94th Congress }
2d Session }

COMMITTEE PRINT

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AN ANALYSIS OF THE FUTURE LANDSAT EFFORT

(by Chuck Mathews)

STAFF REPORT

PREPARED FOR THE USE OF THE

COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES UNITED STATES SENATE

AUGUST 10, 1976

U.S. GOVERNMENT PRINTING OFFICE

75-422 O

WASHINGTON : 1976

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 70 cents
There is a minimum charge of $1.00 for each mail order

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United States Senate

COMMITTEE ON
AERONAUTICAL AND SPACE SCIENCES
WASHINGTON, D.C. 20510

MEMORANDUM August 10, 1976

TO: All Committee Members

FROM: Frank E. Moss, Chairman

The Earth Resources Survey experiment, which focuses primarily upon the Landsat satellite, has, in just five years, developed into a system with major potential for application in solving many of the problems facing the inhabitants of this globe. As a result of this potential, the Committee has observed a dramatic increase in the use of Landsat data. Very interestingly, a growing number of users are initiating their own applications of these data.

Great concern has been expressed by many users that Landsat seems to remain in an experimental status when, in their minds, the time has passed since this experiment proved itself a success. Steps should have begun that would lead to a fully operational Earth Resources Survey System. As early as August and September of 1974, our Committee conducted hearings on two measures that would have begun the steps necessary to place Landsat on an operational footing. Following the hearings, it was determined that Landsat should not yet become part of an operational system, and a new bill, S. 156, was introduced and provided for the continuation of Landsat in an experimental mode. S. 156 was later incorporated in part into H. R. 4700, the FY 1976 NASA authorization bill.

All of the foregoing events clearly pointed out that the goal of our efforts should be more than establishment of an operational Landsat system. It has been widely recognized that Landsat data can be combined with those from other sources to provide a variety of users with better information on world resources and environment. Thus, it is my hope that we can develop legislation for an organizational structure based on Landsat that will provide the base for a Global Resources Information System.

The requirement to address the need for more permanent provisions for Landsat and a Global Resources System still exists. On April 25, 1976, the Committee contracted with

Charles Mathews, the retired Associate Administrator for Applications of NASA, to study possible alternatives for a permanent Global Resources organization centered around Landsat. Mr. Mathews' study, which was conducted in close coordination with the Committee staff, is being sent to you with this memorandum.

This report and the Senate bill, which was drafted as a consequence of the report, are a preliminary effort. I have instructed the Committee staff to solicit comments on both the report and the legislation from knowledgeable government and industry sources, including some from other countries. I have requested the Subcommittee on Aerospace Technology and National Needs, chaired by Senator Ford, to determine requirements of the states relative to Landsat and to provide for those requirements in the Senate bill. The Subcommittee has been further requested to investigate organizational arrangements of certain other satellite systems that might provide guidance on this bill. Based on the information gained, this study will be revised and reissued. In addition, I have instructed the staff to make recommendations for this bill that may arise as a result of the solicitations and conferences. At that point, I will call for a Committee hearing, and I would hope that we could report legislation early next spring.

August 2, 1976

The Honorable Frank E. Moss
Chairman
Committee on Aeronautical and
Space Sciences
Washington, D. C.

Dear Mr. Chairman:

The enclosed report is submitted in conformance with the contract agreement between the Committee on Aeronautical and Space Sciences of the United States Senate and myself.

Sincerely,

Charles W. Mathews

AN ANALYSIS OF THE FUTURE LANDSAT EFFORT

Introduction

This report on the Landsat system has been prepared under contract with the Senate Committee on Aeronautical and Space Sciences. It is concerned with the operational configuration of a Landsat system and associated institutional arrangements and is intended to provide background material for possible legislative action. The report is comprised of three sections.

The first section is largely background material about what Landsat is and what it does, including descriptions of specific uses and their value. Also included are some characteristics of a Landsat operational system compared with the current experimental one.

Section II deals with alternative institutional arrangements for an operational Landsat system and an evaluation of their pros and cons. This section recognizes that the institutional arrangements are likely to change with time as the Landsat operational system matures. These trends and the reasons for them are described.

The third section deals with a number of specific issues involved in the Landsat program. The issues discussed are both programmatic and institutional in nature. An analysis of each issue is made, and some actions are indicated.

Finally a series of general recommendations is provided, as is a list of recommended action items.

SECTION I

LANDSAT BACKGROUND

Historical Background

Early in the U. S. manned space flight program, astronauts using hand-held cameras took high-quality color photographs of the earth from out the windows of their spacecraft. These broad synoptic views produced a new kind of look at the earth and were received with high interest everywhere. In addition, it was realized that a high degree of practical information content might be inherent in such photos. Investigators rapidly showed this to be the case in many fields of use.

In the meantime, other types of instruments having certain improved capabilities for this application were being investigated using aircraft. These instruments, known generally as multispectral scanners, will be described in a later section of this document. These two activities resulted in a concept of a new global data acquisition system consisting of a multispectral scanner mounted on a satellite observation platform, a concept that was ultimately to be named Landsat; however, before Landsat ever flew, continued work with cameras in the manned Gemini and Apollo programs and continued investigation with cameras and scanners on aircraft allowed the experimental Landsat system to be designed. This design has proven outstanding in all aspects of its performance. The manned spacecraft and the aircraft flights devoted to this activity also served to ready the investigator teams to experiment with the Landsat data once Landsat was flown in July of 1972. This experimental phase has now been active for four years.

The first Landsat was joined in orbit by a second launched in February 1975. Both of these satellites continue to operate, although loss of tape recorders on Landsat I has limited its data acquisition capabilities considerably. A third Landsat is being prepared for flight in late 1977. It is similar to the first two, but has a number of important added features that enhance the information content obtained from its instruments.

The schematic arrangement of the experimental Landsat system is shown in figure 1.

In the United States the basic processing of Landsat data is accomplished at NASA's Goddard Space Flight Center at Greenbelt, Maryland. Master copies of all data are sent to the EROS Data Center operated by the Department of the Interior at Sioux Falls, South Dakota. There the data are stored, reproduced and disseminated to the general public on demand. The Departments of Commerce and Agriculture also operate dissemination centers but on a smaller scale.

Three other countries, Canada, Brazil and Italy, are operating terminals capable of receiving Landsat data directly from the satellite and processing it into usable products. These countries, by agreement, are also required to make these data available to the general public on demand and at reasonable prices. Three other countries, Iran, Zaire and

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Chile, have signed agreements and intend to or are actually in the process of building terminals.

Landsat Technical Capabilities

Landsat orbits the earth approximately once every 103 minutes. In doing so, it looks at a swath one hundred miles wide along a path going from pole to pole on both sides of the earth. The next time around (103 minutes later) it looks at another swath, but because the earth has rotated about its own axis (about 26^{o}), this next swath is at a different location from the first. In all, fourteen of these great circular swaths are traversed each day. The next day another fourteen swaths at still different locations are traversed until after eighteen days the satellite has had an opportunity to look at least once at every place on earth. Landsat then repeats this cycle during the following eighteen days and so on continuously as long as the satellite lasts. If two Landsats are working at the same time, as indeed Landsats I and II are as of this writing, then this repetitive cycle for covering the earth can be shortened to nine days.

As Landsat looks down along these swaths, its instruments make separate and individual measurements at every point underneath. Each point is slightly greater than an acre. The main instrument, the Multispectral Scanner, actually makes four individual measurements at each of these spots. The measurements determine the intensity of the sunlight reflected from a particular spot on the surface, but rather than just the overall intensity, the instrument individually examines the intensity in four different color bands--the blue-green, the red and two different bands in the infrared, essentially two colors beyond the range of the human eye.

Different materials on the surface reflect sunlight differently. For example, water does not reflect in the infrared bands or at least hardly at all, but does reflect in the blue-green band and also in the red band if significant amounts of sediment are present. On the other hand, vegetation reflects extremely strongly in the infrared bands but not much in the red or in the blue-green even though the human eye sees such reflections from plants as green. Each class of material on the surface tends to have its own characteristic combination of reflected intensities in the four color bands. Therefore, it is possible to identify what is on the surface, not just in terms of whether the material is a general class of say, water, bare earth or vegetation, but whether the vegetation is wheat or corn, for example. This ability exists for other types of surface classifications at this level of detail. This capability is possible with the present Landsat instrument if a significant number of individual spots corresponding to a field size of about 25 acres can be consistently aggregated. If the spatial resolution of the current Landsat instrument is doubled, the ability to detect objects with linear dimensions of half the size, the 25-acre figure would be reduced to approximately 6 acres (one fourth).

The measurements just described are stored in a tape recorder and then sent to the ground by telemetry, or in some cases they are telemetered directly to the ground as the measurements are made. These data are in the form of a digital code and flow to the ground at the very high rate of ten million bits each second. Deciphering the code in essence determines the magnitude of the intensity measured for each of the four color bands and also determines the time at which the measurements were taken.

Knowing the time, it is possible to determine very precisely the location of the measurement in terms of latitude and longitude from a knowledge of the position of Landsat in its orbit.

This flow of coded data, called a bit stream, can be put into a special data processing device, and, if desired, a series of images of what is below the satellite in any 100 x 100 mile area can be obtained for each one of the four color bands. This is something like the function of a photographic camera, although a camera in many ways is very much limited compared to Landsat's Multispectral Scanner. The Landsat images so created allow the human to "visualize" generally what is "down there" using photo interpretation techniques. A considerable amount of detail exists in a synoptic view of 100 x 100 miles. These images are almost perfect in their geodetic or map-like character because the satellite is many hundreds of miles above the earth's surface and is designed to always look straight down. It is very easy to put these images together to make larger images of a given state or of the whole United States--see the July 1976 issue of the National Geographic Magazine. Many times, however, a user will not necessarily need to create these photograph-like images but will use a computer in conjunction with the data processing equipment to directly and rapidly extract "thematic" information. This might be a classification of agricultural crops growing in a given area as to type, location, and the area under cultivation for each type. A more specific discussion of the kind of information that can be extracted from these data follows.

Landsat Use-Oriented Capabilities

A detailed and comprehensive discussion of all the Landsat capabilities and uses is beyond the scope of this document; however, such aspects will be briefly summarized here in a number of important use areas. A more complete picture can be obtained from the compilation of papers published following the three Landsat symposia conducted by NASA in recent years and also from congressional testimony on the NASA Applications Program.

Agriculture--Probably the greatest potential contributions of the Landsat capability are in agriculture and similar areas relating to food and fiber. As already mentioned, Landsat can identify many food crops and, if they are grown in moderate to large size fields, can determine the acreage devoted to individual crops in a region. This ability is important to food production estimates, which with Landsat can be done frequently and worldwide. Economic analyses have shown such data to be of high economic value. The Department of Agriculture now makes production estimates both domestically and in foreign areas using data laboriously gathered on the ground. For some countries the data are questionable, late or not available at all.

In addition to this general capability in agriculture, Landsat can determine the extent of crop damage produced by such factors as drought, flooding, winter kill, late planting, severe storm damage and blight. These damage measurements can be used in altering production predictions and in addition can help in planning and tracking the recovery actions taken.

Numerous other uses of Landsat data to the benefit of agriculture have been demonstrated such as monitoring of critical cropping and irrigation practices. For example, destruction of certain pests requires that stubble be plowed under shortly after harvest. Landsat can monitor such activities. Water management, of course, is a major part of agriculture where irrigation is practical. This subject will be discussed in a later paragraph.

Allied activities dealing with vegetation, such as range and forest operations, can similarly benefit from Landsat data. Landsat can follow the seasonal cycle of range grasses (biomass) as well as local conditions as an aid to determining where and when the land should be grazed. Extensive forest inventories are also possible, and the ease with which this can be done has resulted in several major timber companies seriously experimenting with Landsat data, in some cases on a large scale. Comprehensive mapping of wildlife habitats based on vegetative conditions determined from Landsat data is just another example of use in this general area.

