FINAL REPORT OCTOBER 1970

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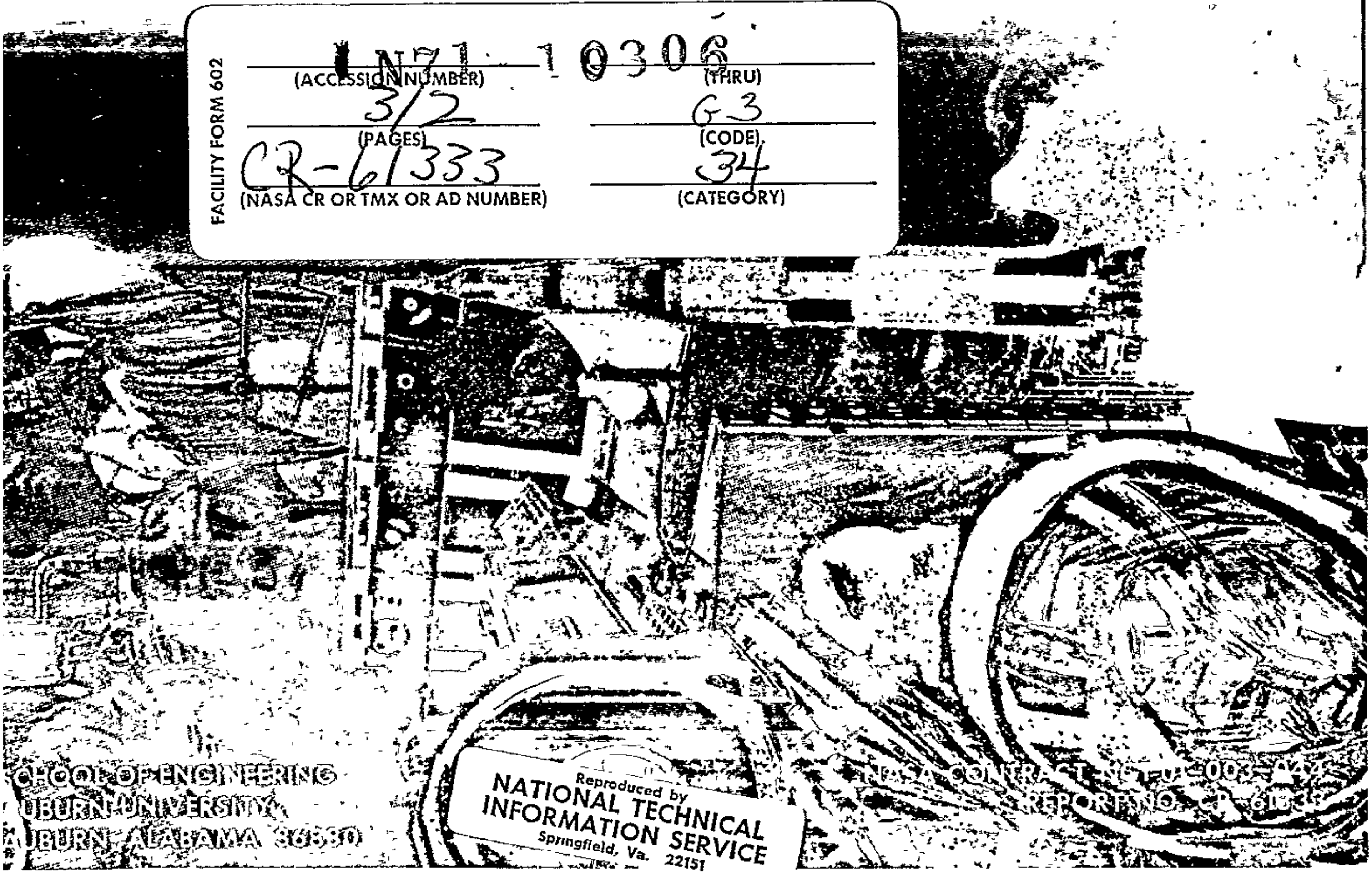
UNISTAR*

*User Network for Information Storage, Transfer, Acquisition and Retrieval

Prepared under NASA AUBURN-ASEE SUMMER FACULTY FELLOWSHIP PROGRAM IN ENGINEERING SYSTEMS DESIGN



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UNISTAR

User Network for Information Storage, Transfer, Acquisition, and Retrieval

FINAL REPORT
CR-61333

Prepared Under

CONTRACT NGT 01-003-044
UNIVERSITY AFFAIRS OFFICE HEADQUARTERS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

with the cooperation of

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

and

PROGRAM DEVELOPMENT
GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

AUBURN UNIVERSITY ENGINEERING SYSTEMS DESIGN
SUMMER FACULTY FELLOWS

OCTOBER 1970

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ABSTRACT

UNISTAR, an acronym for User Network for Information Storage, Transfer, Acquisition and Retrieval, represents a management system for scientific and technological information under the executive branch of the United States Government and a training exercise in the systems approach.

The information management problem — the acquisition of data, the analysis of data, and the dissemination of data as information — pervades the sociological, political, and technological aspects of our national goals and priorities. A summary of the salient points of this study indicates that:

- A national policy on the goals and purposes of an information management system (IMS) must be established.

- Although other Government agencies [such as the National Science Foundation (NSF), the Atomic Energy Commission (AEC), and the Department of Defense (DOD)] could provide a prototype IMS, the National Aeronautics and Space Administration (NASA) seems to be in a unique position to provide leadership to develop an IMS for space-related data. The IMS developed by NASA should be heavily user oriented and should be a model IMS for other data groups.

- A truly useful IMS should assume an active as well as the usual passive role in handling information. Depositories, such as libraries, perform a passive role in the management of information in that the user must ask for a piece of information before it is forthcoming. It should be possible to entice or actively encourage users to take advantage of the available information.

- The leaders in the scientific-engineering community will naturally develop on IMS that will serve their needs. To truly benefit mankind, equal emphasis should be placed on seeing that the entire educational community is well served by an active IMS, because educators are the obvious group through which information can be transferred to the world community.

Although the final report on Unistar emphasizes the preliminary design aspects of an IMS, the participant's exposure to the training exercise in systems engineering was the most important part of the summer program. The success of the training exercise in systems engineering is perhaps best conveyed by the following unsolicited comments given at the close of the final presentation by one of the participants at Morris Auditorium, Marshall Space Flight Center, August 26, 1970:

"We thought we were in trouble when we first started to use the systems approach, but with the program behind us, I think that all of us have become some sort of true believer. Systems engineering fosters an intellectual 'give and take' that is particularly well-suited to handling the complicated interrelationships that are inherent in so many of our contemporary problems.

