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NASA PLANS FOR FUTURE EARTH RESOURCES MISSIONS

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ABSTRACT

LANDSATS have proven that earth observations from space are capable of providing information which is useful in a number of applications that are of vital concern to society. These applications include the management of food, water and fiber resources, exploration and management of energy and mineral resources and measures to protect our life sustaining environment.

However, in order to fully satisfy the needs for such applications, it will be necessary to: (a) improve the present satellites and sensors; (b) extract useful information from these observations more quickly and reliably; and (c) improve the mechanism by which this information is transferred to end users.

A number of developments are now underway to improve sensors and observing systems. They include the third LANDSAT, to be launched in 1977, which will make high resolution images of surface temperatures to improve crop, other vegetation and soil classifications. A Heat Capacity Mapping Mission (HCMM) is also planned for 1977 to map surface temperatures at hours of maximum and minimum heating. It is expected that soil moisture patterns, and soil or rock compositions, can be distinguished better with such a satellite

than with LANDSATS which do not scan the earth at times that are optimum for this purpose. A Thematic Mapper is now under development to make earth surface images with a radiometric accuracy of about 0.5 percent in six spectral bands, and with a spatial resolution of about 30-40 meters. This instrument could be used for earth observations by 1980; however, a satellite mission to fly this Thematic Mapper has not yet been approved.

Automatic identification and classification methods are being developed to extract information such as crop and forage acreages, amounts of water run-off and types of land use directly from the satellite observations. A number of Applications Verification Tests are being conducted particularly in the areas of crop and land use inventory and water run-off prediction to demonstrate the direct transfer of space acquired information to end users.

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When speaking about plans for the future, it is not only desirable, but, I believe, also necessary to look back at one's accomplishments in order to establish the basis on which future developments can be, and should be based. In the area of surveying the earth's resources and environment from space, we can look back upon a very solid basis, indeed, which provides us with a clear understanding of the objectives and needs for future developments.

For more than a decade, weather satellites have made global observations of atmospheric and earth surface conditions which could be applied to a better understanding of geophysical processes involving earth resources and the environment. Recently, LANDSATS have proven that earth observations from space are capable of providing information that is of vital concern to society; namely, for the management of food, water and fiber resources, for the exploration and management of energy and mineral resources, and for the protection our life sustaining environment.

From this experience, we have learned that in the future it will be necessary to concentrate on three general activities:

1. to improve our space-borne observing and measuring techniques, in order to make them more specific to the applications which they will be designed to achieve.

2. to provide for ground based facilities and to organize ground operations such that specific useful information can be extracted more rapidly and more reliably than is now possible with the highly experimental LANDSATS.

3. to improve the mechanism by which the information that results from satellite observations filters down to the end-users and is integrated, not only in their day to day operations, but also in their planning and budget considerations.

This last aspect of our planning depends not only on past technical achievements and on the soundness of our technological approach to the future, but it also depends very strongly on economic and political considerations. I am very much concerned that our most diligent and competent technical plans for future space observing systems will be fruitless and doomed to fail, if users are not willing to make the necessary investments and commitments to reap the benefits of this new technology.

Let us now take a brief look at the present state of earth resources and environmental surveys from space. Table 1 summarizes the types and purposes of both, satellites that are now operating and satellites that are being built to firm launch schedules. Thematic maps can now be obtained, at least theoretically, every nine days, anywhere in the world (outside a circle of 10 degrees around each pole) with the two LANDSATS that are in orbit now. These maps

TABLE 1

EARTH RESOURCES AND ENVIRONMENTAL SURVEY SATELLITES

• OPERATING AS OF OCT. 75

LANDSAT 1 – 1972 LANDSAT 2 – 1975	4 BAND THEMATIC MAPPING (80 M. RES.)
NOAA 3 -- 1973 NOAA 4 – 1974	SEA SURF. TEMP. ICE & SNOW (OPTICAL, 1 KM. RES.)
NIMBUS 5 & 6 – 72 & 75	SEA ICE (MICROWAVE, 30 KM. RES.)
SATELLITE TRACKING – CONT.	GRAVITY FIELD

