PAPS - Global Ch

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR GEOSCIENCES

November 15, 1990

Dr. Dallas L. Peck, Chairman
Committee on Earth and
Environmental Sciences
U.S. Geological Survey
101 National Center
Reston, Virginia 22092

Dear Dallas:

I am pleased to submit the report entitled "The Value of Landsat to the U.S. Global Change Research Program: A Report by the Committee on Earth and Environmental Sciences." This report was prepared at your request by an ad hoc task group of individuals from member agencies of the Committee on Earth and Environmental Sciences (CEES). A list of the individuals and their participating agency on the Task Group is enclosed. The agency representatives on the Task Force concur with the contents of this report, and it is transmitted to you with their concurrence.

The report addresses the issues you requested in your letter dated June 4, 1990, namely the availability, accessibility, and maintenance of past and current Landsat data for use in global change research, and identification of future requirements for land remote sensing specifically in support of the U.S. Global Change Research Program (USGCRP). The report points out that existing Landsat data and a continuing Landsat program throughout the lifetime of the Earth Observing System (EOS) missions are essential to the USGCRP. It also points out that commercialization of Landsat is currently impeding the use of large quantities of Landsat data necessary for global change research because of the high commercial costs. The report encourages efforts directed at preserving and improving the utilization of existing Landsat data and accelerating data conversion to ensure the availability of older Landsat data for global change research.

Finally, the report urges the Federal Government to (1) determine the approach to meeting the Nation's needs for Landsat-type capabilities that provides the maximum net benefits, including cost effectiveness, (2) investigate all options for providing Landsat data to the user community at prices scaled to recover the recurring costs of reproduction and dissemination, and without

trade secret or other use restrictions, (3) resolve as soon as possible the management, policy, and technical issues concerning the follow-on satellite systems after Landsat 6 so as to avoid data gaps, and (4) identify funding for acquisition and archiving of Landsat-6 data for the USGCRP.

I would be pleased to discuss the report with you at your convenience.

Sincerely,

Robert W. Corell
Chairman

CEES Landsat Task Group members:

Dr. Robert W. Corell, National Science Foundation, Task Group Chairman

Dr. Galen Hart, Department of Agriculture/ARS
Dr. James F. Hays, National Science Foundation
Captain Robert W. Reny, Department of Defense/USN
Ms. Eileen Shea, Department of Commerce/National Oceanic and Atmospheric Administration
Dr. Gene A. Thorley, Department of Interior/U.S.G.S.
Dr. Shelby Tilford, National Aeronautics and Space Administration

Dr. Jerry W. Elwood, CEES Staff
Mr. Paul V. Dresler, CEES Staff

November 14, 1990

THE VALUE OF LANDSAT TO THE U.S. GLOBAL CHANGE RESEARCH PROGRAM

A Report by the Committee on Earth and Environmental Sciences

THE GLOBAL CHANGE RESEARCH PROGRAM

The fundamental goals of the U.S. Global Change Research Program (USGCRP) are to reduce key scientific uncertainties concerning global environmental change and to develop more reliable scientific predictions to guide the development of sound policy and response strategies. This can only be accomplished by obtaining a scientific understanding of the Earth system on a global scale, which will lead to improved predictive models of the processes of interaction among its atmospheric, ocean, and land components.

Developing this scientific understanding will require comprehensive interdisciplinary research efforts supported by consistent, long-term, repetitive measurements and observations of the mechanisms and processes associated with global change. Earth-orbiting satellites such as Landsat are an essential source of these data.

This report examines (1) the value of Landsat data to the U.S. Global Change Research Program, (2) alternatives for obtaining the Landsat-type data necessary for global change research, and (3) issues that need to be resolved to facilitate the full use of Landsat data for global change research.