Mineral Exploration--Perhaps the most comprehensive commercial use of Landsat data to date involves exploration geology of the kind in which the mining and petroleum industries are heavily engaged. Such industries have already made great use of surface geologic manifestations of underlying mineralization, and they have found Landsat to be a new and powerful tool. The synoptic view provided by Landsat enables better interpretation or revision of geologic maps, particularly in the location of previously undetected faults in the earth's crust, an important factor in mineral exploration. In addition, other subtle surface characteristics, circular shapes and clustering of lakes have served similar purposes. Other features involving subtle surface color and vegetative pattern changes produced by seepage of mineral indicators to the surface have been detected by Landsat and have proved very valuable to these industries.

Some have argued that because geological features generally are not changing rapidly (most changes occur over millions of years), only one-time coverage by Landsat is needed. Not so say the exploration geologists for they are generally looking for very sutble features. Different sun angles or lighting conditions are needed. Sometimes a light snow cover is helpful in distinguishing such features, and sometimes comparison of vegetation is the factor needed to reveal these features.

Geologic information obtained from Landsat is valuable to others. Knowledge of faulting allows for better routing of highways and location of bridges to avoid earthquake hazards. Landsat geologic information has helped find sources of underground water in arid regions. These are but two of many examples.

Water Resources--Water resources management is another area of critical concern in many places of the world where the analysis of Landsat data can contribute to better management and to the solution of problems. Landsat can easily monitor the changing characteristics of impounded water bodies as to their number, location, size, sediment load, algae condition and the like. This can be highly useful information to those responsible for a water district or a watershed area. Landsat can also determine the surface cover of a watershed. Because the nature of the cover affects the water runoff, absorption, evaporation and transpiration of the watershed, such information is needed and used by managers of dams and reservoirs in the conduct of their activities in conserving water, in preventing floods and in determining the proper electric power production duty cycles.

Snow accrued atop mountainous watersheds is an important source of water in many areas of the world, including the western slopes of the

U. S. Rockies. Landsat can monitor the buildup of the snow during the winter and the rate of depletion during the spring and summer. This information is very important in managing the supply of water to cities and farms, as well as for flood warning and avoidance.

Flooding is a continually occurring disaster in this country and in the rest of the world. Landsat can monitor flooding conditions. A number of state and federal agencies have shown that during a flood period Landsat data can be used effectively in establishing evacuation routes and procedures, finding where aid is needed, assisting in relief efforts and determining breach patterns of flood protection systems. After the flood the Landsat data provide an added tool for estimating total damage claims and aid requirements, planning better protection, mapping the altered course of rivers and monitoring the general recovery of the land.

Other uses of Landsat in water management have been demonstrated. One was mentioned previously in connection with the geologic use of Landsat for locating underground water sources. Although the discussion herein has been purposefully limited, the foregoing examples should provide a general understanding of this class of Landsat use.

Land Use--Many states now have or are contemplating statutory requirements relating to a better determination of the use of land within their boundaries and the tracking of changes in use. Many developing countries have even more demanding needs in this regard for most have very little in the way of information. This is a very natural capability of Landsat. Just as it can classify agricultural areas, it can classify forested areas, urban areas, coastal wetlands, deserts, swamps, rangeland and others. Of particular importance, it can measure changes caused by fires, cutting, urban growth, expansion of deserts, agricultural abandonment, shore erosion and the like. Furthermore, this information quite naturally can be put together in a common and understandable format.

Even in urban areas where Landsat is somewhat less useful because of the detail required, general changes can be detected in relationships between industrial areas, individual-dwelling residential areas, multiple-dwelling residential areas, commercial areas and so forth. This provides a rapid update on the overall picture so that detailed surveys can be conducted more effectively.

In other countries, it may be desirable to analyze and isolate the most desirable areas for new arable land considering soil type, water supplies and transportation. Landsat is well suited to such purposes. The same is true in opening up new mining areas because other factors such as access to the area enter into the consideration along with the presence of minerals.

Coastal Zone Monitoring--Another area where Landsat has demonstrated an ability to make solid contributions is in the monitoring of coastal zone areas. These areas are undergoing continuous changes as a result of natural causes such as storms and in many instances as a result of human activity such as subsidence produced by withdrawal of well water from the adjacent land.

It is very simple for Landsat to detect quite precisely the land/water interface along any shoreline. With this ability and the repetitive coverage inherent in the system, it is possible to measure changes whether they are caused by beach erosion, sediment deposits or subsidence.

Analysis of these changes helps establish their mechanisms and to determine preventative actions where indicated.

A special case involves the wetland areas. Much of our coastal wildlife inhabits these areas and uses the areas as spawning grounds. Again Landsat can provide data important to preserving the ecology of these regions not only in detecting changes in their size but also in monitoring the various species of marsh grasses and other wetland flora. Of particular importance are the effects of human encroachment on such areas as developers turn portions of the area into industrial or residential sites. Landsat data have already been used in negotiations with developers or industrial firms in such cases. Similar negotiations have occurred in cases where Landsat has detected sediment plumes in outfalls of rivers and dumping of pollutants in coastal areas.

Mapping--The last area to be discussed is mapping. Landsat has received criticism in some circles in not being able to meet topographic standards for large-scale maps, say a scale of 1/22,000, for example. Landsat was not designed to support mapping at large scales, and such requirements are in conflict with Landsat requirements for complete global coverage and for a truly synoptic view. Nevertheless, Landsat provides excellent support to the mapping community in many ways and is seeing ever-increasing use by this community.

Landsat more than meets mapping standards at a scale of 1/1,000,000 and is excellent for updating maps that meet standards at a scale of 1/250,000. The detection of changes made possible by the Landsat data has proven extremely important at all scales, including the largest currently in use. The reason for this apparent paradox is that the large-scale maps with their great detail and precision get updated very infrequently because of the workload involved. In fact, the average age of the latest topographic maps in the United States is eight years. In most regions of the world the ages are much greater, if accurate maps exist at all. Although Landsat cannot detect small features, the changes it does detect are many, and they frequently are not found on the latest maps. One might suspect this to be true in remote areas, but investigators have shown this to be true even in major metropolitan areas such as Washington, D. C. In this way Landsat provides outstanding support to the mapping community.

Summary of Capabilities

Landsat has evidenced outstanding value or the potential in the areas just discussed: agriculture and associated areas, mineral exploration, water resources management, land use, coastal zone monitoring and mapping. A number of other areas exist in which Landsat data are being used or investigated. Oceanography, environmental quality of land and water, meteorology and marine resources (fishing, for example) are areas where Landsat data, although perhaps more limited in applicability than the areas listed above, will develop significant and valuable uses.

Estimates of Landsat Value

The specific use capabilities enumerated in the previous paragraphs provide a qualitative impression of the very considerable value of Landsat data. The question arises as to whether it is possible to arrive at a quantitative estimate of the value of Landsat data. The answer in a total sense is probably no, but in a limited way such estimates have been attempted, based on thorough economic analysis effort.

Economic analyses made to date generally indicate positive economic benefits, although a large spread exists in the estimates of benefits. One very conservative study completed two years ago predicted benefit-to-cost ratios in the range of .7 to 1.4 at a discount rate of 10%. Discounting is a way of recognizing that any investment for which benefits accrue in future years is competing with conventional investments for which there is some annual rate of return--say 10%. A rate of return of 10% is a good investment even in today's world, so any future system such as a Landsat operational one that projects a benefit-cost ratio of one with a 10% discount rate would seem to have a promising capability.

Another study completed at about the same time projects annual benefits at a 10% discount rate in the range of $400-to-$600 million, a projection of truly outstanding capability when compared with systems and operational costs in the range of $100-to-$150 million a year. Although both studies produced what most observers would consider positive results, a question frequently asked is why should there be such a difference. The first study in its conservative view considered only the existing experimental Landsat performance and only analyzed those uses for which such performance had been demonstrated after one or two years of experimentation (up to 1974). The second analysis took a more forward-looking view in assuming that performance of Landsat systems would exhibit an evolutionary improvement up to 1985 and also analyzed potential uses that had not yet been specifically demonstrated. Some differences did exist in the economic models used in the two studies. The second study plowed some new ground in modeling the "value of information" and has received considerable attention as a result. Mostly these differences were a result of differences in the projection of Landsat performance and the additional uses that would be included in considering this performance.

With such a range of results, some people do not think such economic analyses are of much use. It is true that the uses perhaps are limited in the context of a true quantitative basis for decision; however, the studies are valuable for a number of reasons. First, they provide a feel for whether a new capability has potentially positive or negative economic possibilities. In the Landsat case, the result was positive. Second, they indicate which aspects of system performance are likely to be most important economically and thereby provide valuable inputs to system design. Probably most important, in modeling economic situations insight is obtained as to how present economic mechanisms work and how future mechanisms might work or might be influenced by new innovations. In the Landsat case, for example, the effects of more timely and entirely new information coverage on a global scale were included, producing an entirely new framework for thought and analysis.

With the large economic benefits projected for Landsat, a system of this kind would seem to be an outstanding opportunity for private ventures. This situation is not likely to be the case in early phases of the Landsat activity partly because of the high capital costs involved but mostly as a result of peculiarities associated with the value of such information systems and the associated difficulties in aggregating the market.

Precise and timely information on a subject, say agricultural production, is obviously valuable. In this example, information provided by Landsat would be very valuable to a given commodity company if it were the only one to have it. Once that information is generally available as is the case under the present Landsat data dissemination policy, it may be less valuable to a given company. Nevertheless, the second economic study previously discussed indicates that freely available Landsat information has a high overall value to the United States and to other countries as well because the inefficiencies and non-productive effort associated with misinformation are eliminated. With poor information or misinformation everybody tends to lose. In effect, misinformation is an added cost like a tax or surcharge on a particular commodity.

A question frequently asked is who are the recipients of this added value. In simplistic terms if a competitive situation exists, the improved efficiency should drive the price down or result in an improved product or service because each competitor's primary objective is to increase his profits by capturing as large a part of the market as possible. Thus, in this situation the individual consumer reaps most of the benefits.

A market involving consumers, which is everybody when viewed on a worldwide basis, is a difficult market to aggregate, particularly when services involve indirect relationships with the consumer. In other words, the benefits of Landsat, while real, are so diffuse on an individual basis that the consumer is unaware of them. This problem is a general one with information systems and services, and Landsat is no exception. However, many groups and individuals are recognizing the need for better-integrated and more precise information on which to base decisions in this complex world. Landsat provides the nucleus of just such a capability and is applicable to many problems involved with resources and the environment. Just as important, it gives impetus to the general development of rational information systems and decision processes.

As with any venture, the questions to be answered involve what will it cost? How much will I save? What are the future possibilities? Landsat also raises other questions, including what are the social values? Is it good for the country? Does it have a positive international role? Many people prefer this more classical approach to value determination compared with economic analyses. Regardless of which approach is preferred, Landsat offers outstanding value to this country and the world. A policy of public, worldwide information will also reaffirm some long-standing and strong principles of the United States on open and free world trade. A disadvantage to the United States and its consumers can be eliminated by removing the information monopolies that some countries maintain.

The Landsat Operational System

In the discussion of Landsat technical capabilities, the method by which data is acquired by the satellite and transmitted to the ground has been described. This description applies to the current experimental Landsat system. The general features of a Landsat operational system will now be described and compared with the experimental system.

The satellite itself might have the same performance characteristics as now exist or might have those improvements being incorporated in Landsat C. It may be desirable, however, to go one step further in improving the performance of the satellite sensor by incorporating the Thematic Mapper, a sensor having a strong generic relationship to the sensors now being flown but with a greater spatial resolution (the ability to detect objects of a smaller size) and further improvements in the multispectral characteristics. These improvements would enable the Landsat data to meet a broader segment of user requirements.

