FAIRCHILD SPACE AND DEFENSE SYSTEMS
A Division of Fairchild Camera and Instrument Corporation
300 Robbins Lane, Syosset, New York

FINAL REPORT

EARTH RESOURCES DATA PROCESSING CENTER STUDY

Contract No.: NASW-1811
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VOLUME I: PROGRAM SUMMARY

Submitted To:
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HEADQUARTERS
Washington, D.C.

SECTION 1

INTRODUCTION

FOREWORD

Fairchild Camera and Instrument Corporation is pleased to submit this Final Report to NASA Headquarters in fulfillment of NASW-1811, Contract for Earth Resources Data Processing Center Study. In accordance with the requirements of the work statement, Fairchild's Space and Defense Systems Division has, during the early months of 1969, reviewed experimenter requirements relative to the NASA Manned Spacecraft Center aircraft program for Earth Resources Sensor Development, and has surveyed the existing data processing laboratory facilities at Houston.

Based upon these efforts, and working with material supplied by NASA/MSC, the general evolution of the program at Houston has been delineated and priority growth requirements have been identified. As a result, a general development plan concept has been established for implementing this growth in a timely fashion, and several recommendations have been developed concerning execution of the plan. These areas are considered in some detail in following sections of the report.

Before considering specific results of the investigation, it is advantageous to summarize briefly the purpose and scope of the study, and to fix the requirements for data processing facilities in the broader context of the entire Earth Resources Program. The remainder of this section is devoted to these tasks.

SECTION 1 CONTENTS

1.1 STATEMENT OF THE PROBLEM

The world requirements for improvements in meeting human needs are expanding at an ever increasing rate. A fruitful area for improvement lies in a more effective utilization of the earth's resources and environment. It is particularly appropriate that the emerging technologies developed in connection with our aircraft and space efforts are being applied to further our understanding of the problems associated with such utilization. Today, there is substantial evidence to indicate that the exploitation of remotely-sensed data for the purpose of detecting, locating, and measuring terrestrial and environmental phenomena will contribute materially to our ability to solve many of these problems.

To realize the full potential inherent in remote sensing of the earth for resource assessment and utilization, several factors must be considered. To begin with, a program must be established to evaluate, both analytically and experimentally, the capability of existing remote sensors to collect data useful to the resource analyst. Preferably, widespread use should be made of actual measurements from airborne platforms to simulate conditions which ultimately will be encountered by operational systems. Where successful experiments are conducted and/or useful techniques are discovered, efforts to develop better sensors must be undertaken.

In parallel with the sensor evaluation and development effort, improved methods of handling data on the ground must be developed so as to extract more information more rapidly than has been done heretofore. Thus, techniques for improved man/machine interfaces, multi-sensor data correlation, signature extraction and analysis, reduction (or even elimination) of instrument and environmental variables, increased reliability of the acquired and processed data, and semi-automatic and automatic image enhancement, normalization, calibration, annotation and interpretation in general are required.

Finally, consideration must be given to the total demands which will be placed upon data acquisition and data processing systems when the earth resources program becomes fully operational. Techniques

which are not amenable to the rapid collection/processing/ analysis/ dissemination cycle, or which are unfit for high volume applications, must largely be eliminated in favor of methods which are responsive to user needs on an operational basis.

The basic steps involved in bringing the earth resources program through the research and development phase and into operational status are indicated in Figure 1-1. Today, within NASA and the primary government user agencies (i.e., the Department of Interior, the Department of Agriculture, and the Navy Oceanographic Office) various aspects of these problems are being investigated. In particular, all elements of the R&D program for data acquisition and data processing are under especially intensive study. Throughout the history of the earth resources program, the one NASA field center which has been most heavily involved in the program has been the Manned Spacecraft Center. A determination of the role which MSC occupies in the earth resources program, the uses which must be made of ground-processed data, the problem areas which arise as MSC attempts to fulfill its functions, and the various ways of potentially alleviating or solving these problems constitutes the central theme of the study undertaken by Fairchild and reported on in the present document.

1.2 STUDY CONSIDERATIONS

The role which the Manned Spacecraft Center plays in the developing earth resources program is an extremely significant one. Referring to Figure 1-1, MSC has much of the current responsibility for conducting the aircraft sensor evaluation program, utilizing sensor equipment and data processing facilities presently available at Houston. While the total earth resources program involves other aircraft and sensors, and while much of the data analysis and sensor evaluation is performed by various government agencies and university experimenter groups, the MSC contribution clearly is central to the entire effort, particularly insofar as NASA responsibility is concerned.

More recently, in recognition of the trends which are becoming evident in the earth resources program, MSC has begun to plan in detail for future program requirements. For example, studies have

