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*STUDY BY THE STAFF  
OF THE  
U.S. GENERAL ACCOUNTING OFFICE*



LM098301

BEST DOCUMENT AVAILABLE

**Land Satellite Project**

National Aeronautics and  
Space Administration

LANDSAT is a NASA experimental project to determine the utility of satellite-acquired earth resources data for the management of our environment and natural resources.

This study provides the Congress with information on the project's need and expected benefits; status and progress related to cost, schedule, and performance; uncertainties; and international implications.

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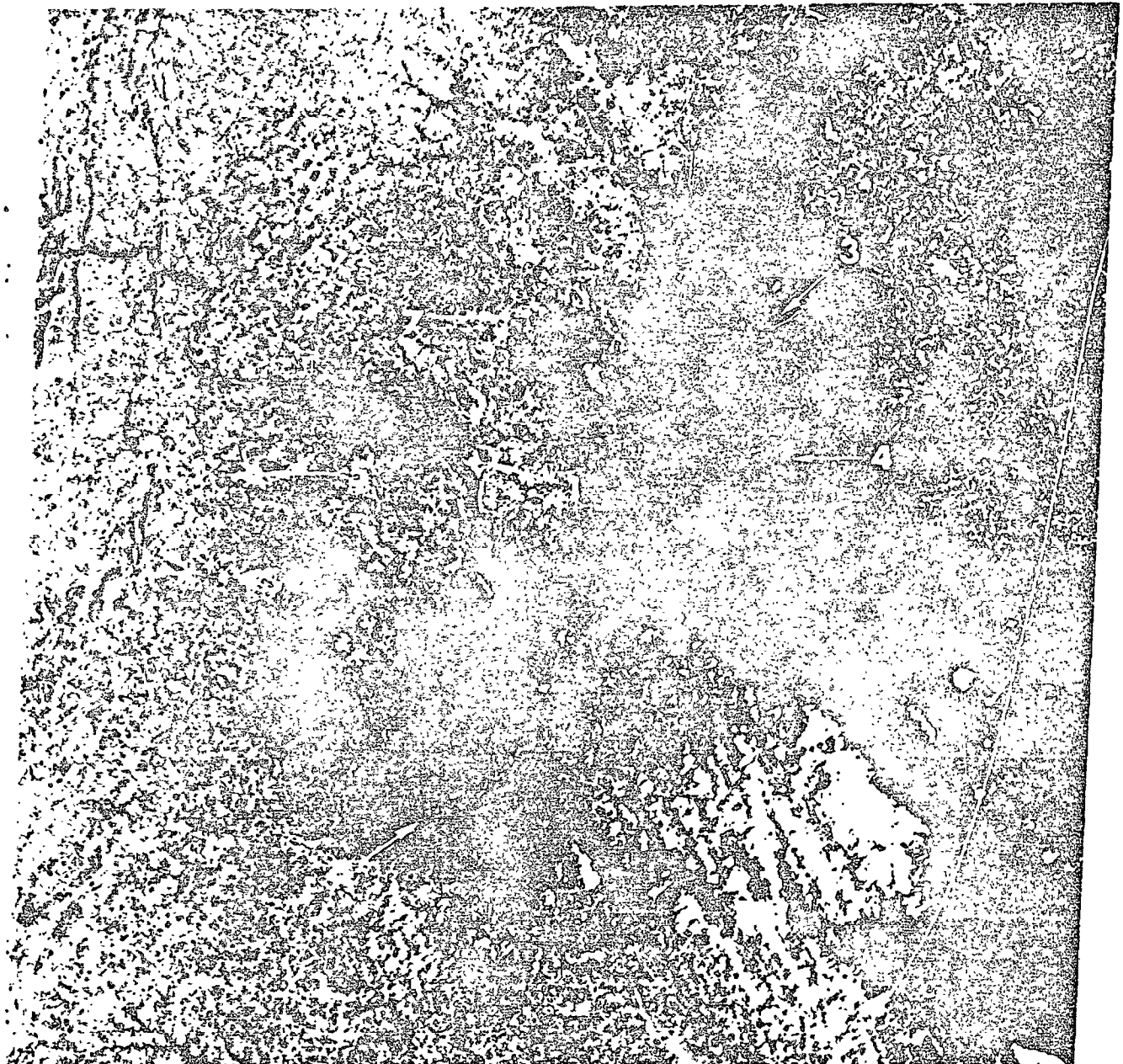
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WASHINGTON, D.C. AREA AS SEEN BY NASA SATELLITE



- 1. Washington, D.C.
- 2. Baltimore, Maryland
- 3. Chesapeake Bay Bridge
- 4. Chesapeake Bay
- 5. Dulles Airport
- 6. Potomac River



7. Interstate 95



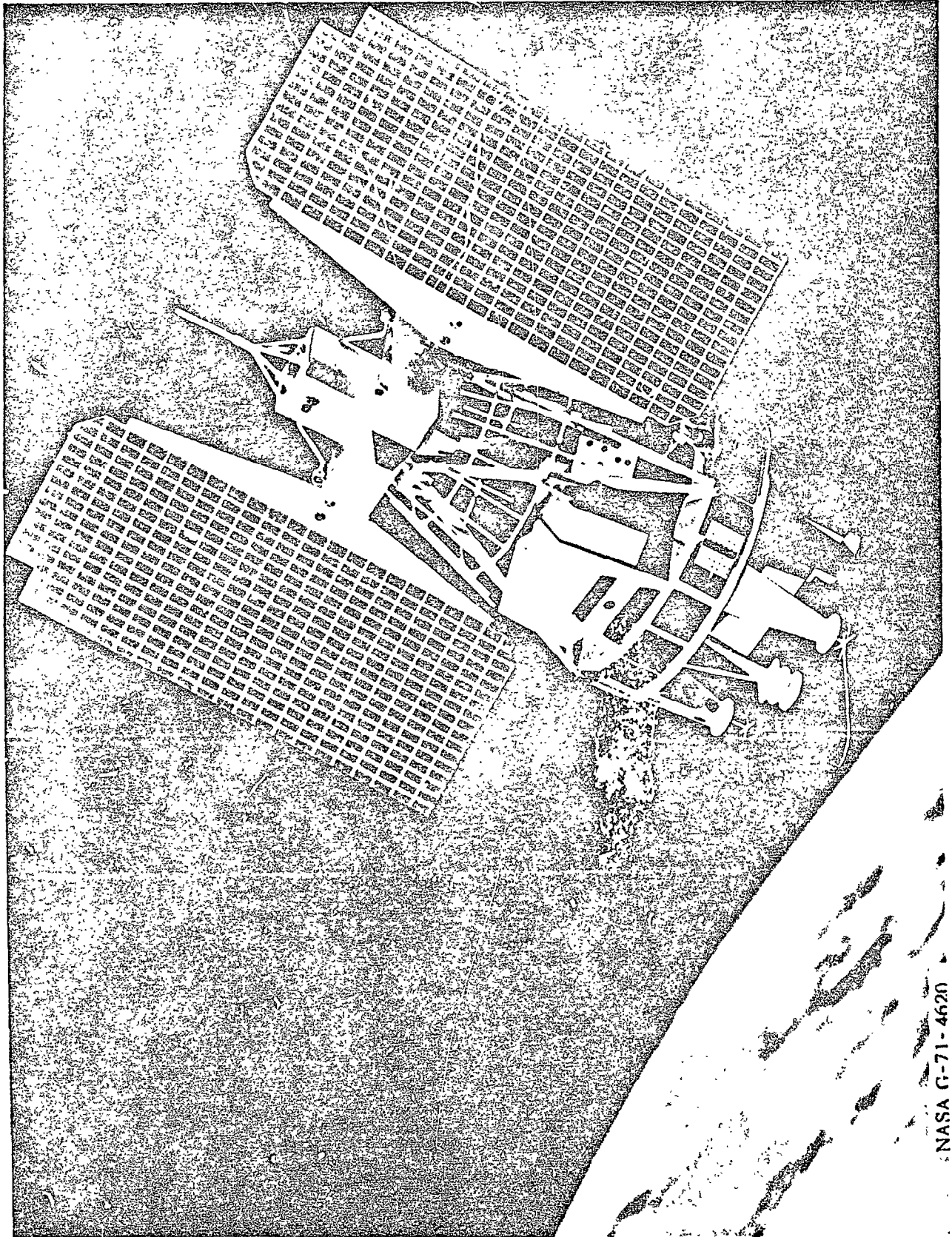
National Aeronautics and  
Space Administration

