RESPONSIBILITIES OF THE DEPARTMENT OF THE INTERIOR IN MANAGEMENT OF AN OPERATIONAL LANDSAT SYSTEM

by

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U. S. Geological Survey

July 1979

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EXECUTIVE SUMMARY

Earth-oriented satellite remote-sensing programs have been studied by an interagency task force, commissioned by Presidential Directive NSC-42, to determine how they may be integrated into a National system and how the private sector should be involved. Congressional legislation has also been introduced to create an operational Landsat system.

The Department of the Interior's response to these steps has been to consider the position it should take with regard to leadership and operation of an operational Landsat program, under the assumption that the transition from an experimental to an operational program will be made in the mid-1980's.

The Department of the Interior is the logical agency to manage and operate an operational Landsat system because of the broad land and resource management responsibilities, its wide constituency among Federal, State, and local agencies, its relations with resource producers, and its experience with the current Landsat system. The Department has proven its leadership in the Landsat experimental system through its work in defining system performance, technical interfaces with NASA, data dissemination, user training, and applications of Landsat data to resource problems.

The responsibilities that the Department must assume, if it is to manage an operational Landsat program, are:

1. Programmatic considerations

    a. Assume a major role in the basic decisions on how Federal funds for remote sensing will be allocated among Federal agencies.

    b. Provide a high-level Departmental interface with NASA and other Federal agencies to cope with major management and policy issues.

    c. Represent the information requirements of data users in development of satellite sensing and ground data processing systems and ensure that timely, adequate data is available to users.

    d. Study the potential involvement of the private sector in the management and operation of the operational system.

2. Technical considerations

a. Aggregate the information needs of Interior and other users as a basis for satellite sensing systems.

b. Prepare performance specifications for satellite and ground systems.

c. Recommend candidate instruments, spacecraft, and orbits for optimum information gathering.

d. Acquire, process, and distribute data to users.

e. Develop methods and facilities for data analysis, information extraction, and application to resource and land problems.

f. Provide training and assistance to data users.

The report discusses the programmatic and technical responsibilities in some detail, concludes that the Department of the Interior is capable of managing an operational system, and recommends that Interior should aggressively seek the role of lead Federal agency for both the space and ground segments of the operational system.

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I INTRODUCTION

On October 11, 1978, a White House release based on PD/NSC-42 stated:

1) "NASA will chair an interagency task force to examine options for integrating current and future systems into an integrated national system." (Integrated Remote Sensing System Study (IRS^3))

2) "The Defense community, NASA and NOAA, will conduct a review of meteorological satellite programs to determine the degree to which these programs might be consolidated in the 1980's and the extent to which separate programs supporting specialized defense needs should be maintained."

3) "Along with other appropriate agencies, NASA and Commerce will prepare a plan of action on how to encourage private investment and direct participation in civil remote sensing programs." (Private Sector Involvement Study (PSIS))

4) Communications Satellite Service: "The Agency for International and Interior will work with NTIA in translating domestic experience in public service programs into potential programs for lesser-developed countries and the remote territories."

These four points are quoted in full in Appendix A which has been extracted from the White House release.

The White House action, a beginning NASA effort to study an Operational Earth Resources (OER) program, and proposed legislation regarding operational systems all require consideration and decisions regarding the future of remote sensing activities within DOI. Accordingly, this paper discusses the role of remote sensing in DOI as an attempt to prepare for a proper response to any results from these efforts. In particular, it recognizes that the White House policy is very clear in stating that the "US will continue to provide data from the developmental Landsat Program for all classes of users" and that "operational uses of data from the experimental system will continue to be made to public, private and international users."

Such a commitment to continuity requires that ongoing functions not be disrupted, that technological system changes be logically planned/implemented, and that effective management be established by the resolution of organizational and policy type questions.

II BACKGROUND

DOI pioneered with aircraft remote sensing to help with many of its responsibilities such as cartographic mapping, geological studies, water resources and land use inventories. It was among the first to recognize the potential of the early Gemini and Apollo space photography and, consequently, assumed a major role in the concept, design, and implementation of the Landsat remote sensing program. It established and operates the EROS Data Center (EDC) at Sioux Falls, South Dakota, as a major facility for the archiving, processing, reproduction and dissemination of Earth resources remotely sensed data. The Landsat activities have been a cooperative interagency effort by NASA, DOI, DOA, AID, COE, and DOC, with NASA in the major role. NASA has been responsible for the space segment, satellite command and control, data acquisition and data processing. DOI, through EDC, has archived, reproduced, and disseminated the data. It has served as the Landsat interface with the data users and provided training/assistance in data applications. DOA and DOC also functioned in an archiving film reproduction role until September 30, 1978, when EDC assumed this role for the entire user community. Currently, DOA and DOC, along with AID, COE, and others are concentrating on the applications of remote sensing to their operating responsibilities. The Landsat cooperative effort has been successful in demonstrating the utility of space data; however, it has been hindered in developing routine applications because:

1) NASA has never considered Landsat, including Landsat D, other than an experimental program.