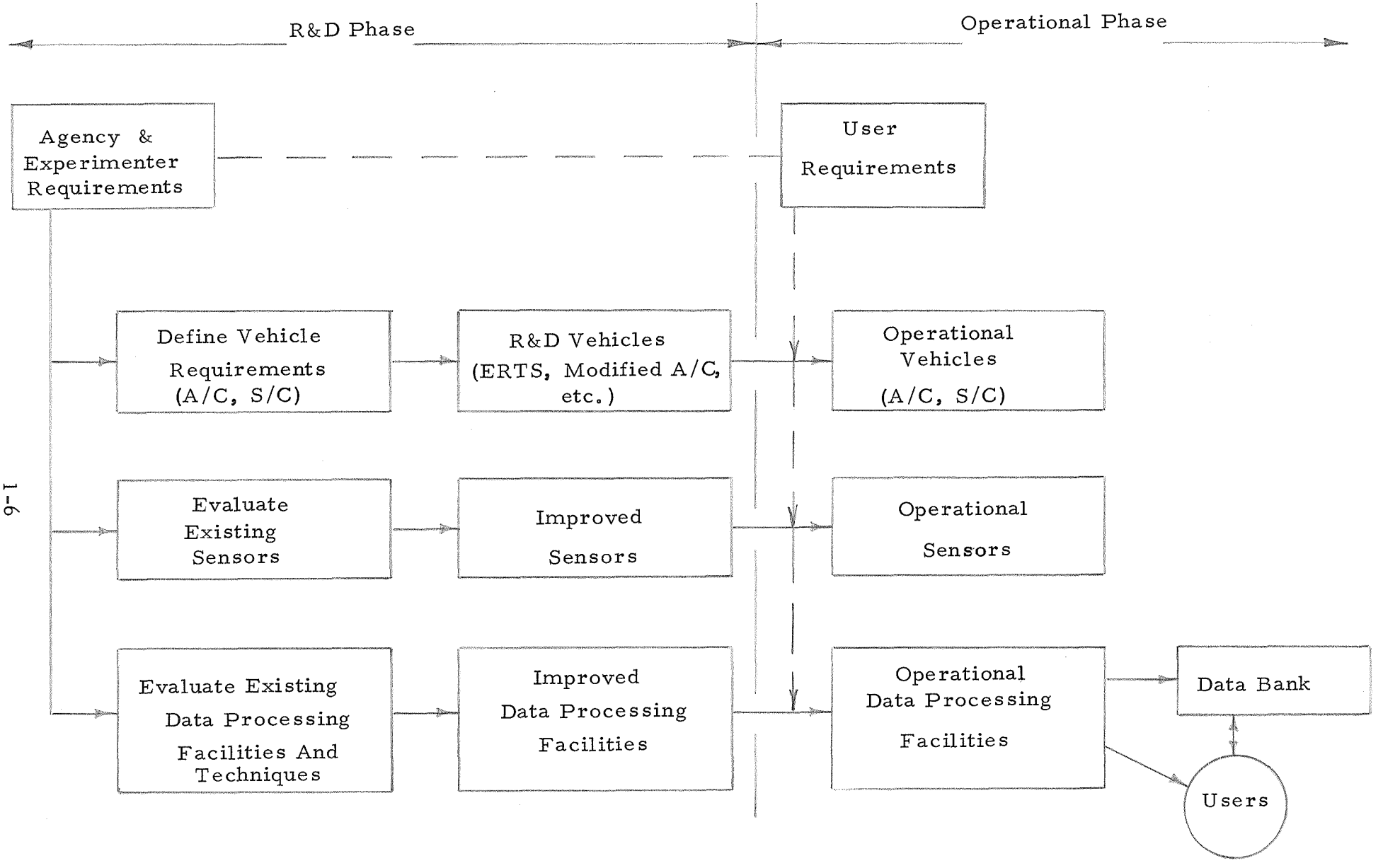

FIGURE 1-1 DEVELOPMENT OF THE EARTH RESOURCES PROGRAM

been (or are being) initiated, both in-house and with external contractors, to more fully computer-automate the raw data reduction process, to determine optimum techniques for signature data processing, to develop methods of multi-sensor data correlation, etc.

It appears certain that program growth will lead to a substantial enlargement of MSC's responsibilities. Current activities in data collection and data processing are essentially of an R&D nature but, as techniques are refined and management skills developed, the program will gradually assume an operational character.

This is illustrated symbolically in Figure 1-2. The accuracy of the curves is of little concern; however, recognition of the trend is of major significance in comprehending MSC activities and directions of growth.

An anticipated two-to-four-fold increase in the number of aircraft flights by 1972 will produce a considerably enlarged volume of data, and spacecraft collections will eventually expand the input load enormously. A forerunner of this type of activity was the SO 65 experiment involving multispectral photography from the Apollo IX. It seems inevitable that such experiments will continue and that their scope will be further extended, and routine procedures established, when a permanent space station becomes a reality.

As these changes come to pass, the associated ground-based data processing facility must concomitantly build a capability to transform massive amounts of raw data into useful information products. This means that it must operate on a smoothly functioning, production-type basis. The alternative is engulfment and a structural collapse of the Earth Resources Program.

Hence, the study was aimed at identifying problem areas and recommending methods of solution pertinent to Houston's impending data processing responsibilities.

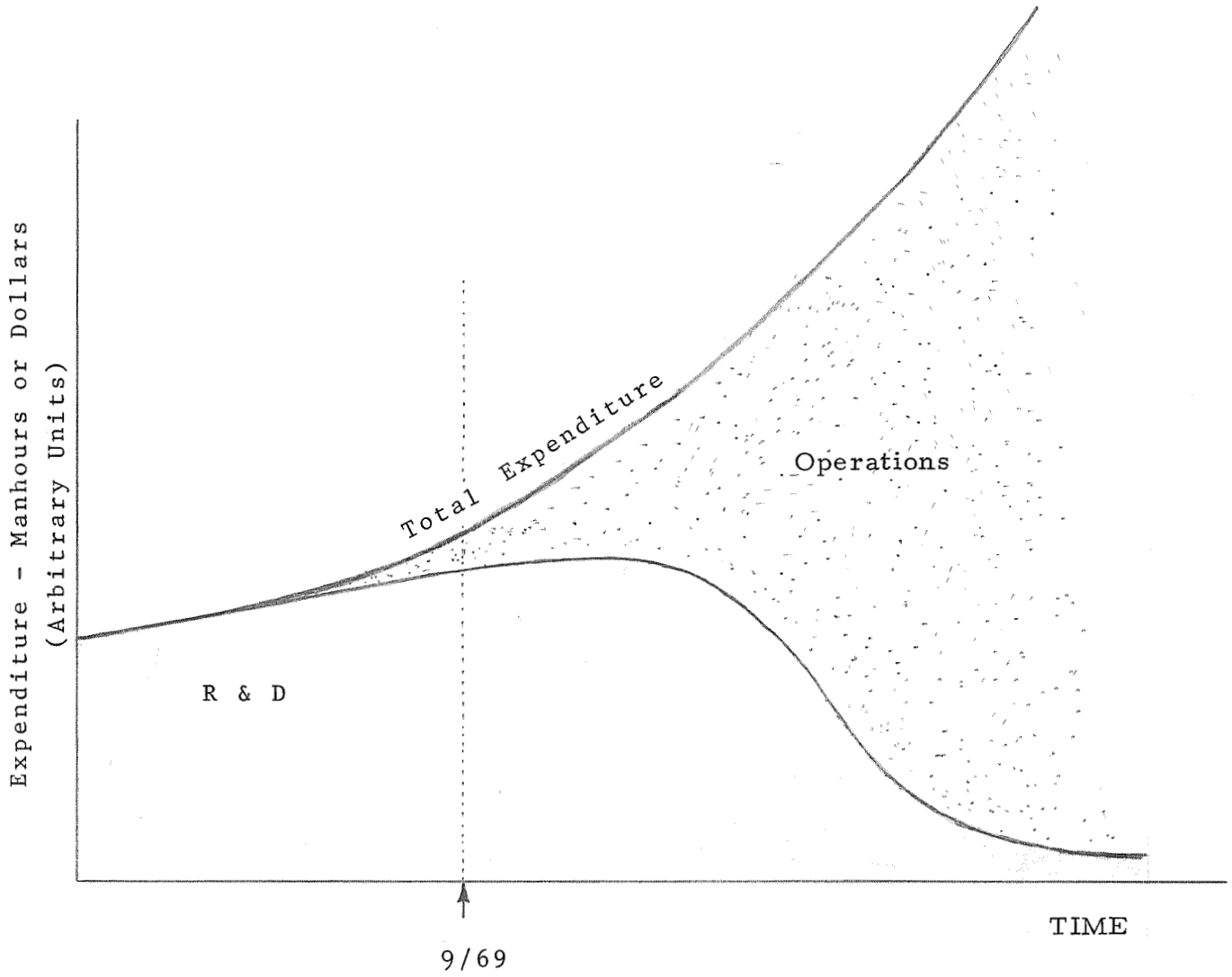

FIGURE 1-2 R&D VERSUS OPERATIONAL ASPECTS OF THE EARTH RESOURCES AIRCRAFT PROGRAM

To gain perspective on the situation, it was necessary to begin with a broad but detailed review of current MSC Earth Resources activity and planning. Then, program projections were analyzed and a number of conclusions drawn.