**Goddard Space Flight Center**  
Greenbelt, Maryland 20771  
AC 301 982-4955

### NATION'S CAPITAL VIEWED FROM SPACE

An 891 kilogram (1,965 pounds) satellite named LANDSAT-2 "snapped" this unique photo of the Washington D.C. area at approximately 11:00 AM, EDT, April 26, 1975, from an altitude of about 905 kilometers (555 statute miles). This is a false color composite photograph. Three colors, green, red and infrared seen and recorded separately by the satellite were combined at NASA's Goddard Space Flight Center, Greenbelt, Md., a suburb of Washington D.C. Healthy crops, trees and other green plants which are very bright in the infrared but invisible to the naked eye are shown as bright red. Suburban areas with sparse vegetation appear as light pink and barren land as light gray. Cities and industrial areas show as green or dark gray and clear water as black/dark blue. Clouds appear white. Notice the sedimentation in the Potomac River and Chesapeake Bay caused from heavy rain a few days before this photo was taken. Clouds permitting, the "butter-fly"-shaped observatory repeats its photographic coverage every 18 days. The LANDSAT photos are being studied by scientists to monitor the environment and natural resources man needs for survival, such as Mineral/Land Resources, Land Use and Mapping, Water Resources, Marine Resources/Oceanography, Agriculture/Forestry/Range Resources and Pollution. The LANDSAT Program is managed for NASA's Office of Applications by the NASA/Goddard Space Flight Center. Other Federal agencies participating with NASA are the Departments of Agriculture, Commerce, Interior, the Environmental Protection Agency and the U.S. Army Corps of Engineers. Also participating are land use planners at the city, county, and state levels of more than 40 states. LANDSAT photos of any given area may be purchased for a small fee by writing the EROS Data Center, Sioux Falls, South Dakota. Prime contractor for the LANDSAT spacecraft is the General Electric Company. Prime contractors for the "cameras" which make the photos possible are the Hughes Aircraft Company for the Multi-Spectral Scanner and RCA for the Return Beam Vidicon Camera.

PHOTO CREDIT: Office of Public Affairs, NASA/Goddard Space Flight Center,  
Greenbelt, Maryland 20771



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UNITED STATES GENERAL ACCOUNTING OFFICE  
WASHINGTON, D.C. 20548

PROCUREMENT AND SYSTEMS  
ACQUISITION DIVISION

B-183134

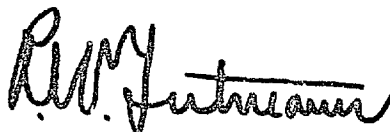
The General Accounting Office has performed a study of the National Aeronautics and Space Administration's Land Satellite Project. The study was primarily concerned with the project's need and expected benefits; status and progress related to costs, schedule, and performance; uncertainties; and international implications.

This staff study is our first review of the project and its purpose is to provide information that will aid the Congress in exercising its legislative and review functions. A copy of this study was reviewed by agency officials associated with the management of this project and their comments are incorporated as appropriate.

Copies of this study are being sent to the Chairman of the Subcommittee on HUD and Independent Agencies, Senate Committee on Appropriations at whose request we performed this review. Copies are also being sent to the Chairmen of the Senate Committees on Appropriations, Aeronautical and Space Sciences, Government Operations, Budget, Agriculture and Forestry, Interior and Insular Affairs, Foreign Relations, Commerce, Public Works, and Permanent Subcommittee on Investigations, Senate Committee on Government Operations; and the House Committees on Appropriations, Government Operations, Science and Technology, Budget, Agriculture, Interior and Insular Affairs, International Relations, Interstate and Foreign Commerce, Merchant Marine and Fisheries, and Public Works and Transportation; the Chairman of the Joint Committee on Reduction of Federal Expenditures; members of Congress from the States of Maryland, South Dakota and Utah; and other members of Congress who have requested copies of staff studies.

B-183134

We are also sending copies to the Administrator, National Aeronautics and Space Administration; cognizant officials in the Departments of Agriculture, the Interior, Commerce, Army, Transportation and State; the Administrator, Environmental Protection Agency; and Director, Office of Management and Budget.

A handwritten signature in cursive script, appearing to read "R. W. Gutmann".

R. W Gutmann  
Director



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ABBREVIATIONS

ERS        Earth Resources Survey  
GAO        General Accounting Office  
LACIE      Large Area Crop Inventory Experiment  
MSS        Multispectral Scanner  
NASA       National Aeronautics and Space Administration  
NOAA       National Oceanic and Atmospheric Administration  
RBV        Return Beam Vidicon Camera  
USDA       United States Department of Agriculture

## SUMMARY

### WHAT LANDSAT IS

LANDSAT is a NASA experimental project to determine the utility of satellite-acquired multi spectral earth resources data for the management of the environment and natural resources. Two LANDSATs ("1" and "2") have been launched to date and a third ("C") is planned for launch in September 1977. The General Electric Company, Space Systems Division, is the prime contractor for the LANDSAT satellite.

### STATUS

Our observations regarding the progress and problems occurring in the LANDSAT project are presented below:

--NASA's March 1975 planning estimate was \$35.7 million. We believe the current estimate should be \$47.2 million based on the inclusion of related payload costs and the Goddard Space Flight Center's October 1975 estimated increases. NASA's position is that the current estimate is \$42.7 million which now includes the related payload costs.