2) A system to provide continuity of data after Landsat D (mid-1980's) has not been defined.

3) DOI has maintained that the data are being used operationally and that the data users are not concerned with an "experimental" or "operational" lable. However, many users have not made major commitments to use the data because of a lack of assurance of data continuity and prompt delivery of data applicable to their problems.

4) Interagency efforts to design, implement, and operate a total system are cumbersome, inefficient, and often approach the unworkable because of:

   A) Differences in assigned responsibilities between the agencies; i.e., NASA is chartered to conduct space research and development; whereas, DOI is an operating department with responsibilities specified by law for land management, conservation of resources, mineral and water resource inventory.

B) A failure to recognize that the constraints of assigned (or unassigned) responsibilities create a situation wherein no department or agency has taken the lead in establishing a long-term program that matches the proven capability of remote sensing to the operating needs of the US Government.

C) No common organizational element existed to establish policy, prepare priorities, formulate budgets, define institutional responsibilities, resolve legitimate differences and proceed toward established objective(s) prior to creation of a Policy Review Committee-Space.

D) Budget preparation, approval, authorization, and appropriation cycles in DOI and NASA are separate processes. Budget requirements, in separate agencies, to implement complementary parts of a total system often do not survive through final appropriations, are commonly on a fiscal year (not program) basis, and, in the cases where they do survive, the timing is rarely optimum. This leads to missing vital components of a system or to different parts of a system being delayed to a point that effective system management is impossible.

Consideration of the background must mention that major segments of and the total Landsat/Earth resources program have been studied, reviewed and considered almost constantly over the past seven years. Appendix B is a partial listing of the various studies and reports. The studies required by PD/NSC-42 are the latest in this unending "study" effort. No study, however, has proceeded under the fundamental concepts that:

A) Remote sensing is one of the valuable new tools that can be used to obtain vital information on how to better understand, develop and manage the finite resources of the Earth.

B) In many cases, remote sensing provides resource and environmental information that cannot be acquired routinely by any other method.

C) Provision of basic information is a legitimate and necessary Government responsibility. In this context, remote sensing data are analogous to census statistics, topographic maps, weather forecasts, and cost-of-living projections; all of which are compiled by the Government for the good and welfare of the Nation.

D) Useful information is a major factor in promoting international understanding, increasing cooperation, and in serving to stabilize relations between nations.

Accordingly, this paper is based on the precept that: 1) there are DOI responsibilties established by law which must be met, 2) there are real current and future problems with the Earth's resources, 3) these responsibilities and problems can be met better with remote sensing information, and 4) in some cases, the responsibilities cannot be met without remote sensing information.

III DOI RESPONSIBILITIES

Present DOI responsibilities are grouped into: 1) Energy and Minerals, 2) Fish and Wildlife and Parks, 3) Indian Affairs, 4) Land and Water Resources for the 50 States and Territories.

These responsibilities include off-shore activities and the need for information on the oceans out to the 200-mile limit. Additionally, elements of DOI cooperate with the Department of State (AID) in the lesser-developed countries throughout the world on a variety of resource problems. These total activities result in the need for global sensing. They also result in the need for an unconstrained operational Earth resources program including a National data center to archive, process, reproduce, and distribute remotely sensed data, and to provide the vital training/applications assistance.

IV RECOMMENDATIONS

Based on the above introduction, background and DOI responsibilities and on the discussion that follows, it is recommended that:

A) Legislative authority be sought to assign total responsibility to DOI for furnishing operational Earth resources data to the user community, and for management and operation of both the space and ground segments of the operational system.

B) The assigned responsibility includes a major role for DOI in establishing how the total funds for remote sensing in the Federal budget will be allocated.

C) An organizational element be explicitly defined within DOI to assume the assigned responsibility.

D) The organizational element be the single focus for all Departmental space technology and remote sensing applications requirements.

E) The organization be responsive to Departmentally established budget guidelines and priorities.

F) Some organization (OSTP, OMB, or other) be made responsible for assuring that projects originating external to DOI are carefully reviewed and consistent with the resources available to DOI.

G) NASA continue its research and development role for remote sensing.

H) The single DOI organization be responsible for the NASA interface that will seek to assure that the research and development will support future operational needs.

I) The private sector be encouraged to participate in a total Earth resources program with expanded analytical services, tracking and data relay satellite system (TDRSS) services, data relay services and data collection (from in-situ platforms) services.

J) Private sector management involvement in the space and ground data handling segments of an operational Earth resources program be delayed until the technology has further matured, until a controlling policy can be established, and until private industry is willing to proceed with the total venture without a substantial Government subsidy.

K) The civil Earth resources program remain distinct and separate from military and meteorological programs except for possible convergence on common spacecraft "buses" and on systems like the Global Positioning System (GPS) that appears very useful for orbital position determinations.

V LEGISLATIVE AUTHORITY (POLICY)

As indicated in Sections II and III, NASA is authorized to conduct an experimental Landsat program. USGS, through its EROS Program, has established and operates the EDC, has done research on the uses of Landsat data, and has trained scientists throughout the world on data applications techniques.