More specifically, the tasks undertaken were, to:

1) Review the basic objectives and requirements of the major government support agencies and experimenter groups associated with the Earth Resources Program;

2) Review experiments and sensor and auxiliary equipments currently associated with the MSC aircraft program;

3) Review MSC plans for program growth plus anticipated new sensors;

4) Survey the existing MSC data processing laboratory facilities associated with the aircraft program;

5) Develop data flow models representing the existing ground processing of all sensor and auxiliary data;

6) Identify facilities required for the program which are neither presently in existence, nor under development;

7) Generate development plans to estimate the costs and lead times entailed in acquiring necessary data processing equipment and facilities;

8) Develop recommendations for follow-on work aimed at furthering the growth of the earth resources data processing capabilities at the Manned Spacecraft Center.

Table 1-1 indicates the correspondence between these program tasks and final report sections.

TABLE 1-1

CORRESPONDENCE BETWEEN STUDY PROGRAM TASKS AND SECTIONS OF THE FINAL REPORT

	PROGRAM TASK	SECTION OF REPORT (or other documentation)
1.	Review of Experimenter Program Goals	3.2, Appendix B
2.	Review & Analysis of Aircraft Program Sensor Equipment	3.3, Appendix D
3.	Review Growth Plans	4.1
4.	Survey & Analysis of MSC Data Processing Facilities & Techniques	3.4, Appendix C
5.	Development of Data Processing Flow Models	3.4, Appendix E
6.	Identification of Facility Requirements	4
7.	Generation of Development Plans	5
8.	Development of Follow-On Program Recommendations	2, 5 and Attachment I & II of the Third Monthly Report

SECTION 2

RECOMMENDATIONS AND CONCLUSIONS

FOREWORD

Recommendations and conclusions are presented in this section in a series of summary statements highlighting the major results of the study. Both general and specific recommendations are included, the former covering broad philosophical areas and the latter devoted to subjects which are identified and discussed in detail in the body of the report. The conclusions drawn deal primarily with the need for increasing the rate at which the Earth Resources Program is developing.

SECTION 2 CONTENTS

2.1 GENERAL RECOMMENDATIONS

The following recommendations pertain primarily to the general philosophy of the Earth Resources Program. They represent a summation of ideas expressed by legislators, experimenters, and NASA personnel which were found to be most cogent.

2.1.1 Increased Participation

NASA should make a concerted effort to increase participation in the Earth Resources Program by additional Federal, State and Local Government Agencies, by more scientific disciplines, and by industrial firms and public utilities. A task force should be established with the specific function of contacting potential users of Earth Resources data, educating them in its application to their particular problems, and encouraging their involvement.

2.1.2 Program Communications

Machinery should be established to ensure communication among program participants. Specifically, a form should be prepared which accompanies every set of data forwarded by NASA to an experimenter. An example of such a form is shown in the main body of the Study Findings, and its purpose is to facilitate a realistic appraisal of program effectiveness. Similarly, communication among all participants should be promoted and encouraged by NASA, to the fullest extent possible.

2.1.3 Central Data Processing Facility

Such concepts as cost-effectiveness, maximum participation, and maximum return on investment imply the desirability of a Central Data Processing Facility as opposed to independent disciplinary or geographic facilities. Furthermore the active data bank (or library) should be closely associated with this Center, if not actually an integral part of it. The function of this Facility is to perform all services between the data collection agency and the ultimate user, including routine processing, special processing, and dissemination. This is recognized as an ultimate goal, and

interim processing centers must exist. Furthermore, there is no implication that the Central Facility should not set up appendage facilities on either a geographical or disciplinary basis; only that efficiency and a minimization of duplication of effort will be best served by the recommended structure.

2.1.4 Dissemination of Information

This subject actually falls within the purview of several of the preceding ones, but it is believed to be of such importance that it deserves additional emphasis. Unless an adequate quantity of high quality information reaches the experimenter or other user in timely fashion, the program cannot succeed. This function should either become an additional task for the "Participation Task Force", or a separate panel should be established to ensure its accomplishment.

2.1.5 Program Expedition

Fairchild personnel who participated in this study are convinced that the Earth Resources Program is a most significant endeavor. A great many of mankind's problems, including the population explosion, air and water pollution, critical shortages of minerals and, above all, the threat of mass starvation, emphasize the need for systems management of the earth's resources. Intelligent management demands continuing, current knowledge, and the Earth Resources Program certainly offers the greatest possible promise of providing this knowledge. Hence, its expeditious pursuit on all fronts is recommended and urged.

2.2 SPECIFIC RECOMMENDATIONS

A number of specific activities are vital to the Earth Resources Program and appropriate for consideration at this time. Undoubtedly, many of them are familiar themes to some NASA personnel, and at least two have been brought to a point where study contracts have been awarded. Even so, it is convenient to tabulate them here in order to have a concise list available for reference purposes.

Recommendations are grouped into priority and supplementary items, and section numbers are included to indicate where corresponding detailed discussions may be found in the main body of the report.

2.2.1 Priority Recommendations

The more important items identified in the study are those listed in Table 2-1. All these activities should be given prompt attention, and formal programs should be initiated at the earliest times feasible.

2.2.2 Supplementary Recommendations

Other efforts which are necessary, but of substantially less importance than the priority items, are summarized in Table 2-2. These tasks should be performed reasonably soon, but there is no urgent need to undertake them at the earliest possible dates.

2.3 CONCLUSIONS

During the course of the study it became evident that the Earth Resources Division at the Manned Spacecraft Center has performed well in executing an extremely difficult program. By coordinating the efforts and talents of many government agencies and scientific personnel around the world, MSC personnel have, to a large extent, satisfied most of the early earth resource mission requirements. They have supplied aircraft, containing a large variety of sensors to cover many different sites and subject areas, on a continuous operational basis since the program's inception in 1964. MSC has also developed a substantial data processing capability within the constraints imposed on the Center by the much higher priority Apollo program. Finally, this total performance has been accomplished within the bounds of what is essentially an R&D program, requiring continuous improvement in data processing techniques and in the development of new sensors.