(See page 10.)

--The LANDSAT-C project budget does not include an amount for the project's principal investigator program. (See page 14.)

--None of the Federal agencies involved in the LANDSAT project has developed a long-range comprehensive plan which includes user requirements to assist in deciding if and when LANDSAT should become an operational system.

Related to this is the question of the Federal Government's role in supporting satellite-based remote sensing technology. (See page 18.)

--Potential users have expressed a need for training programs in the use of LANDSAT data.

(See page 27.)

--Two major cost/benefit studies were performed separately by the Department of the Interior and NASA to assess the potential economic costs and benefits to the United States from an operational space-based earth resources survey program and to provide a basis for future investment decisions. These studies reported widely divergent results because of different assumptions used. (See page 31.)

--The contrast between the United States open-data dissemination policy and the attitudes of certain countries raises the question as to which type of operational earth resources satellite system--national, regional or global--will best serve the interests of the United States. (See page 35.)

#### RECOMMENDATIONS

GAO recommends that:

--NASA include and identify as part of the LANDSAT-C cost estimates provided to the Congress amounts for the principal investigator program.

--NASA take the lead, in conjunction with potential users, in developing a plan for providing formal training to LANDSAT data users.

--NASA take the initiative to lead the other participating agencies in developing a plan which includes requirements, milestones and dates for evaluating progress being made toward the goal of deciding if and when there should be an operational earth resources satellite system. We recognize that such a plan must postulate a Federal Government policy role in satellite-based remote sensing technology. Accordingly, the plan could address (1) the assignments of roles and responsibilities to the involved agencies, (2) inter-relationships among oceanographic, meteorological and earth resources satellite systems, (3) alternative organizational arrangements for operational systems reflecting differing degrees of Government, private sector and international participation, and (4) estimated resource and funds requirements to be filled by the Federal Government.

KEY ISSUES FOR CONSIDERATION  
BY THE CONGRESS

During the fiscal year 1977 budget hearings the Congress should discuss the following with NASA:

- The reasons for not including all costs in the current estimate for LANDSAT-C.
- The need for a comprehensive long-range plan to assist in deciding if and when LANDSAT should become an operational system.

- The need for United States policy on the Government's role in supporting satellite-based remote sensing technology.
- The need to establish a formal training program for LANDSAT users and to designate the institutional responsibility for such a program.
- The validity of the assumptions and data base for the cost/benefit studies used as a tool for making major program decisions.
- The type of operational earth resources satellite system--national, regional or global--which will best serve the interests of the United States.

#### QUESTIONS

The following questions relate to matters identified but not fully developed during our review. The Congress may want to pursue these matters further with NASA during the authorization and appropriations deliberations.

- Why does NASA headquarters disagree with the field center's cost increases?
- What is the status of the LANDSAT-C principal investigator program?
- What actions are being taken to insure that LANDSAT data users have the necessary training to effectively utilize LANDSAT?
- What does NASA intend to do concerning development of a long-range plan for deciding if there should be an operational earth resources satellite system?

--Does NASA have any position on whether a national, regional or global earth resources satellite system would best serve United States interests?  
--Are there any national security problems the LANDSAT project has encountered or which may be foreseen?

AGENCY COMMENTS

A draft of this report was reviewed by NASA officials associated with the management of this project and by officials of agencies participating in the project. The agencies' views regarding differences of opinion are reflected in the relevant sections of this study. Further, as far as we know, there are no residual differences in fact.

## CHAPTER 1

### INTRODUCTION

Constant reminders of global energy and food shortages make it increasingly apparent that man must find the means to more intelligently manage the environment and natural resources if he is to survive on this planet. LANDSAT (Land Satellite), an earth resources surveying satellite, is an attempt to explore the possibility of using space technology to assist in achieving better management of our environment and natural resources. The LANDSAT project has generated a great deal of interest in the Congress, the United States, and the international community. This interest is the result of the potential offered by LANDSAT to provide previously unobtainable information about our natural resources and environment.

We undertook this review because of this interest and our responsibility to provide the Congress with objective information on issues of current national importance. This report provides information on the progress being made and problems encountered in the LANDSAT project which could impact on its future ability to provide information useful in managing the environment and our limited natural resources.

#### MISSION

The LANDSAT project is part of the National Aeronautics and Space Administration's (NASA) Earth Resources Survey (ERS)



program within the Office of Applications. The purpose of the ERS program is to develop technology for acquiring and interpreting multispectral remotely sensed data to assist in managing natural resources. LANDSAT-1 and LANDSAT-2 have used a Multispectral Scanner (MSS) to acquire data in four different areas of the electromagnetic spectrum simultaneously; hence, the term "multispectral" sensing. In addition, the MSS data is handled digitally, permitting data processing and analysis with the aid of computers. There are a number of aspects to the ERS program, including sensor research and development, development of new data interpretation techniques, remote sensing from aircraft and satellite, and the transfer of these capabilities and the ability to use them to the user community.

LANDSAT's main objective is to acquire earth resources data from space on a repetitive basis over many of the major land masses and coastal waters of the world. This data is used in research investigations and quasi-operational demonstrations to obtain the necessary knowledge and experience to decide whether the United States should proceed with design and development of an operational earth resources satellite system.

#### BACKGROUND

LANDSAT-1 was launched on July 23, 1972, with a minimum design life of one year. The spacecraft carried two sensor systems for acquiring earth resources data. Data is being acquired operationally from one of these systems. Due to a power system malfunction, NASA turned off the other system after about two weeks of operation.

On January 22, 1975, LANDSAT-2 was launched with the same sensor systems as LANDSAT-1. One of the systems has been turned off to be used as a backup system. A picture of the LANDSAT and an example of a LANDSAT image/data product provided by NASA are shown inside the front cover.

NASA is in the early stages of developing the third earth resources surveying satellite--designated LANDSAT-C. LANDSAT-C is discussed further in Chapter 2.

SCOPE OF STUDY

Our review of the LANDSAT project included work at the  
2 Goddard Space Flight Center, Greenbelt, Maryland, and at 432  
NASA headquarters. We also performed work at the headquarters  
3,95 of the Departments of Agriculture, Commerce, Interior, 42 33  
6,3,8 Justice, State, and Transportation. Other organizations 37 32 29  
1) included the Environmental Protection Agency, Army Corps of 29 305  
11,2 Engineers (Civil Works), World Bank, National Academy of 1, 2, 938 + AGC 06, 364  
Sciences, and the Office of Management and Budget. Visits 27  
were made to Interior's Earth Resources Observation Systems  
Data Center, Sioux Falls, South Dakota, Agriculture's Western  
Laboratory, Salt Lake City, Utah, and the National Oceanic  
14 and Atmospheric Administration's Satellite Data Services, 68  
Beltsville, Maryland.