An even more needed difference between the operational system is a configuration of satellites that provides a reasonable degree of assurance that Landsat data can be made available on a continuing basis in spite of a satellite failure or failure in other parts of the system. This requirement, which is a very strong requirement of operational users, can be accomplished by incorporating appropriate backup (standby capabilities) or redundancy (duplicate capabilities) in the system. In the satellite part of the system, for example, two satellites in orbit, as already stated, would provide repetitive coverage throughout the world once every nine days and if one satellite failed, coverage would continue to be provided by the other satellite but on a once-every-eighteen-day basis. Even in this case, at least one other backup satellite should be available on the ground to assure operation over a number of years because it takes at least three years to build a satellite and prepare it for flight.

The frequency of the repetitive coverage in itself is of considerable importance to users. For most cultivated crops eighteen days repetitive coverage is probably adequate. Range monitoring, however, demands more frequent coverage and a nine-day repetitive cycle is needed for this application. Some types of monitoring, pollutants and flooding, for example, might desire much more frequent coverage but this is not practical at the Landsat resolution because of the data handling load. Other surveys involving forest inventories and urban change detection require less frequent coverage than an eighteen-day interval. All in all, considering that some data are lost because of clouds covering some areas of the earth at any given time, a nine-day repetitive coverage appears to be a good compromise.

Another very important consideration in an operational system is how rapidly useful data products can be made available to users. In many cases, the users would indicate this availability should be a matter of a few days at most. In the experimental system this availability has been measured in weeks and, in some cases, months. The situation is less demanding when one is experimenting because the data are not being used for decisionmaking.

The first requirement for rapid data product availability is to get the data back quickly and reliably from the satellite. In the Landsat operational system, this will be accomplished through use of a Tracking and Data Relay Satellite System now under development for NASA use in the 1980's. This system should be much more reliable than data transmitted from the satellite tape recorders now being used in the experimental system.

Once the data are on the ground, it will be necessary to process them into usable form much more rapidly than the present capability provides and to get it rapidly into the hands of the users. This ability can be attained by incorporation of two features into the operational system. One is to enable the Landsat digital data to be processed digitally and duplicated instead of undergoing a lengthy process of analogue conversion and photography currently in use. This requirement applies both to the development of data master copies and to the more specialized products needed by the users. The second feature is to provide for rapid transmission of data between geographic points. This need applies if more than one geographic location is used in the processing activity and also applies to the dissemination of data to the users. Such capability can be obtained through use of commercial satellite communication links already in existence or planned.

A final requirement of the operational system is that the data products made available to users are in a format they can use. Most users are interested only in the information contained in the data product and not in the process of extracting it. Image products are generally useful and familiar to lay users and should be in one form. Computer-compatible tapes are coming into ever-increasing use because of the flexibility provided by using digital computers to extract information from the data. Computer programs for various types of information extraction need to be made available, as well as special equipment for information extraction and display. This equipment will probably be developed and made available as commercial ventures.

SECTION II

INSTITUTIONAL ARRANGEMENTS

Background and Definitions

Some possible institutional arrangements for an operational Landsat system are presented as a matrix in Table 1. Such arrangements must consider four individual segments of the system. These segments at any given point in time are likely to involve different organizational elements and different institutional arrangements. This is due to the different functions to be performed within each segment, the associated differences in skills required and the differences in the institutional environment in which the various segments operate. The fact that there must be compatible interface between the segments is an important consideration.

The four segments are: a space segment, a centralized ground segment for data handling, a segment comprised of installations having separate receiving terminals and data processing facilities, and a segment comprised of installations offering interpretive services to users. Both the space and ground segments involve three major activities: research and development, procurement of equipment and system operation.

The space segment consists of a system of satellites for data acquisition and a network that brings the data back to a single location. The space segment is envisioned to end at the point where all of the satellite-acquired data are aggregated at this single location and preprocessed to provide the basic radiometric and geometric corrections, time and location tagging, and a common format needed to make the data usable by a central data handling facility. The output form of this corrected data will be a high-density digital tape from which the data can be retransmitted through commercial satellite communication links to the operators of the central data handling facility. Because of the very high data rates involved, satellite communication is the best way to minimize transmission delays.

The centralized ground data handling segment provides for the archiving, retrieval, further processing and dissemination of data. It serves the public domain with a few basic data products for both unsophisticated and sophisticated users. The products are likely to be in the form of images (prints and negatives), digital tapes of the type compatible with existing general-purpose computers and high-density digital tapes for specialized applications. This ground data handling segment produces master copies of these products and then stores, retrieves, duplicates and disseminates these products on demand at fair prices.

In addition, a wide range of separate receiving terminals and data processing facilities could be established. These facilities would operate under proper agreements and could involve many elements of the world's society, including international organizations, foreign regional federations, foreign nations, federations of states, individual states, federal government agencies and elements of the private sector. These terminals could receive data directly from the Landsat but, if desired, they could also receive data in an intermediate stage of processing subject to additional charges.

Interpretive services involve the manipulation of the basic data to extract useful information, to amalgamate it with information from other sources and to put it all in a suitable form for decisionmaking or other uses. This activity is envisioned to be conducted either by the user himself or as a service generally provided in a competitive environment by private industry. User training is closely associated with this interpretive service activity.

In addition to these four segments of the Landsat system, each of which possibly involves different arrangements, another factor influencing such arrangements is that of evolution. The evolution from an experimental Landsat system to a mature operational Landsat system is expected to involve roughly four phases. The four phases are: the experimental phase (currently under way), an operational validation phase, an early operational phase and a mature operational phase.

The experimental phase of Landsat is well along and is the basis for much of the material already presented. It will not be discussed further other than to describe activities that need to be carried out during the remainder of the experimental phase in order to get ready for the operational phases.

In most well-planned endeavors, one does not go from a successful experiment directly to a full-blown operation. Usually after successful experimentation a prototype or pilot plant operation is initiated. It closely simulates the operational system but at a reduced scale of investment and on a conditional basis. In addition, the institutional arrangements during this "pilot plant" activity are likely to differ from the later operational phases. It is usually desirable to use and retain the experience of the experimental group during the validation phase and then make institutional adjustments as the operational phases are initiated.

Thus, in the Landsat case, the operational validation phase involves the implementation of the early operational system in prototype form. The physical configuration of the system in terms of number of satellites, their instruments and the ground facilities should be the same as that defined for an early operational system, although modest changes would be expected as experience is gained. The institutional arrangements should recognize this phase as a period of transition from experimental to operational status. This method assures that the institutional configuration provides for participation by the incumbent agencies in order to carry over experience from the experimental phase. At the same time, some of the arrangements more suited to the later operational phases should be initiated. This operational validation phase should be characterized by conditional financial and institutional commitments pending the success of the validation. It should also be committed to and enable a continuing activity into the early operational phase if the validation is successful.

The early operational phase will continue to provide those services justified in the operational validation phase. In many cases these services will be justified on the basis of an economic benefit or a social need; however, the financial risk in some areas or international sensitivities in others probably preclude a completely free enterprise initiative during this period. The thrust, however, could generally be in this direction and could be encouraged by appropriate federal support to industry. If necessary, regulations could prevent the development of unnecessary international sensitivities or similar institutional difficulties.

It is expected that the effort in the early operational phase would be characterized by a single service, generally supporting users in many different areas.

Although this general multi-user service would likely continue during the mature operational phase, many other types of activities are likely to be going on in parallel. Initiatives suited to their special purpose are likely to be undertaken by the private sector. An example is a stereoptical survey satellite sponsored by the extractive industries. In fact, there could be a strong shift toward such free enterprise activities with a competitive profit-making environment.

At the same time a significant involvement of federal users is expected. Various federal agencies such as the Department of Agriculture may very well have their own systems dedicated to their particular needs, and states might have special terminals enabling rapid access to and processing of data peculiar to their own uses. Foreign nations, as well as the United Nations, are likely to be undertaking significant efforts and providing services in this time period.

The operational evolution just described will be characterized initially by strong, early federal involvement and support to facilitate the transition to later activities more characterized by individual initiatives, both private and public. A point worth noting, however, is that all four phases, from experimental to mature operations, go on more or less in an overlapping continuum because the evolution to a mature operation will progress more rapidly in some areas than in others. In a corollary sense, experimentation with new techniques and systems will always continue.

Each one of the three operational phases will now be discussed in terms of alternative institutional arrangements and their pros and cons.

Operational Validation (prototype) Phase

In all phases, the effort in the space segment consists of three parts: research and development, procurement of system hardware and operation of the system. Research and development of space systems have generally been conducted by industry under the sponsorship and management of NASA. During this early stage of the operational Landsat program, continued federal support of R&D is needed. Because the present relationship has been highly successful and satisfactory to all parties involved, no alternatives will be explored in this area.

In the area of procurement, only three organizations have been involved with the procurement of global satellite systems for civil use. They are NASA, the National Oceanic and Atmospheric Administration's National Environmental Satellite Service (NESS) and the Communications Satellite Corporation (Comsat). Each of these organizations uses the capabilities of private industry to design and produce the hardware. NESS draws on the resources of NASA as its procurement agent and also for management of the industrial contractors involved. These same organizations operate the satellites that are built for them and also operate other related space system elements.

Landsat has already been used for four years of successful experimentation. This forms an adequate basis for a decision to conduct an operational validation. However, when the lead time required to procure satellites and equipment and to otherwise establish readiness for this validation is considered, an additional four to five years appear to be necessary to establish the system even if the currently involved organizations are allowed to proceed following decisions in the next budget cycle. Any new organizational arrangements would delay this activity further because of the time required for the formulation of such arrangements, the ensuing negotiations and any legislative actions required, not to mention the learning cycle entailed.

Thus, based on the need to keep the time for implementing the operational validation phase to a minimum, the associated consideration of continued availability of Landsat data and the need to maximize the effectiveness of the services in this early phase, it appears desirable to use one of the three organizations mentioned in the previous paragraph. Further, the present international relationships are good, and the risk of adversely affecting international acceptance is a consideration in establishing new arrangements. No great motivation currently exists for other federal government or private sector elements to undertake space segment activities in this particular time period. For these reasons, only NASA, NESS and Comsat will be considered as alternatives for the procurement and operations functions involved with the space segment during the operational validation phase.

Of the three, NASA has the only direct experience with Landsat-type systems. In addition, NASA has by far the broadest experience in the procurement and operation of satellites and associated equipment. Thus, it would appear that NASA is a highly likely choice, unless there is a desire to consolidate all satellite operational missions within NESS or unless there is a demand to undertake this activity as a commercial venture in this early period.

NESS now conducts an operational program using earth observational satellites largely focused on meteorology. It plans to extend these efforts to other aspects of environmental monitoring. NESS would be a possible choice if consolidation of all operational activities involving earth observations by satellite is the decision for the time period under consideration. NOAA has informally examined the possibility of NESS undertaking operational Landsat efforts and has concluded that it would be undesirably diversionary for its chartered mission to expand activities into the Landsat area.

Comsat would be a reasonable choice to procure and operate the space segment if it were possible to make Landsat a viable commercial operation during the operational validation phase. The space segment of a Landsat operational system involves a considerably greater capital investment than has been the case for communications satellites. Although the market potential for Landsat data is evident, this market is very diffuse and much more difficult to aggregate than in many other areas of satellite services. Therefore, though strong interest in the subject by commercial entities is apparent, a reluctance to move into ventures requiring the financing of the space segment also is apparent. One other point worth noting from the Comsat experience is that it has been more difficult to set up arrangements and to carry out international activities in space with commercial interfaces than with governmental interfaces because generally one must deal in either case with the governments of other nations.

As with the space segment, the ground segment involves research and development, procurement of hardware and operation of a data handling system. To date, NASA, in conjunction with industry, has conducted most of the R&D associated with Landsat data processing. A transfer of at least some of this activity to whatever agency operates the ground segment would seem in keeping with normal roles and missions relationships.

At the present time, the Earth Resources Observation System (EROS) program of the U. S. Geological Survey operates the primary data handling facility in support of the Landsat system. This facility is known as the EROS Data Center and is located at Sioux Falls, South Dakota. Other data centers are operated by the Department of Agriculture and the Department of Commerce, but these two have more limited capabilities and deal with a more restricted and specialized clientele concerned with subjects of interest to the respective departments.

