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LATEST RESULTS FROM THE EARTH RESOURCES PROGRAM: SUMMARY OF DISCUSSION SESSION

by

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The results summarized here deal exclusively with observations from the first Earth Resources Technology Satellite (ERTS-1) and with the interpretation of these observations in terms of surveying and mapping Earth resources over large areas. This summary is based on nine reports presented to the IAF Congress on 14 October 1972. The titles and authors of these reports are listed below as References.

The ERTS-1 was launched on 23 July 1972 and with minor exceptions, has transmitted multi-spectral images of approximately 6.5 million square kilometers of the Earth's surface every day since 25 July 1972. Sunlight reflected by the Earth is imaged and measured by two sensor systems, namely, a set of three Return Beam Vidicon (RBV) television cameras and a Multi-Spectral Scanner (MSS), in the 0.5-0.6, 0.6-0.7, and 0.7-0.8 micrometer wavelength intervals. The MSS alone provides photometric images in one additional interval of 0.8-1.1 micrometers. Measurements from each sensor are recorded on two wideband video tape recorders when the satellite is not within transmission range of a receiving station. The satellite also carries a Data Collection System (DCS) which acquires messages from randomly transmitting platforms, distributed over North America, and retransmits these messages to a central analysis facility. These messages consist of measurements of such parameters as water quality, rainfall, snow depth, and seismic activity which are made by the platforms directly and automatically at remote and inaccessible sites.

The optical measurements made by the RBV and MSS systems are transmitted to three receiving stations in the U.S.A., located in Maryland, California, and Alaska, and to a Canadian station in Saskechewan during each daytime pass of the satellite over these stations. A fifth station is planned to be in operation in Brazil. During nighttime passes, measurements recorded on the tape recorders, over other parts of the world, are transmitted to the three U.S.A. stations. RBV and MSS observations made over the 6.5 million square kilometers every day amount to about 10^{11} digital bits which are converted to about 1350 photographic images daily at the NASA Data Processing Facility (NDPF) in Greenbelt, Maryland. Approximately ten copies of each of these images are reproduced photographically and distributed to several agencies of the U.S. Government who conduct experiments to determine the applicability of ERTS observations in various operations related to resource management; such as, cartographic mapping; survey of land use, crops, timber and soils; assessment of water quality and supply; exploration of mineral resources; and detection of environmental hazards. Both the U.S. Departments of Commerce and Interior archive all photographs at their respective data centers. ERTS-1 photographs may be purchased from at least one of these archives at nominal cost by anyone, simply by writing to the EROS Data Center at Sioux Falls, South Dakota. Canadian pictures may also be purchased from the archives in that country.

In addition, NASA has reached agreements with about 330 investigators who analyse the ERTS-1 observations for specific applications in the fields of agriculture and forestry, geography, geology, hydrology, oceanography, meteorology, and other sciences dealing with the quality of people's environment. These investigators are affiliated with federal and local governments, universities or private industrial organizations. Over one hundred of them are from countries other than the United States.

In order to observe most areas of the world, the satellite is in a nearly polar orbit and could make observations anywhere, during about 14 passes in a southwesterly direction, from 80° north to 80° south, every day. Passes occur at approximately the same local time (about 0930 at the Equator) at each location to assure uniform illumination of the imaged scenes. The fields of view of the MSS and RBV cameras are the same and encompass a strip, 185 km wide along the satellite's path. Images are taken daily along selected portions of such strips, about 1800 km apart, at mid latitudes. The orbit is adjusted such that a strip observed on one day is contiguous with the strip observed on the previous day. As each strip advances by about 180 km from a pass on one day to the same pass on the next day, the entire world could be covered by observarions once every 18 days. However, power and data transmission capacities of the spacecraft, as well as processing throughput of the NDPF are limited such that contiguous images every 18 days are possible only over North America. Over the rest of the world strips amounting to a total length of about 26,000 km (and of course 185 km wide) can be taken every day. These strips are distributed over areas which are forecast to be cloud free and in which at least one of the 330 investigators has agreed to conduct his analysis. Depending on contrast and geometric shape, objects larger than 50 to 100 meters in diameter may be easily identified in the ERTS-1 images. The images are sufficiently free of distortion so that they can serve readily as maps on scales up to 1:250,000. This combined with the ability of ERTS to view very large areas repeatedly, makes this satellite a most effective and economic tool to map features not previously detected as well as variations in environmental characteristics (Risley).

