NASA'S LAND REMOTE SENSING PLANS FOR THE 1980's

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INTRODUCTION

My remarks this morning will be restricted to the NASA Land Remote Sensing program. Within this context, I will outline the past program which concentrated on near-term applications and will describe the emerging Land Processes program. The major goal of this new program is the improved understanding of long-term land processes. My comments will be largely programmatic in nature.

BACKGROUND

Satellite multispectral land remote sensing originated with the Landsat series of satellites beginning with the launch of ERTS-1 in 1972, (subsequently renamed Landsat-1) which has provided a continuous source of global data.

Research since the launch of Landsat-1 has been primarily directed to the development of analysis techniques and to the conduct of applications studies designed to address resource information needs. These studies were conducted not only in the United States, but in many other countries, as well, because of an early U.S. policy decision which resulted in the widespread availability of Landsat data. The United States has remained a leader in developing this technology because of a continuing NASA commitment to land remote sensing research and development and the availability of a continuing flow of satellite and now Shuttle-acquired remotely sensed data.

Landsats 1, 2, and 3 provided data in four spectral bands in the visible and near infrared regions of the electromagnetic spectrum with an 80 M IFOV (Instantaneous Field of View). Consequently, the vast majority of the early research was directed to better understanding the information contained in these multispectral data. This research resulted in an understanding of the limitations of the current system and an identification of requirements for more advanced capability. The early work also clearly indicated a need for a better understanding of the physics and mathematics of the remote sensing process itself. For example, the analysis of the early Landsat data indicated that the utility of the data would be greatly expanded if the spatial resolution were improved by a factor of 2 to 3. Concurrent research using aircraft scanner data indicated the potential of other wavelengths, particularly those in the short wave infrared region (1-2.5 μm), for improving the utility of multispectral data in vegetation and geological studies. This led to the design of the Landsat Thematic Mapper (TM) in the middle 1970's. The TM, launched in 1982, has seven spectral bands and a 30 meter IFOV for all but the thermal infrared channel. Also, to support the increased volume of data associated with the TM, a new data processing system was initiated to accommodate a high throughput rate and to produce digital tapes on a timely basis.

In addition to the Landsat series of satellites, two other satellite remote sensing systems have provided the opportunity to analyze spectral data not previously available. The Heat Capacity Mapping Mission (HCMM) Satellite, launched in 1978, acquired broad band thermal infrared data

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which were analyzed for geological and agricultural applications. The HCMM data expressed the natural land surface by representing diurnal variations in thermal radiation from the ground. This mission proved that thermal infrared data were useful for the identification of certain geologic and vegetative features, as well as other surface materials and soil characteristics.

Seasat, also launched in 1978, initiated research in the utility of active microwave sensors for characterizing surface cover and structure. This mission proved the utility of space based radar for the study of geological features, for improving vegetation classification accuracies, and for mapping soil moisture.

Measurement technology continues to develop with emphasis on sensors of finer spectral resolution using both aircraft and the Space Shuttle as platforms. The results to date suggest that finer spectral resolution in both the reflected and thermal infrared regions would be useful for improving our ability to classify surface lithologies. Finer spectral resolution in the visible and reflected infrared also appears promising for vegetation classification and condition assessments.

GLOBAL RESEARCH

In formulating a new program thrust, NASA Headquarters recently completed a planning & review exercise which identified a series of science issues of global significance. They have been documented in a report entitled, *Land-Related Global Habitability Science Issues*. This document is one of several that have been prepared in this planning activity. To date, these individual science issues documents have not been integrated into an overall program plan. Remote sensing research clearly can make a contribution to the understanding of these global issues and, further may be the only technology that can adequately address them on a global basis. Such an undertaking will require a properly focused multidisciplinary Land Science program.

In general, the ability to extract information about vegetation, geology, and hydrology on a continental or global scale was only achieved early in this decade. This capability was primarily the result of the NASA R&D program in Land Resources but was facilitated by parallel developments in computer and communications technology. For example, in technique development between 1978 and 1980, the amount of preprocessed data used by an analyst to estimate crop proportions was cut 50%. The initial technique required four bands and four date acquisitions, while the later technique required only two bands, the greenness and brightness transformations, with the same number of acquisitions. By 1983, the data volume handled by the analyst was further reduced with the development of a greenness profile that required even fewer acquisitions and yet provided for vegetation discrimination based on the rate of green-up and decay of greenness determined from the profile. The concurrent automation of some previously manual techniques led to an overall CPU-analyst time reduction of over 90%. However, this development did not reduce the amount of data that must be acquired and initially processed (registered, transformed, and combined with ancillary data). The effort to reduce data acquisitions and pre-processing has led to research into large area sampling strategies and analysis of data from low spatial resolution sensors such as the AVHRR flown on the NOAA series of satellites.

The combination of large area sampling techniques and preprocessing methods designed to reduce the dimensionality of multispectral imagery will greatly improve our future ability to extract meaningful physical information from remotely sensed data. We are ultimately heading for a day in the not too distant future when multispectral imagery acquired by various sensors on different Earth orbiting satellites may be used to survey regional variations in phytomass on a routine basis. This type of capability would provide a whole series of new opportunities to study atmospheric and climatic phenomena and man's impact on the long-term habitability of the Earth.