The reasons for continuing the on-going arrangements for the space segment during the operational validation phase also seem to apply to the centralized ground data handling segment. This has been the responsibility of the EROS program; however, EROS has done little in the way of technology-oriented R&D in this area. NASA could support it in such efforts. EROS also has had rather limited experience in the procurement of developmental and production hardware. Therefore, if EROS were to undertake these augmented functions, commitments of support in terms of personnel and fiscal resources would be necessary from the Department of the Interior, the Office of Management and Budget and the responsible congressional committees. This should be done in a way not to interfere with a concomitant buildup in the USGS (EROS) R&D role.

NESS is also a valid candidate for ground systems responsibility. In the meteorological area, it now performs (with support from NASA and industry) all of the required ground functions in an effective manner. As was indicated in the discussion of the space segment, however, NESS (NOAA) is disinclined to extend its activities into the Landsat area.

There exists another source for the ground segment responsibility during the operational validation phase--the private sector. A number of comments from industry indicate that under certain conditions such an arrangement would be an attractive option (in terms of a profitable venture). The conditions are generally based on the assumption that the government would finance and operate the space segment and would use some of the data services to be provided with appropriate pricing levels. Elements of industry claim that ground segment operation is a natural avenue for a private venture and, in areas such as this, the industry is structured and motivated to provide more efficient and more responsive service than the government.

Some countries may be sensitive to U. S. industry operations largely because of potential economic advantages to the companies. Therefore, some regulation or licensing arrangements would appear advisable in order to assure equitable activities and that the public domain concept is maintained.

Separate receiving terminals and data processing facilities for Landsat data already exist in Canada, Brazil and Italy. Iran, Chile and Zaire are implementing such stations, and Canada is planning a second one.

Other countries around the world are seriously considering such facilities. The only similar facility in the United States is located at NASA's National Space Technology Laboratories and services the Corps of Engineers as well as NASA. It is expected that other agencies, for example, the Department of Agriculture, will require such facilities in the near future. These terminals currently receive data directly from the satellite and are limited to acquisition of data in the general region of the station (approximately 1,000 miles radius) since a station can only "see" the satellite when it is above the horizon. In the future, such terminals may, if desired, receive data after preprocessing, relying on satellite communications links for rapid dissemination services. Even further central processing is possible without incurring significant delays in the availability of data. This option may be a valuable one for some users.

The growth of these remote terminal installations is likely to be considerable. Such terminals and their associated processing facilities are already an attractive marketable product for both U. S. and foreign industry. During the operational validation phase, it is expected that the main buyers of such facilities will be foreign governments and U. S. federal agencies, although purchases by companies to compete with more efficient data and information services is another growth potential.

No special institutional arrangements for use and operation of remote terminals are recommended. The evolutionary growth in these facilities will take place as a normal free enterprise process. Suitable agreements will, of course, be required to assure satisfactory relationships as to price, data availability and similar factors. Some of these factors are included in the present bilateral agreements between NASA and the foreign entities having such facilities. A copy of such an agreement is included as Appendix A of this report.

The final element of Landsat operational activity, interpretive services, has a broad potential involvement because it shows promise of significant economic return to those providing such services. Interpretive services involve further manipulation of basic data products to extract, integrate and display valuable information. Federal agencies are experimenting with such services. Examples of the types of products obtained are agricultural production forecasts and geologic, topographic, and land use maps. Industry already provides these services on a limited scale. In addition, many firms perform such efforts for their own use. Natural resources exploration companies are prime examples of an industry involved with information extraction activities.

Because Landsat interpretive services have great potential value, much of which is compatible with a free enterprise activity, the ultimate role of the government in providing such services should be limited. The usual paradox exists, however, in that there must be sufficient government support early to create familiarity with these valuable capabilities.

This support can be accomplished by guarantee of a base market or by other means to assure transfer of this capability from government to industry at the earliest opportunity. It would also appear desirable to limit government agencies to traditional services and to their normal clientele. This is a significant factor with the mission agencies. NASA's involvement with interpretive services has been strictly of an R&D nature and should continue to be.

In the early phases of Landsat operations, where the source of support to the system will come mainly from taxation, some control appears necessary to assure that the benefit is available to all on a reasonably equitable basis. For example, organizations providing interpretive services to others might be constrained from unduly "selecting" their clientele through high prices or other means. Equity of involvement of foreign entities, of course, can be controlled through proper agreements and charges made by the U. S. for Landsat data acquisition.

Early Operational Phase

The early operational phase will continue mainly as a single effort with highly focused institutional arrangements in both the space and ground segments. However, an important trend in going from the operational validation phase to the early operational phase will be toward a greater scope of involvement and in commitments to the use aspects of the activity. In particular, industry involvement will grow because the value and profitability of Landsat uses will be readily apparent. NASA is expected to continue its support to R&D efforts on the space segment in order to maintain a solid lead by the United States in this important technology. Competition from foreign elements could develop rapidly in this period. Some initiatives in space segment R&D will develop within the private sector, but these will be largely of the nature of evolutionary improvements to the existing system.

With regard to the procurement and operations activities involved in the space segment during this early operational phase, consideration of a transfer of some of the responsibilities from government to the private sector is certainly reasonable. The form that such new arrangements might take could be similar to that now existing with communications satellites--the establishment of a public-private corporation. Other arrangements on both sides of this option, such as a licensed private corporation or a federal corporation, are also possible. The main objective of such a move would be to obtain private capital and to help assure that operations are conducted on as close to a pay-as-you-go basis as possible. A potential disadvantage to this approach is that undue resistance toward the introduction of new capabilities could develop.

Continued government operation of the space segment is an alternate possibility. If this were the case, a suitable pricing policy could assure a minimum requirement for appropriated funds. Such a policy needs to be developed. If a need for improved services arose and more money was required, continued government responsibility would afford a relatively straightforward means for obtaining the necessary funding. If continued government responsibility is desired, it would appear that the agencies with such responsibilities in the operational validation phase should retain it in the early operational phase.

The suggestion has already been made that in this time period, foreign elements might exercise initiatives to place their own satellites in orbit to acquire data of the Landsat type. Because such systems are global, a natural question arises as to why the space segment should not become international. Experience has shown that it is extremely difficult to obtain sufficient organizational strength and agreement among the many nations involved to initiate spontaneously an international system of this kind. An international system may develop, however, as a user, integrator and disseminator of data from the various national systems. This already has proven to be the case in meteorology.

Assuming that these activities in space will be carried out as national efforts, hopefully with the United States as the technological leader, one would have to anticipate that some degree of international sensitivity may continue to exist because the economic value of the information acquired would become progressively more apparent. Therefore, the United States must exercise care in the selection of the operator of such a system and also exercise adequate control over the operation. Also, as a means of reducing such concerns, the United States should foster meaningful and useful international agreements in this area, affirming a general open data policy.

In the early operational phase, no reasons seem to be apparent as to why the private sector in a competitive mode should not provide on its own initiative the data processing hardware to be used by the operator of the centralized data handling facility and by the operators of separate terminals deployed worldwide. If foreign competition is as great in this phase as it is expected to be, some support by the U. S. government of R&D efforts of U. S. industry may be appropriate.

A pure private sector operation of the space segment during this period seems unlikely because of questions of capitalization and earnings. If a public-private corporation is selected to operate the space segment in the early operational phase, its operation of the ground segment would also seem justified because it would provide a better interface with the using community that will have to pay the corporation for data and data services. The corporation also would be the procuring agency for new data processing equipment needed to update the central data handling facility. Hopefully, these procurements would be for already-developed equipment or at least based on sufficient prior R&D so that procurement on a fixed-price basis, with payment occurring on delivery, is practical.

If the government is selected to operate the space segment, it need not operate the ground segment, which could be operated by a public-private corporation or indeed by a properly regulated element of private industry. In this case the ground segment operator would through a negotiated agreement buy the raw satellite-acquired data from the responsible government agency. The formula for this purchase would depend on the data volume required by the ground operator and the demand of other data procurers, primarily operators of separate terminals. In some respects, this arrangement would be similar to the launch services agreements now in effect between NASA and various users, such as Comsat and other domestic and foreign organizations.

The expected growth in Landsat use will produce large increases in data purchases from the central data handling facility and rapid increases in the number of separate terminals. Industrial use of such terminals will in part come from firms that provide data analysis and information services to others. But other industrial organizations, in particular those that have far-flung regional enterprises requiring periodic inventory such as the forest and range industries and the petroleum and mining industries, will invest in such equipment for internal uses. Some regulation of these activities may be necessary to prevent an inequitable distribution of data to users, particularly where time advantages might occur. During the early operational phase, the federal agencies that have requirements for earth resources or environmental information also will be using their own terminals.

Such using organizations would have their needs met by the operating elements on a "best effort" basis. An institutional problem would likely exist, however, in that each of the using organizations could have quite different requirements for data in terms of quality, timeliness, geographic location, frequency of coverage, volume and a number of other factors. These requirements could place a heavy burden on the operator of the space segment or the operator of the ground segment or both, depending upon whether the data go to the terminal directly from the satellite or with some intermediate ground processing at the central data handling facility. To a lesser but still significant degree, this same situation might exist in handling data from state agencies because some of the more technically sophisticated states probably would have begun to use their own terminals. Some mechanism analogous to an arbitration board will be needed to assemble, evaluate and resolve the conflicting requirements.

Rapid growth in the installation and use of separate terminals will also occur in other areas. Many foreign nations will have one or more. For those that do not, regional federations such as the European Space Agency will be organized to provide such capabilities. Similarly, in the United States groups of states within specific regions may share terminal facilities. In all likelihood, United Nations organizations in such areas as food, environmental quality, and land use will be using such terminals. This last group of operators will serve a fairly diverse community of users and will generally need and receive all the data available from its region (within approximately a 1,000-mile radius from the terminal). This requirement does not produce especially difficult burdens on the space or ground segment operators, as was discussed in connection with federal agencies, American industry and individual states.

A condition under which both foreign and domestic elements would want equitable consideration of their needs is the generation of new requirements for performance, capacity, or other capabilities within either the space or ground segment. Again, some mechanism for handling this multiplicity of data in a reasonable manner will be needed during the early operational phase and perhaps even before.

During the early operational phase the largest growth is likely to occur within the industry providing interpretive services. This activity will be pursued by foreign elements, both industry and government, that could represent real competition for U. S. industry in certain areas such as services to the smaller or developing nations. Domestically non-profit organizations may also provide interpretive services. These organizations might be federations of states, university affiliates, or non-profit corporations or foundations.

In order to give private industry the best opportunity in this market, federal agencies generally should be constrained from undertaking those efforts that could be provided by the private sector. Federal agencies will have legitimate internal requirements to extract information from data acquired by earth resources satellites, but even in these cases consideration should be given to having the service provided through contracts with private industry.

Mature Operational Phase

The space and ground segments in the early operational phase were characterized by a single mainstream activity and institutional focus. The mature operational phase is characterized by a number of parallel activities and institutional arrangements. For example, many industrial firms are involved in and compete for the same business. The same is true for nations. This situation is typical of most mature successful enterprises.

The mainstream activity of the early operational phase will continue, however, and will provide the general multidisciplinary data acquisition and handling support as in prior phases. Activities by this time should definitely be on a pay-as-you-go basis, and prior institutional planning should be designed to accommodate this eventuality.

The private sector may very well desire to sponsor the development of and procure its own special satellites to meet specific needs. Initially, these ventures are likely to be relatively simple and low cost, but they will become more sophisticated with time as value is received from early investments. In addition, industry will sponsor research and development with its own resources. Therefore, only part of the R&D in this area will need to be funded by the federal government. This statement applies to both the space and the ground segments.

