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A SURVEY OF USERS OF EARTH RESOURCES REMOTE SENSING DATA

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ABSTRACT

Uncertainties exist as to the extent that LANDSAT and related remote sensing data are currently being utilized. This paper summarizes the results of a NASA supported Battelle survey[1] to obtain user views on the nature and value of LANDSAT data use, on current LANDSAT capabilities, and on ways to improve data use. Questionnaire and interview responses from over 1000 private and public sector users are analyzed and discussed. Survey results should help both NASA and data users develop even more beneficial satellite data applications programs.

1. INTRODUCTION

In response to a request by the Space Applications Board of the Assembly of Engineering (National Research Council of the Academy of Sciences), the Director of NASA User Affairs - Office of Applications funded Battelle's Columbus Laboratories to undertake a survey to clarify and document the application and effectiveness of the use of Earth resources survey (ERS) data by the user community.

The scope of the study was limited in "data used" to only high-altitude aircraft (>60,000 ft: RB 57 and U-2 type aircraft) and satellite (primarily LANDSAT) data; but, in terms of "data user", the scope was to be comprehensive and include all data user communities (i.e., industry, government, educational, and non-U.S. or foreign users). The study was not a market survey to identify new markets but rather a user survey to determine current ERS data use/user status and recommendations for strengthening use.

2. SURVEY METHODOLOGY

The Earth resources data use survey basically involved a two-phased research procedure, see Figure 1. The first phase focused on identifying, obtaining, and reviewing information from such direct sources as (1) the three ERS data centers (EROS Data Center, Souix Falls, South Dakota; USDA Data Center in Salt Lake City, Utah; and, the NOAA Satellite Data Services Branch in Suitland, Maryland),(2) structured and unstructured personal and telephone interviews. (3) tailored and comprehensive questionnaire surveys and (4) selected ERS user presentations/publications. The second phase of the survey involved the aggregation and analysis of the information and data according to the following user groups: (1) industrial users, (2) state, regional (substate) and local government users, (3) federal government users, (4) academic/educational users, and (5) non-U.S./foreign users. Within each user group an effort was made to determine who are the current users, how they are using the ERS data, what is the current significance of their ERS data use, and lastly, how can ERS data use be strengthened. An ERS data use summary and outlook assessment for each user community as well as for the total study were prepared using all direct and indirect information sources. This paper only summarizes the survey data base and some of the major survey findings. The detailed results are contained in the final research report available through NTIS.[1]

3. SURVEYS CONDUCTED

During this study three separate, but structurally related, surveys were conducted: (1) Houston ERS Symposium survey, (2) user interviews, and (3) mail survey. Figure 2 provides an overview of the statistics for all surveys conducted by user group. With the exception of

non-U.S. data users, a fairly uniform distribution of responses within each user category resulted from the total 1161 users contacted.

3.1 Houston ERS Symposium Survey (All Participants)

Because of the coincidence of the timing of this study with the first comprehensive symposium on the practical application of Earth resources survey data (held by NASA in Houston, Texas in June 1975), it was considered opportune to conduct a questionnaire survey of all conference attendees. Hence, a simple one-page (both sides), primarily multiple-choice questionnaire, developed in concert with NASA, the Space Applications Board, and the Office of Management and Budget, was included in the ERS Symposium packet distributed to all participants. Of the 1337 registered participants, 373 (or ~ 28 percent) completed and returned the questionnaires. The user community distribution, for those questionnaires returned, is shown in Figure 2.

3.2 User Interviews

Much of the effort expended during this survey activity related to conducting telephone and personal interviews with the more frequent/experienced ERS data users. Approximately 400 user interviews were conducted between July 1975 and March 1976. The distribution among user groups was as shown in Figure 2. Information obtained from interviews was considered to be of higher information value than that contained in questionnaire responses, and accordingly had more impact on conclusions drawn and recommendations made in the final report.(1)

3.3 Mail Questionnaire Survey

In this broader survey, questionnaires were mailed to attendees of recent remote sensing symposia, LANDSAT I and II investigators, members of professional remote sensing societies, individuals identified from NASA Headquarters, JSC, and GSFC mailing lists, and others from ERS data center information. Individuals who returned questionnaires from the Houston ERS symposium and non-U.S. users were not included in the mail survey. In brief, some 1200 questionnaires were mailed and 389 were returned for a 32.5 percent response rate, which is quite acceptable for a mail survey. In this mail survey, lower priority was given to the educational community, but returns from other user groups were fairly evenly distributed, as seen in Figure 2.