"The problem of designing an information management system to which we applied the systems engineering approach this summer cuts across various academic disciplines. It is the stuff of our real world. Such problems are the outgrowth of our complex technological society. They seem insolvable at first glance but they demand solutions.

"At the beginning of our study the term 'information management' itself posed a problem. What was meant by it? We were helped in our understanding by a wide spectrum of lecturers from NASA, other Federal agencies, the Congress, libraries, and private industry. In addition, we did a vast amount of reading ourselves in the technical literature on the subject. It is astounding how much 'information on management' 19 energetic professors can amass in a relatively short time. In group meetings, we subjected our ideas, drawn from our individual expertise and reading, to discussion and analysis by the entire group. The dynamics of this group interaction led to a clarification and refinement of our ideas and thoughts. Although tempers became frayed occasionally, we have shown restraint and have respected each other's point of view, while not always agreeing with it. There are frustrations in this method but, having experienced them, I think that we will be better equipped in the future to deal with them in similar situations.

"For a good part of the program we did not prejudge solutions because this is the very essence of the systems approach. It permitted the introduction into our thinking of many different ideas and the exploration of many alternatives. As a result, when the limitations of time necessitated a coalescence of our views, the crystallization took place easily, with a minimum of argument.

"The timing of this coalescence was critical to the program. If it had occurred too late in the time frame of the program, there was danger of panic. On the other hand, too early a consolidation would have led to a limited transient solution. I think that the staff directing the program helped the group to bring its ideas to fruition at just the right point in time.

"In closing, I speak for all the 1970 summer faculty fellows when I say that this has been a very enlightening, worthwhile summer. We are grateful to NASA and the American Society for Engineering Education for making it possible. I know that our stimulating experience with systems engineering has encouraged many of us to try this approach in interdisciplinary courses and programs at our home institutions."

PREFACE

Program Description

The National Aeronautics and Space Administration and the American Society for Engineering Education (ASEE) have sponsored faculty fellowship programs in Systems Engineering Design for the past several years. NASA, having used and developed this systems approach and realizing its general usefulness, has shared its experience with the educational community through Summer Faculty Fellowship Engineering System Design Programs conducted jointly by a NASA center and a cooperating university. Four such programs were conducted during the summer of 1970:

- Marshall Space Flight Center — Auburn University
- Langley Research Center — Old Dominion College
- Manned Spacecraft Center — University of Houston
- Ames Research Center — Stanford University

The George C. Marshall Space Flight Center (MSFC), Auburn University, and the University of Alabama conducted two systems design programs in 1967 and 1969, and MSFC and Auburn University conducted the 1970 program reported herein.

Each program uses a "real-world" training exercise to give the approximately 20 faculty participants an opportunity to test the approach and live through, and evaluate, the group dynamics of the effort. The training exercise has an added advantage in that each center and NASA, through sharing the support of the programs, benefit from interaction with faculty. The result of the training represents an unbiased study and opinion on a topic of interest to NASA. Each participant then carries this experience to his home institution where either he may develop class projects that use a similar approach, or he, with others, may select a project to involve faculty and students to solve a real problem using this approach. An outstanding example of "spin-off" is an effort planned for 1971 by "graduates" of the MSFC-Auburn-Alabama 1969 program. Dr. Ordean Anderson and Professor Mel Forthun of North Dakota State University are developing a systems approach, faculty summer program applied toward development of the Red River Basin of the North. This program is patterned after their experience in 1969 at MSFC. This project, funded by the Office of Water Resources, shows a concrete result of involvement with NASA and demonstrates "spin-off" of a technique from NASA applied to the civilian economy. Dr. Anderson has stated that without the 1969 experience, their project would have been next to impossible.

The Systems Approach

The "systems approach" has been adopted as a more general terminology than "systems engineering" to describe the philosophical approach to the solution of complex multidisciplinary problems. The definitions given to the systems approach are as many as the definitions of beauty, which exists in the eye of the beholder. Two encompassing definitions for consideration are: (1) "the solution of a complete problem in its full environment by systematic assembly and matching of parts to solve the whole problem, in the context of the lifetime use of the system or plan, considering all aspects";[1] or (2) an optimal solution or strategy to a complex multidisciplinary problem. Figure 1 shows the steps involved in the systems approach and emphasizes the four steps of the approach: (1) translation, (2) analysis, (3) trade-off, and (4) synthesis. These terms are defined as follows:

Translation — determining a common language (or terminology) for the statement of problem objectives and constraints that are acceptable to, and understandable by, all participants.

Analysis — determining as many alternative approaches as possible to solve the problem as a whole or to solve portions of the problem.

Trade-off Study — applying selection criteria and constraints to choose the approaches or tasks to be implemented.

Synthesis — a combination of the analysis and trade-off phases to achieve a "best" solution to the problem statement that was structured during the translation phase.

Figure 2 shows the steps within the approach, and Figure 3 shows that a systems approach consists of a sequence of cycles. Each succeeding cycle gives more detail to the developing strategy or solution. These diagrams

1. Frosch, Robert A.: A New Look at Systems Engineering. IEEE Spectrum, Vol. 6, No. 9, 1969, p. 24.

THE SYSTEMS APPROACH (Deductive/Inductive)