TABLE 2-1

PRIORITY RECOMMENDATIONS

ITEM		REF. SECTIONS
1.	Assess current program effectiveness	3.5, 4.5
2.	**Develop** appropriate management techniques and plans: · Plan program growth · Coordinate with other programs · Long range planning of experiments · Plan integrated sensor systems · Management Information System	4.5
3.	Plan and construct a new complex of ground facilities: · Data Exploitation Center · QC Photo Processing Laboratory · Space Data Simulation Laboratory · Data Library Center · Calibration & Environmental Laboratories	4.4
4.	Study the requirements for, and develop, suitable data processing systems: · Automatic Data Correlation System · Signature Analysis System · Space Data Simulation System	4.3
5.	Develop data handling techniques: · Data screening · New sensor simulation · Image enhancement · Data storage and retrieval · Establish QC standards for film and tape raw materials · Maintain continuous efforts in software and hardware R&D · Error budget control · Correction of environmental degradations · New signature techniques · Accommodate new sensors · Data collection standards	4.2, 4.3

TABLE 2-2

SUPPLEMENTARY RECOMMENDATIONS

ITEM		REF. SECTIONS
1.	Study the management techniques used in the S O 65 experiment	3.2.4
2.	Develop a workable ADAS system	Appendix E
3.	Investigate improvement techniques:	
	• Stabilized sensor mounts	3.2.6
	• Acquisition of ground truth	3.2.2

It has also become apparent that the Houston earth resources program has reached a key point in its evolutionary development. Basic decisions must be made with regard to the size and scope of the program, and it is the considered opinion of Fairchild project personnel that the program growth rate should be accelerated. The momentum that has been created over the past few years should increase, for the following reasons:

- Many types of earth resource data have been identified which can be collected more efficiently by spacecraft remote sensing than by any other means.

- Deadlines have been established for orbiting two experimental Earth Resources Technology Satellites (ERTS) in 1971 and 1972; the satellite program will require coordination with the MSC earth resources activity. In addition, the Apollo Applications Program will soon be in operation. The Earth Resources Program must be in a position to exploit the data gathered by these programs and make the information available to the nation.

- If the Manned Space Station is approved for development, the multi-sensor earth sciences laboratory on the spacecraft will supply a wealth of data requiring a sophisticated ground data processing capability.

- The science of remote sensing should be extended in order to better comprehend the problems involved and to discover appropriate solutions. This effort is required to make data collection and ground data processing useful, efficient and cost/effective.

- The data collected and the associated technology developed in executing the program should be made available to the nation. The contributing technology will be of particular value to many areas of public utility, commerce and industry.

By far the most significant long range requirement on the overall Earth Resources Program is the development of a National Data Processing Center. This is viewed as a vital element in what will eventually be a world-wide Earth Resources data network.

A complete facility would contain a coordinated group of laboratories, service centers and special purpose offices:

- A quality-controlled Photographic Processing Laboratory and Magnetic Tape Data Processing Center to accommodate mission inputs.
- A Data Exploitation Center to perform data correlation and signature analysis functions.
- A Space Data Simulation Laboratory to adjust aircraft-collected data so as to simulate data acquired from satellite altitudes.
- R&D facilities to experiment with film and tape data processing techniques, in order to improve current methods and develop others suitable for new sensor data.
- Calibration Laboratories to establish and maintain standards for all instruments and to advance the state-of-the-art in environmental measurement techniques.
- A Library Center which would contain data archives, printing and publishing facilities, and equipment for data examination and comparison.
- A Program & Systems Development Office to manage all on-going discipline application and data collection programs, on national and international scales.
- A Public Relations & Education Office to spur interest in the Earth Resources program by providing lecturers, course materials, reports, sample data, etc. on as broad a basis as possible.

- A Management Office to provide the necessary planning and central administrative control functions.

Because of the magnitude of the program and the evolutionary nature of the technical requirements, economic factors and political forces which shape it, the only practical course is to plan and develop an interim facility first, then use that experience to refine the approach toward end goals.

The final facility should be achievable by 1980, may cost on the order of 300 million dollars to establish, and will be an operation requiring some 4700 people, a floor space of about 1.2 million square feet, and a sustaining annual budget of approximately 140 million dollars.

It is of interst to compare these figures with those which the 18 July, 1969, issue of SCIENCE* magazine presents for the Manned Spacecraft Center:

Initial cost----------	$245 million
Personnel----------	4,600
Operating cost--------	$140 million/year

Thus, the eventual new Center will be a complex fully as vast as the existing MSC operation.

Facility requirements are explored in considerably greater detail in Section 4.4 of the Study Findings (Volume II of this report); size and cost estimates are developed in Section 5 of that volume.

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* Plate, Thomas Gordon "Houston MSC: Community with a Space Complex" pp. 265-269

APPENDIX A

EARTH RESOURCES

DATA PROCESSING CENTER PROGRAM

FOREWORD

Appendix A presents some general thoughts on the direction which the national earth resources program appears to be taking, and attempts to summarize trends and estimated program costs relative to the ground data processing facilities required. This document was prepared by FSDS personnel during the present study, specifically for the National Space Council. It was accomplished on company funds and is included because of its relevance to the study findings.

PREFACE

The world requirements for improvements in meeting human needs are expanding at an ever increasing rate. A fruitful area for betterment lies in a more effective utilization of the earth's natural resources and environment. It is particularly appropriate that the emerging technologies developed in connection with our aircraft and space programs are being applied to further our understanding of the problems associated with such utilization.

Convinced of the vital role which the earth resources program will play in meeting future human needs, Fairchild Space and Defense Systems has committed its talents to a study of the problems of creating a centralized processing facility and has developed preliminary guidelines on its design and functions. We feel confident that our efforts will prove to be useful in pursuing and accomplishing this critical element in what must surely be considered a significant national goal.

Robert Bruce, Jr.
Vice President and General Manager

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EARTH RESOURCES DATA PROCESSING CENTER PROGRAM

SECTION I

PROGRAM OBJECTIVES

Substantial evidence exists to indicate that the utilization of remotely-sensed data for the purpose of detecting, locating and measuring terrestrial and environmental phenomena will contribute materially to a more effective utilization of the earth's natural resources (Figure 1).

In conjunction with aircraft and space efforts, recent studies have documented the need for development of a Center capable of processing the requisite variety and volume of earth resources data to satisfy numerous user disciplines on a timely basis (Figure 2).

EARTH RESOURCES DATA PROCESSING CENTER

GOALS — NATIONAL & INTERNATIONAL TO CONTRIBUTE TO THE IMPROVEMENT OF:

- THE WORLD'S FOOD SUPPLY
- ENVIRONMENTAL HAZARD WARNING SYSTEMS
- MINERAL RESOURCE DEVELOPMENT
- WEATHER FORECASTING
- TRANSPORTATION
- COMMUNICATIONS
- MAN'S HEALTH AND WELL BEING
- WORLD WIDE CATASTROPHE DETECTION, LOCATION AND SURVEY

FIGURE 1.