- Federal agencies also may be using their own dedicated satellite systems to meet their particular needs in cases where the compromises associated with the multi-use system are deemed too great or where the value of having an independent capability warrants this dedicated approach. These agencies may continue to use NASA as their procuring agency for the space segment of their dedicated system because of NASA's broad R&D background in the field; however, each agency will probably specify and procure its own ground equipment since it will be designed to accommodate the specific needs of that agency. Every major agency might operate its own dedicated system or at least might like to do so. It would be a part of the normal budgetary reviews of the executive branch and the Congress to assure that the requirements of agencies for a dedicated system are sufficiently unique to justify funding.

The procurement and operation of space and ground segments by other countries is inevitable, but a prediction of just when such systems will appear is difficult. Some may be active during the early operational phase; however, the incentive for other countries to develop and deploy their own systems will depend very much on how adequately the U. S.-deployed system meets their needs. In the case of polar orbiting meteorological satellites, for example, the data provided by the U. S. satellites to other countries have obviated the need for foreign system developments. When foreign earth resources survey systems do appear, hopefully they can be complementary through use of international agreements rather than competitive.

In the area of separate terminals, the growth will continue to accelerate during the mature operational phase. Domestically, all states will be so equipped, and in many instances multiple installations will be provided within a state in order to meet the diverse needs of the various state agencies. Foreign industry will demand such installations or else place pressures on their own governments to establish a competitive system. In some instances, foreign industry may develop its own dedicated satellites and negotiate for launch services. The United Nations and, in particular, many of its suborganizations will request and install terminals in order to provide data to their working groups and also to service various constituents within the world community. This U. N. activity might very well approach the equivalent of a complete ground segment capability.

One would expect that the various data acquisition and processing centers distributed worldwide would be tied together in an overall network, allowing data and information in various stages of refinement to be exchanged under proper agreements.

Summary of Trends During Operational Phases

As the Landsat program proceeds from its present experimental phase to an operational phase, certain institutional changes probably should and will occur. However, between the first two phases (experimental to operational validation), the desirability of institutional change is not immediately obvious. The driving forces are to assure the continued availability of data while getting the hardware system and procedures into an operational configuration so its performance can be validated. The success of the validation will greatly depend on the degree to which maximum service is provided to the using community in terms of the timeliness and the quality of the data. All of these factors lend substance to the approach of carrying over basically the same institutional arrangements being employed in the experimental phase into the operational validation phase, thereby avoiding delays and inefficiency inherent in the early phase of a new arrangement. The continued need to assure international acceptance of this global system also is an argument for retaining the incumbent arrangements because they are largely under the control of the federal government and have proven very satisfactory to the international community.

On the other hand, the long-term thrust (toward the mature operational phase) will be to maintain U. S. technological leadership in this important field while minimizing federal expenditures. This objective demands aggressive involvement of U. S. industry. This will happen eventually if the Landsat operational system is successful, but some degree of encouragement in the early phases will be necessary. Most certainly, undue competition on the part of the federal government for service that could be provided by industry will not provide this encouragement. Therefore, careful consideration should be given to roles that the private sector can play in the operational validation phase. Industry should be involved in the provision and perhaps operation of terminals and the same is true for the provision of information extraction and display equipment and interpretive services. Government-financed training and user consultive services carried out by industry would be a stimulus. In any case, though the federal agencies also need to encourage user understanding and involvement in Landsat data use, they should not compete with industry where industry can and will do the job equally well.

In addition, consideration should be given as to what role the private sector can play in the major segments of the operational system. During the operational validation phase, industry involvement in the space segment does not appear practical because of the high capital costs involved and the time it will take to aggregate the market. The aerospace industry will develop the space hardware under government contract. The private sector, however, could with some degree of government support undertake the modification, extension or operation of the centralized ground data handling segment.

A possible approach to the early operational phase is to create a public-private corporation along the lines of Comsat to procure and operate both the space segment and the ground segment. This would provide a firm initiative and solid evidence toward putting the Landsat operational system on a pay-as-you-go basis. This type of institutional arrangement could be carried over to the mature operational phase operating in parallel with other more specialized systems by continuing to provide the general multidisciplinary data acquisition and dissemination services. During the mature operational phase, the activity will be broad and in general self-determining. Domestically, no special institutional arrangements appear necessary beyond those developed in the early operational phase.

International acceptance and participation will always be an important consideration with the Landsat operational system because of the frequent repetitive global coverage of the system and the fact that the data acquired will have economic value. Because of difficulty in unifying the international community in any effort, an international system probably will not evolve spontaneously but rather will result from an amalgamation of national systems. If a U. S. system is responsive to needs of foreign or international elements, it will make it less likely that other nations will develop space systems of this kind. The U. S. should continue to pursue foreign involvement in Landsat through proper bilateral and international agreements. Although there may be some early international sensitivity to major U. S. industry involvement in Landsat-type operations, it should diminish with time if activities of industry are properly controlled through evolution of adequate regulations.

SECTION III

EVALUATION OF LANDSAT ISSUES

A number of outstanding issues are in evidence that pertain to the future Landsat program. Some concern Landsat as a system; others relate to institutional matters. In all, fourteen significant issues are analyzed here. They were identified during the conduct of the experimental phase of the Landsat program or in the course of discussions of the future Landsat program with the various organizations now dealing with the subject.

The analysis in some cases determines specific actions or alternative actions and their pros and cons. For other issues, a general approach is spelled out with a justification of the approach. Each of the fourteen issues is posed as a question, and each is handled separately. A summary of these issues is presented in Table II.

Issue #1 Should a commitment be made that assures the availability of Landsat-type data in the 1980's?

All knowledgeable elements would propose to continue the Landsat program in some form. The experimental Landsats have been an unqualified success. There are many users in federal and state agencies, the international community and the private sector who will make operational use of these data once a commitment is made to their continued availability. The questions at issue relate largely to whether the system should continue in an experimental mode or become operational and whether the system should be improved or basically maintain its present performance.

Action to continue in an experimental mode is a viable one in some respects, but it has a number of drawbacks. Unquestionably, an experimental program should continue. Landsat is at an early stage in its evolution, and like most systems major improvements can be expected over the next several decades. These improvements will add considerably to the value and expand the uses of Landsat-type data. Federal support of R&D will be necessary to maintain U. S. leadership in this important field. Significant first steps in new developments have already been taken or are being contemplated. In particular, all digital data processing capabilities and the Thematic Mapper, a sensing instrument with superior multispectral capabilities and improved resolution over the present Landsat sensor, are being developed.

The chief deterents to carrying along an experimental program by itself are twofold. Such a program is characterized by a "single-threaded" activity where an inadvertent failure of the experimental satellite can jeopardize the continued availability of data. Secondly, many users want to continue with the present capabilities because of the prior investments they have made that are compatible with the ongoing capability. An example of this is the situation pertaining to the existing foreign ground terminals. The operators of these terminals would like to realize further returns on their present investments and also become familiar with the improved system before uprating these terminals. Another important consideration involves the question of how to minimize R&D funding requirements while maintaining technological leadership. Ways of solving such problems will be described in the following paragraphs.

An action that would set up an operational validation effort appears to be a very sensible option at this point. Landsat experimentation has verified its potential value in many fields, yet only limited efforts have been possible in demonstrating that it can be used on a continuing routine basis. This condition is mainly caused by the reluctance of users, even in the face of highly successful experiments, to invest in equipment and services when there is no guarantee of a continuing source of data. The configuration of the system used in the operational validation would have sufficient backup capability to provide such assurance and to enable a continuing operational program if the validation is successful. This condition also is partly the result of deficiencies in the existing data processing capability, particularly as to the timing of availability of the data, a situation that can be corrected in the operational system to be validated.

Combining the experimental program with the operational validation program integrates the good features of both, while generally avoiding the bad features. This combination is physically accomplished by integrating the existing Landsat instrument, the Multispectral Scanner, and the improved instrument, the Thematic Mapper, on the same spacecraft and flying both of them on the same mission. In this way the operational user would have the existing proven data available while at the same time he would have the opportunity to evaluate and become familiar with the improved capabilities. In doing this, care must be exercised not to alter significantly the requirements of the operational system in order to conduct the experiments. Only when there is a general acceptance of the new instrument should the old one be phased out. The idea of conducting tests of a new instrument or other R&D on an operational spacecraft is a means of minimizing the R&D costs compared with conducting separate R&D and operational programs. This combined approach to R&D and operational support would be continued into later phases of the program and might be applicable to other elements of the nation's space applications efforts as well. In fact, this concept is currently being used in the meteorological satellite program.

Going directly to an early operational system is feasible, but it does involve some risk in that no opportunity exists to test the overall concept prior to commitment. The risk considerations involved with this particular approach might militate against any major changes from the present Landsat system and preclude flying the improved experimental sensor. Because the institutional arrangements are likely to be different for the early operational phase than for the experimental phase, some difficulties could be encountered in shifting directly to an operational arrangement. A greater loss in program momentum could thus occur. The operational validation provides a transition regime that should largely avoid such pitfalls because time would be allowed for the proper development of the new institutional arrangements while the operational system configuration is being validated.

Issue #2 Should improvements in the quality of Landsat data and services be initiated at this time?

With the success of the experimental Landsats, one could assume that no improvement is needed. This is only a half truth and dangerous to the future leadership of the U. S. in this field. The current Landsat system has performed beyond expectations and has proved exceedingly valuable. Yet the ongoing program, as expected, has shown deficiencies that could be corrected as logical next steps and without significant risk. Economic analyses have verified that the incremental value of planned improvements is considerably larger than the incremental cost. Some improvements are already a part of the ongoing program in that Landsat C will incorporate an additional multispectral channel (a fifth band affording thermal sensing) as well as limited improvement in the spatial resolution of an ancillary sensor. Partial conversion to digital data ground processing is also under way.

A minimum positive action involves the logical next steps in improving ground segment performance, the area where the greatest improvement is needed. Such activities include conversion of the central processing facilities to an all-digital system to improve the speed and fidelity of data reproduction. In addition, the use of satellite communication links would reduce the present significant delays in transmission of data from one facility to another to negligible ones. Quick-look terminals would provide extremely rapid on-site access to data of somewhat reduced quality. Experience has shown each of these features is needed for a truly operational capability.

If such improvements were incorporated in the later phases of the Landsat C missions, it might be possible to test out and introduce in a quasi-operational sense some of the ground segment institutional arrangements envisioned for the early operational time period, thereby expediting the incorporation of such arrangements.

A further action would provide the potential of improved data acquisition through incorporation of the Thematic Mapper on board the spacecraft (on an experimental basis). Because the existing Landsat instrument would also be carried and because the ground segment improvements are also included, this action would produce a very good system.

The Thematic Mapper addition would enable the realization of important advantages of a higher performance instrument. This instrument is already under development. The range of individual channels of this multispectral instrument has been adjusted, based on current Landsat experience, to improve its water penetration capabilities and its ability to differentiate classes of vegetation. A new channel has been added (a sixth band) to improve the detection of stress conditions in growing crops, forests and range grasses. The measurement accuracy of each of the channels is double that of the current instrument. Perhaps most important, it detects areas as small as a fifth of an acre compared with the 1.2 acres now possible with the existing Landsat. All of these features will greatly improve Landsat usage not only in agriculture, forestry and range areas, but also in other areas such as urban land use, coastal zone monitoring and water resource management.

Another possible action, one which contemplates an entirely new system, suffers from the difficulty of causing problems for certain users, those who have invested in equipment and services associated with the current capability. In addition, considerable risk exists when flying entirely new equipment for the first time. The approach described here avoids these problems while still taking proper advantage of new capabilities as they are developed.

At this stage in space progress, the spacecraft itself is less important than the instruments it carries. The spacecraft must be reliable, point accurately and handle the power and data transmission requirements. All of these are already quite mature developments. Nevertheless, it is expected that the spacecraft in the 1980 time period will be different from the existing Landsat. It will be a spacecraft development that can support many varied projects operating in low earth orbits. Because the development and production costs of these spacecraft will be shared among the many projects, considerable cost savings in Landsat follow-on efforts are expected.

