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ABSTRACT

The purpose of this paper is to identify the nature and scope of earth resources activities at the Kennedy Space Center (KSC). Because of recent developments from space exploration, NASA and KSC have evolved an earth resources program which focuses on applied R&D activities of direct benefit to a variety of federal, state, and local users. The historical development of this program is traced, and several projects are identified with special emphasis on the use of sidelooking airborne radar in several Brevard County, Florida test areas.

INTRODUCTION

One of the most promising direct benefits from space exploration is that of earth resources activities. From the perspectives of space and lower altitudes, a variety of problems facing citizens of "spaceship earth" can be solved. Primary credit must be given to a number of military agencies which have recognized and exploited higher altitudes for reconnaissance purposes since Civil War times. This need served as an impetus for the greater use of synoptic views of activities on earth. Military applications, coupled with significant scientific space developments and the needs of society, have resulted in the birth of earth resources applications and their present state of development.

NASA'S EARTH RESOURCES PROGRAM

NASA's overall earth resources activities are being accomplished through the Earth Resources Survey Program (ERSP) under the overall direction of the Earth Observations Programs Office, Office of Applications, at NASA Headquarters. The Johnson Space Center (JSC) serves as Lead Center for earth resources. The ERSP is an experimental endeavor to transform data into useful information which will assist in the solution of ecological problems and improve management of our resources and environment. The program is founded and dependent on the use of remote sensing techniques. These techniques include the use of remote sensors to detect and measure various parameters, communications systems to collect and transmit data, computers to store and sort great quantities of data, and management direction of scientists and engineers of a variety of disciplines to transform these data into understandable and usable information for decision makers concerned with and responsible for the management of our world's resources. Without question, NASA has a great deal of expertise in the development and utilization of these essential techniques, and the application of this expertise is a direct benefit of space exploration.

Several primary goals have been established to direct NASA's overall activities. They are to: (1) develop the capability for remote sensing of the earth from aircraft and spacecraft, (2) develop experimental and operational applications of earth resources survey technology to meet user requirements, and (3) develop methods of handling large quantities of remotely sensed data, improving its transmission, reduction, processing, storage and retrieval, and dissemination.

These goals are consistent with the primary goal of the ERSP to assist a variety of decision makers at all levels of federal, regional, state, and local government agencies and industry to find a more favorable balance between the consumption and conservation of our natural resources. Our society requires that certain resources be consumed for our survival. Conservation of resources, however, is essential for the world's future generations of consuming citizens. Our contemporary challenge (and probably the greatest challenge for the future) will be to find more effective and efficient means to balance the consumption and conservation of the earth's resources. Finding this balance was not difficult in earlier days because of our small population and the quality and quantity of resources available. Ignorance of cause and effect relationships and the use of intuition in decision making were usually tolerated by a somewhat forgiving nature. Today and tomorrow, however, these methods will not suffice, and quantitative and qualitative information will be required to achieve this optimum balance in our decisions concerning consumption and conservation of our resources.

NASA's overall activites are directed toward the development and transfer of remote sensing technology to a number of users and beneficiaries. User federal agencies include the: Department of Agriculture, Department of Commerce, Department of the Interior, Environmental Protection Agency, and U.S. Army Corps of Engineers. Many regional, state, and local organizations also directly benefit from these R&D efforts. NASA serves as a research and development agency assisting these organizations in solving their operational problems by the use of more cost effective remote sensing techniques. NASA thus serves as a catalyst -- a multiplier of technology, techniques, and applications. Hopefully, entire new industries will develop and existing commercial ventures will expand from these R&D activities.

Remote sensing for earth resources purposes is a direct benefit of manned and unmanned space exploration and offers great promise for providing useful and even essential information. Coupled with new and improved aircraft sensors, space systems, such as the Earth Resources Technology Satellite (ERTS) and the Skylab Earth Resources Experiments Package (EREP), make it feasible to observe large areas of the earth repeatedly over a period of weeks, months, and years. Using these multi-altitude systems, it is now possible to conduct both large scale and detailed surveys at reasonable costs leading to a better understanding of the dynamic aspects and interrelationships on our changing earth.