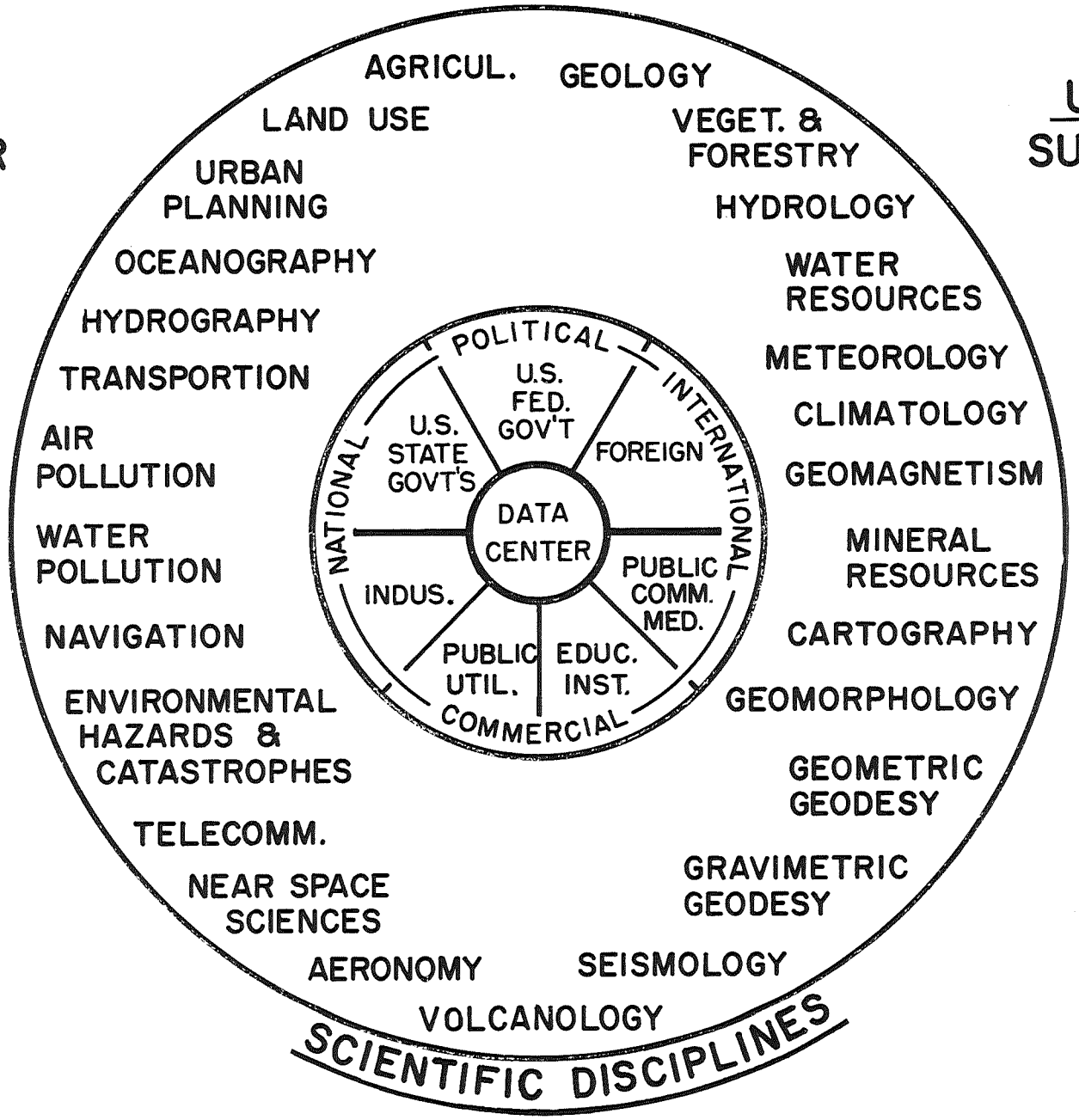

FIGURE 2.

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SECTION II

FUNCTIONS OF EARTH RESOURCES DATA PROCESSING CENTER

The Center must satisfy the objectives of the overall Earth Resources Program and comply with user requirements. To accomplish this, the Data Processing Center must be capable of performing a number of functions (Figure 3) including:

mission planning and user interface

command and control

data processing, storage and retrieval

conversion, correlation and annotation of primary and auxiliary data to satisfy user requirements

interpretation and extraction of synthesized information

timely production and dissemination of processed data

R&D in support of advancing technology related to the above functions

The fashion in which these functions are satisfied is dictated by the internal process flow within the Center (Figure 4).