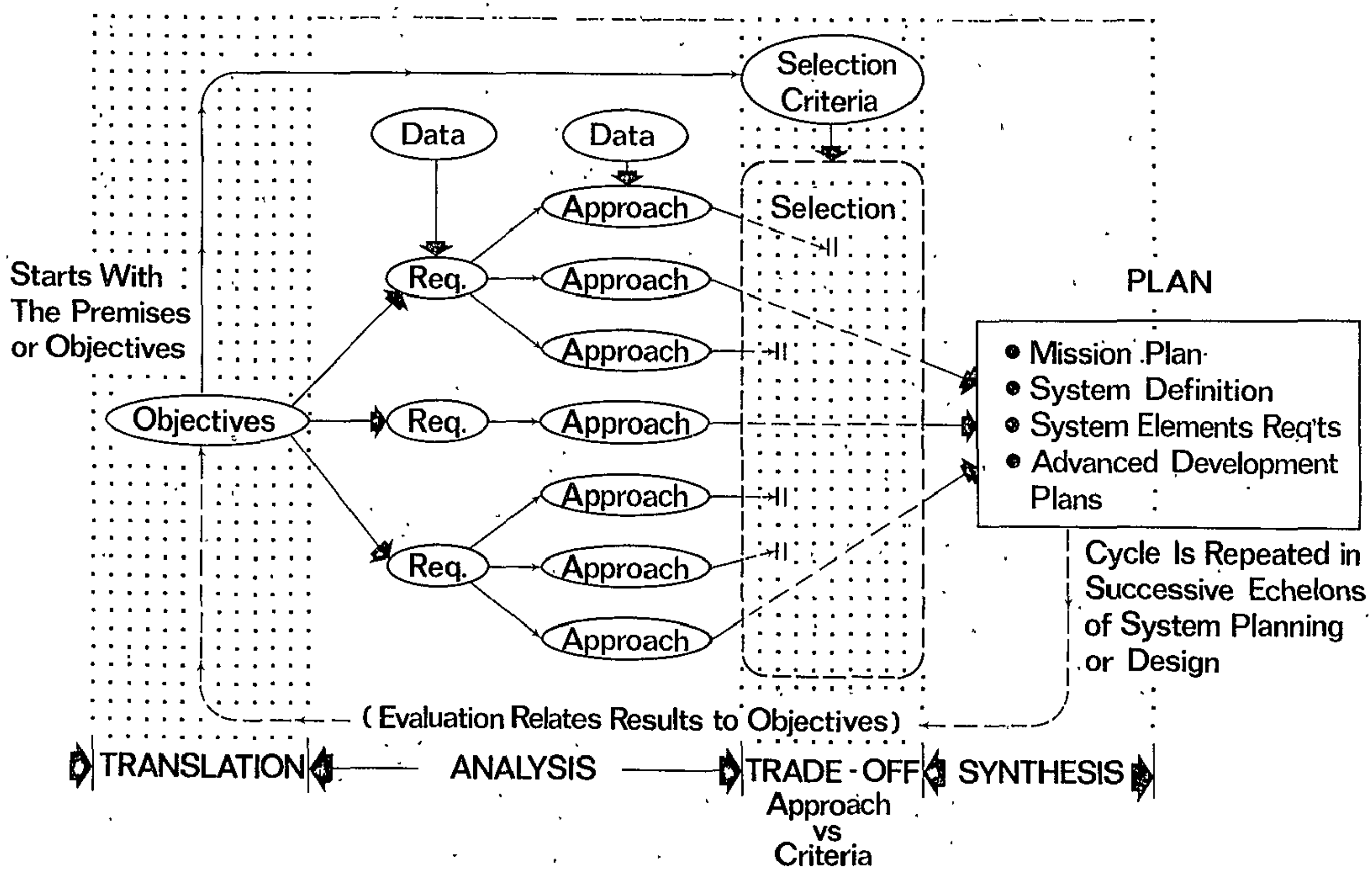

Figure 1. Steps in the systems approach.

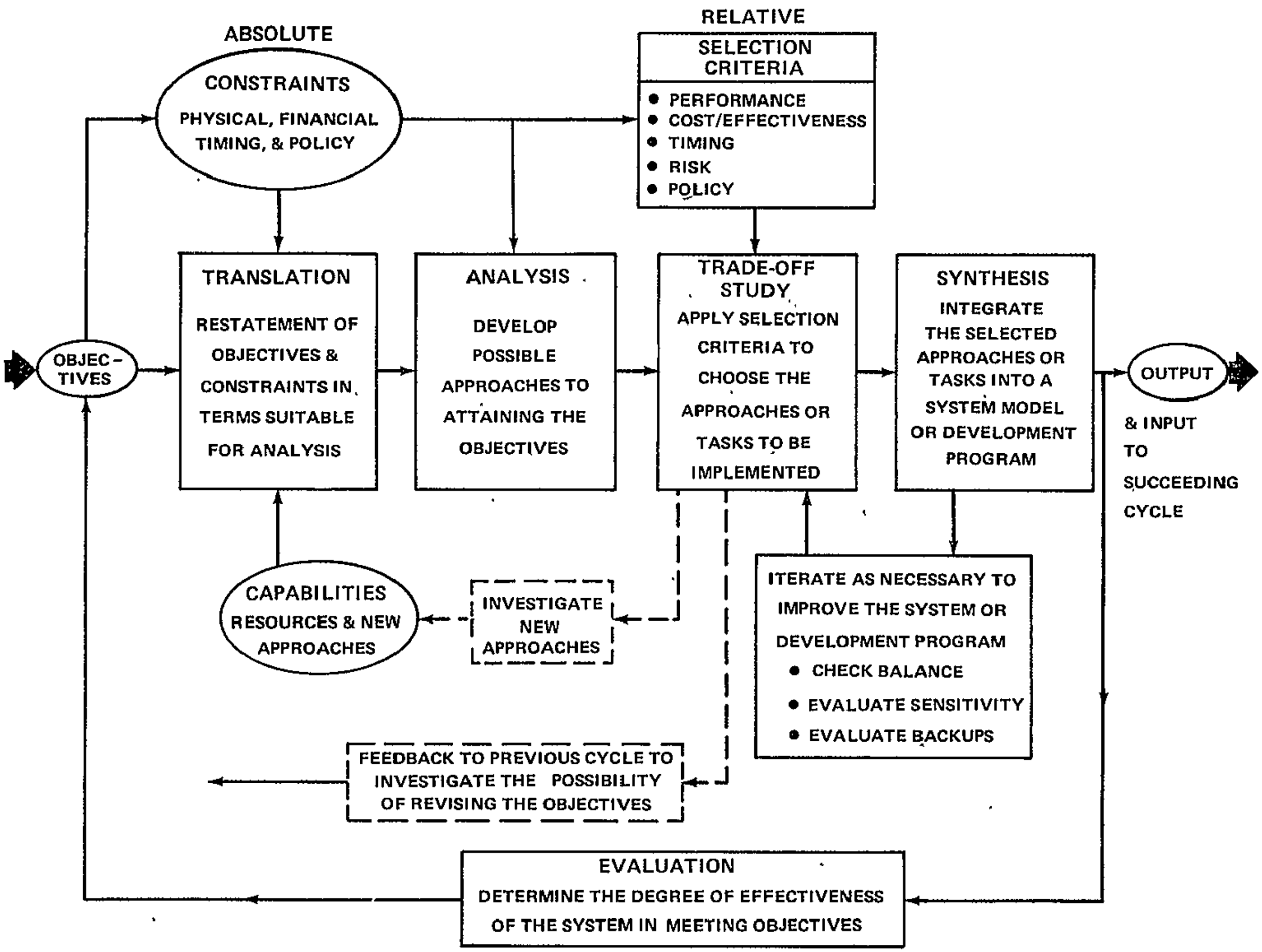

Figure 2. Steps within the systems approach.