4. SUMMARY OF SURVEY RESULTS

One factual representation of the extent of current ERS data use can be obtained by aggregating the business statistics from the three operational ERS data centers in the United States. Figure 3 depicts these statistics, which indicate a fairly substantial annual dollar volume increase since FY 1973, and projected through FY 1976 (a total volume of over 3 million dollars). These figures indicate that the purchase of both LANDSAT frames and tapes continues to increase. For FY 1976, it was estimated that 280,000 LANDSAT frames and 2250 magnetic tapes would be purchased. This would make a total of over 700,000 LANDSAT frames sold since FY 1973.(2)

4.1 Data Users

Figure 4 shows the overall survey results in terms of Earth resources survey data users and data applications. The survey indicated the existence of a substantial number of current ERS data users. During this survey alone, over 1000 users of several thousands estimated were contributors. Lists of principal data users in the industrial, governmental, and academic communities have been included in the final report.(1) Based on federal data center LANDSAT sales (FY 73-FY 75) of slightly over $2 million and 500,000 LANDSAT frames, industrial (private sector) users are the largest single user group (in terms of both dollars and items), followed very closely by non-U.S./foreign data users. Federal governmental agencies and academic/educational users are about equal, but considerably less than users from the industrial sector. Very small in relative comparison is the apparent degree to which state, regional (substate) and local governmental units are purchasing LANDSAT data.

4.2 Data Used

Types of ERS data currently being used are also indicated in Figure 4. Survey results indicate that more users are involved with LANDSAT imagery than with any other type of ERS data. The use of high-altitude aircraft data follows a close second. LANDSAT digital data and Skylab

data were being used in about the same relative proportion (that is, by little less than 50 percent of users surveyed).

4.3 Data Use/Utility

As shown in Figure 5, current data applications among the various disciplines are fairly uniform with the exception of the peaks occurring in land use and geological applications. Actually, geologically related applications by the private sector account for the largest single data use category. Estimates are that industrial use of ERS data for mineral and fossil fuel exploration may be 10 times greater than other current applications. Other industrial applications include: land use/land cover studies; agricultural, forestry and other resource inventories; and facility siting assessments. Federal governmental agencies are actively pursuing all application disciplines, with the most substantial effort occurring in land use, agricultural, water/marine resource and geological applications. Because of the availability of funds and expertise, this user group represents the key to the effective transfer of ERS technologies to other governmental user communities. State, regional (substate) and local governmental users have been slow in developing operational ERS data programs, primarily because of a combination of funding and capability limitations, inadequate spatial resolution of LANDSAT imagery, and institutional arrangements and policies which adversely affect the technology transfer process. To date, the most progress made by this user group has been land use/land cover inventorying and mapping applications. Academic users are providing some of the leadership in developing techniques for using ERS data. Often the academic user is the means whereby geographically associated governmental and private organizations are being made aware of the application potential of ERS data. Foreign users are currently involved at all stages of data use from specialized, problem-solving experiments (such as general range condition monitoring in Lesotho, South Africa) to completely operational programs (viz., sea ice monitoring in Canada). U.S. training and user assistance programs, private industry involvement, and international support (UNDP and World Bank) are contributing factors to the growing impact of ERS data on developing countries.

As shown in Figure 5, most questionnaire responses indicated LANDSAT-type data to be of high utility. Most users surveyed consider current ERS data and data products to represent a complementary data source which has the potential of becoming an important data source. Most users feel that current ERS data products are of the greatest benefit to them because they represent a unique/new data source and a cheaper data source. Also, most users believe that ERS data systems have the potential of providing better data for most application areas. User assessments by discipline show that current ERS data products are most relevant to geological applications, land use activities and water resources interests. Most users feel that ERS data products will eventually be of most value to land use, agriculture/forestry, and water resources. Future ERS data were also considered to have high potential for providing unique data for environmental needs.