We reviewed plans and programs dealing with the LANDSAT project and numerous reports on LANDSAT results. We also reviewed and analyzed the two major cost/benefit studies conducted since the first LANDSAT was launched. Discussions

were held with officials of each Department and agency visited as well as a major trade association involved with LANDSAT data. We also sent questionnaires to the LANDSAT-2 principal investigators and state and local government officials to assess the utility of LANDSAT information.

CHAPTER 2

LANDSAT-C

PROJECT STATUS

Funds to begin developing LANDSAT-C were included in the President's Fiscal Year 1976 Budget and approved by the Congress. The mission objectives are to:

- extend the period of earth resources data acquisition started by LANDSAT-1 and LANDSAT-2 and
- determine the utility of data acquired by improved sensor systems.

COST INCREASES, REAL AND POTENTIAL

NASA's planning estimate dated March 1975 of \$35.7 million for LANDSAT-C project costs was given to the Congress during the fiscal year 1976 budget hearings. This estimate did not include \$7 million for the five-band Multispectral Scanner (MSS) even though it was to be part of the LANDSAT-C payload. The MSS was identified and funded as a separate budget line item although NASA associated this cost with LANDSAT-C in oral testimony presented to its authorization committee during its fiscal year 1976 hearings. The planning estimate also excluded costs of the project's principal investigator program. NASA has, however, included the MSS estimated costs of \$7 million as part of LANDSAT-C project costs in its current estimate included in the fiscal year 1977 budget.

Since the 1976 hearings, the project office at Goddard Space Flight Center has estimated cost increases amounting to \$4.5 million which NASA officials have not included in their current estimate of \$42.7 million.

Including the recent addition by NASA of \$7 million for the MSS and the projected increase of \$4.5 million by the project office, the current estimate would be at least \$47.2 million. The unidentified additional amounts for the cost of the principal investigator program would increase the current estimate further.

Presented below is the official NASA planning estimate and the project office's estimate. The project office's reasons for the projected \$4.5 million increase are discussed following the table.

	March 1975 Planning Estimate	October 1975 Project Office Changes		Project Office October 1975 Estimate
		Inflation	Other	
-----millions-----				
Spacecraft	\$19.15	\$ .51	\$2.24	\$21.90
Payload	6.75	.25	.95	7.95
Ground Operations	6.20	.70	--	6.90
Allowance for Program Adjustment (1)	3.00	--	--	3.00
Institutional Manage- ment System	<u>.60</u>	<u>.04</u>	<u>(.19)</u>	<u>.45</u>
<b>Total</b>	<u>\$35.70</u>	<u>\$1.50</u>	<u>\$3.00</u>	<u>\$40.20</u>

(1) Referred to hereinafter as "contingency fund".

#### Project Office Projections

In October 1975, the LANDSAT project office at Goddard Space Flight Center projected cost increases of \$4.5 million. They believed that the planning estimate of \$35.7 million did not include sufficient recognition of inflation. During a reassessment, they made adjustments of varying percentages to the project cost elements which resulted in a total project cost increase of \$1.5 million for additional inflation.

The remaining \$3 million increase resulted primarily from subcontractor bid prices being higher than anticipated. These bids are for items to be bought by the General Electric Company, Space Systems Division, for the primary LANDSAT-C spacecraft contract. This first phase of the fixed-price contract was awarded in January 1976 for \$15.7 million. Project officials attribute the increased subcontractor prices to additional inflation and to inclusion of amounts to recognize the added risks associated with contracting on a fixed-price basis. A \$3 million provision for contingencies included in the \$35.7 million estimate was not used to offset part of the cost increase.

It is the NASA position that, despite inflationary increases to date in some project cost elements over the planning estimates, all program and mission objectives can be achieved within its \$42.7 million budget, assuming that further inflationary pressures are moderate. NASA officials informed us that current negotiations for the spacecraft contract indicate that inflation has caused an increase in the cost of this segment which will eat into the contingency fund which was established, in part, for this purpose. Because of the repeat nature of the program and the fixed-price nature of a major portion of the contracts, NASA feels that the projected remainder in the fund will be sufficient.

It is NASA's policy to continually assess the validity of field center resource estimates. These assessments bring to bear the collective experience and judgment of various

levels of NASA management over all field center resource requirements. This frequently results in increases, decreases and consolidations over the original field center estimates. NASA believes that field center identified resource requirements should not be considered hard facts until they have been approved by higher NASA management. It is NASA management's view that the LANDSAT-C budget, although tight, does not warrant an increase in the runout estimates.

#### Multispectral Scanner

The five- and MSS will have the additional capability of measuring temperatures on the surface of the earth, whereas, the current MSS only measures energy being reflected from the earth.

As previously noted, the MSS was not included in NASA's \$35.7 million LANDSAT-C project cost estimate presented to the Congress during fiscal year 1976 budget hearings. NASA officials advised us that their testimony during the budget authorization hearings indicated that the MSS would be a part of the LANDSAT-C payload.

We were informed by NASA officials that, subsequent to the fiscal year 1976 hearings, the MSS costs were merged into the LANDSAT-C budget and were included in the October 15, 1975, LANDSAT-C Project Status Report prepared for the Chairman, Senate Appropriations Subcommittee on HUD and Independent Agencies. They advised us that the MSS costs are included in the fiscal year 1977 budget estimates for LANDSAT-C.

### Principal Investigator Program

Plans at this time are that the LANDSAT-C principal investigator program will be funded separately from the project. We do not agree with this approach. The LANDSAT-1 and LANDSAT-2 investigator programs were funded by the LANDSAT project and the costs were substantial. We believe the investigator costs are valid project costs because LANDSAT-C is an experimental satellite, the LANDSAT-C principal investigators work only on LANDSAT-C, and one aspect of the program is to conduct investigations to determine the utility of the data received.

We recognize that the investigator program has not been precisely defined. This is not unlike the situation faced by NASA on the LANDSAT-2 program in 1971. At that time, the LANDSAT-2 investigator program had not been well defined; however, an amount was included in the project cost estimate for the investigations.

NASA officials informed us that they do not foresee the type of investigator support in conjunction with LANDSAT-C that was required for LANDSAT-1 and LANDSAT-2. They stated that

"The character of the program is changing compared with the LANDSAT-1 and -2 period, and we expect that nearly all of the investigations which need to be conducted would be supported by the user agencies and organizations. The residual effort is expected to be relatively small, and our plan



is to contain it in the Applications Research and Technology Development program. It is not appropriate to tie these investigations to LANDSAT-C since (1) they have not yet been defined, (2) most can be expected to utilize data from other LANDSATs and remote sensing aircraft in addition to LANDSAT-C, (3) costs are expected to be minimal as compared with previous investigation programs, and (4) NASA is planning to provide for them adequately elsewhere."

#### PERFORMANCE GOALS

NASA is planning on more than two years of operations for LANDSAT-C. The systems aboard the spacecraft are very similar to those on the two previous LANDSATs and, therefore, the performance expected should be comparable. There are several exceptions. One of these includes the additional capability of the five-band multispectral scanner which provides for measuring earth surface temperatures.