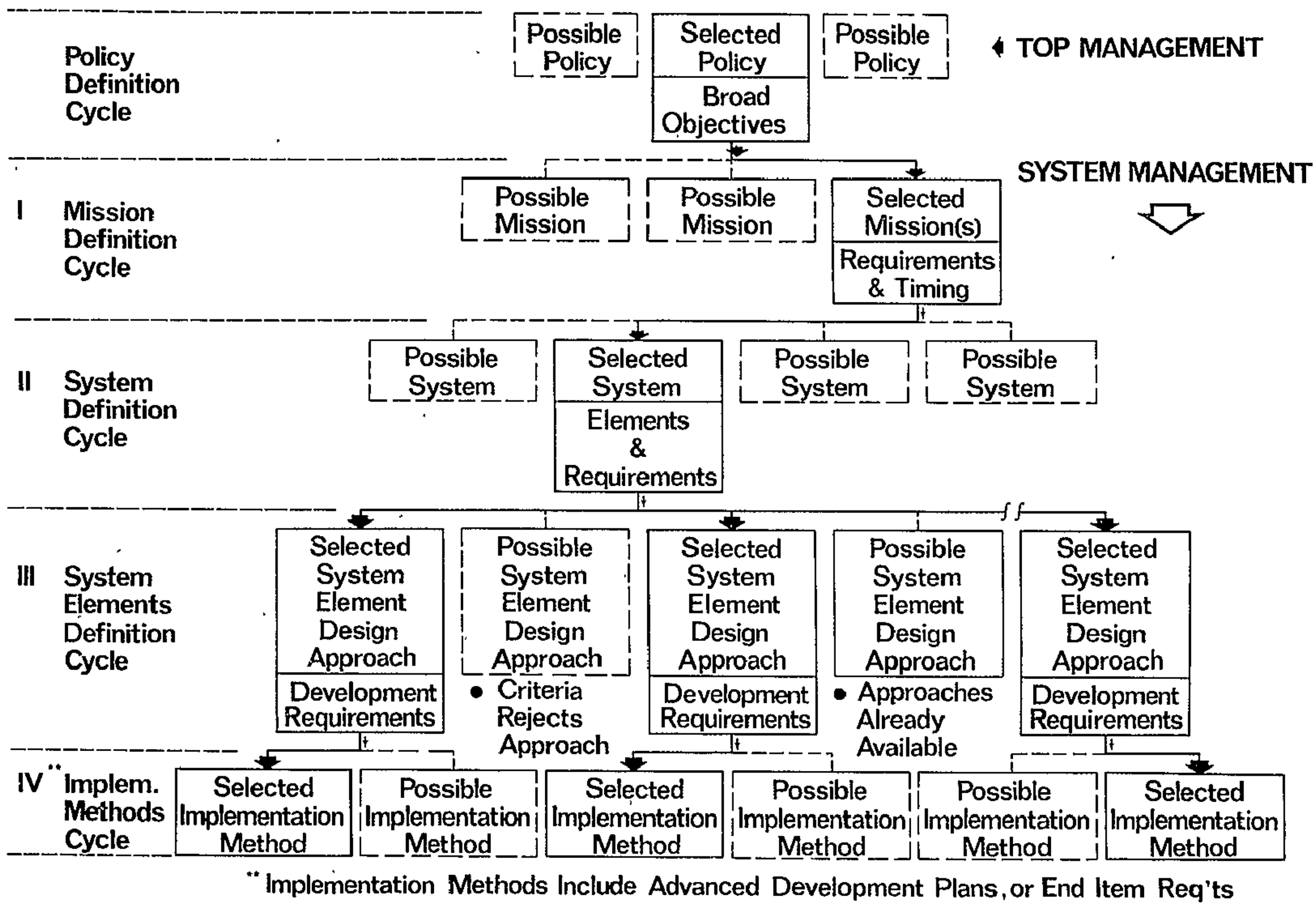

Figure 3. The concept of sequence of cycles.

do not indicate the necessity for involving many disciplines, nor do they indicate the necessity for attention to the group dynamics involved in progressing to a solution, strategy, or plan, whether it is embryonic or a final system.

MSFC-Auburn Systems Approach Experience

The training exercise selected for study by the 1970 MSFC faculty participants has centered on the theme of an information management, dissemination, and utilization system. No constraints or criteria were given to the participants during the 11-week study period. The statement provided the participants was as printed in the program brochure:

> "The participants will be involved in the complete systems design of an information management, dissemination, and utilization network. . . . . it is envisioned that an information system would be applicable to many non-space related activities."

The selection of the topic for the 1970 program was an outgrowth of the study performed the previous year at MSFC. In 1969, the faculty participants applied the systems approach to the concept of a manned orbiting laboratory.[2] In their study, it became apparent that the information management problem would be substantial. However, the general problem associated with the transfer of information is not limited to the space effort but is universal in nature; for that reason, it is particularly well suited for consideration by a summer group with multidisciplinary backgrounds. The American Society for Engineering Education provides the primary vehicles for contacting faculty concerning the forthcoming summer programs through announcements in its Engineering Education periodical and through mailouts to its membership. Since the nature of the problem involved more than just the engineering community, an additional effort was initiated by the Directors of the MSFC program to secure participants from outside the physical sciences. Individual letters were directed to some 300 college and university presidents seeking their assistance. As a result, the 19 faculty participants in the 1970 program represented a wide cross-section of the academic community with engineers being in a minority.

The initial approach to the problem was to decide on a general objective and the requirements for the objective, and then to develop alternative

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2. STARLAB — an Orbiting Space Technology Applications and Research Laboratory. Auburn, Report No. CR-61296, NASA Contract NSR 01-003-025, August 1969.

approaches for trade-off. It is interesting to note that the wording of the objective changed in the course of the program as a result of the learning process during interaction with seminar speakers and during group discussions. The initial objective reflected the consensus of opinion based on limited knowledge and influenced by a feeling that the summer study should begin as quickly as possible; this consensus was reached at the end of the first week of the program when the thinking of the participants ranged from the implementation cycle of the problem to the policy-definition cycle. As the program progressed, it was realized that the information problem was immense and that no apparent emphasis had been given to defining alternative policies for handling the problem on a national basis.