4.4 Data Limitations/Recommendations

Although questionnaire responses from all user communities showed strong agreement that most current LANDSAT data capabilities could be considered as adequate, with the exception of data delivery (see Figure 6), interviews with representative ERS data users did not substantiate this assessment. A more accurate representation of current user views relative to the adequacy of current LANDSAT capabilities and corresponding user recommendations for improving LANDSAT data use are summarized in Table I. Strongest user concerns related to the need to improve data delivery and spatial resolution. Lesser concerns related to the width and coverage of spectral bands and frequency of repetitive coverage. User recommendations having the highest overall potential for strengthening current LANDSAT data use included improving data quality on user products, providing more high-altitude aerial photography to be used in concert with LANDSAT data, and providing more user assistance/training programs. For improving data utilization of future LANDSAT-type systems, the greatest user impacts would result from significant improvement in data delivery (including a quick-look capability), more extensive spectral coverage, higher spatial resolution, development of specialized satellites, and acquisition of user data on an "as-needed" basis.

5. DATA USER PROFILES

5.1 Industry Users

Private industry is currently the most prominent user of LANDSAT data, buying a fourth of all LANDSAT data sold by the data centers annually, at a cost of $483,000. Private industry

consists essentially of two types of LANDSAT data users: the industrial end user, who requires the data to locate new or monitor existing natural resources, and the industrial service-to-user who provides the end user (private, government, foreign) with hardware, software and/or services for the accomplishment of his mission. Among the private end users, the exploration industry for minerals and fossil fuels has used the data most successfully. All other end users have used the data less successfully. The use of LANDSAT data in the service-to-user industry is also routine; however, the resulting products are not always routinely used by the recipient. An evaluation of LANDSAT data by the industrial sector revealed that most industrial users want additional spectral coverage in the thermal infrared bands (1-2 μm), better spectral and spatial resolution (at least 2X), more foreign and remote area coverage, quick-look capability, stereo coverage, better data processing, and (above all) much faster delivery of data (days instead of weeks). Since a large part of the industrial sector is made up of exploration end users or image-processing service-to-users, the demand by the industry user for LANDSAT data in its present format is expected to decline, unless improved or new data formats or new data become available.

5.2 State, Regional (Substate) and Local Government Users

Use of LANDSAT data on the state and local level was assessed to be in one of three stages of development: (1) planned/potential - 10 states; (2) experimental - 23 states; (3) demonstrational/quasi-operational - 17 states. No state was found to use LANDSAT data on a routine operational basis, but some states, such as Alaska, were found to place much importance on the value of ERS data. State and local users purchase only 1 percent of all LANDSAT data, but are frequently aided in research and funds by federal agencies, and in research by private and university remote sensing technologists. State-level utilization of LANDSAT data is most impeded by: (1) insufficient time for technology transfer of a highly complex technology, (2) political processes wherein decision-makers and R&D priorities are frequently changed, (3) the spatial resolution of LANDSAT data, and (4) lack of commitment to an operational satellite system. Of this, the spatial resolution of the data appears to be the most critical factor. Many state users were attracted from the beginning to the unique perspective provided by LANDSAT multispectral coverage, but were disappointed by the lack of detail when trying to determine detail at their conventional 1:24,000 scale. Acceptance of LANDSAT data by state and local users will involve a long process in which federal support (in terms of funding incentives and technological leadership) will continue to play a dominant role. Preference for NASA data will be for high-flight data; LANDSAT data will be used primarily for regional inventory and mapping. The planned introduction of 30 to 40-meter resolutions of future ERS satellite data systems will hasten the acceptance of ERS data, but until state users employ digital processing techniques, such data will remain underused.

5.3 Federal Government Users

Federal government ERS data efforts, to date, have been piecemeal, experimental, investigative, or continuing demonstrational efforts, and many federal agencies have taken a "wait and see" attitude and have made no real commitment to develop the technology. In terms of EROS data sales, federal users represent the third most prominent data user group. Most advanced governmental satellite data users involve agencies within the Departments of Agriculture, Defense, Interior, and Commerce. These agencies routinely utilize high-altitude aerial photography and are attempting to use LANDSAT data in their day-to-day operations. These agencies are committing significant staff and funds to cooperate with NASA in developing methodologies and procedures for operationally using data from current ERS satellites. This user group has the necessary budgets, facilities, and remote sensing expertise to develop and implement operational programs. These federal agencies represent the key to ERS data technological transfer and development, and progress in the use of this technology, not only within the federal sector but also as it relates to the transfer and acceptance by other user groups. Increased spatial resolutions, added spectral coverage, and improved data handling capabilities in the LANDSAT follow-on programs will significantly expand data use within federal agencies. In the meanwhile, user groups will continue to demand better resolution data on or more timely basis as they attempt to operationally utilize LANDSAT-type data.