Recent improvements in sensing and interpretation techniques now provide an even greater potential for understanding. Furthermore, the use of thermal scanners, multipolarization multiband radar systems, and multispectral systems, as well as photographic systems, has greatly expanded our perspective and vision to include a wider spectrum of nature's electromagnetic activities.

KSC'S PROJECT ACTIVITIES

Earth resources activities at various NASA centers are organized along regional lines with project activities directed toward those problems which are somewhat unique to the local area. KSC earth resources projects are the responsibility of the Earth Resources Branch of the Sciences, Applications, Skylab, and ASTP Programs Office, which was formally created on October 1, 1972. Its regional interest covers the southeast portion of the U. S. (Florida, Georgia, North and South Carolina) and the Caribbean.

A variety of earth resources activities are accomplished using a specially instrumented KSC aircraft equipped with photographic and thermal scanning systems. Overflight requirements in excess of the 12,000-foot limit of the KSC aircraft are supported by middle and high altitude aircraft of NASA's Johnson Space Center and Ames Research Center. In addition to photographic systems, a 24-channel multispectral system is available. ERTS and Skylab EREP imagery are also used to support project activities.

A data analysis facility furnished with a wide variety of equipment and trained personnel is available for the analysis of various forms of earth resources imagery and data. Electronic, optical, automatic, or manual analysis can be performed while an increasing capability to perform programmed computer analysis is being developed.

Many challenging earth resources activities are presently underway at KSC. In general, they fall into four categories. They are: (1) aquatic environment research, (2) agriculture and forestry research, (3) regional applications, and (4) automated techniques development. A listing of active projects by category is shown in Table 1. The user organizations and major beneficiaries of project results are also indicated. This listing is representative of the nature and scope of KSC project involvement. While a number of projects are dependent on the KSC aircraft, several require ERTS, Skylab EREP, and higher altitude aircraft imagery and data. In general, the imagery and data are analyzed at KSC by NASA and user investigative personnel on a real time, interactive basis. It is important to realize, however, that the ultimate objective of these R&D project activities is to provide the user/beneficiary community with specifications (or "packaged techniques") for cost effective and efficient data gathering and analysis systems and techniques, which they can use as part of their ongoing activities and responsibilities.

RADAR APPLICATIONS

The projects listed in Table 1 are fairly broad in scope, varied in discipline, and diverse in sponsorship. One common characteristic, however, is that the imagery base is usually in or very near the visible portion of the spectrum. Photographic and television sensors on spacecraft and aircraft are functionally limited to the visual or near infrared wavelengths. Multispectral scanners operate over a wider span of frequencies but the "channels" selected for use are typically in or near the visual band. Ground based interpretive devices also function predominantly in these frequencies. A wealth of information is available at these familiar wavelengths which can be viewed and interpreted without reorientation.

The use of these "natural" frequencies causes man to accept several important limitations imposed on him by nature as reasonable. Among them are: (1) the inability to "see" in darkness, (2) the inability to "see" through clouds, and (3) the lower optical resolution of distant objects. Radar offers an opportunity to overcome these restrictions. Radar images, which do not rely on reflected sunlight, can be taken by night as well as by day. Because microwave energy penetrates most clouds, weather restrictions are substantially relieved. (In comparison, infrared photography requires almost cloud free

skies for effective data collection.) Finally, by using synthetic aperture radar, resolution becomes independent of range. This will permit high resolution even from orbital altitudes.

While radar offers an opportunity to overcome these four "natural" limitations, the usefulness of the microwave region remains in question. Potential applications have not been well studied, and the state-of-the-art of radar equipment suitable for earth resources use is still experimental. Airborne radar equipment is bulky compared to scanner and film systems. The film product of current dual wavelength radar systems experiences an inherent loss of the high dynamic response of the radar. The imagery is unfamiliar to man's senses and the training time required for a potential user to become qualified to interpret the imagery is unknown. These questions deserve study.