However, there is no legislation that assigns single Governmental lead responsibility for space derived operational Earth resources data. Interagency cooperation has not been satisfactory during the experimental phase(s) and will not work in an operational phase because of the previously cited reasons. An operational program vital to understanding and managing the Earth's resources must not be hampered by the same problem(s). However, an operational program must have continuing research and development, of the type provided by NASA's efforts. Failure to establish a single lead agency total responsibility for an operational program assures that the information will not be available as needed and the United States will be at a disadvantage and possibly forced to obtain data from the emerging Japanese and European programs. DOI should no longer assume an undefined responsibility or continue with a role that is based on many different perceptions as to scope, resource requirements, and appropriate functions.

VI FEDERAL BUDGET ALLOCATION FOR REMOTE SENSING

During the next several years, it is expected that the United States will spend about 450 million dollars per year on remote sensing. It is understood that this amount includes:

1) The civil and military meteorology programs, including GOES;

2) The Landsat program;

3) A planned ocean program (NOSS); and

4) Proposed new programs like:

   A) The Large Aperture Multifrequency Microwave Radiometer (LAMMR);

   B) Repeat shuttle sorties for the Shuttle Imaging Radar (SIR);

   C) A large format camera system on a shuttle sortie; and

   D) The development of an operational Landsat D follow-on to include a High Resolution Pointable Imager (HRPI).

It cannot be proven that the estimated total available funds are adequate or inadequate for the ongoing and planned programs. Therefore, the total must be considered as a given. There is no factual basis for a contention that certain programs are too expensive and are, therefore, candidates to be trimmed or canceled. There is a solid basis for the contention that the balance between expenditures on space hardware, ground systems, and data application efforts be reexamined.

There is also a sound basis for DOI and other operating departments to insist that their operating responsibilities require a continuing, dependable and stable remote sensing program, supported by ongoing research and development consistent with their operating responsibilities. The past research and development methods that centered around the creation of new instruments, new spacecraft and new missions have resulted in probably well over 50% of the funds being spent on space hardware. More significantly, it has resulted in an instability with the ground systems and application efforts. These efforts are characterized by a requirement to change and stay compatible with "new" or different space hardware and by a reluctance to invest in ground processing and applications equipment. The elimination of such instabilities and reluctance to invest requires long-term planning to:

1) Establish realistic remote sensing requirements.

2) Synthesize the requirements into an operational system consisting of space and ground segments.

3) Conduct research on system improvements; and

4) Phase the improvements into the system without major expensive upgrades and loss of capability.

VII ORGANIZATIONAL ELEMENT

DOI responsibilities obviously cannot be satisfied with Landsat acquired remote sensing data alone. The Department requires high resolution metric quality photography, HCMM-type thermal data, Seasat-type microwave data, Magsat-type magnetic data and possibly "Gravsat" gravity data. The Department also will have increasing space communications, space data relay, and data collection (from in-situ sensors) requirements. All these areas of activity require some degree of "space expertise" and experience with user applications such as that gained from operation of the EROS Program over the past decade. Interfaces with NASA and other agencies can be managed better by a single organization containing the expertise and experience. Such an organization must evaluate data/information requirements, attempt to find an optimum match between requirements and sensors/spacecraft, do cost estimating, prepare budgets, and manage the program's implementation. The organization must include the capacity/capability to make technical and cost tradeoffs, establish supporting research and development, implement operating programs, operate a National data center, stay abreast of the state of the art in the science and technology of remote sensing.

VIII DEPARTMENTAL BUDGET, GUIDELINES, AND PROCEDURES

The concept of a single organization to integrate and implement all Department wide space activities creates a need for a Departmental program budget line item. Such a requirement, if included within any bureau's budget, is constrained by that bureau's guidelines and priorities. In the past, this constraint has resulted in EROS, as an organization, being designated and responsible for a Departmental program, but limited by the budget and personnel ceiling of the USGS budget. It is envisioned that resources to implement a specific remote sensing requirement (project) should remain a budget requirement of the bureau or organization originating the project. The single organization and recurring Departmental budget line item concept is analogous to a Departmental space applications program office with generalized responsibilities to conduct studies, provide integration of requirements, manage external interagency interfaces and operate a National data center. All of these are to be done with the objective of implementing specific projects required and funded by any element of the Department.