Each of the spectral intervals of the sensors permits the discrimination of different sets of features which are related to Earth resources. For example, the 0.5-0.6 micrometer interval provides for the greatest transparency of water such that shoals, sand bars, coastal shelves, and similar underwater features which might relate to ocean or lake dynamics or pose hazards to navigation can be mapped. The 0.6-0.7 micrometer interval provides for somewhat lesser transmission in water, but is especially useful to map suspended material and sediments. It also shows the greatest contrast between areas covered by vegetation and those denuded naturally or by people's activities, and is therefore most useful for mapping cultural patterns and land use. The two infrared intervals take advantage of the very low reflectivity of any kind of surface water and the relatively high reflectivity of vegetation, depending on type and state. This has led to the production of excellent maps of watersheds, drainage patterns, wetlands and swamps. In particular, in the Amazon region, maps were revised drastically on the basis of even these very early ERTS observations (Mendonca). In the same area, those rivers and tributaries, primarily the Amazon, which carry heavy silt and sediments could be clearly distinguished from those which were clear and free of turbidity, namely, the Rio Negro and all but one of its tributaries, by analyzing the 0.6-0.7 micrometer interval. Geological formations could also be delineated on the basis of vegetation changes in this and other regions by analyzing the 0.7-0.8 and 0.8-1.1 micrometer intervals.

In the 0.6-0.7 micrometer as well as in the infrared intervals one can clearly map linear features which relate to geological structure and one can recognize boundaries, between geological formations (Porter). Geological evidence of glacial surges were found in the Canadian arctic, and various geological stages of river flow were mapped in that region (Morley). Even in thoroughly explored areas of the world, between 10-20 percent of these linear features had not been mapped before. In unexplored areas the number of such features relating to geological structure first observed by ERTS is even greater. The mapping of these structural features is of significance to mineral exploration, the location of ground water and possibly the recognition of hazards to construction.

The most powerful analyses made, however, from ERTS-1 observations are those which combine all four spectral bands so that features may be identified and mapped on the basis of their varying spectral characteristics throughout these intervals. For example, snow cover of the Arctic Ocean ice and of the North American mountain chains was not only mapped for its areal extent and variations with topographic height but incipient melting conditions could also be recognized (Davis). This was based on the fact that snow appears increasingly darker at longer wavelengths as melting and water amount increase. This type of analysis when made over a period of time can lead to the computation of the amount of water run-off and therefore of water supply in large watersheds.

Of great significance to environmental surveys is the finding that burnt forest and agricultural areas stand out clearly in the multi-spectral images and they can be mapped very precisely. This makes it possible not only to assess fire damage very economically, but to plan more efficiently for reforesting and reclamation of the affected areas (Thorley).

Similar findings have been made for areas affected by strip mining or floods (Porter). Water pollution resulting from the dumping of acid wastes by barges in New York harbor was detected and mapped by analyzing MSS images in all four spectral intervals (Davis).

Multi-spectral analysis of images in California and in the Southwestern U.S. permitted easily the classification of agricultural crops, grazing lands, soils and various land use practices by the population. Almost instantly, a land use map of the entire San Joaguin County in California was produced from the first ERTS-1 picture of that area (Thorley). Automatic classifications of land use and agricultural features were made employing computerized "clustering" techniques (Landgrebe). These showed that about 13-18 different classes of vegetation, soil and land use features can be recognized in one typical ERTS-MSS image covering an area of 185 x 185 km.

Finally it was pointed out that ERTS pictures could provide observations extremely useful to the analysis of hydrodynamic processes in harbors, inlets, lakes or even in the open oceans. The spatial structure of vortices and other flow patterns displayed in ERTS pictures could be analyzed similarly to laboratory experiments, except that in this case, nature itself is staging the experiment (Napolitano). Particularly prominent displays of such hydrodynamic features were shown for the sedimentation plumes associated with the Mackenzie River in the Beaufort Sea (Morley) and with tidal patterns in Long Island Sound, Delaware Bay and other regions of the Atlantic coast of the Northeastern U.S. (Davis).

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