Plans also call for improving the spatial resolution of the Return Beam Vidicon (RBV) camera. Spatial resolution is defined as the instantaneous field of view of the sensor. It is, therefore, the minimum sized area on the ground for which the sensor data can be analyzed for content. NASA hopes to improve the resolution of the RBV from 80 to 40 meters. Data from this instrument should supplement the lower resolution MSS data, thereby increasing the utility of the MSS data.

The usefulness of these new data will be determined by the investigator programs supported by the principal user agencies and NASA.

Another performance goal of LANDSAT-C is to improve the capability and reliability of the wideband video tape recorders. In each of the first two LANDSATs, one of the tape recorders malfunctioned early in the mission. Without full tape recorder capability, the amount of data which can be acquired over foreign countries is limited because all data acquired by LANDSAT while out of range of a receiving station must be recorded until LANDSAT regains contact with a receiving station. NASA is making improvements to increase the tape recorder reliability. We were informed by NASA officials that the LANDSAT-C budget would provide the funds for these improvements which would cost something less than \$1 million.

SCHEDULE

LANDSAT-C, scheduled to be launched in September 1977, should provide LANDSAT data continuity into early 1980. Some of the key project milestones are presented below.

<u>Milestones</u>	<u>Planning estimate March 1975</u>	<u>Current estimate October 1975</u>	<u>Change (months)</u>
Delivery of hardware			
to prime contractor:			
Return Beam Vidicon Camera	3-77	2-77	-1
Multispectral Scanner	7-76	7-76	0
Wideband Video Tape Recorders	1-77	1-77	0
Begin Spacecraft/Payload			
Integration and Test	3-77	2-77	-1
Spacecraft Launch	9-77	9-77	0

## CONCLUSIONS AND RECOMMENDATIONS

We believe the Congress should have the most complete and up-to-date cost estimates for NASA projects. This has been a matter of continuing concern to GAO. As recently as July 25, 1975, we recommended in our report to the Congress on the "Need for Improved Reporting and Cost Estimating on Major Unmanned Satellite Projects" (PSAD-75-90) that the Administrator of NASA provide for summarizing and reporting costs to the Congress which include the project cost and all additional costs directly identifiable with the project.

In our opinion, in the case of the MSS, the Congress would have been better informed if MSS costs had been included in the LANDSAT-C budget presented during fiscal year 1976 hearings rather than having been identified and funded as a separate budget line item.

With regard to the principal investigator program, we recommend that NASA estimate the costs, qualified, if necessary, and include them in the LANDSAT-C budget. This will provide the Congress with a more realistic estimate of the total project cost.

### CHAPTER 3

#### LANDSAT, ITS UNCERTAIN FUTURE

A major goal of the LANDSAT project is to gain sufficient knowledge and experience to decide whether there should be an operational earth resources satellite system. None of the involved agencies has developed a comprehensive long-range plan, however, which includes operational requirements to assist in deciding whether LANDSAT should become an operational system. Consequently, it is not clear what must be achieved and when it must be achieved before this operational decision can be made.

We believe NASA should take the initiative to lead the other participating agencies in developing a plan which includes requirements, milestones and dates for evaluating progress being made toward the goal of deciding if there should be an operational system. Such a plan will assist in the transition from a predominantly experimental program to a predominantly operational program. This plan can be utilized by the user community to help them determine whether they will become involved in the project. The following sections discuss our findings regarding the usefulness, needed improvements and potential of LANDSAT data.

#### USERS OF LANDSAT DATA

There is a broad community of users in and out of Government throughout the world who have used LANDSAT data products.

Due to this diversity of users, an exhaustive review of user opinion regarding LANDSAT was not possible. However, we did visit agencies within the Federal Government using LANDSAT and obtained information from a questionnaire sent to state and local government LANDSAT users and NASA's LANDSAT-2 principal investigators.

Department of Agriculture

The U.S. Department of Agriculture (USDA) is responsible for acquiring and distributing useful information on agricultural subjects to the public. In carrying out this responsibility, USDA uses remotely sensed data where applicable. USDA is potentially one of the largest users of LANDSAT data because of its extensive involvement with natural resources.

Most USDA agencies have had at least limited exposure to LANDSAT data but, due to their operational responsibilities, they are limited in the amount of time and resources they can devote to determining the usefulness of LANDSAT data. The Foreign Agricultural Service, the Economic Research Service, the Agricultural Research Service, the Forest Service and the Statistical Reporting Service have all been involved in either the NASA Principal Investigator program or the Application Systems Verification Tests program. Results from the Principal Investigator program have sufficiently interested the Statistical Reporting Service that it is funding an expanded test of techniques to determine the suitability for use for improved crop acreage determination in the United States.

Although we found no operational functions being carried out using LANDSAT data in USDA, the following areas have shown some potential for LANDSAT data application:

- crop identification, acreage, and yield measurement,
- soil mapping,
- forest inventory,
- range management, and
- insect infestation of forests.

USDA is conducting a study to determine the role of remote sensing data, including existing and potential satellite-acquired data, in meeting the Department's information requirements.

Experiments using LANDSAT data have been conducted in the above areas as well as others. In most cases, improvements in LANDSAT technology are needed before the data can be used in day-to-day operations. The required improvements include more frequent coverage<sup>1</sup> by the satellite, and improvements to the sensors, such as higher resolution, the ability to penetrate clouds and the ability to measure earth surface temperatures. In addition, more timely receipt of LANDSAT data after it has been obtained by NASA is an essential requirement of nearly all USDA agencies.

Large Area Crop  
Inventory Experiment

NASA, in conjunction with USDA and the National Oceanic and Atmospheric Administration, is conducting the Large Area

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<sup>1</sup>The orbit of each of the LANDSAT satellites permits complete earth coverage every eighteen days. Together they provide coverage every nine days.

Crop Inventory Experiment (LACIE). LACIE is USDA's major involvement with LANDSAT. The purpose of LACIE is to determine the utility and cost effectiveness of using LANDSAT data in conjunction with weather and climate data to predict global production of major agricultural crops. Wheat was chosen as the test crop for the LACIE project because of its importance in world trade. In its early phases LACIE will concentrate on the North American data plus selected foreign sample segment data. If the early phases are successful, the test will be expanded to include other major wheat-producing regions of the world. To be successful, it must significantly improve USDA's ability to forecast international wheat production. Current cost estimates for conducting LACIE total more than \$40 million among the three agencies, with NASA contributing more than 60 percent.

Errors in USDA wheat production estimates have ranged in recent years from less than five percent to more than <sup>1</sup> twenty percent. Major inaccuracies in forecasts can lead to unsound economic and agricultural decisions on the part of government and business. There is considerable debate and uncertainty as to whether current LANDSAT technology can aid in improving the Department's domestic crop forecast accuracy. However, it should permit improvements in the timeliness, objectivity and accuracy of international crop production estimates. According to a Department of Agriculture official,

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<sup>1</sup> See GAO report of August 27, 1975, on "What the Department of Agriculture has done and needs to do to improve Agricultural Commodity Forecasting and Reports," RED-76-6.

the improvements discussed earlier, such as more frequent coverage, would benefit the LACIE effort. The results regarding the utility and cost effectiveness of an operational LACIE-type crop forecasting system are expected to be available during fiscal year 1978.