Such a Departmental program office with its own budget line item to implement projects funded by a bureau's line item appears to provide the necessary Departmental insight and control for any DOI projects. However, if the program office is responsible for implementing remote sensing Earth resources projects that originate outside DOI, then some additional review and control must be provided. Senate Bill S657, that was considered during the spring/summer of 1977, proposed this interdepartmental overseeing function within OSTP. Other suggestions are no doubt feasible and workable. The problem should not be ignored because DOI cannot be responsible for implementing non-DOI programs without: 1) understanding the external requirement, 2) establishing a low risk situation for the resources required to implement the project, and 3) receiving guidelines, policy and priorities for conflicts between DOI and non-DOI projects. In addition to this Departmental concern about being swamped by projects from outside the Department, it should be expected that the other departments (DOA, DOC, AID, etc.) would be concerned that their projects would suffer from DOI's internal priorities. It should be the function of any interdepartmental group to strive for the proper balance between these conflicts when they arise. Inherent in this problem is the concept that DOI/EDC will continue to service the public (nonfederal government user). Gathering requirements from other departments, establishing feasibiity and system requirements, estimating resources required to implement and implementing the project are very similar to the functions envisioned for the single program office functioning for DOI. The difference being that the resolution of problems and the resultant consequences, in one case, are confined to DOI; whereas, in the case of external requirements that result in conflicts, the problem(s) cannot be kept confined in DOI. If an interdepartmental review and control function is established and made effective, the similarity of efforts for DOI vis-a-vis the non-DOI efforts suggests that the single DOI program office should satisfy both the Departmental and nondepartmental project requirements.

IX CURRENT ACTIVITIES

There are established routine remote sensing operations within the DOI that should not change in response to the recommendation for a new organization. To attempt to make these established routine operations a responsibility of the proposed single organization would create confusion, cause the new organizational element to be unnecessarily large, and generally lead to a loss of efficiency in satisfying individual bureau needs.

X APPROACH TO REMOTE SENSING

Sections V through VIII establish the need for a Departmental action on a remote sensing program and recommends an organizational concept for implementing it. Sections XI through XVI below discuss various system factors that the organization would consider. The discussion is structured by considering, in sequence, the following system factors:

A) Information needs;

B) Sensors to acquire the data (information);

C) Orbits from which the information will be gathered;

D) Spacecraft considerations;

E) Data acquisition; and

F) Ground data handling.

XI INFORMATION NEEDED

Throughout the Landsat program, DOI has repeatedly responded to the question, "What are your requirements?" Many surveys have been conducted to find the "real" user requirements. Nearly all these efforts have intermingled system capabilities and limitations with information requirements. Such pragmatic responses have served to "rubber stamp" or refute system concepts that generally were establised prior to any in-depth analysis of the requirements. Accordingly, the EROS Program, after going through these "requirements" exercises has decided to try and establish a structure for remote sensing requirements. Hopefully, the structure, now developing, will be useful throughout the Department, will provide insight necessary for planning and budgeting, and serve as a requirements model for other departments. In concept, at least, the structure should provide accuracy and flexibility, it should allow management insight into the requirements of a bureau, and provide a sound base for planning a remote sensing program. After the structure is established and tested with information requirements entries, a Departmentwide review will be required to:

1) Validate the requirements;

2) Eliminate duplication; and

3) Consider merging of similar requirements.

Such a requirements data base should be very valuable in establishing:

1) What is being accomplished;

2) What may be possible in the near-term; and

3) An optimum set of requirements for use in establishing program plans including the required research.

At present, requirements for information known to exist in data banks, such as those at DMA, NCIC, NOAA, and DOA will not be included in this new DOI requirements structure. It is assumed that these data banks will continue to furnish their specialized data/information, essentially without change, and that some future systems engineering effort will be directed toward making data from them available in a "normalized" format to ease the data analysis task, especially in those cases that require merging of disparate data sets.

XII SENSORS

Sensors are required to provide information on radiance and reflectance from features of the Earth. Both radiometric and geometric properties of the features are of prime importance. Analysis of the features generally is by photogrammetric photo interpretive and digital comparison techniques. Digital merging techniques are further discussed in the ground data handling section of this report. Such merging techniques will significantly enhance the usefulness of the separate types of data.

A VISIBLE AND NEAR-IR

1) PHOTOGRAPHIC

High resolution, metric quality photographs are essential to the map generation and map revision responsibilities of the USGS at scales of 1:100,000 and larger. Information about the relief features requires stereographic images that can be obtained from something like the forward-nadir-aft configuration of Multiple Liner Arrays (MLA) proposed for "Stereosat" and other programs.

2) ELECTRO-OPTICAL SCANNERS

Multispectral data similar to that from the Landsat MSS can be obtained by a mechanical scanner such as the Landsat D TM or by the multispectral MLA of solid state detectors. The TM is an adaptation of the mechanical scanning arrangement of the Landsat 1, 2, and 3 MSS. Its specified 30-meter IFOV with a 185km scan probably is approaching a limiting plateau for mechanical scanners. IFOV's of less than 20-meters appear feasible with the MLA's. However, the performance of the MLA's with low contrast target and their limited sensitivity in the near-IR portion of the spectrum requires some additional consideration. Additionally, the calibration of several thousand individual detectors for a multispectral MLA instrument appears to represent a significant data processing requirement.

B SOLAR INFRARED AND THERMAL-IR

Data in the infrared spectral regions are being collected by HCMM. The sensor is a two-channel (.8-1.1 and 10.5-12.5 micrometer) radiometer. To date, there has not been enough analysis of the HCMM data to establish the suitability of these channels versus additional or different channels. As this analysis effort proceeds, concepts for an improved instrument will emerge. Feasible applications of the data in the search for geothermal sources, rock discrimination and thermal mapping will also emerge. A system that includes the capability to gather, process and furnish this type data is a DOI requirement. The requirement probably will best be met with a thermal-IR sensor on a separate free-flying spacecraft in a pre-dawn and mid-day data acquisition orbit.