• IN PREPARATION

LANDSAT 3 – 1977	4 BAND THEM. MAPP. (80 M. RES.) THERMAL MAPPING (200 M. RES.) PANCHROMATIC IMAGING (40 M. RES.)
APPLICATIONS EXPL. 1 – 1977	"HEAT CAPACITY" MAPPING (500 M. RES.)
NIMBUS 7 – 1978	OCEAN COLOR & TEMP. (500 M. RES.) SEA ICE & SEA STATE AIR POLLUTION
SEASAT-1 – 1978	SEA ICE & SEA STATE
TIROS N – 1978	GLOBAL ATMOSPHERE & SEA SURFACE OBSERVATIONS

can be obtained from the images acquired by LANDSATS 1 and 2 in four spectral bands of reflected solar radiation along 185 km wide swaths. But, LANDSAT 1, which was 3 years old in July 1975, can transmit data only directly to receiving stations; it cannot store pictures on its tape recorders anymore. Therefore, observations every nine days are possible only where such receiving stations exist. This is the case for North America, via three stations in the U.S. and one in Canada; over South America, via a Brazilian station; and over Europe and North Africa, via a station in Italy. Direct transmissions of observations over Southwest Asia, Southeast Europe and Northeast Africa will soon be possible via a station that is being procured by Iran. A station to be located in Zaire will cover most of the remainder of Africa. Interest in such receiving stations has also been expressed by a variety of additional countries, so that thematic mapping every nine days using two LANDSATS, is expected to cover increasingly large areas of the world. Other areas, which are not within range of such receiving stations, must epend on the data stored on the tape recorders that still function on LANDSAT 2. Such coverage occurs, of course, much less frequently; namely, one to several times per year, depending on interest expressed by people in these areas.

In addition, observations relating to earth resources management and environmental protection are available from the operational weather satellite system that is maintained by the National Oceanic and Atmospheric Administration (NOAA). Aside from continuous observations of cloud formations and atmospheric temperature soundings for the purpose of weather forecasting, these satellites also provide global maps of surface temperatures and images of snow and ice cover in the visible and infrared spectrum with about 1 km resolution. NOAA 3 and 4 are operating now and as soon as one of these satellites fails, it will be replaced by a new one, to keep two in operation at all times.

Microwave sensors on NIMBUS 5 have mapped the extent, and to a certain degree, the structure of Polar Sea Ice, and of the Greenland and Antarctic ice sheets, since December 1972.

Another significant geophysical result was obtained through tracking of more than thirty satellites over the last 10 years. Analyses of perturbations of the orbits of these satellites have made it possible to determine the earth's gravity field on a global scale with a spatial resolution that would be economically prohibitive by any other means.

Now, I should like to turn to our plans for the immediate future. These involve satellites and missions which are being readied for launch during the next few years. Our highest priority is to supplement the thematic mapping, which has been so eminently successful with the first two LANDSATS, with images of surface temperatures. The multispectral scanner, which will be flown on the third LANDSAT in 1977, will include a fifth band to measure an image radiation emitted by the earth's surface in the 10.5 to 11.5 micrometer wavelength range.

It is expected that surface temperature maps with a spatial resolution of about 200 meters can be obtained from these measurements. Adding this temperature mapping capability to the LANDSAT system, is expected to improve significantly our capability of classifying crops, vegetation and soils.

Experiments conducted with Skylab and with aircraft flights have shown that for some applications, higher spatial resolutions than those of LANDSAT 1 and 2 are desired, especially for urban land use mapping and for the detection of transient phenomena. The Return Beam Vidicon (RBV) cameras which have seen very little use with LANDSATS 1 and 2 will be reconfigured for this purpose on LANDSAT 3. Instead of three cameras in three spectral bands, two panchromatic cameras will be used to cover the same 185 km wide swath that the MSS covers, but the cameras will provide twice the spatial resolution of the MSS, namely, about 40 meters.

The potential of deriving soil moisture and surface composition information for both agricultural and hydrogeological purposes, is being further pursued with the socalled "Heat Capacity Mapping Mission" (HCMM) which is expected to fly on the first applications explorer satellite in 1977. In contrast to the observatory class spacecraft of the NIMBUS or LANDSAT type, which carry many or very complex instruments, each applications explorer will carry only one relatively simple instrument. The HCMM, for example, will only carry a 10.5 - 11.5 micrometer temperature mapping radiometer, with a spatial resolution of about 500 meters. For reference purposes, a visible radiation channel of the same spatial resolution will also be included. The advantage of such a mission is that the orbital characteristics can be chosen to suit one and only one objective. In this particular case, the objective is to map surface temperatures at hours of maximum and minimum heating; that is, during early afternoon and early morning hours.

