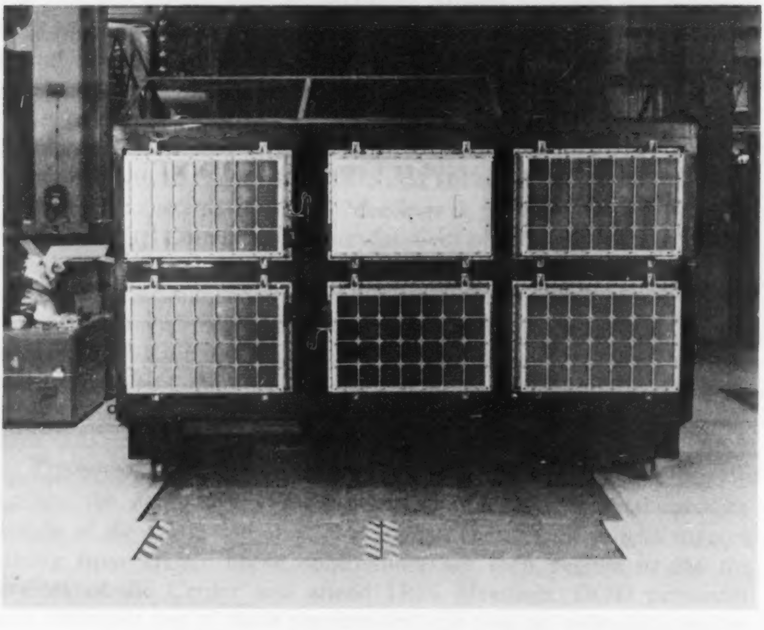
The Largest Instrument Ever Flown in any Satellite

When the first High Energy Astronomy Observatory (HEAO) is launched, it will be the most powerful X-ray observatory ever placed into earth orbit.

NASA's HEAO will contain a massive X-ray detector developed by NRL, and weighing almost 1,000 pounds and about 20 times larger than any of its predecessors, with a sensitivity level of close to 100 times that of any previous spacecraft instrumentation. The Large Area X-ray Survey Array, designated as Experiment A-1, is the largest space instrument ever to be flown on any satellite.

The A-1 experiment will map the entire sky within the first six months of operation and will probably discover several thousand new X-ray sources.

Earth's atmosphere, blocks out X-ray and gamma rays from celestial sources. This limits man's knowledge of the stars, since high frequence radiation conveys much information about what is happening deep within their interiors. But NRL's A-1 instrument on board HEAO will orbit high above the earth's atmosphere and will record a clearer, closer look at the high energy radiation output of stars, thus revealing extensive data on their inner workings.



The Naval Research Laboratory's 1,000-pound large x-ray detector will make HEAO the most powerful X-ray observatory ever placed into earth orbit.

Among the celestial sources that produce intense X-ray emission are: neutron stars, black holes, quasars, radio galaxies, clusters of galaxies, and very hot gas that may permeate the entire universe. Since evidence for neutron star pulsars is very positive, it is only a short step then to postulate the existence of black holes.

When a collapsing star contains more than twice the mass of our sun, no known physical force can stop the collapse at any density. It disappears in a "singularity" of infinite density and zero volume, surrounded by a region known as a "black hole" from which no light or matter can escape.

X-ray astronomy offers the best means of studying black holes by their secondary effects. As gas is captured by a black hole, it spirals inward to form a spinning disk before being swallowed by the black hole. The inner edge of the disk reaches billion-degree temperatures and radiates intense X-rays. NRL's A-1 instrument will reveal the characteristic dynamics of the black hole environment.

Various hypotheses and theories have evolved over the years since quasars were discovered. Quasars' phenomenal brightness – up to 10,000 times that of the Milky Way – led theorists to suggest some "new physics" to explain the source of the energy. Present speculation, however, attributes the fundamental energy source to gravitational collapse. The final configuration generates X-rays, whose energy, time variations and spectral distribution give definitive clues to the detailed physical processes involved.

HEAO will have powerful diagnostic capabilities for explosive galaxies. There is X-ray evidence of only one quasar – the nearest one, 3C 273. It is expected that HEAO will detect quasars of similar power to the edge of the observable universe.

X-ray astronomy already has detected galaxy clusters out to 3 billion light years by virtue of their hot gas filling. HEAO-A may extend the reach of observations of clusters of galaxies beyond the range of optical telescopes and provide new clues to the volution of galaxies.

Evidence of NORDA Study Shows Hurricanes can Affect Ocean Bottom

For the first time there is evidence that a hurricane is powerful enough to affect even the ocean depths, according to a study just completed by Dr. Patrick Taylor, Naval Oceanographic Laboratory, Naval Ocean Research and Development Activity. He has found that the force of at least four hurricanes that surged over the Atlantic Ocean last summer was felt all the way to the ocean bottom some five kilometers or nearly three miles below the surface.