If LACIE is successful in the North American test area, it should be possible to extend coverage to other agricultural crops of major world importance. If followed up with an operational system using the techniques developed, benefits should accrue not only to the United States but to all countries. The more timely and accurate information should provide a basis for better planning and utilization of one of the world's critical resources, food.

#### Department of the Interior

The Department of the Interior is responsible for managing the nation's natural resources, including over 500 million acres of Federally-owned land. Interior has investigated LANDSAT as an additional data source for managing the nation's land and water resources.

The Earth Resources Observation Systems program of the Geological Survey conducts research in applying LANDSAT and other remotely sensed data to Interior programs. The program operates a distribution and training center in Sioux Falls, South Dakota, that distributes LANDSAT and other remotely sensed data. This center provides training and assistance to domestic and foreign users.



Interior's interest in the LANDSAT program is evidenced by its participation in over fifty NASA-funded LANDSAT investigations. During fiscal year 1975, Interior funded more than 65 LANDSAT experiments. According to a Geological Survey official, the experiment results have been encouraging and LANDSAT data are being used in some operational programs. However, we were unable to document any significant operational uses of LANDSAT data. Interior has identified the following areas as having potential operational application:

- inventory natural resources,
- assess forage conditions of rangelands,
- plan and manage water conservation on public lands,  
and
- monitor vegetation and wildlife habitats for  
National Park planning.

According to Geological Survey officials, the costs and institutional factors necessary to implement these potential uses have not been identified. Several of these potential uses are also dependent upon the successful operation of LANDSAT-C.

In summary, we found that LANDSAT has not greatly impacted Interior operational programs to date, but has contributed as an information source to a number of them. We were informed by a Geological Survey official that major impacts will not occur until there is some assurance of continuous data availability.

Department of Commerce

The National Oceanic and Atmospheric Administration (NOAA) conducts the majority of remote sensing activities of the Department of Commerce in carrying out the responsibility for improving man's comprehension of oceanic life and the weather. Although LANDSAT's sensors were not designed for oceanographic or weather-related use, experiments have been conducted to determine potential operational applications of LANDSAT data to NOAA missions.

Through participation in the NASA investigator program and self-initiated projects, NOAA has identified the following as having potential operational applications:

- identification of fish-habitat potential for increasing yields,
- aeronautical and navigational charting,
- identification of ocean currents and water masses, and
- snow mapping.

The results of LANDSAT experiments show remote sensing from space provides a viable method of obtaining a rapid and continuous assessment of marine resources and that LANDSAT's present resolution and sensor capability can provide data useful in conducting oceanographic research.

The nine-day coverage of LANDSATs 1 and 2 and data delivery are not adequate for day-to-day operations in a dynamic discipline, such as oceanography. NOAA plans to continue conducting research, however, and when LANDSAT-C is launched, experiments will be conducted using data from the improved sensors.

U.S. Army Corps  
of Engineers

The U.S. Army Corps of Engineers (Civil Works), responsible for Federal water resources development activities, has been actively involved in the LANDSAT project. LANDSAT experiments in the areas of hydrology, ecology, oceanography, and geography have identified the following as having potential operational application:

- Coastal processes-identification of erosion and circulation patterns, harbor planning, and dredging operations;
- Water resources-snow and surface water mapping, flood plain mapping and damage assessment, and dam inventorying; and
- Environment-preparation of environmental impact statements.

We were informed by a Corps of Engineers official that the Corps is rapidly expanding the use of remote sensing technology in water resource planning. LANDSAT imagery is used in the development of information on landforms, geologic structure and land cover. However, the official also informed us that the Corps has been reluctant to make the investment necessary to fully exploit LANDSAT data prior to the determination of continued availability.

Environmental Protection Agency

The Environmental Protection Agency, responsible for collection and evaluation of physical, chemical and biological

data relating to environmental quality, is involved in a program to explore the potential of using remote sensing data, including LANDSAT, to fulfill these responsibilities.

The Environmental Protection Agency has used LANDSAT data in research projects where broad area coverage is necessary to analyze regional phenomena. Some additional mirror research is being conducted to determine the ability of multispectral scanning techniques to detect environmental conditions more precisely. Officials of the Environmental Protection Agency have stated, however, that regardless of the outcome of this research, considerable improvements must be made in LANDSAT's resolution, frequency of coverage and speed of delivery of data products before it will be adequate for operational purposes.

#### Department of Transportation

The United States Coast Guard is the only agency in the Department of Transportation that has used LANDSAT. The Coast Guard has experimented with LANDSAT data in three areas-- detecting oil slicks, routing ships through sea ice, and monitoring icebergs. Partial success was achieved in routing ships through sea ice in the Antarctic; however, the coverage is inadequate and inhibits operational use of LANDSAT for this purpose.

#### NEEDED IMPROVEMENTS

As can be expected with an experimental project, the usefulness of the data varies depending on the specific

needs of resource managers. Frequently mentioned improvements needed to increase the utility of the data currently available are:

- higher spatial resolution,
- an earth surface temperature measuring sensor,
- more frequent cycle of coverage, and
- faster data product delivery times.

NASA is incorporating some of the above improvements in LANDSAT-C, such as higher spatial resolution and a sensor to measure earth surface temperatures. Another improvement which should be available for use with LANDSAT-C involves NASA's ability to more quickly process LANDSAT data and distribute it to the Federal dissemination centers. It has been averaging fifteen days for data to be sent out from Goddard after receipt. The hope is to cut this time to two days. Information obtained from responses to the questionnaires sent to LANDSAT-2 principal investigators and state and local users indicated that the same improvements would substantially increase the effectiveness of LANDSAT data.

Furthermore, 87 percent of the state and local government officials who responded to our questionnaire indicated a strong need for training in the use of LANDSAT data. Although the Federal Government is a user of remotely sensed earth resources data, the resources managers at the state and local level are a large group of potential users of LANDSAT-type data. Such an overwhelming response rate strongly suggests that this

group lacks sufficient knowledge in the use of LANDSAT data. To realize maximum return from the large investment made in the LANDSAT project, we believe a plan for formally training LANDSAT users needs to be developed. However, before such a plan can be developed, institutional responsibilities should be resolved.

#### NEED FOR LONG-RANGE PLANNING

Many current and potential users of LANDSAT data consider the uncertainty regarding continuous data availability as a major deterrent to more extensive use. In many cases, a capital investment is required for special processing and interpretation equipment and personnel must be trained or analysis services obtained to realize maximum benefits from LANDSAT data. To justify such investments, it is necessary to have some assurance of a long-term program.