DATA PROCESSING CENTER FUNCTIONAL FLOW

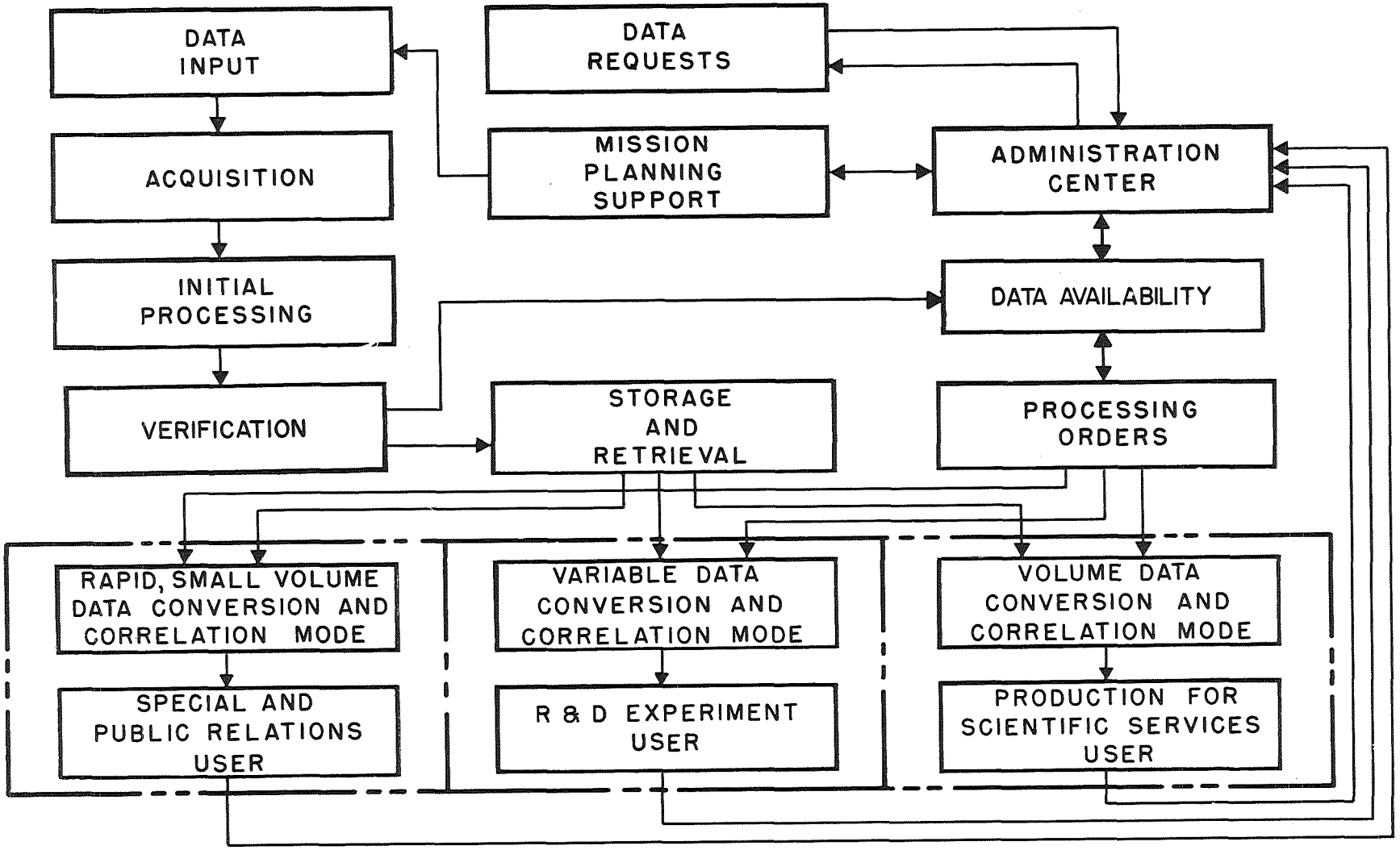

FIGURE 3.

CENTER PROCESS FLOW CONSIDERATIONS

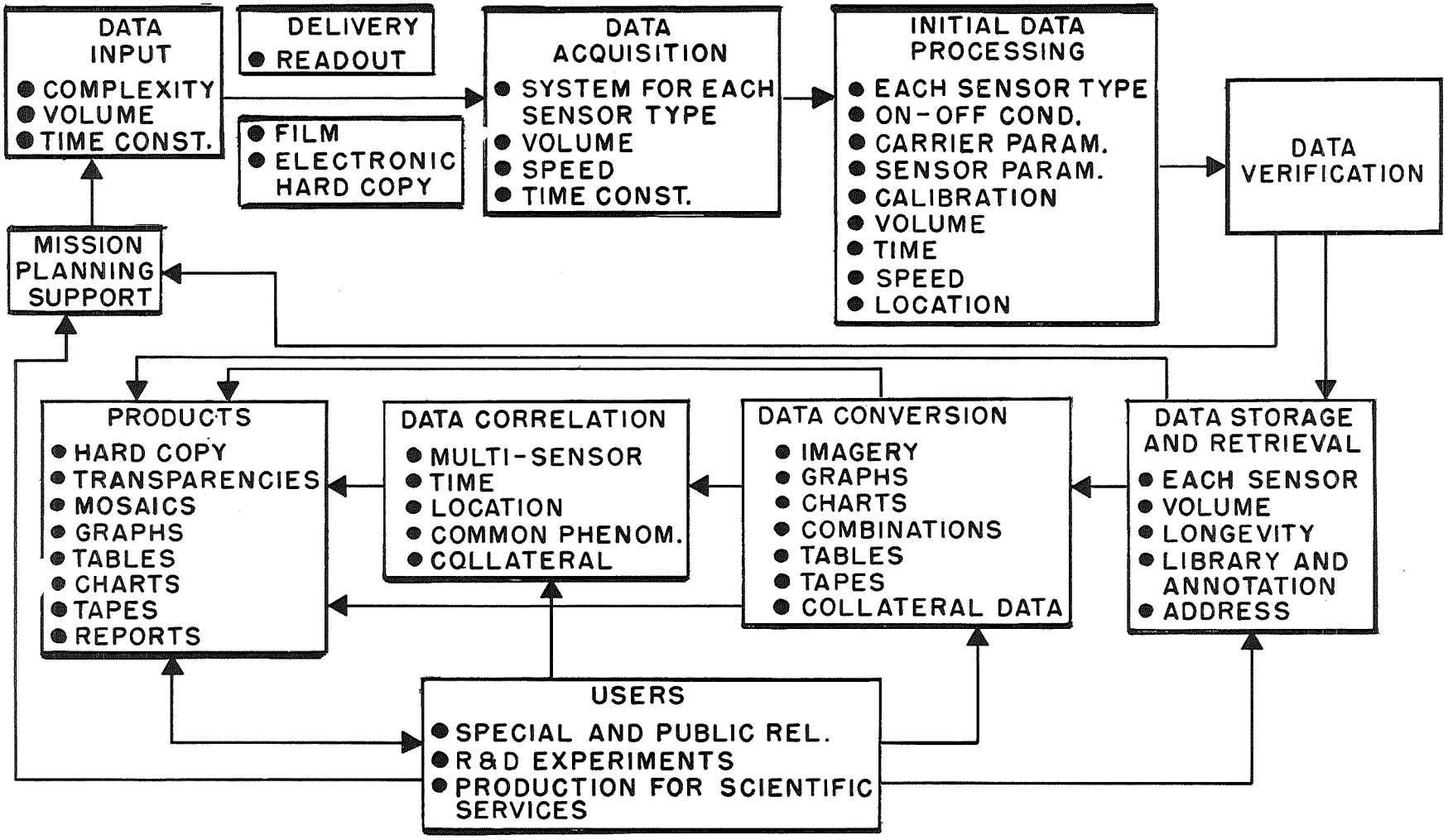

FIGURE 4.

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SECTION III

CENTER/USER INTERFACES

In response to user needs, the Center must accept diverse sensor inputs and supply requisite output products. The Center's output to users must consist of both primary sensor and collateral data (Figure 5).

Of particular significance is the degree of interpretation and detailed analysis which each user will demand of the Center; the sum total of these needs may well be the pacing factor in establishing facility development and operational costs. Some major agency users, essentially self sufficient in terms of data analysis capability, may require direct data links to provide only relatively raw data from the Center. The majority of users are without extensive analysis capability and will have to depend upon the Center to provide this function (Figure 6).

Extensive benefits will accrue in reduced costs if centralized facilities are provided at the Center to service user organizations. At a very minimum, this may permit time-sharing of centralized computer, processing, analysis and ancillary equipments.