C MICROWAVE

The off-shore responsibilities of DOI include a need for the use of Synthetic Aperture Radar (SAR), Scanning Multifrequency Microwave Radiometer (SMMR) and scatterometer data similar to that which was taken by Seasat. Scatterometer and SMMR data are planned to be taken by NOSS, if the program is approved. SAR is not currently planned to be included on NOSS; therefore, the DOI requirement may be reduced to a need for SAR data for off-shore regions and over selected land masses. Further discussion of this omission versus the need and costs for SAR data will be required.

D MAGNETIC FIELDS

The magnetometer measurements such as will be made by Magsat are needed for use in models of the magnetic fields and for updating magnetic charts. The models are used to refine localized magnetic field strength measurements. The use of localized magnetic field measurements digitally merged with the Landsat visible and near-IR data appears to provide the exploration geologist with a valuable analysis technique. While direct merging of the Magsat and Landsat data is not yet planned, it should be considered; merging data, refined by the magnetic field models, is planned.

E GRAVITY

Gravity measurements to continue the improvements in defining the geoid are universally required. Such measurements, again, do not have the granularity and sensitivity for direct merging with Landsat data as a geological analysis technique. Accordingly, DOI should support the "Gravsat" development efforts as well as to continue to obtain localized gravity measurements by existing methods.

XIII ORBITS

Under the reasonable assumption that sensor state of the art precludes gathering the required information at the specified resolutions from geosynchronous altitudes, the Earth resources information generally should be from polar sun synchronous orbits whose height ranges from 700-925km. Landsat 1, 2, and 3 have operated from a 919km sun synchronous orbit at 99° inclination with a descending node crossing of 9:30am local time. Because of shuttle compatibility constraints, Landsat D is planned for a 716km orbit at 98.2° inclination and a 9:30am Equator crossing. Future orbital changes such as these should be avoided because of the need for different reference systems, different archive data bases and the concomitant difficulty in merging historical data with current data.

The 700-900km family of orbits allows sensors with a total field of view of 10°-11° to cover a swath on the face of the Earth of about 185km wide. Data swaths of this size are manageable by ADP equipments with reasonable memories, and these size swaths do not present serious rectification requirements for the resulting photographic products. Smaller fields of view from higher orbits could alleviate the rectification problems but make the sensor design problems more difficult in terms of sensitivity.

The Landsat 1 orbit gave repeat coverage for any area on the Earth's surface every 18 days. Adding Landsat 2 reduced this to 9 days. Optimum orbital phasing adequate command/control and data acquisition capacity could have lowered this frequency to 6 days for a system of three satellites (Landsat 1, 2, and 3).

Such orbital coverage fundamentals must be kept firmly in mind when specifying data requirements at specific intervals. Because of something like a 50% cloud cover probability, visible and near-IR data required on an 18-day cycle has to be interpreted as a need for two satellites. Three satellites probably will average cloud-free data on something like a 12-day cycle. Obviously, a data requirement with a specified interval of, say, 3 to 5 days becomes impractical from the 700-900km family of orbits.

Such facts must be considered with requirements that specify a 24-48-72-hour data processing/dissemination delivery cycle after data acquisition. It is believed that the ground processing/dissemination system should be sized with some excess minimum pipeline capacity to assure that the data from one acquisition cycle are delivered prior to data being gathered on the next cycle; i.e., data acquired every 18 days should be delivered in about 15 days, data acquired every 9 days in 7 days, etc. It should also be designed with some quick-reaction capability/capacity to provide critical data within some reasonable (24-72) hour turnaround. There are (and will be) cases when "good" data are acquired and will be used if the processing/dissemination system is designed to accommodate a small amount of critical data on a "quick turnaround" basis. Some examples are crop yield assessments, flood and tornado disasters and ice surveillance. Also, there are situations where a user needs the most current "good data" although orbital phasing and/or clouds may mean that the data are 18 to 36 days old. This approach avoids a backlog for a pipeline system that doesn't have the capacity to clear itself of one acquisition cycle prior to the start of the next cycle. With the quick-reaction capability, such a system could react to any true emergency and to the critical turnaround requirements. However, a pipeline system to process and deliver all data in 24 to 48 hours that may be 6, 9, or even 18 days old does not seem logical or economical.

Generally, the 9:30am (local time) Equator crossings for the satellites taking visible and solar-IR data seems to be an acceptable compromise between the photo interpreter's need for shadows in the images and the sensor designer's radiometric sensitivity requirements. The thermal IR data, however, should be collected from an orbit designed for maximum coverage of areas of interest when they are near thermal equilibrium (02:30am local solar time).

XIV SPACECRAFT

Several attempts have been made to establish a universal spacecraft bus (one that with little or no modification could carry and service a variety of sensors into a variety of orbits). Such attempts have had mixed success because it is impossible to build one spacecraft to do everything. This mixed degree of success has also resulted from the dynamic changes in sensors, launch vehicles and in the quantity and types of data being handled.