The lack of policy definition or alternative policies prevents development of the true systems approach. When they realized that top policy had not been dictated, the participants believed that their contribution to the information management problem would be to explore the problem, define the various aspects of the problem, and establish alternative approaches of solution. This evolutionary attack on the problem resulted by avoiding prejudgment of the solution (a key facet of the systems approach). The participants had an instructive training exercise in the systems approach since their work resulted in: examining many ideas from a multidisciplinary viewpoint; making decisions subsequent to examination; and debating the various aspects of the problem.

The participants divided themselves into four Task Groups and established a Glossary Committee, as is shown in the program organizational chart of Figure 4. The Glossary Committee, which was organized during the first week, was necessary because of the nature of the problem and the variety of disciplines of the participants. It should be noted that the Project Leader and Task Group Leaders were elected three times during the course of the program, and that the Task Groups were not established until the end of the second week. The titles of the primary Task Groups and their functions coincided with the problem requirements. The system effort consisted of essentially three phases or periods (not coincident with the three equally spaced periods of leadership held by the Project Leaders and Task Group Leaders).

The first phase involved a series of intensive lectures by speakers from industry and government. Members from the Committee on Scientific and Technical Information were invited to speak on the various types of government information sources, processors, and users and to comment on how the Federal Government was trying to cope with the information problem in

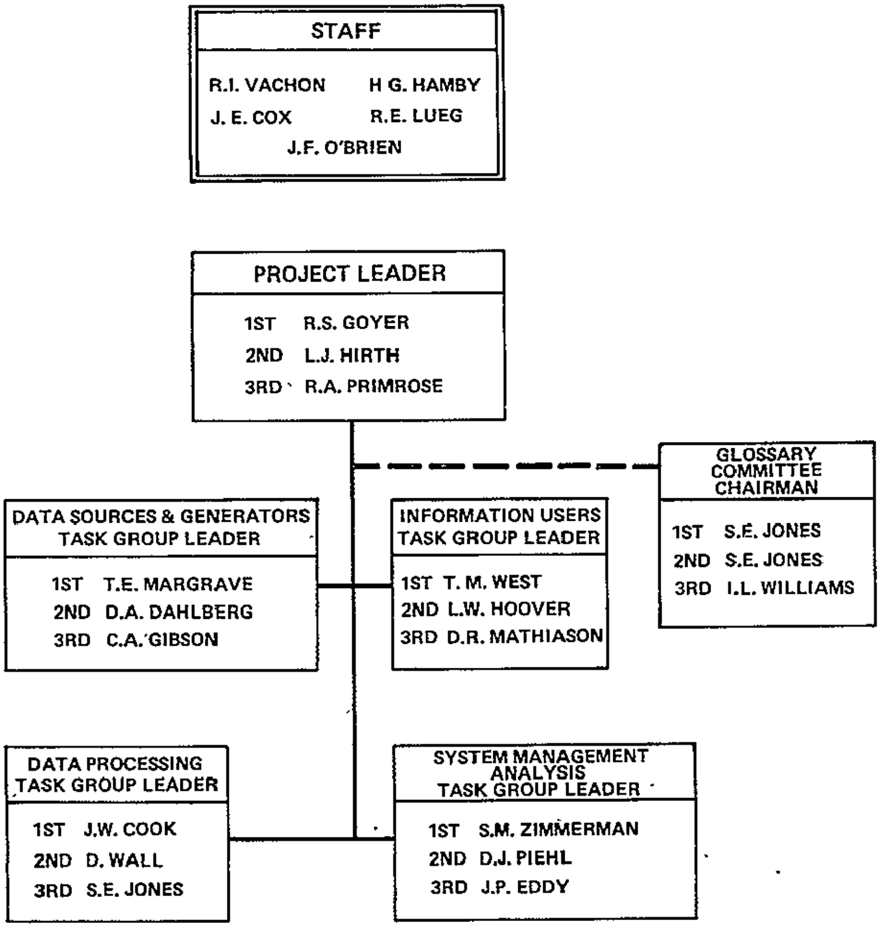

Figure 4. Program organizational chart.

general. Speakers from industry provided the necessary viewpoints directed to the handling, transmitting, and processing of data and the utilization of information. As spokesmen from each sector were heard, the problem complexity grew.

The second phase consisted of translation and analysis. The groups questioned their function and purpose. The domain of the system was explored. Some wanted a global system that was run by an international group while others wanted a system restricted to SKYLAB. The final phase of trade-off and synthesis saw the ideas of both groups blending, and concepts that were applicable in one area were seen to be applicable in other areas.

Three working visits were conducted during the summer effort. These were at the: (1) Manned Spacecraft Center (MSC), (2) Kennedy Space

Center (KSC), and (3) Goddard Space Flight Center (GSFC) and NASA Headquarters. The entire group visited MSC and KSC, and six representative members of the group visited GSFC and NASA Headquarters. These working tours provided an overview of the capabilities within NASA for data handling, processing, dissemination, and utilization. The Redstone Scientific Information Center (located at MSFC) provided input on the operation of a large information depository and retrieval system.

Group Dynamics

The human elements associated with the working philosophy of the systems approach are not apparent, and one cannot fully appreciate the operation from mere discussion or from seminars examining the operation. Furthermore, the administration and management requirements of a systems approach are not apparent. It is one thing to study human reactions in a detached academic way and still quite another dimension to live through the group dynamics of talented, creative professionals of different disciplines striving toward a solution of a complex problem. The professor who tries to teach the systems approach is inadequately prepared if he has not lived through a systems approach experience to a "real-world" problem. The group dynamics, a key to the success of the systems approach, can be predicted. Although one cannot always stimulate a predictable result, one can identify the various stages of development.[3] The group expanded and contracted the scope of the project. Ideas were created and evaluated. Premature evaluation often led to bruised egos and some reaction. The "not invented by me" attitude gave way to "let's list all approaches and trade-off" as time went by. The group was given freedom to think and explore, and then toward the last, when the participants were introduced to the threat of having to present their ideas to the public, the group performed and learned. The forte of the program at MSFC is the Center's willingness to give the participants a free hand and let them experience and discuss the administrative and personal interaction aspects of accomplishing a difficult task. The support of MSFC, and each person at MSFC with whom the group has interacted during each summer of these programs, has been cordial, helpful, and, in one word, outstanding. Only time will reveal the contribution of the 1970 design group to NASA and MSFC.