CENTER/USER INTERFACES

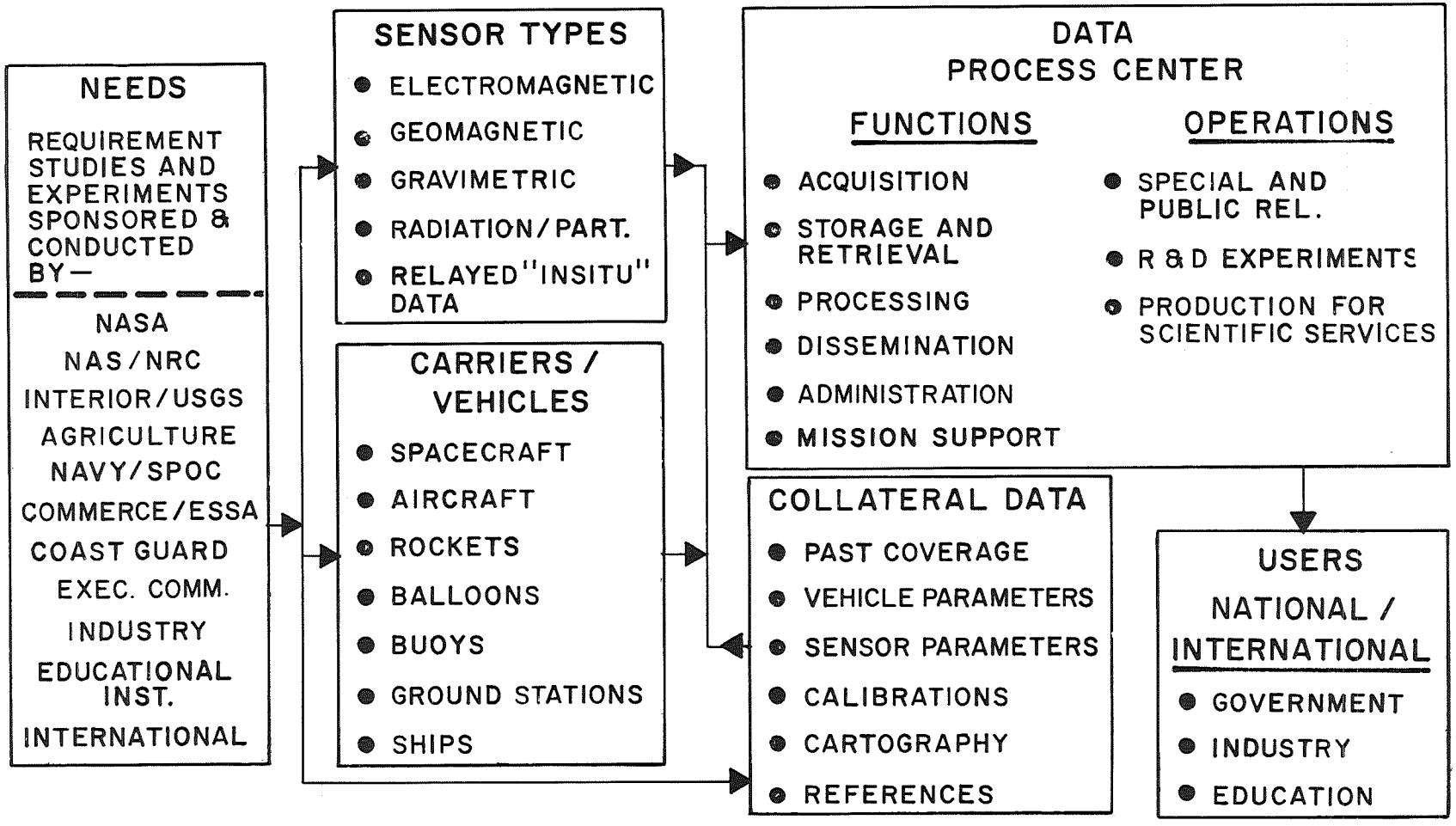

FIGURE 5.

CENTER OPERATIONS FLOW

USER DATA ANALYSIS CAPABILITY CORRELATED WITH DATA PERISHABILITY

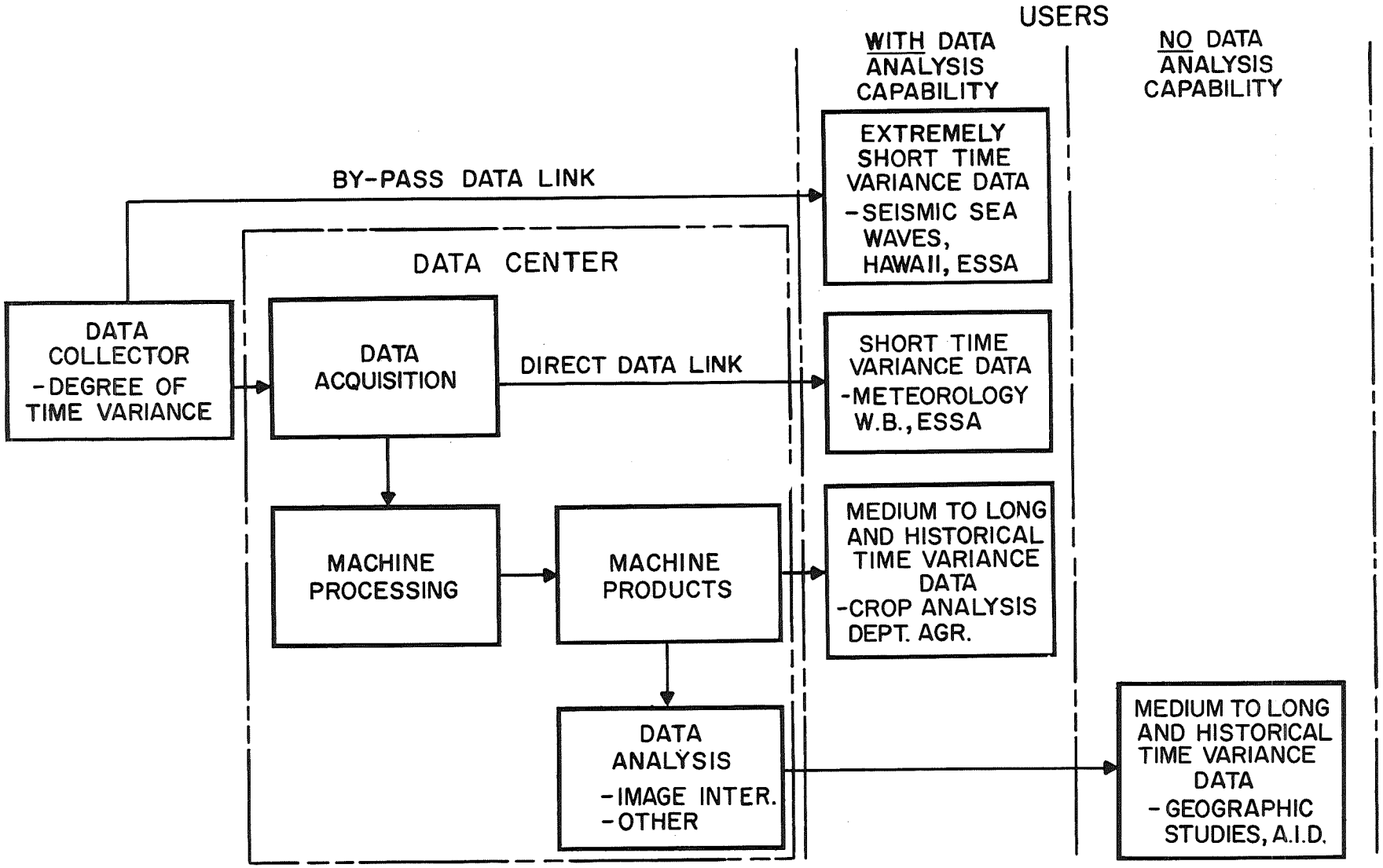

FIGURE 6.