5.4 Academic/Educational Users

The academic user community has been primarily instrumental in developing techniques and providing assistance to other user groups for using ERS data. Educational institutions purchase 15 percent of all LANDSAT data at an approximate cost of $100,000 annually. While academic users are primarily research-oriented, they also use ERS data for educational

purposes. Probably no other user community has utilized LANDSAT data for so many applications, the most frequent investigations being for land use and agriculture applications. Academic users are heavy users of digital data but have also used a variety of conventional photointerpretation techniques. Academic users in general consider most LANDSAT data parameters as "adequate", except for data delivery time. This user group will continue to utilize ERS data in research and educational programs, but probably not to the extent displayed in the past.

5.5 Non-U.S./Foreign Users

Non-U.S. users of ERS data currently represent a large user community which has the potential to become the predominant single user group in the near future. Foreign use of ERS data centers and the establishment of independent ground stations are steadily expanding. Major benefit is in areas where maps are inadequate and/or unavailable as required for resource development and economic programs. Current data capabilities are finding extensive use, but improved capabilities involving more and better foreign area coverage and data delivery will produce more extensive uses and benefits.

6. MAJOR CONCLUSIONS

An Extensive and Increasing Number of Explicit and Identifiable Data Users Do Exist. They include (1) users purchasing and analyzing ERS data routinely using their own resources (selected private industry and most foreign-country users), (2) users developing and testing systems for routinely using ERS data for large-area, small-scale resource inventorying, monitoring, and modeling applications, and (3) users analyzing the data experimentally to evaluate the feasibility of additional applications.

The Extent of ERS Data Center Use Varies Significantly Among the User Communities. The primary current ERS data user group is private industry, with both end-users and service-to-users participating (major use within the private sector relates to mineral and petroleum exploration interests). The second largest user community of ERS data is non-U.S./foreign users. Federal governmental agencies and the academic community are roughly tied for third place in extent of ERS data use, which involves all application interests. In last place are state, regional (substate) and local users, who appear to be more involved than data center records indicate.

Relative Discipline Use of ERS Data is Fairly Uniform. Although land use and geological applications appear to represent the largest current discipline application interests, overall data use is fairly uniform. The exception is environmental use which has considerably less current user interest than the other disciplines.

ERS Data Utility Varies Among Users and Uses. Most mineral and oil companies are of the opinion that current data use varies from important to very important in both domestic, and especially in foreign exploration, decision-making activities. In contrast, most other users, although positive, were not as strong or consistent in their views as to the effectiveness and value of current ERS data products. User assessments by discipline show that land use and geology applications are the most relevant current uses of ERS data, but land use, agriculture/forestry and environmental applications are expected to increase in importance with time. In terms of overall benefits, users believe that land use and water resources areas will benefit the most from ERS-type data.

Significant Increase in ERS Data Users, Uses, and Value Will Result From Planned and Possible Improvements in Future LANDSAT System Capabilities. Extensive progress has been made in (1) linking users and user problems with ERS data capabilities, (2) identifying and conducting experiments to assess technical and economic application possibilities, (3) developing demonstration/quasi-operational systems (LANDSAT II and ASVT programs) for using the data routinely, and (4) identifying and developing improvements to upgrade operational uses of future systems. Planned, short-term improvements (e.g., LANDSAT C) will result in some use/user increase, but more extensive improvements in data acquisition, data processing (on-ground and on-board), data delivery and end-user experience and capabilities will be required before extensive, user-financed, ERS data use occurs on an operational basis.

7. MAJOR RECOMMENDATIONS

Based upon information collected and evaluated during this survey, the following recommendations were offered:

(1) NASA should accelerate plans and programs to develop satellite ERS systems capable of providing improved data which can be more effectively utilized (technically and economically) by a larger cross section of private and governmental end users.

(2) NASA should develop and implement specialized technology transfer scenarios/ plans to improve ERS data utilization within each user community and within each discipline area. Establishment of regional application training centers and specialized user workshops should receive high priority.