Issue #3 Should government ownership and operation of the various Landsat system elements be curtailed?

One possible approach to future Landsat efforts envisions a continued major government involvement. The major government involvement up to now has been quite appropriate. This is a pioneering effort in a new operating regime with great future benefit on a broad scale. The R&D investment was sufficiently high to preclude a purely private sector initiative. Further government involvement in the immediate future appears warranted for the same reasons; however, as this activity grows in scope, benefits, and interest, the government effort, at least that supported by direct federal funding, should probably be more reduced. Operational services should be provided on a pay-as-you-go basis, and even capital funding ultimately should come largely from other sources. The traditional source in this country is private ventures.

A plan for transfer seems to be a generally proper approach to handling the relationship between the government and the private sector. Such a plan should be developed. Heavy government responsibility should probably continue through the operational validation phase. It should continue at least for the space segment since only the government now has the necessary experience and resources. Nevertheless, the plan for transfer of effort needs to be established prior to the operational validation phase. This will ensure a readiness for transfer to a greater effort in the private sector upon entering the early operational phase. In the case of ground-based activities, this can perhaps be accomplished during the operational validation phase. The plan should include all aspects of the relationships between the public and private sectors. Roles, pricing policies, financing, regulatory considerations and time phasing need to be spelled out. On the other hand, the plan will need to have long-term flexibility to meet changing national and international needs and situations. The plan naturally should delineate clearly the future federal government efforts--in particular, the NASA role in R&D, procurement and operations of the space segment and the EROS Data Center ground activities.

Possible public-private corporation involvement suggested previously appears particularly appropriate when one considers the early operational phase. A longer continuing role for such an interprise may even be appropriate. The need in the early phases for federal financing and then the eventual turnover of ownership of a large government system to a purely private enterprise is difficult to envision. The public-private corporation, perhaps involving a consortium of private companies, does facilitate an early transfer of effort in the direction of the private sector. The public-private corporation probably is more attractive in the international arena than a purely private activity. A historical problem, however, is that such a corporation is envisioned by many foreign nations as a purely commercial venture. If it were desired to go this way, the planning could probably provide for major activities in the ground segment on the part of the corporation during the operational validation phase. The operation of the space segment probably could be turned over to the corporation at the beginning of the early operational phase.

One question is whether the public-private corporation should be a new one or an existing one such as Comsat. A new corporation could involve the elements of the private sector that have worked aggressively in the Landsat area. On the other hand, Comsat has considerable experience in working under this general arrangement and would not require new enabling legislation, which might prove difficult to pass. In any case, some consideration must be given to the fact that private ventures already exist in some facets of this activity.

Another possible action to consider is the transfer of the Landsat activity to a free enterprise operation. Although it is difficult to envision this early on for the reasons given previously, a point worth noting is that the private sector is already heavily involved in a number of ways on a free enterprise basis. Even greater involvement and rapid growth in some areas is envisioned. It is desirable that no policy on the part of the federal government inhibit private enterprise except for avoiding unfair or inequitable practices or other critical sensitivities. The transfer to purely private enterprise likely will be gradual, but private ventures ultimately should constitute the largest activity by far, at least in this country. Government and possible public-private corporation roles will be continued in altered modes, however.

<u>Issue #4</u> How can industry initiatives in Landsat activities be accelerated?

Aggressive pursuit of Landsat data uses in industry has occurred in areas where there has been a combination of "in-house" need and a general familiarity with high-technology approaches such as exist in the extractive industries. In many other non-aerospace areas where the data are potentially very useful, their use is inhibited by a lack of familiarity and/or a lack of assurance that the data will be available on a continuing basis. Even in the aerospace industry, this situation has greatly limited the extent to which corporate funds are invested in equipment and service development. Therefore, a particularly important action involves a policy determination on data availability. This policy must be clearly stated. The foregoing statement of need also is true of pricing policy, the relationships between federal and private capitalization, the timing of data availability and proprietary and regulatory considerations. There is no question that the industry will pay considerable attention to and desire involvement in the development of any planning of this nature.

The use-oriented industry will be discussed further in issue #5 and the remainder of the action items concerned with this issue (issue #4) deal with the service or equipment industry. A major industry question concerns the government's role. Significant efforts exist within government agencies not only to provide their own internal information using Landsat data but also to provide services to outside clientele. The role of federal agencies in this area should be clearly established and probably limited to internal services and to established client services.

Even in these cases a policy where agencies procure as many of these services as possible from industry would be highly encouraging to commercial enterprises.

Industry access to and use of remote ground terminals should be clarified since they may determine competitive posture in profit-making ventures. For equipment manufacturers, clarifications of the future federal support to Landsat-type operations and some indication of the extent to which government agencies intend to use Landsat data would be extremely helpful in market analysis. Further, an important clarification involves the extent to which such agencies will contract for equipment, software and services relative to efforts undertaken "in-house."

Along similar lines, the training and consultive service activities needed by many potential users could be undertaken largely by industry. This approach would have two advantages in that it would stimulate communications between the user and the service industry and would accelerate the industry's own knowledge of capabilities, uses and techniques. Where government funding is provided, this technique represents a cost-effective method of support to industrial involvement. In any case, the federal government should not compete unduly with either the industrial or university communities in providing training and education.

All of these suggestions involve stimulation of industry. This stimulation comes not through direct subsidization, but in providing necessary equipment and services through government contracts and by clarifying the likely extent of government business.

<u>Issue #5</u> How can user knowledge of and involvement with Landsat capabilities be accelerated?

Whenever a user has become sufficiently involved with Landsat data and truly understands its capabilities and applicability, he generally becomes a very enthusiastic supporter. This situation has been the case in a number of states, yet other states, with needs just as applicable, have had little or no involvement. Frequently, users who have heard of Landsat but have had little practical exposure have misconceptions of what the data can really accomplish. Cases of over-optimism are as bad as cases of undue pessimism. The former has frequently been encountered in the smaller developing nations. There is also the feeling in some circles that, although the technology is valuable and promising, it has not been sufficiently responsive to specific requirements of users.

A need exists to assemble representative groups of users in the various use-oriented areas in order to better understand their requirements and the relationship of these requirements to existing or planned Landsat capabilities. Such activities have been initiated by NASA, EROS and others, but a broader base of support for such activities is needed. It is also important for users to understand what Landsat can do and what it cannot do as well as to understand the relations of Landsat data to data from other sources (e.g., ground surveys, aircraft, etc.). Are these data complementary, competitive or mutually exclusive, and how should they be amalgamated to a more complete and capable information system? Generally, the user is interested in all the relevant data systematically put together for use in analysis and decisionmaking.

Once a Landsat-based information system has been worked out and proven effective, the results need to be transmitted to a broader segment of the community involved. Symposia need to be conducted for various user groups, e.g., state agencies, developing nations, extractive industries, water management districts and the like. The need for specialized training will follow.

All of these efforts require human resources and funds. Initially, a substantial part of such resources must come from government sources because they have the basic understanding and experience. Quite soon afterward such activities can be undertaken as profitable ventures as the value of the data becomes broadly apparent. The government should then bow out and leave this effort to other organizations such as industry, universities, the U. N., and foreign entities. Some of this non-federal government activity is under way. Right now, however, the federal government must play a major role. The cost of these user-oriented activities are quite small compared with hardware developments and other costs involved with the system.

One other aspect of being responsive to user needs involves the implementation of dedicated systems compared with a multi-purpose system. Because of cost considerations, dedicated systems, i.e., ones specifically tuned to a particular set of requirements, may not evolve immediately. However, such systems are likely to be a future trend. NASA should help other agencies and other organizations who have the need to define and evaluate such dedicated systems. As already stated, in the mature operational phase many organizational elements in industry, as well as agencies of our government and foreign nations, might sponsor, develop and operate such systems. The existing trend of applying better data acquisition systems (in this case, satellites) will always serve to broaden the base of user involvement. This broadening will occur provided the timing is such that the user is able to justify the better system based on such considerations as value versus cost, amortization, depreciation, and obsolescence of his present system.

One other major point involves equipment costs and the need to reduce them. In many cases, the user does not need the most precise and sophisticated equipment, or at least will do without it, if the required investment is too high. Again state governments are a good example of this situation. With limited budgets, they find that the simpler, lower-cost data techniques for information extraction from Landsat are very valuable. Industry should be encouraged to provide low-cost information extraction equipment. Government-provided "seed money" in this area might very well be effective. This part of the Landsat system warrants particular attention because the effort will be enhanced by a diversified approach.

Finally, the existing Landsat systems can be improved to provide better data for uses already validated and to extend uses into new areas. In the satellite the greatest improvement will be obtained from instruments with better spatial resolution. This can be done fairly easily, but going too far in this direction is not desirable because a massive data handling problem could result. In addition to this improvement, better services in terms of more frequent coverage (through use of additional satellites) and more rapid availability of the data once they are acquired are important to many users. The Landsat system involved in the operational validation phase should be uprated in this way.

Issue #6 How can the U. S. avoid undue international sensitivities to a U. S. owned and operated Landsat system?

Landsat is the type of system that can easily acquire data any place in the world and at frequent intervals. Generally, this activity has been looked upon favorably by foreign nations large and small, particularly those that have made use of the data. Sovereignty questions have been raised in a few quarters. In some cases, these have been related to the data acquisition itself, but most are related to the availability of the data to countries other than the U. S. and the one observed. Segregation of data on a country-by-country basis is not very practical. Generally, it is not felt to be particularly desirable by the U. S. and by many international and foreign organizations.

Some proponents of an international Landsat system exist. For example, there are groups proposing that such a system be owned and operated by the United Nations. Such arrangements could exist as a future possibility, but because of the diverse objectives of the many nations involved, i.e., large and small, highly developed and developing, etc., it is unlikely that such an integrated program can be developed successfully at the outset. More likely is the situation that already exists with weather information. The World Meteorological Organization accepts, integrates and distributes data and encourages compatibility of various national data acquisition systems. Even if an international Landsat system were possible, there are questions about how nations would be compensated for their innovative technology, how demands for uprating would be met and how special needs of individual nations would be met. These factors indicate that the present technological leader, the U. S., should proceed with its own system to meet its own operational needs, but that it must act in the context of operating a system that has great international interest and use.

One way to maintain international acceptance and enthusiasm is to continue to provide open public access to Landsat data by all interested parties. This proposed policy not only involves a continuation of the "public domain" policy, but it also involves consideration of the existence and future growth of receiving terminals on foreign soil sponsored by other nations. While this growth has and probably should continue to be encouraged, questions arise about fair return to the U. S. for its investment in the satellite system. This situation is made even more complex by the fact that although a payback is needed, the foreign station charges for data must be compatible with those of the U. S. if such stations are to have a satisfactory economic basis.

Another question is involved with future capability. Worldwide data centrally gathered and processed by the U. S. could be rapidly disseminated at various stages in the processing to almost any place in the world through use of communication satellite links. This situation would obviate the need for foreign receiving and processing stations in their present form. It would also affect the regional character of the current foreign stations: the Canadian station receives most of Canada and much of the U. S. but no more; the Brazilian station receives much of South America but no more; and the Italian station receives much of Europe and North Africa but no more.

The general availability of Landsat data throughout the experimental period of the 1970's should allow stations now in existence to capitalize on their investments. However, the nature of foreign terminals, the types of data available and the associated changes in requirements should be clarified in the very near future in order to avoid ill-considered surprises.

Assuming the desirability of continued heavy international interest and participation in the Landsat program, another important question involves the method of establishing priorities for global data acquisition. It will not be practical to acquire data at every place at every opportunity. Arrangements should be made so that foreign elements can be involved in these issues with appropriate mechanisms to assure that their data needs are being adequately considered and filled. In like manner, concerns may develop over whether foreign elements have an adequate input to future systems planning and implementation in relation to their needs and their ability to accommodate new systems. Similar arrangements need to be made to assure satisfactory U. S. responsiveness. If this is done effectively, foreign nations may very well continue to use the U. S. system rather than develop their own competing system. Currently, there is a dominant dependence on U. S. meteorological satellites.