Last August, Dr. Taylor placed an array of current meters on the ocean bottom in three locations northeast of Bermuda. Following retrieval in February, Dr. Taylor learned that a bottom current or more than 30 centimeters per second (0.6 knots) was generated by three of the hurricanes as they passed over the surface and nearly that speed by a fourth. This is strong enough to scour the ocean bottom and move sediment on the bottom and redeposit it elsewhere. The long term effect is to modify the contours of the sea floor. The measurement of these bottom currents is particularly significant since few such measurements have been made due to the difficulty of placing current meters on the deep ocean bottom and retrieving them.

It is important for the Navy to understand the formation of the sea floor and to map its contours since its composition and shape significantly affect the propagation of underwater sound. Dr. Taylor, a marine geologist, initiated his study to find out precisely what has caused the distribution of sediment on the flanks of the Gilliss Seamount, a submarine volcano recently discovered about 360 miles northeast of Bermuda rising three kilometers (nearly two miles) above the sea floor. There are a chain of at least 32 of these undersea volcanoes in the Atlantic.

In 1973, Dr. Taylor led a team of marine geologists who conducted a photographic survey of the Gilliss Seamount. This study obtained more than 200 striking photographs of the bottom that were taken and processed by Walter Jahn of the Sea Floor Division. Through seismic soundings sediment was found to be as much as 668 meters (nearly 1900 feet) thick on the lower slopes of the seamount. It was thought then to have been caused primarily by sediment deposited at higher levels and then sliding down the slope, but now it appears that strong occasional bottom currents play a major role, with hurricanes as one source of these events.

Further study will be needed to determine the long-range effect of the deformation of ocean-bottom sediment by these rapid currents.

Fiber Optics Status Board

A fiber optics status board, activated by computer-punched IBM cards, has been developed by Dr. Paul Fletcher and Parviz Soltan, both of Naval Ocean Systems Center, San Diego. The board employs fiber optic light transmission paths to transfer coded light signals from an information source to the visual output location, the status board.

Preparation of a patent application covering the concept has been authorized.

Dr. Fletcher heads the NOSC Electromagnetic Systems Department and Soltan is a member of the technical staff, EO/Optics Division.

A prototype of one form of the status board is now used daily to give a visual presentation of the current financial status of various projects within five branches and the EO/Optics Division staff.

The inventors point out that the board eliminates human intervention in the updating process and likely will save considerable time and cost wherever conventional office of field status boards are used.

Fiber optics, a technology which permits light transmission over flexible strands of glass or plastic materials, has the advantages of light weight and low cost. The strands are immune to electromagnetic interference, electromagnetic propagation and grounding.

The display is made of seven fiber optics segments and each segment, or light guide, is composed of several fibers. All numbers can be displayed through the proper combination of the seven segments. Fiber segments are brought together into a closed box and illuminated with a high intensity light bulb. Selective masking provides control of any or all of the segments receiving light within the box. Masking is achieved by insertion of a standard IBM prepunched card which has the desired numeric information.

The status board contains six information areas for each division branch. Planned expenditures and balances are extracted from the weekly computer printouts and punched on IBM cards. These figures are automatically updated on the status board by manual insertion of cards. Total for each information area is emphasized by use of a green filter.

Light source for each pair of read heads is three small flourescent tubes with a total output of 21 watts. Above and below each light source is a hinged door, behind which is the IBM card entry port for each fiber optics digit area.

The greates portion of the board's surface is for display of appropriate project code numbers and titles by use of magnetized, plastic characters. Surface of the board is thin gauge steel and is lightly scribed with horizontal and vertical lines for exact alignments.

Office status boards traditionally are updated by translation of notes, receipts, computer printouts, etc., and then finalized by manual changes. Time can average several hours a week. Now, the simple method of inserting prepunched computer cards updates the board in seconds each week. Cost for each computer run is less than two dollars. Large scale future use throughout NOSC and system command management offices is anticipated.

Poly Optics, Inc., Santa Ana, built the prototype operational model now in use.

A more advanced application of the status board concept is currently under development jointly by NOSC and Westinghouse Corporation. This is a liquid crystal/thin film transistor matrix switching concept which is computer operated and replaces the IBM card to quickly update alphanumeric and graphic information. Naval Air Systems Command (Code 34OD) and Naval Air Development Center, Warminster, Pa., are sponsoring this project for possible application in advanced naval aircraft of the 1980 time frame.