(3) NASA should make more information available to existing and potential satellite data users that will make them more cognizant of space plans, capabilities, and specific data participation opportunities. In remote sensing applications; the following information aids are very much in demand:

- More newsleters of the GSFC LANDSAT NEWSLETTER type
- A users' guide to availability of remote sensing data (high-altitude aircraft data as well as satellite data)
- A users' dictionary of remote sensing terms
- A users' guide to hardware/software for ERS data analysis
- A users' guide to remote sensing research and service industries and contractors
- A users' information hot-line so users can contact NASA relative to data applications inquiries
- User handbooks for individual ERS data application areas.

(4) NASA should take another hard look at the technical, cost, and application implications of developing specialized satellites (e.g., ice monitoring/ navigation, geological exploration, environmental monitoring, etc.), especially in view of upcoming Shuttle and Spacelab opportunities.

(5) NASA should review on-going technology development programs and plans relative to their significance to future ERS systems and ERS data use. Programs having the highest potential for significantly improving ERS data use relative to user requirements should be discerned, and a determination made of the implications of accelerating their completion.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

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2. Staff Interviews and Reports, EROS Data Center, (Sioux Falls, S.D.), USDA, Aerial Photography Field Office (Salt Lake City, Utah), and NOAA Satellite Data Services Branch (World Weather Building, Wash., D.C.) 1975-1976.