In general, a spacecraft provides for the sensors and its own subsystems (subassemblies):

1) A mechanical structure;

2) An electrical power supply;

3) A thermal control subsystem;

4) A subsystem to accept ground commands;

5) A tracking subsystem for orbital position determination;

6) An attitude control subsystem;

7) Telemetry subsystems to transmit sensor data and spacecraft status/"health";

8) Antennas to receive commands and transmit telemetry;

9) Usually an orbit adjust capability;

10) Electrical/electronic integration equipment; and

11) Provisions for interfacing with the launch vehicle.

At present, spacecraft technology has matured to a point that a "universal bus family" concept should be reconsidered. A small family of "buses" for a group of applications probably is feasible and should significantly reduce the costs of the space segment of a program. A tentative list for a family of spacecraft buses is:

1) Earth-looking polar orbiter for missions like ITOS, DMSP, Landsat, NOSS, and Stereosat;

2) Polar orbiter with small specialized payloads; i.e., Magsat, HCMM, GEOS, and Gravsat.

3) Synchronous satellites such as GOES and TDRSS-type.

Specialized requirements no doubt will prevent the use of a standard "bus", in some few cases. In such cases there will be no choice except to pay the design and implementation costs to meet a unique requirement. However, the convergence on three classes of satellites which can be designed and produced in quantity for the classes above is an integrated concept that should be considered because of possible inherent savings. Such spacecraft would be shuttle compatible if the contention that shuttle is the feasible and economical means for launching, retrieving, and refurbishing application spacecraft proves valid.

The multi-modular spacecraft (MMS) effort at NASA/GSFC is not completely understood and as of now is not flight proven. However, the effort could very well be a valuable pilot effort for the type of convergence on a family of "buses" as suggested above.

Convergence on a TDRSS-type capability for commanding the application spacecraft and as a means for collecting the sensor and telemetry data is another integrated concept that should be factored into a National remote sensing system. A TDRSS spacecraft bus might also be suitable for the GOES spacecraft requirements. Additionally, convergence on the DOD Global Positioning System (GPS) as the method for determining orbital position and precise time should be a planned part of any integrated remote sensing system.

Apparently the United States is committed to a position that contains no choices except to use shuttle for spacecraft launches and TDRSS for data acqusition. However, the costs for a shuttle launch and the availability of a TDRSS-type service do not appear, at this time, to be firm commitments. The launch of a Landsat or NOSS class spacecraft may require the full capabiity of shuttle and result in a launch cost equal to the costs for a dedicated shuttle mission. A NASA-operated TDRSS will be used for data acqusiiton from several experimental spacecraft and for data from the manned shuttle missions. Since the handover and setup procedures will be time consuming and there are only two single access channels provided by TDRSS, there probably will be conflicting priorities on TDRSS single access channels which will result in the service not always being available to operational spacecraft.

XV DATA ACQUISITION

Landsat 1, 2, and 3 data have been collected at facilities in Fairbanks, Alaska, Greenbelt, Maryland, and Goldstone, California. Data taken from areas of the world outside the real-time coverage of these three facilities have been stored on an on-board tape recorder and subsequently dumped at one of the three facilities. Additionally, data have been directly transmitted to foreign GDA facilities in Canada, Brazil, Iran, Sweden, Japan, and Italy. Similar facilities are in the process of becoming operational in Australia, India, and Argentina.

For Landsat D, the TM and MSS data now collected by the three U.S. sites will be collected by TDRSS. Reception by the foreign stations for MSS data will continue over an S-band telemetry link. The foreign GDA stations will require modifications to receive TM data over a Landsat D direct broadcast X-band link. As indicated earlier, Earth resources global data acquisition requirements can be satisfied by a TDRSS-type capability. In concept, such a capability is a proper replacement to be phased in for the distributed U.S. network of GDA stations. In addition to cost savings, TDRSS should eliminate the requirement for on-board data storage tape recorders. However, such an elimination probably is not feasible if "operational" spacecraft are forced to rely on the single NASA-operated TDRSS (because of the conflicts in its availability such as the cases where manned space flight operations require emergency procedures and the conflicts resulting from handover and setup required for the experimental spacecraft). Reverting to on-board tape records to eliminate such conflicts should be avoided. A dedicated TDRSS-type data acquisition system is considered a feature suitable for practically all elements of a National operational remote sensing program.

XVI GROUND DATA HANDLING

A COMMAND AND CONTROL

Ground commands are radiated to a spacecraft to:

1) Operate the spacecraft to keep it "healthy" and functional; and

2) Operate the sensors to satisfy the data requirements.

Technically, a system to send these commands via TDRSS is a single system. However, the two purposes for commanding are separate considerations. Commands to operate the orbit adjust subsystem, to change the charge rate for batteries or to adjust thermal control require different expertise, different philosophies, different priorities and more stringent monitoring than does commanding to operate the sensors.