THE NEED FOR LANDSAT DATA

Global monitoring of the Earth's land surfaces and shallow seas was made possible for the first time in 1972 with the launch of the Earth Resources Technology Satellite (ERTS-1), now known as Landsat-1. For more than a decade, the multispectral scanner (MSS) on Landsats 1, 2, and 3 was the principal sensor employed for this purpose. The MSS was augmented by the launch of the thematic mapper (TM) on Landsat 4 in 1982. An enhanced TM is being developed and will be placed on Landsat 6 which is scheduled for launch in 1992.

Environmental "inventory" data from the Landsat series of satellites are particularly suited to the long-term estimation and monitoring of standing vegetation biomass, biological productivity, land cover type, snow and ice cover, rate of deforestation, desertification, and changes in fragile ecosystem borders. At present, about 1 percent of the Earth's land surface is covered by urban development, while ice, bare ground, and cropland each account for about 10 percent of the total. The remaining 70 percent of the land area is covered by forests, woodland, grasslands, shrublands, tundra, and other vegetation types which vary markedly in properties such as reflectance and absorbtivity, water content, surface roughness, carbon storage, and chemical composition. Each of these properties responds in different ways to

anthropogenic pressures and to the processes of global change. Changes in vegetative cover and other land surface/land cover changes are intrinsically linked to global climate change, both as an early indicator of climate change and as a contributor to changes in the chemical composition of the atmosphere. Repetitive data from Earth-orbiting satellites like Landsat provide a capability to observe changes in land surface/land cover that are not obvious from other space- or even ground-based measurements.

Thirty- and 80-meter ground resolution Landsat data can be acquired every 16 days, depending on atmospheric conditions such as cloud cover. These data can be combined, using multi-stage sampling methodologies, with 1-km to 4-km ground resolution data acquired daily from sensors on meteorological satellites (e.g., the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR)) and with ground-based observations to provide the basic land characterization data needed to improve many predictive global change models. AVHRR data are complementary to, but not a substitute for, the data provided by Landsat.

Moreover, Landsat data, consistent in characteristics and data format, have been collected without interruption during the last 18 years. By the launch of the first National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) polar platform in 1997, Landsat data will have provided a 25-year head start on the repetitive long-term monitoring of the Earth's land surface and shallow seas from space. Existing Landsat data will provide a unique baseline of land conditions existing in the 70's, 80's, and 90's that will not be available from any other existing data source. A disruption in the flow of Landsat data will impede our ability to monitor changes in land surface conditions that are occurring in response to climate and other environmental change.

Table 1 provides a ranking of the value of Landsat data to the seven science elements and research priorities under the science elements in the USGCRP. Landsat data are considered essential for three of the seven science elements and important to two others. Moreover, Landsat data are considered important to some research priorities within one of the two remaining elements.

CEES believes that a continuing Landsat program is essential to the USGCRP and should be a important component of the international "Mission to Planet Earth" Program designed to provide the long-term observations necessary to understand global change processes and to predict the magnitude and timing of future changes.

OTHER DATA SOURCES: TWO COMPLEMENTARY PROGRAMS

Two other Earth-observing satellite systems (EOS and SPOT) offer data that are complementary to, but not substitutes for, the data provided by Landsat.

THE EOS PROGRAM: Landsat data are complementary to data to be returned from the NASA EOS polar platform sensors. The primary EOS land-observing sensors are the pointable High Resolution Imaging Spectrometer (HIRIS), the Intermediate and Thermal Infrared Radiometer (ITIR), and the Moderate Resolution Imaging Spectrometers (MODIS-N and -T). HIRIS and ITIR will acquire relatively narrow field of view, hyperspectral, high spatial resolution data, and MODIS will acquire moderate spatial resolution, wide field of view data. No EOS sensors will return data similar in characteristics to Landsat, i.e., high spatial resolution, broad spectral bands, and wide-area coverage. Landsat data will also be needed to develop, test, and validate EOS data processing algorithms prior to and after the launch of EOS.

The EOS was conceived and designed assuming the continuation of Landsat-type data. Landsat makes its observations in the morning at a time when cloud cover is at a minimum. EOS is intended to fly in the early afternoon to observe terrestrial vegetation near the time of maximum thermal and hydrologic stress, thereby revealing the potential for ecosystem change due to such stress. The HIRIS and its Japanese-provided companion instrument, ITIR, have been designed for EOS as highly flexible research tools to study local processes at specific sites around the globe, while the Landsat TM serves as a survey instrument for global monitoring.