Another international concern that may develop pertains to activities of American industry--not so much in hardware and systems as in data use. This concern relates to possible commercial exploitation of knowledge obtained over foreign territory. A strong federal role in this area will be needed to maintain proper industrial interfaces and, if needed, regulate industrial activities to minimize such potential concerns.

Issue #7 What assurances are there that the general public will have a reasonably equal opportunity to benefit from this system?

Such public concerns can be blunted by a public domain policy in which all data are made easily available in simple, usable forms at reasonable prices. When necessary, in the public interest, regulations can be established to control activities having real or potential detrimental effects on public relationships.

Much of these data will be used by federal, state and local governments in providing, either directly or indirectly, information of general value to the citizenry. In industrial commercial activities where efficiencies and economies result, studies show that in a competitive environment, benefits will pass on to the consumer either in terms of lower prices or better products and services.

A recognition is needed, however, that with a broadly beneficial capability of this type no completely equitable arrangement is possible because some individuals or groups are better prepared or more able to use the capability than others. For example, some groups can make better use of the telephone or public transportation than others because of their particular situations even though similar services are generally available to all.

Issue #8 Over the long term how can a loss of U. S. technological leadership be avoided?

Without question the United States has been the innovator and the technological leader in the field of remote sensing from space. Historically, in endeavors involving technological innovation the original leadership is frequently lost to people who are more able to accept and take advantage of such innovation. The United States cannot afford to find itself in second or third place in high technology areas because wage scales and other factors provide tremendous advantages to other nations in competitions involving conventional technology. Russia, France and the Netherlands have activities involving the development of satellite systems of the Landsat type. Industrial firms in Canada, Italy and Germany have already produced Landsat-compatible ground systems or equipment of considerable consequence. Other countries such as Japan, Iran and India have activities under way. The European Space Agency has major plans to use their Spacelab in the Space Shuttle time period (the 1980's) to exploit remote sensing, particularly in the relatively unexplored area of microwave sensing instruments. In many cases the Landsat system is of great interest to other countries because they have an inferior conventional information base compared with the United States. Landsat-type data provide an opportunity to move ahead more rapidly.

U. S. technological leadership in this critical field greatly depends on a continued aggressive program of research and development. At this early stage in the technology of remote sensing, R&D must largely be supported by government funding even though significant industrial funding has been provided. Such funding will continue to grow as profit-making opportunities become evident.

Along the same line, the U. S. should maintain its national program. It should support international involvement, but avoid getting bogged down. In particular, the United States should be extremely aggressive in applying this valuable technology by moving rapidly toward an operational system and rapidly developing productive use through familiarization, training, and other support to the using community, as outlined in issue #5. At the same time international use of this system should be encouraged through bilateral, multilateral or U. N. agreements that are responsive to the desires, objectives and needs of these elements. The worst thing that could happen is for the United States to develop this technology and then not reap either the benefits or profits from it.

<u>Issue #9</u> Can the interfaces between the system's segments be better defined in order to avoid unnecessary overlap and duplication of effort?

Interfaces between system segments can be defined in a fairly straightforward manner and be compatible both from an institutional and a functional standpoint. As already stated, the space segment activities end when the data are acquired, collected at a single location and preprocessed to the extent of being complete, precise and usable by the central data handling facility. The space segment responsibility would entail the procurement, assembly and operation of all the system elements required to accomplish these ends. In the case of R&D, the space segment organization should emphasize the space elements, but it should investigate all elements of the Landsat program in order to understand capabilities and limitations of present or future space segment hardware. This understanding is especially important if the organization is going to operate the space segment efficiently.

As previously stated, the centralized data handling segment effort should begin with the receipt of the preprocessed data from the space segment and end with the capability to retrieve master copies from an archive and meet any and all demands for a few basic data products--images, computer-compatible tapes and high-density digital tapes. More sophisticated information extraction and interpretation should be left largely for commercial ventures, except when they are already normal functions of a mission agency. Excluding the R&D for the space segment, the organization responsible for the centralized data handling segment should conduct R&D in all other areas. This work will enable it to understand the capabilities and limitations of its part of the system, present and future, and will generate realistic requirements for the space segment. The magnitude of this task is at least as challenging as the space segment work.

As already suggested, the segment dealing with interpretive services should involve largely commercial ventures. Some inputs from private industry indicate a need for clarification of governmental and industrial roles. It is felt that the space segment and possibly the centralized data handling segment might initially be operated by a government agency until the activity develops to the point where viable commercial ventures are possible. If in any area or at any time an industrial element feels that such a venture is possible, it should not be inhibited in any way, except for considerations of international sensitivities or public interest. Such factors can generally be adequately handled by appropriate regulations.

In the case of remote terminals, any organization, foreign or domestic, should be able on its own volition to install and operate such terminals, providing it pays proper fees for the data acquisition services and is subject to certain requirements and regulations on timing of release and use of data.

Issue #10 Pertinent to present and future Landsat issues, how can a properly integrated decisionmaking process be provided within the federal government?

The Landsat program has a very broad and complex involvement among federal agencies. This, in turn, produces complexity in the budgetary process because of the different channels within the Office of Management and Budget and the different committees and subcommittees within both Houses of Congress.

NASA has been responsible for the concept of Landsat and for the general program effort to date. However, the Department of the Interior, Department of Agriculture, and the Corps of Engineers are major users. All of these organizations have many bureaus, services and agencies, each of which have different uses for the data. In addition, the Department of the Interior is currently responsible for the centralized data handling facility for Landsat and the Department of Agriculture and the Department of Commerce have smaller facilities of this type.

Other significant users are the Department of Commerce (NOAA, Census), the Department of State (Agency for International Development), the Environmental Protection Agency and several of the agencies involved with national security matters.

NASA has taken the initiative by meeting with the agencies and departments mainly involved. The meetings operate at the policy level, being usually attended by agency heads and assistant secretaries. These meetings are supported by a working group of key persons directly responsible for elements of the Landsat program. This activity should go a long way toward consolidating interagency positions on many matters.

The bigger problems appear to rest in the Office of Management and Budget and the Congress. In OMB each agency or department has different examiners, who frequently report to separate divisions. The elements of the Landsat program do not even come together at the assistant director level. If balanced support is not achieved, the whole program suffers. Any one of the many channels involved can produce just such an imbalance.

Several approaches are possible in overcoming this problem. One is to designate a special team of examiners within the OMB to handle the Landsat area and bring their evaluation and recommendation directly to the OMB Director. Another is to have the participating departments and agencies bring an agreed-upon position directly to the OMB Director. The third possibility involves designation of a lead agency. Then all Landsat effort could go through the normal examiner channels of OMB regardless of which agency requires the funding. There are a number of precedents related to the last approach.

Similarly, in Congress the many committees involved produce multiple possibilities for conflicts in program funding and direction. Again, there are ways of alleviating this problem, such as creating a new committee to handle the needs of all agencies involved in this particular area. Probably the best approach would be to designate an existing committee in the House and the Senate in order to accomplish this end. The Senate Committee on Aeronautical and Space Sciences, for example, is well situated to handle this program, having been involved with all of the cognizant agencies in its hearings.

<u>Issue #11</u> Should the Landsat system evolve to a system of individual satellites, each dedicated to a specific purpose, or should it evolve to a consolidated system of multipurpose satellites?

Because satellites in general must operate continuously for a long time in a remote position, they tend to be high-cost items. The fact that the sensing instrumentation aboard the Landsat class of satellite is technologically sophisticated adds to the expense. This situation produces a strong pressure to go to a multipurpose system because fewer satellites are involved. Fortunately, multipurpose Landsat satellites have already demonstrated an outstanding ability to service many disciplines by adequately providing for their data needs. Some relevant areas are agriculture, forest and range inventories, water resource management, water sedimentation evaluation, flood surveys, monitoring of coastal zone process, general land use evaluation, mapping, mineral and oil surveys and many others. Such capabilities will be extended in all these areas and to other areas by the improved capabilities represented by the Thematic Mapper now under development.

In spite of this current trend, satellites dedicated to specific purposes are likely to come into being in ever-increasing numbers. There are a number of reasons for this projected growth. First, the satellites will become cheaper with the advent of the Space Shuttle because of its ability to retrieve satellites for repair and updating. Second, some needs can only be satisfied effectively through use of a dedicated satellite because of special orbit sensing requirements. For these reasons, several satellites are already under development. Third, trends in this direction are expected to increase as payoffs are demonstrated. A dedicated satellite allows each individual enterprise to optimize and control more closely its own data needs. At the same time users who cannot afford or justify a special purpose satellite will find that many of their data needs can be met by sharing the costs of a multipurpose satellite. Thus, it is expected that both types of systems will be in evidence as Landsat operations mature.

In a broad sense, the current Landsat is both a special-purpose and a multipurpose satellite. As already explained, it supports many uses predominantly associated with the sensing of land areas. Meteorological satellites already developed and operational are very complementary to Landsat. That is, in many uses (in agriculture, for example) both meteorological satellite data and Landsat data are needed. Other satellites now under development in the environmental quality area (Nimbus G) and the oceanographic and ocean dynamic areas (Seasat) will have similar complementary relationships with Landsat.

<u>Issue #12</u> Should the worldwide network of remote terminals obtain its data directly from the satellite or should data be routed to it from a central data facility?

This issue has not arisen so far because the delivery of global data to a central location has depended upon the successful operations of tape recorders on board Landsat. Since these units have the poorest reliability of all the Landsat systems, separate terminals receiving data directly from the satellite are needed as backup whenever possible. Another reason for direct access is that the separate station operators can control the details of their own data processing and data priorities. In some cases, they may even outperform the central facility for certain data products. The Canadians do so now for quick-look data.

In the 1980's and beyond, Landsat-type satellites and others will relay their data to a central ground station through the Tracking and Data Relay Satellite System (TDRSS) now under development by NASA. In all probability, this arrangement will be a highly reliable means to accomplish data relay. Hence, separate terminals as a backup will no longer be needed. Further, by relaying data through commercial communications satellites to separate terminals from a centralized facility there will be no significant time lost in transmission. Operators of separate terminals who opt for this approach appear to gain certain advantages. First, some or all of the data processing can be eliminated by having the central facility do it. Second, all Landsat data desired can be obtained in rapid fashion rather than just the data within the receiving limits of a remote terminal (about a thousand-mile radius).

In spite of these advantages, many nations and private entities may choose to continue to obtain the data directly from the satellite. This choice would stem from a desire to assure data availability from the region; and, in some cases, may also be a matter of prestige. In certain instances, an organization may feel that it can compete favorably with the centralized facility in some facet of the data process. Thus, a continuation of both types of separate terminal types is expected. Some would receive data directly from the satellite and some from the central facility, taking advantage of the data-processing capability of the central facility. With TDRSS, there is no advantage to the United States if separate terminals acquire satellite data directly. However, in the interest of international relationships and to encourage broad international and private participation, such terminals should continue to be allowed.

Another point to bear in mind is that more than one central facility could exist. For example, the United Nations could operate such a facility and provide services to its clientele while the United States could operate its facility and provide services to its citizens and whomever else chooses to do it that way. No objections are foreseen to such arrangements.

Issue #13 Are there alternate sources of data acquisition that might be more cost-effective than Landsat?

In some instances, alternate sources of data exist or could be implemented. Aircraft, ground inventories and other satellites are examples. Two main points need to be understood. First, these systems cannot totally replace Landsat or its predecessors in a number of important and valuable activities associated with global or other classes of broad data coverage. Second, once a Landsat is in orbit it can perform many types of data acquisition at very small additional cost. These extra tasks might not be cost-effective systems if they were the only purpose of Landsat. To illustrate, a survey of the Red River flood last year might not have been cost-effective if the only purpose of Landsat were to monitor such floods. However, while Landsat was obtaining wheat surveys, etc., it "saw" this flood and with essentially no additional cost provided extremely valuable information.