When the health/status factors are satisfied, sensor operation is established by the urgency for data, cloud cover probabilities, the existence of previous takes that were "good" and on user data needs. Such data needs are best known to the organization with a responsibility to the dater users. Therefore, DOI envisions a system with operations responding to the spacecraft health as a first priority and secondly responsive to data needs and priorities of the operational data users.

It is believed that a single integrated facility could command and control all satellites in a total civil remote sensing program. Such a facility could also determine status and health of the several spacecraft; however, any such "National" facility must be responsive to distinct operational data acquisition requirements that can only be established by the organization serving and responsible to the Earth resources data users, meteorological data users and ocean data users. A single integrated command/control and monitoring facility to handle both civil and military requirements probably would not be fully responsive to operational Earth resources requirements because of the military priorities and security requirements.

B ORBIT/ATTITUDE DETERMINATION

The position of an Earth feature observed by a satellite sensor is determined by using the satellite's orbital position (along track, cross track and height) and by use of the satellite's attitude (pitch, roll, and yaw). On Landsat 1, 2, and 3, orbital position was derived by range and range rate tracking from the NASA GDA stations. Satellite attitude was derived from the spacecraft housekeeping telemetry. These two parameters then were combined with ground control points (GCP) information to compute the required geometric corrections.

For Landsat D, tracking will be via TDRSS augmented by GPS. This method should provide very precise orbital position information and timing which when correlated with spacecraft attitude (that also is expected to be more precise because of the stellar reference provisions of the MMS) should result in a significant improvement in geometric accuracy over that achieved by Landsat 1 through 3.

These Landsat D improvements in orbit position and spacecraft attitude will not eliminate the need for GCP correlation to precisely relate the data to the spherical surface of the Earth. Also, they will not eliminate the geometric correction process (precisely relating the data to the figure of the Earth) which is one of the major operations in data preprocessing.

C SENSOR DATA PREPROCESSING

The sensor data (raw data), as recorded at a ground terminal, are not usable by any user other than possibly some user with significant resources and expertise. The first step in making the data useful is generally called preprocessing.

Preprocessing applies the radiometric calibrations that characterize the detectors of a particular sensor and computes the geometric calibrations. The radiometric corrections are dependent on sensor detector characteristics (gain, offset, linearity) and on scene derived parameters such as brightness and contrast. Geometric corrections depend on:

1) Orbital position;

2) Spacecraft attitude:

3) Sensor/data multiplexer design factors;

4) Ground control point correlation; and

5) Desired map projection for the data.

These five factors define a new picture element (pixel) location and are used in a geometric correction algorithm which interpolates (resamples) from measured and calibrated pixel values to most probably pixel values for the new pixel locations. Three resampling algorithms (nearest neighbor, bilinear interpolation and cubic convolution) are most generally used in the interpolation process. The output of the preprocessing operation is in a different (tape) format from the raw (ground station) data tape and is used as input to the subsequent processing operations.

In 1973, a never-published Federal plan recommended that the output product from the data preprocessing operation (high-density tapes (HDT)) be considered the data archive product. DOI continues to believe that recommendation. As implied, preprocessing to insert calibration, compute the geometric corrections, and reformat the "raw" data is a highly specialized function, requires considerable resources and, in general, is an operation that should be done by a single organization, be done only once and as a service to all data users. Archiving the preprocessed product allows the retention of all options for the subsequent processing and dissemination operations. The Landsat D ground data handling plan doesn't implement this concept. In fact, it reverts from the Landsat 3 digital GSFC to EDC interface to the film interface proven to be inefficient for Landsat 1.

D SENSOR DATA PROCESSING

Data processing is a value added operation that produces a useful product (a product from which information may readily be derived). Except for photographic data, the data are digital and processable in state-of-the-art equipment. The cost for such equipment has and continues to drop at a significant rate. It is foreseeable in the near future as memory costs continue to shrink that it will be possible to keep significant quantities of Earth resources data "on-line." Today, the preprocessed data can be taken out of the archives, passed through the processing cycle and delivered by a communications satellite within a small fraction of the time that was required to mail tapes and photographs, as was done in the early Landsat era.

Processing is the operation on the preprocessed data necessary to apply the resampling algorithm and to convert the preprocessed digital tapes into image products and computer compatible tapes (CCTs). Data processing should be responsive to data user options that are not availalbe if the fully processed product is archived. Users generally prefer to specify a need for:

1) CCT's or photographic images;

2) Different map projections for the data;

3) Different data resampling algorithms; and

4) Enhancements such as haze removal, contrast stretch and edge (high frequency) enhancements.

A system to preserve these options, respond to the user needs and to create products that can be merged with other data types has been and remains the DOI data processing concept. It appears to meet the DOI responsibilities and its perception of public information requirements. It is the concept which is consistent with the philosophies and objectives that have been established in the EDC efforts to create a truly useful National data center.