The surface temperature extremes, measured at those times, will provide a better indication of the heat capacity of the ground than the LANDSAT 3 temperature maps which must be obtained at mid-morning and late evening in order to accommodate the other four spectral bands. It is expected that soil moisture patterns and soil or rock compositions can be distinguished better with the HCMM mission than with LANDSAT. Coverage with the HCMM will be such that each area of the earth will be observed at least once every week during consecutive morning and afternoon passes from which heat capacity determinations will be attempted. Data can be read out only via direct transmission to ground stations and the format of the transmissions will be compatible with LANDSAT data acquisition stations.

Probably the last of the big, complex earth viewing observatories before the advent of Spacelab, will be NIMBUS-7 (called NIMBUS G before launch). Aside from making such measurements as the global radiative energy budget, solar ultraviolet radiation, and global ozone distributions, for the purpose of continuously monitoring these important environmental parameters, NIMBUS 7 will demonstrate the feasibility of monitoring air and water pollution from space. Inferences concerning water quality, including nutrient content will be attempted from measurements of water color with a coastal zone color scanner (CZCS). The scanner will map water surfaces in six spectral bands ranging from shortwave blue to the near-infrared with a spatial resolution of about 500 meters. In contrast to LANDSAT images, these measurements will be conducted in spectral bands which are particularly sensitive to the signatures of various water characteristics, such as sedimentation, chlorophyll, various types of pollutants and bottom features. It is expected that observations in all major coastal zones of the world will be made twice every week with the CZCS NIMBUS 7. Test flights of the NIMBUS CZCS on a U-2 aircraft over the N. Y. bight, have shown clearly the dumping of acid wastes by barges and the drift patterns of the resulting pollution. Similar aircraft tests were conducted with U-2's off the west coast of Florida to determine the feasibility of detecting and mapping the occurrence of red tides with NIMBUS 7.

Both NIMBUS 7 and SEASAT will continue the monitoring of sea ice with microwave sensors. But, in contrast to NIMBUS 5 and 6, the passive microwave sensor on NIMBUS 7 and on SEASAT will provide simultaneous images at five different wavelengths with spatial resolutions ranging from 25km at the short wavelengths to 200km at the longest wavelength. In addition to ice mapping, these observations will also permit the measurement of sea state and sea surface temperature, regardless of cloud cover. SEASAT-1 will also carry an imaging radar for the purpose of sea state and sea ice observations; however, because of data throughput limitations on this satellite, it appears very unlikely that substantial amounts of radar observations will be made by SEASAT over land surfaces.

The TIROS-N system to be placed in operation in 1978, is intended to improve the operational observations now made with the NOAA satellites and will include perhaps even such environmental monitoring as sea ice, solar radiation, and atmospheric composition.

Now, I should like to turn to the missions which are not yet in preparation but which we think will be absolutely necessary to provide the information that is needed for efficient earth resources management and environmental planning (Table 2). We believe that the key to LANDSAT follow-on missions will be the development of a new thematic mapper. This instrument would perform measurements with greater radiometric accuracy than the MSS on LANDSAT. Six spectral bands will be more appropriately placed, and afford greater spatial resolutions than the MSS. The spatial resolution will be 30 - 40 meters in all but the surface temperature measuring bands and a radiometric accuracy of about 0.5 percent is expected to be achieved. A spectral band in the near-infrared range around 1.6 micrometers would be included. This band is particularly important for agricultural and vegetation surveys. We are planning to

TABLE 2

EARTH RESOURCES AND ENVIRONMENTAL SURVEY SATELLITES (CONT.)