Vortex Interaction Research at the Massachusetts Institute of Technology

Recently Professor Sheila Widnall at the Massachusetts Institute of Technology discussed the progress of her Office of Naval Research supported study on three-dimensional lifting surface theory with leading edge vortices. This work is concerned with the development of computational techniques for aerodynamic flows with leading edge vortices and associated vortex separation. The flow separation is three-dimensional in nature, generally more organized than two-dimensional viscous separation, and typical of delta wings. While a precise treatment would require the inclusion of viscous effects in the vortex core, the overall behavior can be approximated rather well through an inviscid, potential flow analysis, which forms the basis for the technique being developed here. Arbitrary planforms can be considred, subject to the restriction that the sweep angle be sufficient to give rise to leading edge vortices. The effects of thickness can be included within the constraints of linear theory. Variations in camber and angle of attack also can be considered, although if the angle of attack becomes too large, the analysis breaks down. The study has been restricted to incompressible flows, with the extension to compressible flows being limited to the application of the Prandtl-Glauert rule. Thus at moderate and high subsonic Mach numbers there will be added limitations regarding camber, thickness, and angle of attack. Although not specifically considered in this investigation, the effects of slender bodies in wing-body combinations could be included through an iterative process. Similarly, the influence of wing-generated vortices on the empennage could be considered in terms of interaction with arbitrary free vortices. Calculations of this type can be carried out numerically, using either a vortex lattice method or a continuous loading lifting surface theory in which assumed loadings are represented analytically in terms of Kernel functions. Professor Widnall has chosen the latter approach as being the more promising. The strengths of the leading edge vortices are determined to satisfy the condition of smooth flow at the leading edge. An iterative procedure is used in which the desired angle of attack is reached through a series of calculations beginning with zero angle of attack. While this procedure seems promising, convergence is very dependent on the choice of the first iteration, going from zero angle of attack to a small positive value. This portion of the study currently is receiving the most attention, and although some calculations have been made for flat plate triangular wings at angle of attack, much remains to be done to establish a general iterative process applicable to all configurations.

This work has potential aerodynamic importance in three general areas. First, it should increase our understanding of vortex interaction flows and result in less reliance on wind tunnel testing in design of delta-wing configurations. Second, the occurrence of leading edge vortex separation leads to pitch-up moments, even at low Mach numbers, which may affect aircraft control during landing. However, the importance of this effect has not yet been established for the limited range of angle of attack which can be permitted during landing operations. Moreover, any such calculations also should consider ground effects, which have been omitted from the present study. The third possible area of importance is for high subsonic speed maneuvering. Unfortunately, the slender body, small angle of attack limitations inherent in a Prandtl-Glauert modification of an incompressible analysis greatly restrict the applicability of the current work to this situation.

In the development of any computational analysis of a complex flow field, a comparison both with experiment and with other analytic or numerical solutions is necessary if an evaluation of the accuracy or limitations of the analysis is to be made. Professor Widnall has tried to compare her results with the experimental data in the technical literature; however, such comparisons have not been totally satisfactory in that data are available only for limited geometrical variations and the experimental details usually are not described sufficiently to be sure that the comparison is valid. Also, regarding comparison with other analytical techniques, only slender body theories are available, thereby restricting the domain of comparison to regions of limited interest.

This study has led to the development of an interesting technique for calculation of the aerodynamic performance of three-dimensional lifting configurations with leading edge vortices. What is needed now is a related wind tunnel test program in which the performance of additional basic lifting configurations is measured for comparison with computed values over a significant range of geometries.

A Reformation in Computer Science

It is commonplace that change is a constant of computer science. But change of a fundamental nature, e.g., in the way one approaches problems, is as rare as in other sciences. William McKeeman of UC/Santa Cruz has initiated a program aimed at changing the way computer scientists attack problems of computation. This program is supported by the Office of Naval Research.

It is McKeeman's thesis that a fundamental impediment to progress in computer science is the lack of appropriate notations for problem description and analysis. The default notation is existing computer languages. By a notation McKeeman means something which lies in the broad spectrum between what a mathematician would call a notation (i.e., a graphical shorthand) and what a physical scientists would call a formal theory. Somewhere toward the middle of that range lie special-purpose, formally defined languages; much, but not all, of McKeeman's effort is centered there.

McKeeman's thesis is not yet ready to be attached to the computer-room door, but he has made some interesting preliminary steps toward demonstrating the richness of the idea. One small application of his approach is yet another attempt to do the notorious "telegram problem." This problem was defined in 1972 for the purpose of demonstrating that careful specification of a problem, together with good coding techniques, could produce dependable, correct software. Unfortunately, the example, as worked out by its authors and modified by several subsequent critiques, has proved to contain a number of errors, thereby demonstrating (at least) that the specification techniques used were inadequate. McKeeman has tried a new approach consistent with the thesis discussed above. He invented brief and simple special-purpose languages, precisely specified by formal grammars, which can be used to enunciate the specifications very precisely. The process of creating these lanaguages brought to light some remaining ambiguities in the specifications. McKeeman used these formal specifications to implement a solution to the problem in a subset of PL/I. He did not attempt to prove that the program implements the specifications. Because of the history of incorrect solutions of the telegram problem, it is certain that the McKeeman solution will receive close scrutiny. It should be a considerable boost to the McKeeman thesis if the solution turns out to be correct.