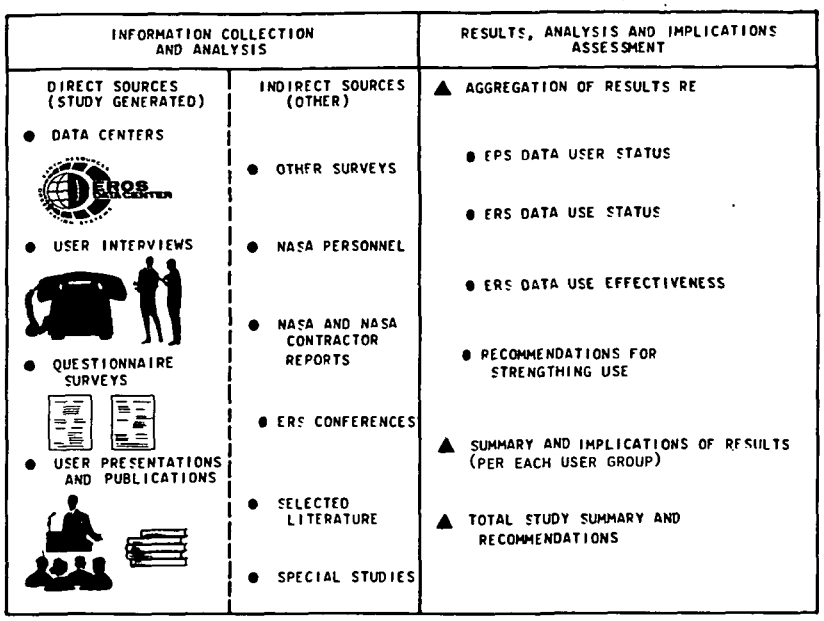

FIGURE 1. SURVEY METHODOLOGY - OVERVIEW

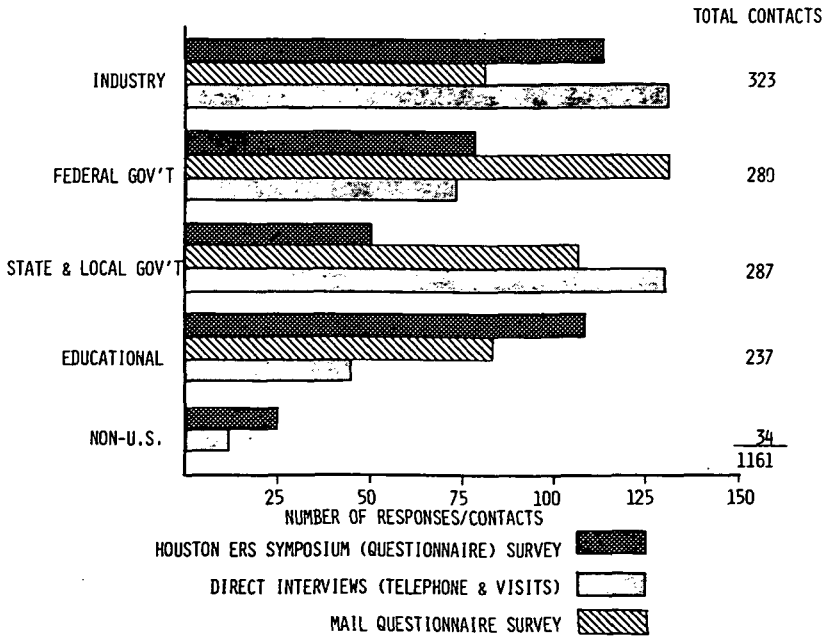

FIGURE 2. TOTAL USER SURVEY STATISTICS

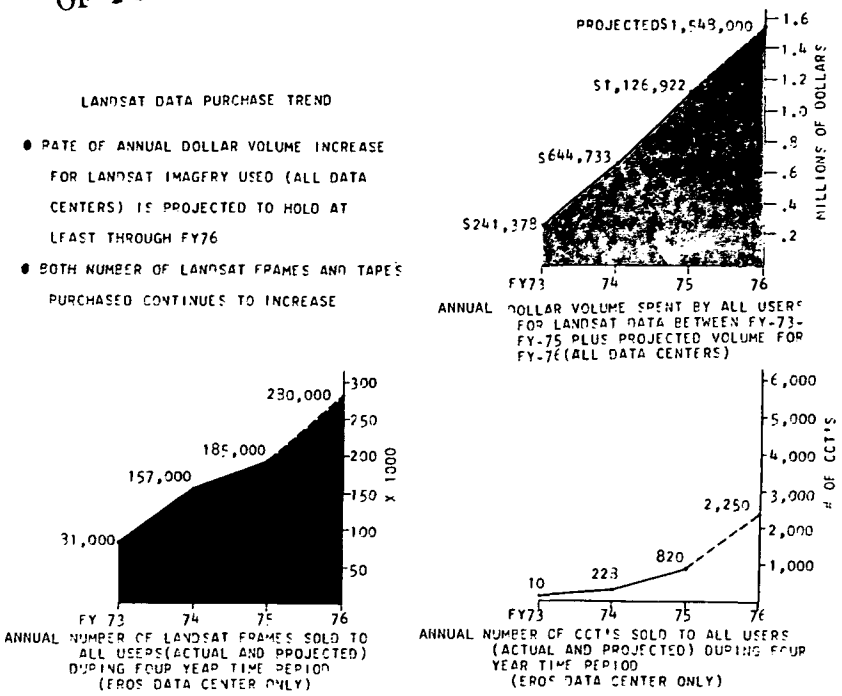

FIGURE 3. DATA CENTERS' RECORDS OF EXTENT OF ERS DATA USE[2]