One of the primary objectives of the LANDSAT project, as mentioned earlier, is to gain sufficient knowledge and experience to decide whether there should be an operational earth resources satellite system. This remains the objective of the project, and it seems certain that a decision to go operational would provide the user community with the assurance it needs. A comprehensive long-range plan which includes user requirements has not been developed, however, for deciding whether LANDSAT should become an operational system. Consequently, it is not clear what must be achieved and when it must be achieved before a decision can be made. Without such a plan it is possible to continue indefinitely with experimental satellites, avoiding

an operational system decision and leaving the users in a continuous state of uncertainty regarding the future, if any, of the program.

Although establishment of a plan will not in itself provide assurance of continuous data availability, it will provide a means for evaluating progress being made toward overall system objectives. In addition, it will provide current and potential LANDSAT users with the knowledge that a decision will be made regarding the long-term aspects of the program.

Related to the establishment of a long-range plan is the question of the Federal Government's role in supporting satellite-based remote sensing technology. The technological and market uncertainties, combined with long timeframes and the magnitude of capital investment, act to discourage private sector support. The question remains--to what extent and how does the Federal Government support this emerging technology?

#### CONCLUSIONS AND RECOMMENDATIONS

There are strong indications that users and potential users of LANDSAT data lack sufficient knowledge in the use of the data. Accordingly, we recommend that NASA take the lead, in conjunction with potential users, in developing a plan for providing formal training to LANDSAT data users.

We believe there should be a long-range plan which includes the requirements of the various users so that it can be determined when the state of the art provides the users with an adequate capability for determining success or failure of the

LANDSAT project. The plan can benefit both NASA and the users in evaluating progress being made and also enable the user community to decide how extensive its involvement should be in the project.

Accordingly, we recommend that NASA take the initiative to lead the other participating agencies in developing a plan which includes requirements, milestones and dates for evaluating progress being made toward the goal of deciding if and when there should be an operational earth resources satellite system.

We recognize that such a plan must postulate a Federal Government policy role in satellite-based remote sensing technology. Accordingly, the plan could address (1) the assignments of roles and responsibilities to the involved agencies, (2) interrelationships among oceanographic, meteorological and earth resources satellite systems, (3) alternative organizational arrangements for operational systems reflecting differing degrees of Government, private sector and international participation, and (4) estimated resource and funds requirements to be filled by the Federal Government.



## CHAPTER 4

### LANDSAT COST/BENEFIT STUDIES

There have been two major studies performed to assess the potential economic costs and benefits to the United States from an operational space-based earth resources survey program and to provide a basis for future investment decisions. These studies, one funded by Interior and the other by NASA, reported widely divergent results. We examined these studies to determine why the estimated benefits were so different and to assess the reasonableness of the results. We did not perform a cost/benefit analysis.

#### INTERIOR STUDY

The Interior study, completed in November 1974, estimated the costs and benefits of an operational system for a 10-year period, 1977-1986. The study concluded that for every \$1,000 in operating costs, benefits could range as high as \$1,900 or as low as \$400. This is equivalent to a benefit/cost ratio of from 1.9:1 to 0.4:1. The study results should be used only with complete knowledge of the effect the assumptions and constraints had on the reported benefits.

Interior, at the request of the Office of Management and Budget, imposed several constraints on the cost/benefit analysis. The following examples are cited only to indicate the effect the constraints and assumptions had on reported benefits.

1. The cost/benefit analysis did not consider any improvements beyond LANDSAT-1 and LANDSAT-2 technology during the 10-year period, 1977 to 1986. This constraint prohibited reporting of benefits resulting from improvements already existing or planned; i.e., computer manipulation, and improved sensors planned for LANDSAT-C.

2. The majority of benefits reported were based on the study team's analysis of the early results from the 330 LANDSAT-1 principal investigators. These investigators attempted to prove the technical capability of LANDSAT data, not its cost effectiveness. The investigators had a very limited view of the resource managers' operational remote sensing and cost effectiveness requirements. Consequently, the study team had to extrapolate operational benefits from the early experimental results.

#### NASA STUDY

The NASA-funded study, completed in October 1974, estimated the costs and benefits of an operational system for a 16-1/2 year period. The study concluded that a benefit/cost ratio of 12:1 could be achieved in contrast to the Interior ratio of from 1.9:1 to 0.4:1.

As with the Interior study, the NASA study results should be used only with a complete understanding of the effect the assumptions and methodologies used had on the costs and benefits reported. Although some assumptions are necessary because of uncertainties associated with projecting future economic benefits,

the wide differences in benefit/cost ratios reported in the two studies, in our opinion, resulted primarily from using different assumptions.

The NASA study, for example, reported that as much as 74 percent of the total benefits to be derived from an operational LANDSAT system will come from improved agricultural forecasting. These benefits are dependent upon the assumption that improvements in LANDSAT technology will be realized. The remaining 26 percent of the benefits are divided among seven other benefit categories.

The Interior study, on the other hand, excluded benefits that may accrue from improved agricultural forecasting. It was believed the sensors and the 18-day cycle of coverage on LANDSAT-1 did not improve on the current conventional method of predicting agricultural production. Since the NASA study did assume an improved LANDSAT would improve agricultural forecasting, the NASA study was able to report far more benefits than the Interior study in the area of agriculture forecasting.

#### CONCLUSIONS

The assumptions used in the studies had a large and direct influence on the widely divergent benefit/cost ratios reported. The principal investigator results used as the basis for estimating benefits in the Interior study seem too far removed from realistic operational requirements to be a reliable

measure of potential benefits from an operational earth resources survey program. Similarly, 74 percent of the benefits reported in the NASA study are based on an assumed capability derived from early research findings.

Accordingly, we believe a more realistic and reliable assessment of the benefits possible from an operational earth resources survey program will result if future cost/benefit analyses are based on the final results of the "quasi-operational" LANDSAT-2 principal investigations and other large efforts, such as the combined NASA, USDA, and NOAA Large Area Crop Inventory Experiment.

Finally, we believe decisionmakers should possess a complete knowledge of the assumptions used in the cost/benefit studies and their effect on the reported benefits if the study results are used in making LANDSAT program decisions.

## CHAPTER 5

### LANDSAT, THE INTERNATIONAL SATELLITE

LANDSAT, although financed, built, launched and operated by the United States for national purposes, is also intended to provide natural resources and environmental information to the world community. Since 1968, the United States Government has solicited participation in the ERS program from foreign countries. The LANDSAT project has attracted the interest of scientists, resource managers and diplomats in many foreign countries, as evidenced by their attendance at remote sensing seminars, their proposals for LANDSAT experiments and the building of LANDSAT receiving stations. Several international organizations, particularly the United Nations, have also been involved in the LANDSAT project.

#### United States Government Agencies with International Involvement

Numerous United States Government agencies have taken leading roles in working with foreign nations to provide them with earth resource remote sensing information. The Geological Survey of the Department of the Interior has sponsored several international remote sensing training programs at the Earth Resources Observations Systems Data Center in South Dakota and in foreign countries.