McKeeman has also applied his approach to the efficient solution of what he calls "space-filling puzzles." Examples are the Soma Cube, Instant Insanity, and the Eight Queens Problem. These are computationally challenging puzzles because the number of potential solutions is enormously larger than the number of actual solutions—brute-force methods don't stand a chance. In approaching this class of problems, McKeeman constructed something more akin to a formal mathematical model of such puzzles. The formal theory suggests a number of ways of greatly simplifying computational approaches to the problems.

The research described above deals with "academic" sorts of problems. McKeeman has also embarked upon a very ambitious effort to apply his methodological insights to the very nonacademic problem of the efficient production of a good quality translator writing system (TWS). A TWS or compiler is a software system (a language and a translator) whose purpose is the construction of compilers. As the creator of the first really successful TWS, i.e., XPL, McKeeman has substantial expertise in the area. The problem at hand is to find a vehicle for appropriately representing his expertise in this subject area and bringing it to bear in a systematic way for the orderly production of a first-rate TWS. The approach taken is to partition the problem of writing a TWS into several sub problems (11 is the current number) and to create a simple formal language for each sub area which embodies all of the power needed to treat that area. For example, there is a brief and simple language for writing scanners, which are part of every compiler. The language embodies all that one needs to know to write any reasonable scanner but will not allow the programmer to do the irrelevant tasks. One can think of these 11 mini languages as a vehicle for communicating the science of compiler writing.

McKeeman and his coworkers have made a good start on their TWS project. Several of the special-purpose languages have been defined, and some implementation has been carried out. The implementation is also being approached in an unusual way. The system is being "evolved" in several generations, with the tools of generation n being used to generated generation n + 1. This bootstrap process is very "recursive" and somewhat confusing to the uninitiated. The components of generation O are the tools necessary to create minimal versions of translator description languages which are sufficient to describe more sophisiticated languages. Several of the generation O tools have been created.

New Super High Resolution Electron-Beam-Lithography

Electron beam lithography has contributed greatly to improving the lithographic resolution of solid state electron devices. While resolution of about 1 micrometer is the best obtainable using ultraviolet light, conventional electron beam lithography using improved resist materials is capable of 0.2 micrometer resolution. Investigators at the State University of New York (SUNY) at Stony Brook operating under ONR sponsorship have recently made a breakthrough in improving the resolution to that of the electron beam itself (e.g., approximately 50 Angstroms). By programming the beam to repeatedly scan a given area of of the object surface, they note that a carbon film builds up on the surface in the scanned area. This film is thought to originate from the interaction of the electron beam and the "back diffusion" oil from the vacuum pump. It can be built-up to a thickness of 1 micrometer in height. A topology can then be created in the object of interest by ion beam machining the entire surface. The unscanned area (without carbon build-up) is machined away while the scanned area (covered with carbon) is not removed in the machining process. The new technique eliminates the resolution limiting problem of scattering associated with the conventional resist exposure by the electron beam. Using this new technology, planar Josephson junction microbridge devices will be made to the tens of Angstroms dimension which were previously the exclusive domain of Josephson tunnel devices.

U. S. GOVERNMENT PRINTING OFFICE : 1977 O - 245-287

Surface Acoustic Wave Excitation Studies

At the University of Illinois, B. J. Hunsinger under ONR sponsorship has achieved significant advances in the areas of modeling, layered transducer configurations and measurement techniques. A theoretical analysis of diffraction has led to surface acoustic wave (SAW) transducer design algorithms which are orders of magnitude faster. In addition, a technique for calculating the fundamental limit of SAW filter selectivity which can be achieved with diffraction correction has been established. Recent improvements in the layered transducer structure which are expected to significantly improve SAW devices have resulted on a 3 orders of magnitude improvement in selectivity. Continued work on a unique time response measurement system has resulted in faster more accurate simultaneous measurements of the weights and delays of more than 100 taps operating in the actual interacting environment. In addition, initial results indicate the exciting possibility of measuring the fine structure of the effective stress patterns formed by interdigital transducers operating in an interactive environment.

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Editor: WILLIAM J. LESCURE

NAVSO P-510

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287

IN THIS ISSUE

VOL. XXX, NO. 7

Cover Caption

Predicting and tracking height and time of arrival of sea swell from a distant cyclonic point source.

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