GOALS AND OBJECTIVES IN RADAR

KSC's broad goal in this area is to assist in the development of a usable radar technology for the solution of earth resources problems. This development is time-phased to Shuttle Program activities since current radar hardware constraints (high power requirements, relatively large bulk, limited service life without maintenance) are minimized by the operational characteristics of the Shuttle.

Several discrete objectives are of great importance to this broad goal. First, the application of radar to earth resources problems requires substantial research. We must find the optimum frequency (or frequencies), polarization, look direction, and depression angle for various earth resource problems. Second, improved processing techniques, which can retain more of the total dynamic range of the radar and generate a product more suitable for automated or semi-automated processing and reduction, are needed. Third, the cost of usable radar imagery must be reduced.

NASA KSC'S INITIAL RADAR WORK

KSC has contracted with the Environmental Research Institute of Michigan (ERIM) at Ann Arbor for a set of investigations in Brevard County, Florida. A two-wavelength multiplex synthetic aperture sidelooking airborne radar (SLAR) was used to simultaneously image three Brevard County test sites at X-band (3.2cm) and L-Band (23.0 cm) radar wavelengths. This radar equipment was developed by ERIM under contract to JSC and provides multiple channels of data similar to those of multispectral scanner and multilens camera systems. A horizontally polarized radar beam transmission mode was selected prior to the flight. The antennae collected both like-polarized and cross-polarized reflected energy at both wavelengths. Four channels of concurrent radar imagery were thus acquired. These multiplexed images had the same imaged swath, the same imaging parameters, the same aircraft motion errors, and the same terrain conditions.

The three Brevard County test sites were selected well in advance of the flight to investigate the feasibility of using radar imagery: (1) for land use planning, (2) for water resources management, and (3) to detect pools of water under canopies of dense vegetation. The first site was on the western side of Merritt Island from the barge canal northward to the NASA causeway and contained some citrus groves and a substantial amount of relatively unaltered land. Water pools covered by up to three layers of dense vegetation were present at the time of the flight and were partially mapped by a ground truth investigation team from the Brevard Mosquito Control District and ERIM. Imagery of the second area, the western bank of the Indian River from just south of Melbourne to the north county line, showed the urban areas of Melbourne, Cocoa-Rockledge, and Titusville as well as the land areas between these cities. Finally, the St. Johns River basin was flown from west of Melbourne to the north county line. This radar imagery was acquired on October 7, 1973. Thermal scanner data and black and white photographic imagery of the test areas were obtained several weeks later to provide a variety of imagery and data for concurrent study.

Radar's potential for land use applications appears quite promising. Vegetation communities in rural areas, including trees, low grasses and/or brush, improved cattle pasture, and (possibly) unimproved cattle pasture, can be discriminated and mapped. (It is worthy of note that some of the vegetation types detected on radar imagery were not identifiable on the companion aerial photography or thermal imagery of the area.) Marsh areas with standing reeds were easily discernible using both frequencies together. However, ground truth was required to identify the type of vegetation community (except in the case of trees).

Urban land use applications of radar imagery are equally encouraging. Open lands within urban areas (golf courses, parks, vacant tracts), lakes, and waterways are distinguishable as are major transportation networks (airports, highways, and railroads). Residential trailer parks commonly appeared as a series of closely spaced very bright points. Strip commercial development, a series of independent buildings along a traffic artery, also showed as a set of independent bright points but more widely separated than most trailer complexes. Newer residential areas (those with less vegetation) can be readily mapped. As trees grow in height and spread, the foliage increasingly shadows the streets and houses, making it more difficult to distinguish an older residential area from forests and range lands. In more northern climates, this limitation may be overcome by imaging during the winter season when nature has conveniently removed the foliage. Schools and hospitals look very similar to shopping centers, but they can generally be distinguished by their regional setting. Although indus-

trial development in the test areas is not sufficient for sound conclusions, it is reasonable to assume that such areas could be identified by their size, possible proximity to railroad yards, and regional setting.