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3. Vachon, R.I.; et al.: A Training Exercise In Systems Engineering Design. Engineering Education, Vol. 60, No. 8, 1970, pp. 819-822.

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ACKNOWLEDGMENTS

The successful completion of project UNISTAR would have been impossible without the enthusiastic cooperation of the offices and personnel of the Marshall Space Flight Center, and the many government agencies and individuals who participated in the program. It is impossible to give recognition to each individual; however, we have attempted to list certain speakers and others who have been most instrumental in the success of the project. These are listed on the following pages.

We are particularly indebted to Dr. E. F. M. Rees, Director of MSFC; Dr. William Lucas, Director of Program Development; Dr. Ernst Stuhlinger, Associate Director for Science; and Mr. Marion Kent, University Affairs Officer. Mr. Herman Hamby, our Co-director, deserves our particular appreciation as does Mr. Jim Downey, Chief of Mission Payload and Planning of Program Development. Mr. W. R. Payne of MSFC has been very instrumental in helping with many support activities, including much of this final report.

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Others to be acknowledged for their assistance on this project are given in the following list.

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GLOSSARY OF TERMS

The definitions of terms presented here are to clarify their usage in the UNISTAR final report and are not intended for use elsewhere.

acquisition	the process of gathering or receiving
administration	that level of organization charged with responsibility for decision
aerospace	the earth's envelope of air and the space beyond
analysis	examination of the parts of a unit and their interrelations
applicability	the quality or state of being put to use
assimilation	the process of absorption, internalization, or incorporation
bit	the smallest possible piece of data in computer language (a choice between "yes" and "no")
byte	a series of bits
channel	the pathway through which data or information is conveyed
communication	shared behavior or response (as contrasted to message or transmission)
commutation	sequential sampling method for identifying data on a time-sharing basis
computer	a machine for performing calculations and programmed transformations on data
configuration	the contour produced by the relative disposition of the parts of a whole
constraint	an imposed limit

control	that which directs or regulates an activity
corridor	a prescribed pathway or band
criterion	a standard of comparison or measurement
cybernetics	the science of coordination, regulation, and control in the animal or the machine
data	units of sensory observation
data bus	a single set of metallic conductors used to transmit multiple signals
data compression	an operation that results in a decreased volume of data
data reduction	systematic consolidation or transformation of data
data redundancy removal	selectively ignoring data that does not contribute significant change
data source	that which generates an observation in the form of an energy output
digitizing	expressing an analog measurement of a variable in discrete units
discrete	discontinuous or distinct
discrimination	the separation of one stimulus from another
dissemination	the act of distributing or dispersing
document	a medium containing information
documentation	the collection, organization, storage, citation, and dissemination of documents
evolutionary	developing change in a certain direction

experimental design	the arrangement and manipulation of variables in an experiment
feedback	influence of a response on the preceding stimulus or operation
figure of merit	relative number or benchmark used to compare alternatives
flexible	adaptable
format	general plan of organization or arrangement of material
generator	the initial source of energy or data
hard data	data that are transported physically (as contrasted with soft data)
hardware	physical equipment as contrasted to procedures or computer programs
information	data that is meaningful from the user's viewpoint
input	energy (data, information) that enters a system
integration	the process of synthesizing components into a larger system or unit
intelligence	the capacity to comprehend and reason
interface	a plane of interaction between units
iteration	repetition of an operation until by successive approximation a satisfactory standard is achieved
management	judicious and systematic use of means to accomplish an end
message	an ordered array of symbols intended to result in communication

modular	made up of an assembly of functionally associated parts
operable	implying a state of readiness
operational	pertaining to the performance of an object or system
optimize	to select a superior strategy subject to a given set of constraints
organizing	arranging elements in a systematic structure
output	the product of a system
parametric analysis	definition of problem characteristics or variables
point design	design that is built around a particular parameter of a system
principal investigator	person or group charged with primary responsibility for a research project
process	a series of actions or operations conducive to an end
processing	subjecting to a given procedure
proprietary	having exclusive right
reaction	the response effect to a stimulus cause
real time	data transfer suffering no delay in time except that caused by sensor response, transmission, and commutation
redundancy	the existence of repetitious means or data for accomplishing a given task
sensitivity analysis	study of system behavior when design parameters are varied

sensor	that which selectively detects energy patterns
soft data	data that are transmitted electromagnetically
software	computer programs and procedures
source	a point of origin or emanation
space	the part of the universe lying outside the limits of the earth's atmosphere
space station	an orbiting, manned space vehicle
spin-off	unscheduled side effects or benefits
state-of-the-art	current status of knowledge or technology in a given discipline
synthesis	the systematic composition or combination of elements to form a whole
system	an aggregate of interrelated components or elements comprising a unified whole
systems analysis	definition of a system by deductive/inductive iteration
transmission	the projection, radiation, or movement of energy or data from one point to another
useful	serviceable; having utility
user	a consumer
window	any interval in a linear continuum

<u>Glossary Committee:</u> S. Jones, Chairman
R. Goyer
L. Hirth
R. Primrose
I. Williams

LIST OF ACRONYMS

ACS	American Chemical Society
AE	Atmosphere Explorers
AFO	Announcement of Flight Opportunity
ARAC	Aerospace Research Applications Center
ATM	Apollo Telescope Mount
CAC	Current Awareness Center
CFSTI	Clearinghouse for Federal Scientific and Technical Information
COSATI	Committee on Scientific and Technical Information
DDC	Defense Documentation Center
DOD	Department of Defense
EROS	Earth Resources Observation Satellite
ERP	Earth Resources Program
ERTS	Earth Resources Technology Satellite
ESSA	Environmental Science Services Administration
ETV	Educational Television
HEAO	High Energy Astronomy Observatory
IAC	Information Analysis Center
IF	Infrared
IMS	Information Management System
KWIC	Key Word in Context