The Department of State is responsible for the coordinated presentation of remote sensing programs to foreign countries to assure consistent development of the international aspects of

the ERS program. The Agency for International Development also has supported and encouraged remote sensing activities in lesser developed countries by disseminating ERS information, assisting in preparing foreign LANDSAT experiment proposals, and coordinating remote sensing training and seminars.

NASA, as the developer of satellite technology, has encouraged international participation in the LANDSAT project through substantial participation of foreign investigators sponsored and funded by 50 governments and through a program of bilateral arrangements for foreign ground stations, again funded by the foreign governments to receive LANDSAT data directly.

#### Foreign Involvement with LANDSAT

The high level of international interest in LANDSAT is evidenced by the 106 LANDSAT-1 investigations carried out by thirty-seven countries. These investigations were selected by NASA based on scientific merit and were funded by the respective countries or international organizations.

There has been considerable foreign interest in building LANDSAT ground stations to receive and process LANDSAT data. LANDSAT receiving stations are currently operating in Canada, Brazil and Italy, and more are being constructed in Iran, Zaire and Chile. Australia, India, Japan, Upper Volta, and the Scandinavian countries are considering building LANDSAT ground station facilities.

Each country that wants to build a LANDSAT ground station must first sign a Memorandum of Understanding with NASA. This agreement requires that each country provide NASA with all data

requested and provide LANDSAT data products to the public at reasonable prices. The agreement also specifically states that NASA does not guarantee a continuing program.

To date, there has been no charge to foreign countries for receiving data at their ground stations. In December 1975, NASA notified countries operating or planning to operate LANDSAT stations that, as provided for in NASA's agreements with these countries, they will be asked to share the costs of the space segment of the LANDSAT program in the amount of \$200,000 per station per year. Cost sharing is expected to begin in the third quarter of 1976 with the three stations presently operating. The remaining countries will begin sharing costs with NASA six months after they begin to receive LANDSAT data.

#### Foreign Programs

We were advised by NASA officials that several nations and groups of nations are conducting or planning to conduct LANDSAT-type programs of their own. The Soviet Union is presently collecting some imagery from manned satellites and is clearly planning a somewhat comparable program but as yet has no dedicated satellite system like LANDSAT. The European Space Agency, Japan, and Canada are also making plans to launch their own remote sensing satellites.

#### International Implications

The United States presently maintains an open-data distribution policy for LANDSAT data. Any nation, state, corporation or individual may purchase LANDSAT data products without regard

to geographic location. The Federal Government maintains three dissemination centers and numerous browse centers throughout the United States to make LANDSAT data available to all interested domestic and foreign parties.

The United Nations has been discussing remote sensing issues since 1972. Most concern has focused on the dissemination and use made of the information obtained from remote sensing data products. Two proposals to limit dissemination or remote sensing data have been introduced in the United Nations--one by France and the Soviet Union and one by Brazil and Argentina. Both proposals would require prior consent from the affected country before remote sensing data acquired over that country can be distributed. The Brazilian and Argentinian proposal would also require prior consent from the affected country before the satellite acquired data. These two proposals constitute the main opposition for future operational programs to the United States open-data dissemination policy.

The United States position has been that the Outer Space Treaty calls for the sharing of benefits derived from space and that withholding of remote sensing data would violate the spirit of the treaty.

NASA officials believe that recent developments at the United Nations indicate increasing support for United States policy and practice. They cited as an example the adoption without objection by the United Nations General Assembly in November 1975 of a resolution (sponsored by more than forty countries, including Argentina, Brazil, France and the



Soviet Union) strongly supporting the May 1975 report of the Outer Space Committee's Scientific and Technical Subcommittee. This report cites as a desirable objective the "dissemination of all data and information to all countries on an equal and non-discriminatory basis." The report recommends that countries in areas where LANDSAT stations are operating or planned collaborate on a regional basis in the establishment of data dissemination and training facilities to assure the maximum use and benefits from LANDSAT data.

NASA officials view LANDSAT as a national system and do not believe its full realization depends on international dissemination or utilization of data. However, they believe there are definite benefits from international participation. They cite such things as foreign-funded experiments, collection of data from overseas stations and access to information of importance to domestic programs.

#### Alternative Organizational Arrangements for Operational Systems

The organizational structure of an operational earth resources survey system takes on added importance because of the international concern over remote sensing data dissemination. A properly structured organization managing a LANDSAT-type satellite system could aid in alleviating the fears regarding possible misuse of satellite acquired earth resources data from space.

Potentially, there are an unlimited number of organizational alternatives for an operational earth resources survey system. Four are listed below simply to demonstrate the types of alternatives available:

- United Nations affiliated agency,
- new international organization,
- United States-controlled agency similar to NOAA, and
- private corporation.

The first approach would involve establishment of a formal agency in the United Nations with all member nations being able to obtain the services as well as having a voice in policy making.

The creation of a new international organization could be similar to the International Telecommunications Satellite organization. This option would entail a multinational treaty among all interested nations, and the organization's activity would likely be limited to earth resources remote sensing. All member countries would retain broad policy and financial control.

NASA advised us that the United Nations is rapidly shifting its attention to the question of the organizational structure of an international operational earth resources survey system. It is not clear, however, how the proponents of such a system view its scope--as between space and ground segments, data processing, analysis, use, etc.

In the third approach, an existing or new United States agency would control and manage an operational system similar to NOAA's role with meteorology satellites. Under such an approach, countries with ground receiving facilities would make earth resource survey data available to other countries under bilateral or multilateral agreements. The United States

would pay for and operate the system with the participation of other countries in the form of cost-sharing arrangements.

Another approach would be a private profit-making corporation to manage and operate a complete earth resources survey system with little or no accountability to the United Nations or other national or international entity. All operations and sales policies would be governed by corporate goals.

### CONCLUSIONS

The United States leads in the technology of obtaining global earth resources data by satellite systems. At the invitation of the United States, there has been considerable international sharing of the benefits of this technology. There has been a suggestion in the United Nations that countries in areas where LANDSAT stations exist cooperate on a regional basis. Regional or global systems will be required if all nations are to benefit from this new technology.

Several countries are making plans to launch their own remote sensing satellites. Also, proposals have been introduced in the United Nations to prohibit the acquisition and distribution of data acquired from operational remote sensing satellites over a country unless the country gives prior consent.

The contrast between the United States open-data dissemination policy and the attitudes of certain countries raise the question as to which type of operational earth resources satellite system--national, regional or global--will best serve the interests of the United States. Although

LANDSAT is a national system, its full realization would be enhanced by international dissemination and utilization of data. It is important, therefore, that any international issues regarding acquisition and distribution of satellite-acquired data be resolved. NASA stated that these issues are not significant and it feels confident that future experimental and operational systems can be deployed without major difficulty.

In formulating any long range plans for satellite-based remote sensing technology, we believe careful consideration should be given to any international implications that could arise.