Specifically, Landsat has a 185-km swath width, fixed nadir viewing, six spectral bands for reflected sunlight and one band for thermal emission, and can image the Earth's surface every 16 days, limited only by atmospheric conditions such as cloud cover. HIRIS will have a 24-km swath, both along-track and cross-track pointing, and 192 spectral bands for reflected sunlight. These characteristics will permit detection of small shifts in ecosystem boundaries, detailed study of inland lakes and estuaries, and the examination of processes in vegetation. ITIR provides complementary capabilities for thermal emission measurements with five spectral bands.

On EOS, the frequent global survey of coarse-resolution vegetation conditions will be provided by the MODIS which will provide global coverage every 1 to 2 days at 500-1000 m resolution. As with the data from NOAA's AVHRR flying today, MODIS will enable the observation of the phenology of land vegetation at finer temporal resolution than TM but lacks the ability to distinguish the spatial and spectral detail associated with ecosystem change and agricultural practices.

<u>CEES believes that Landsat and EOS are complementary systems and, to be fully successful, the international "Mission to Planet Earth" Program and NASA's EOS Program will require the availability of existing Landsat data and continuing the acquisition of Landsat-like data throughout the lifetime of the EOS missions.</u>

THE SPOT PROGRAM: The French SPOT system also provides data that are complementary to Landsat data. SPOT data have higher spatial resolution than Landsat; SPOT panchromatic data have 10-meter spatial resolution; and SPOT multispectral data have 20-meter spatial resolution. Repeat coverage of the Earth is possible with both Landsat (every 16 days) and SPOT (every 26 days) because the ground tracks of the satellite orbit repeat periodically. The

SPOT off-nadir viewing capability also permits coverage of specific targeted sites at least twice a week, but with variable viewing and sun illumination angles. The SPOT system also uses its off-nadir pointing capability to acquire stereoscopic coverage, while Landsat can only acquire stereo coverage in the overlap area between adjacent paths.

However, the Landsat TM has mid-infrared and thermal-infrared spectral bands not available from SPOT that provide important information about vegetation and other Earth-surface conditions. Moreover, Landsat provides a longer-term set of key observations (since 1972) than SPOT, which has only been operating since 1986. Further, Landsat TM data cover a 185-km ground swath; a SPOT scene covers an area measuring 60 by 60 km. Since it takes 9 SPOT scenes to cover the area of one Landsat TM scene, substantial additional cost and effort is required to acquire and process SPOT data for large areas. In general, SPOT data are used more effectively for site-specific studies, and Landsat data are more appropriate for larger area studies and studies where the unique TM spectral bands are needed.

CEES believes that Landsat and SPOT are complementary systems, with Landsat having significant additional spectral capabilities and cost advantages for large area coverage.

ISSUES TO BE RESOLVED

The CEES believes that full utilization of Landsat data to support global change research requires the resolution of three distinct issues:

A) Immediate development of plans and policy for continuation of the Landsat program beyond Landsat 6.

B) Assurance of the availability and accessibility of Landsat data for use in scientific studies of global change.

C) Preservation and improved utilization of existing Landsat data, including the conversion of the existing data to a more permanent, manageable, and retrievable archive medium.

A. DATA CONTINUITY

The National Space Council is acting on the President's commitment to ensure the continuity of Landsat-type remotely sensed data after Landsat-6, which is scheduled for launch in 1992 with an expected 5-year life span. Various Federal agencies have made recommendations to the National Space Council about the technical specifications for a Landsat-6 follow-on system, including higher spatial resolution and stereoscopic imaging capability for developing digital terrain models.