• PLANNED

LANDSAT 4 – 1980	THEMATIC MAPPER
APPLICATIONS EXPLORER 3 – 1980	MAGNETIC SURVEY

• PROSPECTED - MID 1980's

SEASAT FOLLOW-ON	SEASTATE, ICEBERGS, OCEAN CURRENTS
CLIMATE MONITORING	LAND USE, RADIATION BUDGET, STRATOSPHERE
SHUTTLE/SPACELAB EXP.	RADAR SURVEYS
GRAVSAT	GRAVITY FIELD SURVEYS
SEOS	GEOSYNCHRONOUS ENVIRONMENTAL SURVEYS

initiate the full development of this instrument during the next fiscal year. However, a satellite mission to fly this thematic mapper has not yet been approved.

Another significant part of the planning for LANDSAT follow-on missions must be the redesign and reorganization of the data acquisition information extraction and data utilization scheme. LANDSAT 1 and 2 observations had been analyzed for a great variety of purposes by many hundreds of individual investigators in more than 40 countries. Many governmental organizations, especially in the U. S. A., Canada, and Brazil have applied these observations as aids to their operations, such as sea and lake ice surveys, preparations of environmental impact statements, water runoff predictions, flood potential assessments, updating of navigational charts and geological and general purpose maps, especially in sparsely populated or rapidly changing areas. In addition, several tens of thousands of individuals and organizations from all over the world have ordered LANDSAT data for their private purposes from the data center in Sioux Falls. However, all of this happened many months or even years after the observations had been taken. The present LANDSAT data processing and information extraction scheme is not suited for efficient operational applications. For follow-on systems we cannot use the mail to ship raw data tapes from outlying data acquisition stations such as Alaska and California to a central processing station. In fact, we must decentralize the conversion process from raw data tapes to image tapes or hard copies, to the greatest extent possible.

This will be facilitated by an all digital processing system. Worldwide data will be transmitted from the satellite to the U.S. via a tracking and data relay satellite and local data should be acquired by direct transmission to acquisition stations which should be placed to cover all major land masses of the earth.

In the U.S., data should be distributed via efficient communications links to decentralized processing stations which would generate those images, and apply those information extraction algorithms, that are suited to their particular applications. Those who must acquire and process data in real time for operational purposes must now, work with NASA and help plan the data acquisition, processing and information extraction schemes for LANDSAT follow-on systems.

We are also planning another applications explorer mission for earth survey purposes. The third such mission, to be launched in 1979, is planned to carry sensors to map the magnetic field of the earth. Measurements with the Orbiting Geophysical Observatory (OGO), almost 10 years ago, have proven the feasibility of extracting latitudinal and longitudinal variations of the solid earth magnetic field from orbital magnetometer measurements. Similar measurements from a MAGSAT which would be designed specifically to map the field of the solid earth, would be much more accurate and provide higher resolution than the OGO measurements. The results would serve to improve our understanding of the crustal structure of the planet, if not provide supplementary information for geophysical exploration.

Beyond LANDSAT follow-on and the MAGSAT missions, all our plans are highly speculative and not even in the firm proposal stage. In Table 2, they are summarized as "prospective" missions. They include the possible survey of ocean conditions, such as sea ice, sea state, hazards to navigation, oil spills and marine resources on an operational basis. Undoubtedly, satellites will have to be flown to make observations that are necessary to monitor and detect climate trends. Such observations include the survey of land use and concommittant albedo changes. The Spacelab on the "Shuttle" space transportation system will provide an inexhaustable facility for testing new observing techniques, particularly earth survey radars. A set of satellites whose orbital motions will be critically monitored, may be used to make an accurate survey of the earth's gravitational field. Finally, the ultimate earth survey test might be a Synchronous Earth Observing Satellite (SEOS) which would provide essentially continuous observations of LANDSAT quality, over almost an entire hemisphere.

In conclusion, I should like to note that our technical base for planning future earth observing missions is well established. Our objectives for future missions are highly focussed and the technical feasibility of not the missions we are planning, but also those that we are dreaming about is clearly demonstrated. But, the hard facts of life are, however, that in today's environment, neither the best and most competent technical planning nor the most dedicated enthusiasm will suffice.

What is needed is an unequivocal consensus that the new systems which we are planning and which we wish to implement are not only feasible, but are also beneficial. This consensus must include particularly those who are considered the ultimate beneficiaries, namely, the end-users of this new technology. The broader this consensus is and the stronger commitments are made on the part of the users, the sooner we can expect that our plans and hopes for such news systems will be fulfilled.