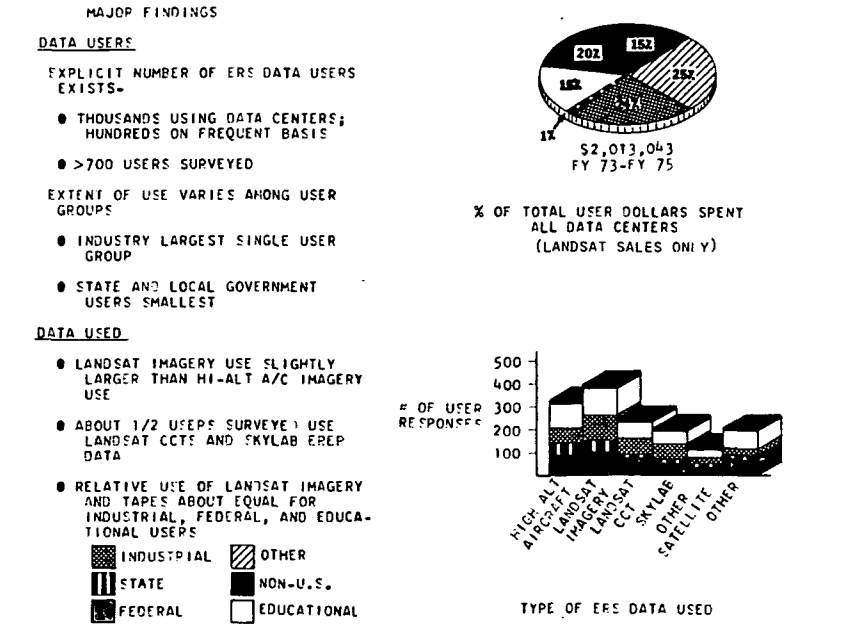

FIGURE 4. SUMMARY OF DATA USERS AND DATA USED

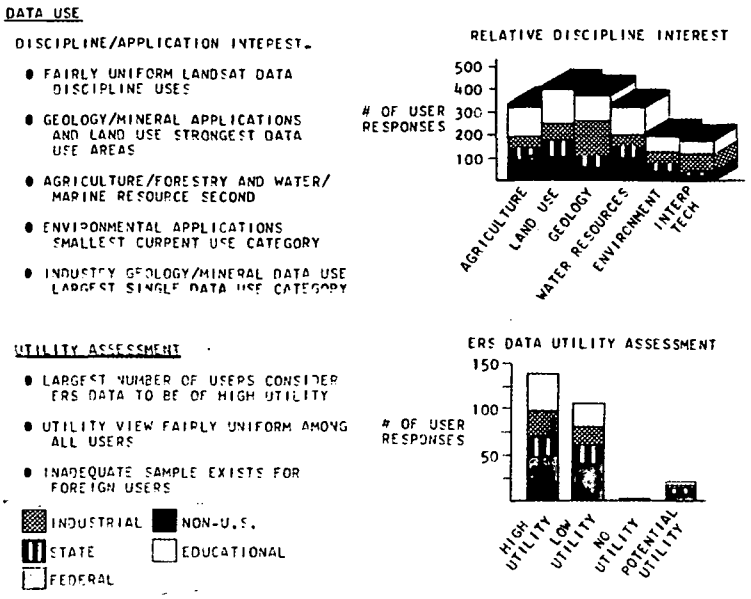

FIGURE 5. SUMMARY ERS DATA USE/UTILITY (ALL USERS)

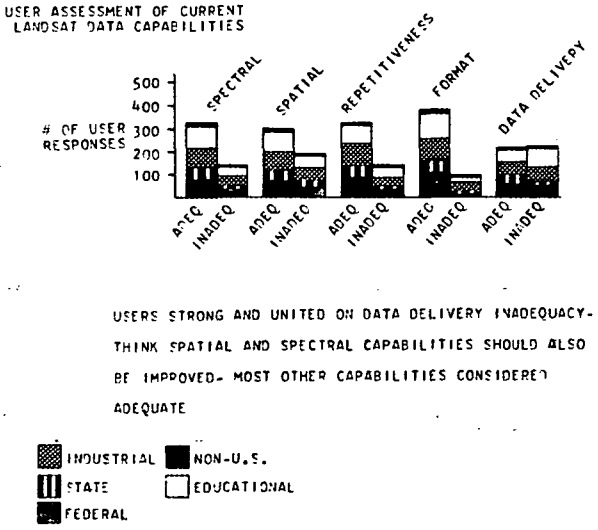

FIGURE 6. SUMMARY OF USERS' ASSESSMENT OF LANDSAT DATA (ALL USERS)

TABLE I. USER ASSESSMENT OF CURRENT LANDSAT DATA CAPABILITIES AND RECOMMENDATIONS FOR STRENGTHENING DATA USE

USER VIEWS	USER RECOMMENDATIONS
• Spectral Coverage - Majority of users satisfied but many strong views as to limitations.	• Most recommendations are for (1) extending spectral coverage into thermal and microwave regions, (2) providing additional visible and near IR bands, and (3) narrowing existing bands.
• Spatial Resolution - Majority of questionnaire responses indicated current spatial capabilities adequate for experimental and large area uses. User interviews (with exception of exploration users), however, showed strong views as to data utility limitations imposed by 80 meter resolution.	• Most users commonly recommended 20-40 and 10-20 meter resolutions. Some users (especially state and local users) desire spatial resolutions in the 1-10 meter range. In contrast, geologists want to retain large area (synoptic) perspective.
• Repetitive Coverage - Most users content with current LANDSAT data coverage except those concerned with environmental monitoring, snow mapping, flood drainage assessment programs, etc. and areas with extensive cloud cover.	• Strong recommendations related to other than repetitive coverage. Industry (and foreign users) in particular want more coverage of remote domestic and foreign areas and stereo viewing opportunities.
• Format Options/Product Quality - Strong user agreement on adequacy of current data quality.	• Most recommendations relate to providing more product options and better quality control.
• Data Delivery - Strongest area of user dissatisfaction in both questionnaire and interview results especially in considerations involving operational use.	• User recommendations were many and very strong on need to significantly improve this function. Desires for quick-look capability and 2-3 days turn around time were stressed.