NERAC	New England Research Applications Center
NET	National Educational Television Network
NIAC	National Information Analysis Center
NMC	National Meteorological Center
NRCST	National Referral Center for Science and Technology
NSSDC	National Space Science Data Center
OAO	Orbiting Astronomical Observatory
OART	Office of Advanced Research and Technology
OGO	Orbiting Geophysical Observatories
OSO	Orbiting Solar Observatory
OSSA	Office of Space Science and Applications
PE	Physics Explorers
PI	Principal Investigator
RAE	Radio Astronomy Explorer
RASH	Request Accounting Status and History
RSIC	Redstone Scientific Information Center
SAS	Small Astronomical Satellite
SATCOM	Committee on Scientific and Technical Communication
SIE	Scientific Information Exchange
UNISTAR	User Network for Information Storage, Transfer, Acquisition, and Retrieval
UV	Ultraviolet

FOREWORD
THE PROBLEM — DESCRIPTION AND RATIONALE

Development of Background Material

The systems approach exercise began by developing a common background through a series of seminars on information sources, existing information management systems, and information user problems. It would have been impossible during the 11-week period to learn of all sources and all systems. Thus, the seminars were used to characterize the types of sources, processors, and users. The study anticipated a changing environment and included latitude for such change.

Seminar speakers were recruited from government and industry. The chairman of the Committee on Scientific and Technical Information was contacted as an initial step. From the membership of COSATI (shown schematically in Fig. 5), a number of speakers (noted in the listing of speakers) were invited to discuss various aspects of the information problem. In addition, each member of the President's Cabinet was contacted and asked to designate a specific contact in his department. The majority of the Cabinet members provided contacts, some of which coincided with persons suggested by COSATI. The interesting point discerned from this approach was that every area of the Federal Government is concerned with the problem of information management, and although there are many aspects common to each problem, each problem is approached differently. This report takes note of the differences in approach and tries to identify requirements common to any information management problem.

The legislative branch of the Government was invited to participate in developing the program background. Senator Jennings Randolph (Democrat — West Virginia), a strong proponent of technology utilization; Representative John W. Davis (Democrat — Georgia), a member of the Science and Astronautics Committee; and Representative Roman D. Pucinski (Democrat — Illinois), an advocate of a national information system, presented seminars to the faculty group. The Information Industry Association was represented by Mr. Saul Herner who presented the information problem in terms of those engaged in this field as a business. Mr. Douglas Miller of Eastman Kodak presented a seminar on commercial systems for handling information, and Mr. Jim Garrison of Stanford Research Institute indicated some of the international aspects of systems management. The present NASA picture with

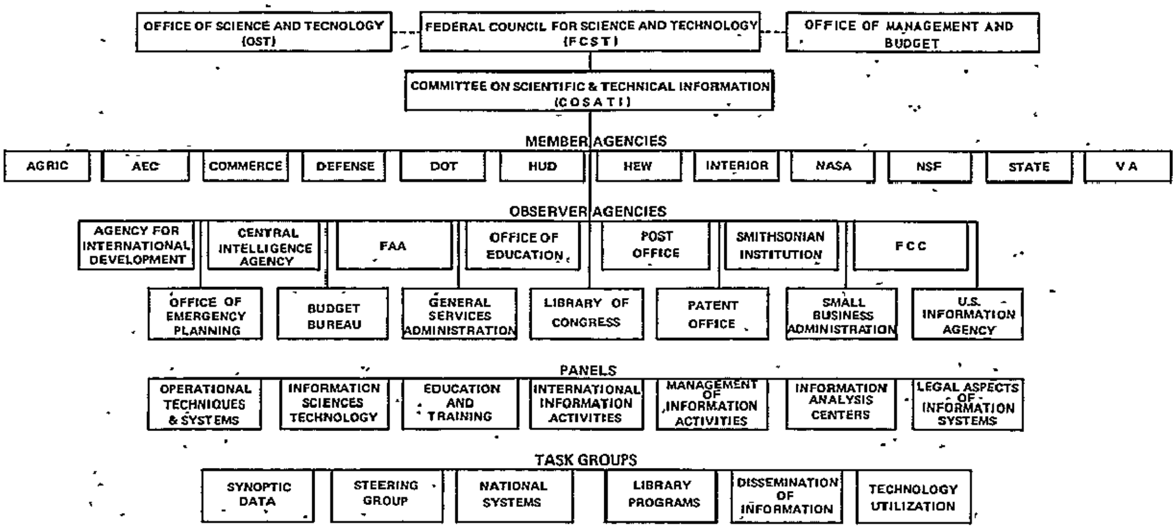

Figure 5. COSATI organization.

respect to experiments in space, the space shuttle announcement of flight opportunities, and NASA interaction with the principal investigator associated with experiments were covered by Mr. K. K. Dannenberg, Mr. James Downey, and Mr. Max Nein. The philosophy of information management pertaining to the space station and space base was discussed by Mr. Tom Barr. Additional data on particular information management systems for SKYLAB were presented by Mr. Andrew Adelman of IBM and Mr. Charles Beers of MITRE. Laser communication was a subject of keen interest explored with Dr. Joseph Randall of MSFC. Dr. K. H. Powers, Director of the RCA Communications Research Laboratory at Princeton, provided valuable inputs on the use of high resolution television for the consumer market.

Information transmission problems of the Post Office Department were discussed by Mr. Donald Haag. The possibilities of electronic mail and use of satellites were explored, and interest in effectively using the Post Office Department in an information management system was explored. The

2. Information costs are but a few percent of scientific and technical work and this represents 0.1 percent of the gross national product.

3. The diversity of user needs and the changes that simultaneously force specialization and a broader horizon on many scientists, engineers, and practitioners have been too little recognized and their implications are too little appreciated. Their importance is greatest for current planning and future management.

4. A reasonably effective, increasingly challenged, pluralistic system of information exchange exists today and continues to develop. There is need for guidance of its evolution for increasing recognition and for acceptance of responsibility by all the organizations — governmental, scientific, technical, and for-profit — involved, for more effective coordination and for broader understanding of problems and opportunities.

5. If it could be economically feasible, each worker should have his own hand-tailored information system or systems.

6. What can be done for groups of reasonable size, of a thousand or so, is a different matter. It is already feasible, and the need is urgent, to provide specialized access.

7. Such special user-oriented services would build upon the foundation of journal, book, and technical report literature and upon access services already developed.

SATCOM recommended that a joint commission on scientific and technical communication, which is responsible to the Council of the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE), be established. This recommendation from a group sponsored by NAS-NAE is not surprising. Another approach may provide the optimal way to solve the information management problem. The SATCOM report contains general statements and presents a good background summary of the problem.