Water resources management applications also appear promising. At the time the imagery was acquired, the water level in the St. Johns River was abnormally high. The imagery clearly showed open water areas including lakes, ponds, river channels, and even the intricately braided channels in Puzzle Lake, west of Titusville. The emergent vegetation in the river including water hyacinths, water lillies, and reeds could be discriminated. Drainage patterns readily seen on the imagery could easily be followed through marshy areas.

The results of the water pool detection investigations were not encouraging. The vegetation effectively concealed the standing water pools at the radar frequencies used. There was no significant penetration of the vegetation in the X-band. The L-band was able to penetrate only low grasses and reeds standing 0.9 to 1.5 meters out of the water. There was no evidence, direct or indirect, of the water pools discernible on the imagery.

SUMMARY

NASA and KSC's earth resources activities serve as an example of the direct benefits derived from space exploration and other related efforts. The development and use of sensors and data analysis techniques will assist decision makers in finding solutions to a number of contemporary, relevant problems. While KSC's efforts are still in an early stage of development, recent progress is encouraging and suggests that a moderately funded, soundly structured program will be of value to a variety of regional users and beneficiaries. The use of radar as a sensor system shows promise for earth resources investigations, especially in land use planning and water resources management.

REFERENCES

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(2) Annual Federal Report on Earth Resources Survey Program (Washington, D. C.: Interagency Coordinating Committee Earth Resources Survey Program, 1973).

(3) Environmental Research Institute of Michigan Final Report, "The Use of Airborne Imaging Radars (L-and X-band) for Solutions to Earth Resources Problems," KSC Contract NAS10-8333 (Ann Arbor: ERIM, 1974).

Table 1. KSC Earth Resources Regional Projects

AQUATIC ENVIRONMENT RESEARCH

PROJECTS	USERS/BENEFICIARIES
Mangrove Flooding for Mosquito Control	• Brevard Mosquito Control District (Florida) • Citizens
Sedementation and Vegetation in Shallow Waterways	• Brevard County (Florida) Health Department • Citizens
Vegetation Growth in St. Johns River Headwaters	• U. S. Department of the Interior • Florida Game and Fresh Water Fish Commission • Various Florida Communities • Citizens
Dusky Seaside Sparrow Habitat	• U. S. Fish and Wildlife Service • Citizens
Biological Control of Aquatic Weeds	• Florida Department of Natural Resources • Florida Game and Fresh Water Fish Commission • Citizens
Broad River Sedimentation	• U. S. Geological Survey • Various South Carolina Agencies • Citizens
Thermal Pollution of Water Bodies	• University of Miami • Various Power Commissions • Citizens
Parasites along Puerto Rican Waterways	• U. S. Public Health Service • San Juan Tropical Disease Laboratories • Citizens
Environmental Study of KSC	• U. S. Fish and Wildlife Service • NASA-KSC

AGRICULTURE AND FORESTRY RESEARCH

Citrus Young Growth Decline	• U. S. Department of Agriculture • Florida Department of Agriculture • University of Florida • Florida Citrus Mutual • Florida Citrus Industry
Citrus Freeze Conditions	• National Oceanic and Atmospheric Administration • Florida Department of Agriculture • University of Florida • Florida Citrus Mutual • Florida Citrus Industry

PROJECTS	USERS/BENEFICIARIES
Soil Classification	• U. S. Department of Agriculture • Various Florida Agencies • Farmers and Industry
Balsam Woolly Aphid Infestation	• U. S. Forest Service • Various North Carolina Agencies • Citizens
Pesticide Runoff	• Environmental Protection Agency • U. S. Department of Agriculture • Various Georgia Agencies • Various Communities • Citizens

REGIONAL APPLICATION PROJECTS

Urban and Rural Development	• Brevard County (Florida) Planning and Zoning Department • Various Florida Communities
Beach Erosion	• Brevard County (Florida) Erosion Control Advisory Committee • University of Florida • Citizens
Remote Sensing for Urban Planning	• Albany-Dougherty County (Georgia) Planning Office • Various Georgia Communities

AUTOMATED TECHNIQUES DEVELOPMENT

Automated Methods of Monitoring Development	• Brevard County (Florida) Planning and Zoning Department • Various Florida Communities