Another important consideration is the complementary nature of Landsat and other means of data acquisition. Sometimes quite high resolution information is required--higher than Landsat affords or is envisioned for its successors. For instance, a data requirement might involve a detailed look at traffic patterns in an urban area. It would be logical to fly an airplane for this purpose, but it would be illogical to try to cover the whole globe in this detail. Even if a satellite incorporates very-high-resolution sensors, it is impossible to get the frequence of coverage desired for many uses. If a high-resolution system operated with the Landsat coverage capability, it would produce monumental data handling problems and costs. On the other extreme, meteorological satellites generally have resolutions ten times poorer than Landsat because they need a wider field of view to get coverage every place twice a day.

Landsat is part of a total system involving data obtained from ground surveys, airplane flights and other satellites. Landsat happens to be a key system in that it is close to optimum for global surveys of land surfaces. Therefore, it can serve as an effective integrating element for the other data.

Issue #14 How should data from all sources be integrated into a total global information system?

The need for better information systems is becoming increasingly apparent. Such needs are being expressed with greater intensity both in government and the private sector, including many individuals in the general public. Frequently, needs are expressed worldwide and involve data on a global basis, as in the cases of food supplies, clean water supplies, environmental quality and mineral resources, among others. Landsat, with its synoptic view, frequent global coverage and practical level of data detail, is an excellent foundation for a global information system. What Landsat is and what it does can be readily perceived, and, as such, it serves as an outstanding base for accommodating and integrating other information sources. The following paragraphs will develop these points in more detail.

Information from one source in most cases is made more useful when integrated with information from other sources. In fact, the integrated information is usually much more valuable than the sum of the values of the elements that contribute. Problems usually arise when integration of information is attempted. A few typical problems will be cited. The elements of information were not taken under the same conditions and not enough is known to correct and correlate. The elements of information are not in the same format, and it is not possible to convert from one format to the other. The information was gathered, but it is not possible to find or retrieve it. The information has insufficient detail for adequate decisionmaking. The information is too complex to filter out the needed understanding.

Most of the important problems of today are highly complex. Usually the information is insufficient for good decisionmaking or it is not in an adequate form for determining and justifying a decision. As a result, pressures develop from all sides. Often no decision is made or the decision is rapidly negated.

In assembling information on broad and complex issues, it is necessary to start with a synoptic view of the problem and at a level of detail that is possible to comprehend. This approach produces a number of benefits. It tends to force a common format over the broad area. It establishes what levels of detail are needed for various conditions. It helps define a strategy for obtaining the augmented information. When more detailed information is available at specific points or places, this approach helps extend and apply this information to like conditions throughout the broad area. Review of these features indicates that the synoptic information produces an integrating effect with respect to other sources of information.

Landsat is basically a comprehensive global information source. A single image covers about 10,000 square miles with all areas of the globe covered once every eighteen days with one satellite or once every nine days with two satellites. The data are highly compatible with existing computers, enabling rapid information extraction with considerable detail for this tremendous range of coverage. Indeed, the data rates to be achieved with the Thematic Mapper to be incorporated in a second-generation Landsat are close to the limit of producibility for current data-handling systems.

For many pruposes, Landsat information is augmented by other information. In agriculture, for example, Landsat can locate and classify crop types and determine the acreage devoted to various crops, but it cannot predict the health or prospective yield of the crops. In many cases, this can be inferred from meteorological data. When an abnormal condition is indicated from the weather information, a drought or flooding for instance, Landsat data can very effectively define the limits of the affected region. This example illustrates the interdependence of information where one data source supports the other and vice versa. Similarly, Landsat can detect the sediment plumes produced by outfalls in lakes, rivers and oceans and thereby can determine where best to place gauges to determine the degree of pollution. In mining, Landsat can examine color alterations, geologic faulting and other features around known mines and then isolate other similar areas for ground exploration. This approach is particularly effective in remote and rugged areas.

There are many more illustrations of this type of interaction of Landsat with other data sources. Landsat can play a key integrating role in information-gathering over a broad area. In addition to providing valuable information in its own right, Landsat serves to make information from other sources more meaningful and, therefore, increases the accuracy, effectiveness and economy of the total information-gathering effort. Thus, Landsat forms a logical foundation for an overall global information system.

GENERAL RECOMMENDATIONS

1. Move aggressively toward an operational Landsat system by implementing an operational validation phase and planning for an early operational phase.

2. Assure data availability through provision of a backup system starting with the operational validation phase.

3. Assure adequate frequency of repetitive coverage by having multiple spacecraft functioning in orbit at any given time.

4. Maintain the public domain policy, including general availability of basic data products at reasonable cost.

5. Augment efforts aimed at greater user familiarization with Landsat capabilities and uses.

6. Stimulate industry participation in all facets of the Landsat program and encourage a smooth evolutionary transition from a primarily government activity to a primarily commercial one.

7. Encourage NASA to continue its technical consultation support to equipment-oriented, service-oriented and use-oriented industries.

8. Spur the development of low-cost ground terminals and information extraction equipment.

9. Encourage government funding of an aggressive R&D program in NASA and other agencies.

10. Strongly support federal interagency coordination activities.

11. Encourage NASA to support other agencies in defining their system and data requirements.

12. Encourage foreign and international use of the U. S. Landsat system.

13. Where necessary, regulate industrial activities to avoid stimulating undesirable international or public sensitivities.

14. Initiate planning for the development of a global information system.

EXPERIMENTAL LANDSAT SYSTEM

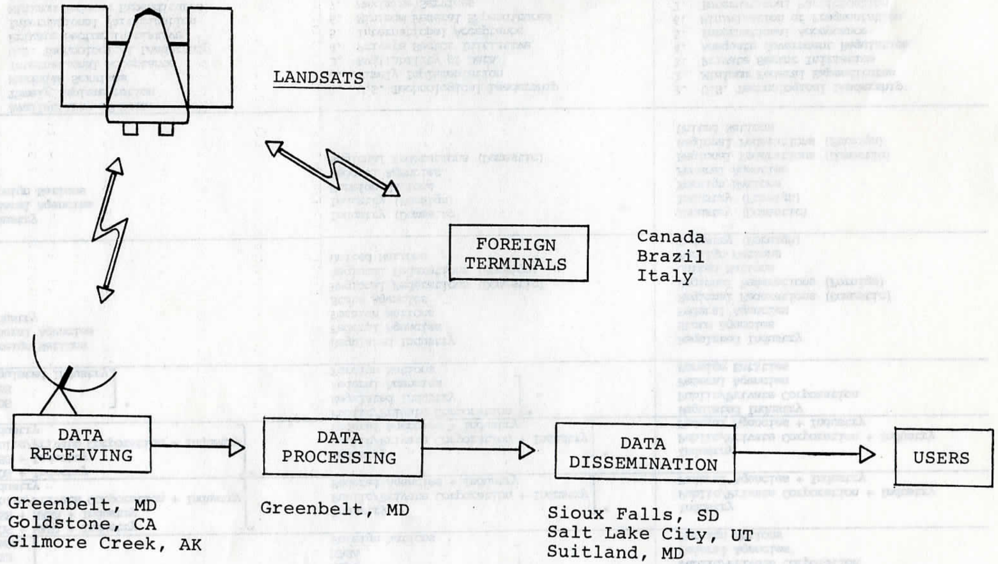

FIGURE 1

TABLE I

MATRIX OF POSSIBLE LANDSAT INSTITUTIONAL ARRANGEMENTS

	1980	1981 — 1984 OPERATIONAL VALIDATION	1986 — 1987 EARLY OPERATIONS	1991 MATURE OPERATIONS
SPACE SEGMENT	R & D	NASA + Industry	NASA + Industry	Industry NASA + Industry
	PROD	NASA + Industry NESS + NASA + Industry COMSAT + Industry *	Public/Private Corporation + Industry NESS + NASA + Industry NASA + Industry *	Industry Public/Private Corporation + Industry Federal Agencies + Industry
	OPS	NASA NESS COMSAT *	Public/Private Corporation NESS NASA Foreign Nations *	Regulated Industry Public/Private Corporation Federal Agencies Foreign Nations
CENTRALIZED DATA HANDLING SEGMENT	R & D	EROS + NASA + Industry NESS + NASA + Industry Public/Private Corporation + Industry Industry *	Industry Public/Private Corporation + Industry Federal Agencies + Industry *	Industry Public/Private Corporation + Industry Federal Agencies + Industry
	PROD	EROS + Industry NESS + Industry Public/Private Corporation + Industry Industry *	Industry Public/Private Corporation + Industry Federal Agencies + Industry *	Industry Public/Private Corporation + Industry Federal Agencies + Industry
	OPS	EROS NESS Regulated Industry *	Public/Private Corporation Regulated Industry Federal Agencies Foreign Nations *	Regulated Industry Public/Private Corporation Federal Agencies Foreign Entities
SPECIAL TERMINALS		Foreign Nations Federal Agencies Industry	Regulated Industry Federal Agencies Foreign Nations State Agencies Regional Federations (Domestic) Regional Federations (Foreign) United Nations	Regulated Industry State Agencies Federal Agencies Regional Federations (Domestic) Regional Federations (Foreign) United Nations Foreign Nations Industry (Foreign)
INTERPRETIVE SERVICES		Industry Federal Agencies Foreign Nations	Industry (Domestic) Industry (Foreign) Foreign Nations Federal Agencies Regional Federations (Domestic)	Industry (Domestic) Industry (Foreign) Foreign Nations Federal Agencies Regional Federations (Domestic) Regional Federations (Foreign) United Nations
EMPHASIS AREAS		1. Availability of Data 2. Timely Implementation 3. Maximize Services 4. International Acceptance 5. U.S. Technological Leadership 6. Private Sector Initiative 7. International Participation 8. Minimum Federal Expenditures 9. Adequate Government Regulation 10. Minimization of Fragmentation	1. U.S. Technological Leadership 2. Timely Implementation 3. Availability of Data 4. Private Sector Initiative 5. International Acceptance 6. Minimum Federal Expenditures 7. Maximize Services 8. Minimization of Fragmentation 9. Adequate Government Regulation 10. International Participation	1. U.S. Technological Leadership 2. Minimum Federal Expenditures 3. Private Sector Initiative 4. Adequate Government Regulation 5. International Acceptance 6. Minimization of Fragmentation 7. International Participation 8. Timely Implementation 9. Availability of Data 10. Maximize Services

*A choice of one is the only practical approach in this phase.

TABLE II

LANDSAT ISSUES

Issue # 1: Should a commitment be made that assures the availability of Landsat-type data in the 1980's?

Issue # 2: Should improvements in the quality of Landsat data and services be initiated at this time?

Issue # 3: Should government ownership and operation of the various Landsat system elements be curtailed?

Issue # 4: How can industry initiatives in Landsat activities be accelerated?

Issue # 5: How can user knowledge of and involvement with Landsat capabilities be accelerated?

Issue # 6: How can the U.S. avoid undue international sensitivities to a U.S. owned and operated Landsat system?

Issue # 7: What assurances are there that the general taxpaying public will have a reasonably equal opportunity to benefit from this system?

Issue # 8: Over the long term how can a loss of U.S. technological leadership be avoided?

Issue # 9: Can the interfaces between the system's segments be better defined in order to avoid unnecessary overlap and duplication of effort?

Issue #10: Pertinent to present and future Landsat issues, how can a properly integrated decision-making process be provided within the federal government?

Issue #11: Should the Landsat system evolve to a system of individual satellites each dedicated to a specific purpose or should it evolve to a consolidated system of multipurpose satellites?

Issue #12: Should the worldwide network of remote terminals obtain their data directly from the satellite or should data be routed to them from a central data facility?

Issue #13: Are there alternate sources of data acquisition that might be more cost effective than Landsat?

Issue #14: How should data from all sources be integrated into a total global information system?