In recent Senate testimony, a senior policy-level administrator from the National Oceanic and Atmospheric Administration stated that "Our experience with the Landsat program, and the results of studies for us, have led us to the conclusion that commercialization of Landsat, as had

originally been envisioned, is not possible." The cost of building, launching, and operating Landsat-type satellites is in the range of $120-$150 million a year, while current annual revenue from data sales and foreign station access fees is $15-$20 million. There is no evidence that the revenue from the sale of Landsat products is growing at a rate that will support continuation of a commercial program into the future without heavy government subsidies. The large gap between costs and revenue indicates that the Federal Government will have to provide most, if not all, of the hardware and launch costs for any follow-on satellite systems after Landsat-6.

The CEES urges that the Federal government determine the approach that provides the maximum net benefits, including cost effectiveness, in meeting the nation's needs for Landsat-like capabilities after Landsat-6. Such a determination should include consideration of the Federal government re-assuming management of any follow-on satellite systems after Landsat-6. The CEES also urges that the policy, management, and technical aspects of follow-on satellite systems after Landsat 6 be resolved as soon as possible to avoid lengthy data gaps.

B. DATA AVAILABILITY AND ACCESSIBILITY

Existing commercialization policy has resulted in higher data prices that seriously inhibit the use of Landsat data for important global environmental monitoring and earth science studies requiring large quantities of data. Researchers at universities and other scientific organizations cannot afford to buy large quantities of Landsat data at commercial prices. In 1983, prior to the 5- and 10-fold price increases in Landsat data, the academic community purchased and used approximately 11,000 Landsat image and digital data products. In 1989 this number had dropped to fewer than 600 products.

Commercialization policies related to both pricing and data acquisition strategy also restrict the amount of data potentially available from Landsat 6 for global change studies. Because the government will not own the data from Landsat 6, these data must be purchased for the government archive from EOSAT, the commercial operator. Moreover, EOSAT has stated that periodic worldwide data will not be acquired unless orders are placed for acquisition. Currently no funds are identified to assure the acquisition of Landsat-6 data for the government archive.

CEES has adopted as a fundamental policy "full and open sharing of the full suite of global data sets for all global change researchers." Other policies adopted are that "data should be provided at the lowest possible cost to global change researchers in the interest of full and open access to data" and that "This cost should, as a first principle, be no more than the cost of reproduction and distribution." Access to Landsat data should be consistent with these policies.

In order to enable more effective use of large quantities of Landsat data needed for global change research, the Federal Government should investigate all options for providing Landsat data to the user community

at prices scaled to recover recurring cost of reproduction and dissemination, and without trade secret or other use restrictions. Recognizing the constraints of standing legislation and current contractual arrangements, CEES believes that this will likely require modification or repeal of the commercialization aspects of the Land Remote-Sensing Commercialization Act of 1984. To avoid data gaps, funds should be identified in future budget submissions to ensure the acquisition and archiving of Landsat-6 data for the USGCRP.

C. DATA PRESERVATION AND IMPROVED UTILIZATION

Responsibility for the long-term maintenance of existing Landsat data is in the process of being legislatively transferred from the Department of Commerce to the Department of the Interior. Approximately 1 million scenes of Landsat MSS and TM data acquired over the past 18 years at a cost to the Federal Government of over $1.5 billion exist in several different formats, in different locations, and can only be processed on one-of-a-kind hardware/software systems. More importantly, the early data are becoming unreadable due to magnetic tape degradation or processing system obsolescence. At the current level of support, one-fourth of the early Landsat data will be lost in the next few years. An accelerated data conversion program will minimize data loss due to tape degradation.

In July 1994, approximately 665,000 scenes of Landsat data, acquired between 1972 to 1985, will revert to the public domain and be available at significantly less than commercial Landsat data prices. Enhanced capability for MSS and TM data production and dissemination, ccupled with the development of improved data calibration procedures, will be necessary to respond effectively to the anticipated increased Landsat data demand of the global change research community when Landsat data become available at substantially lower cost.

The CEES supports efforts to preserve and improve utilization of existing Landsat data, accelerate data conversion, and ensure data availability for global change research.