The scope of our geology program has also been enlarged to address a series of basic scientific problems of potentially global significance. During the past year, NASA sponsored researchers have employed remote sensing techniques to study regional geological conditions in arid regions in fundamentally new and different ways. Radar imagery obtained by the Shuttle Imaging Radar-A (SIR-A) experiment in 1981 has led to the discovery of buried drainage channels in the Eastern Sahara Desert. These features have provided important information about the geological and archaeological history of this important region. In addition, NASA researchers are employing reflectance and microwave techniques to gain new insight into rock weathering processes that operate in arid regions. Continuing studies of chemical weathering processes have recently indicated that various types of fungi play a significant role in altering geological materials in desert regions. Microscopic colonies of these fungi have actually been detected on the surfaces of desert rocks situated in the western United States, Australia, and China. We are currently employing Landsat techniques to study the global pervasiveness of this phenomenon and its long-term effect on the albedo of the Earth.

One of the common areas of interest between our geological and botanical researchers in recent days has been the study of mineral-induced stress effects in natural vegetation. Pioneering research conducted by scientists at the Goddard Space Flight Center has indicated that deciduous trees growing in soils with anomalously large concentrations of metallic elements may possess distinctive reflectance characteristics during the fall season. Researchers at the Jet Propulsion Laboratory have also detected indications of vegetation stress in remotely sensed imagery that have been attributed to the local seepage of natural gas near the Earth's surface. These results tentatively suggest that remote sensing techniques may potentially prove to be powerful tools for detecting and monitoring vegetation stress and its geological causal component on a global basis.

Beyond the satellite research program built around the MSS, TM, and limited L-band radar data, the Space Shuttle era provides a new and unique platform for the testing of advanced measurement instruments and the acquisition of remotely-sensed data. The Shuttle may very well play a role in providing some of the continental or global data sets that are required for land science investigations. In fact, a Shuttle project to provide a digital topographic map of the globe is currently being planned.

THE LAND PROCESSES PROGRAM

The responsibility for the NASA land remote sensing program lies in the Land Processes Branch of the Earth Science and Applications Division. Our primary program objective is to develop remote sensing technology for improving the understanding of long term land processes. A secondary objective is to develop remote sensing techniques useful for meeting the information requirements of different user groups. The program integrates three components:

- Remote Sensing Science—to improve our understanding of the remote sensing process by pursuing the physics and mathematics of remote sensing as a generic science.

- Discipline Science—to support discipline science investigations by developing and using remote sensing tools, and

- Technology Development—to develop and test advanced measurement techniques that appear promising for understanding land processes or for resource applications.

Because the overall thrust of the program is to understand long term land processes, such pursuits as the inventory and monitoring of land cover, the description and modelling of physical systems and processes, and the determination of model parameters that can be remotely sensed are important program initiatives.

The current measurement capabilities represented by MSS, TM, and SIR-A and B, coupled with the present level of remote sensing-understanding and the state of knowledge in the discipline earth sciences, will be the foundation on which NASA will build a new Land Processes Program. The science issues to be systematically addressed in the program include:

Energy Balance—to quantify components of the energy balance between the land cover and hydrologic systems and to model the energy flow within and between these systems.

Hydrologic Cycle—to characterize the hydrology in different biomes and clarify the relationship between plant productivity and available water, and their contribution to the energy balance.

Biogeochemical Cycles—to characterize the elemental cycles (primarily phosphorus, sulphur, carbon, and nitrogen) in the different biomes in terms of fluxes between and within the cycles.

Biological Productivity—to determine factors which control the distribution and dynamics of productivity, to model interactions with the hydrology and geochemical cycles, and to assess the influence on the energy balance.

Rock Cycle—to develop an improved understanding of the temporal and spatial scale of rock transport and model the physical process of rock weathering.

Landscape Development—to determine the response of landscapes to different geological and climatic variations, to determine the balance between soil development and soil erosion.

Geological and Botanical Associations—to understand and model the relationship between plant communities and condition as influenced by crustal geology and environmental conditions.

Land Surface Inventory, Monitoring, and Modeling—to determine the location and rates of change of major surface types using predictive models.

To support the Land Processes Program during the 1980's with improved measurement techniques, we plan a series of Shuttle experiments. To effectively conduct these missions, a continuing and well-funded technology development program must be pursued.

Although applications are no longer the primary driver of the NASA land remote sensing program, it is anticipated that some activity will continue in this area. Present plans call for this program element to include technique development, testing, evaluation, and a feedback mechanism in a problem solving or applications context. A successful model for this kind of activity involves joint research with a user entity where the user provides a test site and ground truth and NASA provides the remote sensing techniques to be tested. The project results are then jointly evaluated.

NASA has invested significantly in land remote sensing. The launch of the first Landsat satellite in 1972 stimulated a decade of research and development and marked the potential for global data acquisition. However, it has only been since the 1980's that global surveys of the Earth's surface could be realistically considered. This is due, in part, to the maturation of remote sensing as a science, but also to the parallel development of computer technology and satellite communications, as well. Thus, the remote sensing community has arrived at a new threshold of capability and investigative thrust.

NASA has formulated the Land Processes Program to provide what we feel should be the direction for future remote sensing research. Our program will emphasize the use of remote sensing for improving the understanding of long term land processes. The nature of these processes will require a global perspective. Secondarily, the program will address user applications. An interdisciplinary association will form the nucleus of the program, to include the discipline sciences, the more generic remote sensing science, and sensor technology development. With the program objective and working components so defined, we feel NASA has developed a rational focus to direct the future of remote sensing research.