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SECTION IV

PROGRAM SCHEDULE, MILESTONES AND COSTS

The establishment of a fully operational National Center for Earth Resources Data Processing within the next decade will be the result of major multiphased program efforts involving:

R&D programs in data management and processing technology

upgrading of interim (existing) processing facilities

analysis, design and specification of Center facilities

Center construction and equipment installation

activation of operational Center

Figure 7 illustrates the schedule, major milestones and expenditures for the program. Major milestones include:

1971 - Initiation of design study for National Center

1972 - Interim facilities used for ERTS-A processing

1973 - Commencement of National Center construction

1974 - Interim facilities used for ERTS-B processing

1975 - Activation of National Center

1976 - National Center fully operational

Total program expenditures for the period of 1969 - 1979 amount to approximately $300 million. This includes $190 million to evolve an operational Center by 1975, and an operating budget of $110 million (approximately $25 million per year) for the period from 1975 to 1979.

NATIONAL CENTER FOR EARTH RESOURCES DATA PROCESSING

PROGRAM SCHEDULE, MILESTONES & COSTS

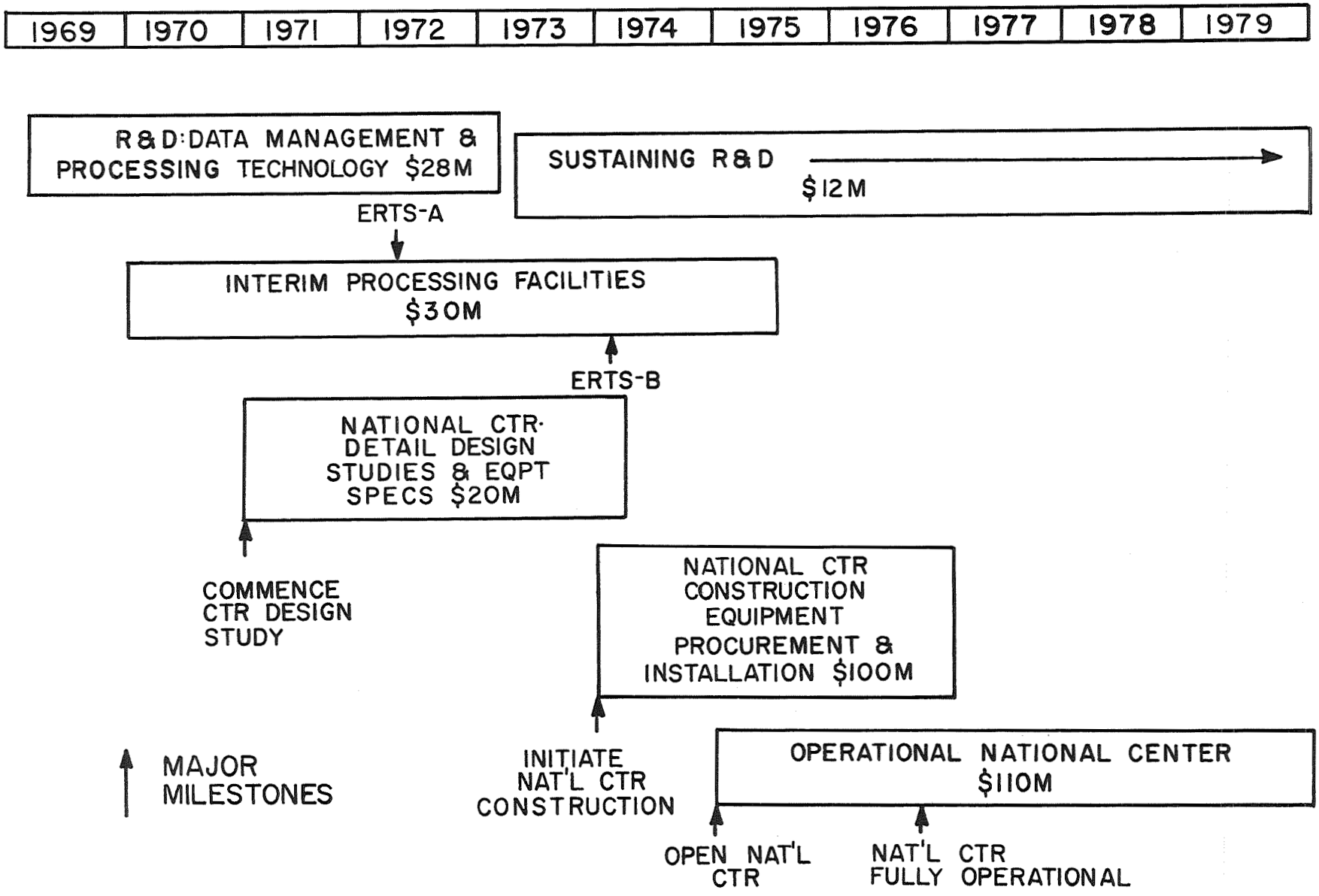

FIGURE 7.

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SECTION V

TECHNOLOGICAL TRENDS

Achievement of the aims of the National Center development program within the next decade is contingent upon a recognition of certain key trends. Generally, these fall into categories of increased user requirements or advancing technology. The first category includes:

- demands for higher data rates
- greater volume of data
- reduction in acquisition/processing/analysis cycling times
- more reliable data
- increased diversity in users/disciplines

The second category of trends represent state of the art developments exemplified by:

- large, faster computers with increased storage capacity and time sharing capability
- faster input/output equipment
- high density storage (satellite readout capability)
- more sophisticated software
- improved man/machine interface
- improved high resolution displays
- greater use of parallel processing systems

- greater emphasis on semi-automatic and automatic image processing (enhancement, normalization calibration, annotation and interpretation)

- near-real time adaptive command and control

The degree to which advancing technology is integrated with user requirements will be critical to the success of the overall program. A strong factor in this regard will be a continuing R&D program to provide for timely and effective integration of advanced technology.