E DATA DISSEMINATION

Section XIII discusses the lack of logic in a requirement for data within 24 or 48 hours, except in specific cases, from a satellite system that covers a specific point on the Earth once in 18 days. A similar caution is applicable for data dissemination. A product useful in making a map or studying a geological feature probably does not represent any real urgency for dissemination so long as the delivery time is within reason. Data used in automated change detection studies and in critical classification studies, i.e., crop assessment, rangeland analysis and disaster assessments, require urgent handling via communication satellites or other high-speed digital data links. Therefore, conceptually, data dissemination should be structured to respond to a user's data needs and objectives. Such needs and objectives will not justify an "instant" dissemination capability for any and all data to any and all data users. In many cases, they can be satisfied by mail delivery; in other cases, on-line memory linked to a communications satellite will be necessary. Equally important to speed of delivery is the requirement to furnish a specific (edited) set of data for use on a given problem involving a known area as against supplying unedited sets that contain unneeded or unwanted data.

F DATA MERGING

Techniques have been developed and demonstrated that merge Landsat data with SAR data, cartographic data, meteorological data and magnetic data. Merging with other types of data is being explored. The merging efforts have been extremely valuable in demonstrating the increased information that can be obtained from merged data as against separate data sets. The effort is constrained and made more troublesome because the various types of data usually are at different scales, with different orientations, on different map projections and with varying IFOV's (resolution cell size). There is no doubt that many problems can be analyzed more effectively when all the applicable data are available in a common format and subsequently merged. Any effort toward a common georeference system and format should not attempt to convert the many data bases to a common format and reference system. Instead, such effort should concentrate on: 1) extracting only the needed data from the various data centers, and 2) on conversion techniques that will convert the disparate data sets to a "normalized" format suitable for the analysis effort.

XVII DATA ANALYSIS

The EROS Program at EDC has not and does not intend to perform data analysis for the public. It has maintained, except for analysis required by internal DOI projects, that data analysis should be performed by industry. In performing data analysis for the public, industry can perform a significant role in getting the technology better understood, in getting the capital equipment in place for meaningful data uses, and in demonstrating that remote sensing information is vital to better resource management.

XVIII PRIVATE SECTOR INVOLVEMENT

PD-42 required a study on "how to encourage private investment and direct participation" in civil remote sensing. Appendix C summarizes the inputs that the EROS Program made to the study. The summary states that the most meaningful involvement for the private sector, now and in the near future, is in providing analytical services. It attempts to support this conclusion and goes farther to show there are real fundamental (policy and cost) problems with private sector involvement in the space segment. It suggests a strawman that has the private sector responsible for the TDRSS and communications (data relay) requirements. Other inputs to the private sector involvement study seem to suggest that the private sector should have full responsibility for remote sensing with little or no Government involvement. It is significant that such inputs do not contain an unqualified offer to attempt the venture as a pure commerical undertaking and that there is no suggestion of the consequences of not having the information obtainable from an operational Earth resources program. There is no disagreement that increasing the role for the private sector is not a desirable objective. There may be no disagreement with a goal to eventually allow the private sector to assume full responsibility much as has been done with the "Intelsats" and "Domsats." However, a near-term involvement of the private sector, in roles other than the obvious (TDRSS-type service, data relay service, analytical service, engineering, and manufacturing service and support contractor service), probably will establish an unworkable policy from which there is essentially no recovery.

XIX DATA COLLECTION SYSTEM(S) (DCS)

The information requirements and system concepts, discussed herein, have not included the requirement for collecting data from in-situ sensors like stream gauges, snow pack monitors, geophysical instruments, etc. Such a data collection system is flying successfully on both Landsat (low polar orbit) and on GOES (geosychronous orbit). There is little doubt that the GOES-type capability is preferrable because it "sees" the platform in one hemisphere on a full time basis. Comsat General has demonstrated a similar capability through one of their communications satellites. However, there doesn't appear to be any aggressive effort for industry to implement and provide a DCS service. Such an effort would appear logical because the Government has demonstrated the technology, the system is simple, inexpensive and believed to have tens, maybe even hundreds of thousands, of applications throughout the world.

XX INTEGRATED REMOTE SENSING SYSTEM STUDY (IRS^3)

Landsat has shown the many problems with interagency cooperation and it generally had no interfaces with DOD. Therefore, expanded major cooperation as suggested by the IRS^3 effort (except possibly in the case of efforts between NOAA and DOD with ITOS/DMSP and NOSS) simply does not appear feasible. The military priority and classification requirements should not be constrained by civil requirements and vice versa. Tasking of military systems to fill a requirement, on a non-interfering basis is feasible. Reverting to anything less than the "open skies" and "unconstrained global data" policies that have prevailed on Landsat 1, 2, and 3 is a policy reversal that would be expected to disrupt much of the international cooperation and stability that the program has established.

Such international cooperation and stability must not be overlooked. At a recent (May 15-17, 1979) Landsat Ground Station Operations Working Group (LGSOWG) meeting, it was established that, excluding the United States and the station in Iran, there are seven foreign ground stations in operation and three more expected to go into operation in 1979. At the same meeting the international operators displayed considerable concern about the additional investment required to make their facilities Landsat D compatible, about some assurance of program continuity and about long-term planning in general.