SUMMARY

Existing Landsat data and a continuing Landsat program throughout the lifetime of the EOS missions are essential to the USGCRP and to the international "Mission to Planet Earth" Program. CEES believes that the commercialization of the Landsat program is currently impeding the use of Landsat data for global change research because of the high commercial cost of large Landsat data sets needed for global studies. CEES recommends that the Federal Government investigate all options to ensure the availability of Landsat data for global change research and endorses a policy that would provide Landsat data to the global change research community at prices scaled to the recurring cost of reproduction and dissemination, and without trade secret or other use restrictions. Recognizing the constraints of standing legislation and current contractual arrangements, CEES believes that the Land Remote-Sensing

Commercialization Act of 1984 will likely require modification or repeal in order to enable more effective use of Landsat data for global change research.

CEES also endorses efforts to preserve and improve utilization of existing Landsat data, accelerate data conversion, and ensure data availability for global change research. To avoid data gaps, funds should be identified in future budget submissions to ensure the acquisition and archiving of Landsat-6 data for the USGCRP.

In examining alternatives for meeting the nation's needs for Landsat-type capabilities after Landsat 6, the CEES urges that the Federal Government determine the approach that provides the maximum net benefits, including cost effectiveness. The CEES believes that such a determination should include consideration of re-assuming management of any follow-on Landsat systems after Landsat 6. The CEES urges that the policy, management, and technical aspect of follow-on systems after Landsat-6 be resolved as soon as possible to avoid lengthy data gaps.

These recommendations will promote the use of Landsat data by the global change research community and by a broad segment of the public and private sector, and will continue to demonstrate U.S. leadership in land remote sensing from space.

Table 1. Value of Landsat data to the science elements and research priorities within these elements of the U.S. Global Change Research Program.

Priority ranking scale:
E = Landsat data essential
I = Landsat data important
N = Landsat data not currently used or not applicable

Science elements and priorities*	Ranking of Landsat Importance
CLIMATE & HYDROLOGIC SYSTEMS	I
Role of Clouds	I
Ocean Circulation & Heat Flux	N
Land/Atm/Ocean Water & Energy Flux	I
Coupled Climate System & Quntitative Links	I
Ocean, Atmosphere, Cryosphere Interactions	E
BIOGEOCHEMICAL DYNAMICS	I
Bio/Atm/Ocean Fluxes of Trace Species	I
Atmospheric Processing of Trace Species	N
Surface/Deep Water Biogeochemistry of Carbon & Nutrients	N
Terrestrial Biosphere Nutrient & Carbon Cycling	E
Terrestrial Inputs to Marine Systems	I
ECOLOGICAL SYSTEMS & DYNAMICS	E
Long-term Measurements of Structure & Function	E
Response to Climate & Other Stresses	E
Interactions Between Physical & Biological Processes	E
Models of Interactions, Feedbacks, & Responses	I
Productivity/Resource Models	E
EARTH SYSTEM HISTORY	N/I
Paleoclimate	N
Paleoecology	N
Atmospheric Composition	N
Ocean Circulation & Composition	N
Ocean Productivity	N
Sea level change	I
Paleohydrology	I
HUMAN INTERACTIONS	E
Data Base Development	E
Models linking:	
Population Growth/Distribution	E
Energy Demands	E
Changes in Land Use	E
Industrial Production	E
SOLID EARTH PROCESSES	E
Coastal Erosion	E
Volcanic Processes	E
Permafrost & Marine Gas Hydrates	I
Ocean/Seafloor Heat & Energy Fluxes	N
Surficial Processes	E
Crustal Motions and Sea Level	I
SOLAR INFLUENCES	N
EUV/UV Monitoring	N
Atm/Solar Energy Coupling	N
Irradiance (measure/model)	N
Climate/Solar Record	N
Proxy Measurments and Long-Term Data Base	N

* Science elements and research priorities from *Our Changing Planet: The FY 1990 Research Plan, The U.S. Global Change Research Plan. A Report by the Committee on Earth Sciences*, July, 1989.