Even though the SATCOM recommendations are good, there is a notable lack in presentation of practical ways to disseminate information for the general benefit of the public. Being educators, the authors of this UNISTAR report are particularly concerned about the role of educators in any meaningful plan for the utilization of information. The goal of concentrating on the needs or desires of the top 1000 or so leaders in the scientific-engineering community is much too narrow and confining if the country is really going to

c. the development of internationally compatible information systems, leading to maximum interchange of the world's scientific and technical information; and
d. the development and application of information — processing technology."[4]

Similarly, the goals of SATCOM are stated in the following way:

> "The creation of SATCOM was a move toward specific implementation of some general policies recommended by several previous study groups. Its mandate called for, first, a very broad and detailed study of the many ways in which information is handled and facts and insights are transmitted, and second, the formulation of specific recommendations to private organizations and to the federal government, particularly with regard to the relation of federal to private activities. Ample time was available, and SATCOM's nongovernmental base enabled us to consult a representative sample of scientific-and-technical-communication activities."[5]

The results of COSATI studies are transmitted to the Federal Council on Science and Technology for approval. Approval, if granted, is followed by possible implementation within agencies or by publication of reports. The COSATI recommendations are recommendations only, as COSATI has no power to enforce recommendations. This fact does not detract from the many good studies and recommendations of COSATI, but does show the need for such an organization to have the power to promote change.

Salient comments drawn from SATCOM reports concerning technology and information were selected as follows:

1. The national expenditure on research and development, private and public (1969), is above $27 billion a year in the United States.

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4. Progress in Scientific and Technical Communications. COSATI 69-5, L.C. Card 68-60748, PB-186-400, 1968, p. 1.

5. A Pressing National Problem and Recommendations for its Solution: A Synopsis. Scientific and Technical Communication, (NSF C-310, Task Order III), National Academy of Sciences, 1969, p. 12.

John Crerar Library in Chicago, the Massachusetts Institute of Technology Science Library, the Library Science and Technology Division of the New York Public Library, the University of California Biomedical Library at Los Angeles, etc. For a more extensive listing of the major libraries, see A Brief Guide to Sources of Scientific and Technical Information by Saul Herner, LC 73-114299, Information Resources Press, Washington, D. C. (1969).

These various depositories have accepted a passive role in the management of information. On request they provide books, drawings, technical reports, etc., and a variety of services including copying, microfilm and microfiche copies, inter-library loans, referencing, translations, bibliographic services, and literature surveys. Some of these services are provided only for a fee.

INDEXING SERVICES

Some groups or agencies perform the valuable function of telling the user where he can find specific items of information. These include the Scientific Information Exchange of the Smithsonian Institution, the National Referral Center for Science and Technology within the Library of Congress, and abstracting services such as the Chemical Abstracts, which are published by the American Chemical Society.

ADVISORY SERVICES

Two prominent groups perform in an advisory capacity in regard to the management of scientific and technical information. These are the Committee on Scientific and Technical Information, which is under the Federal Council for Science and Technology, and the Committee on Scientific and Technical Communication, which was established by the National Academy of Sciences and the National Academy of Engineering.

COSATI is concerned with:

> "a. The evolving scientific and technical information systems in this country — whether or not under Federal management;
> b. the ability of Federal agencies to utilize scientific and technical information effectively and efficiently in carrying out their missions;

Scientific Information Exchange operated by the Smithsonian Institution was reviewed by Dr. Frank Kreysa, and the Library of Congress Science and Technology Division was discussed by Mr. Marvin McFarland. Mr. Charles De Vore presented a comprehensive picture of COSATI and pointed out a number of projects of COSATI and recommended avenues of study. Dr. Ruth M. Davis, Director of the Lister Hill National Center for Biomedical Communication, gave an excellent overview of the practical aspects of how information systems could provide better communication services within the medical world. The Defense Documentation Center was reviewed by Dr. Herman Miles who pointed out the complexities of handling vast volumes of data. The Environmental Science Services Administration's participation in the overall information management problem and the techniques used by ESSA were discussed by Mr. Charles Bristor. The requirements of 182 countries participating in the World Meteorological Organization were reviewed.

Existing Organizations for Handling Information

The aforementioned speakers represent only a few of the more than 50 individuals who addressed our faculty participants in part or in toto. As a group, these speakers revealed that the management of information involves acquiring, processing, storing, transferring, retrieving, analyzing, utilizing, etc. Both governmental and non-governmental agencies are concerned with information management at various levels — some with broad scopes and some with narrow scopes. Some agencies are depositories of information, some act in an advisory capacity, and some provide an indexing service, while still other organizations analyze information for a wide spectrum of users.

DEPOSITORIES

Many depositories of scientific and technical information are now in existence throughout the United States and the world. In this country, these depositories include such federally supported groups as the Atomic Energy Commission Technical Information Division, the Clearinghouse for Federal Scientific and Technical Information, the Defense Documentation Center, the Educational Resources Information Center, the Library of Congress' Science and Technology Division, the NASA Scientific and Technical Information Division, the National Agricultural Library, the National Library of Medicine, the Neurological Information Network, etc. Other major resource collections that lie outside the domain of the Federal Government include the Franklin Institute Library, the Francis A. Countway Library of Medicine at Harvard University, the Iowa State University of Science and Technology Library, the profit from the available information resources. The top leaders need and should have a sophisticated information acquisition, storage, and retrieval system, but the general public is quite capable of making profitable use of information that is properly prepared for dissemination. As Mr. Lee G. Burchinal states:

> "The roles of the universities in strengthening communication programs are virtually ignored. Education and training programs for preparing future professionals, engineers, and technicians to use information systems effectively were not presented as significant ways for reducing user apathy. Continuing education is also given relatively short shrift."[6]

INFORMATION ANALYSIS CENTERS

More than 200 information analysis centers are currently providing digested and interpreted information for user groups, thus extending greatly the usual bibliographic services provided by libraries. There are about 300 information analysis centers now established, and approximately 120 of these are federally supported. The Panel on Information Analysis Centers (Panel 6) of COSATI defines an information analysis center as:

> "An information analysis center is a formally structured organizational unit specifically (but not necessarily exclusively) established for the purpose of acquiring, selecting, storing, retrieving, evaluating, analyzing, and synthesizing a body of information and/or data in a clearly defined specialized field or pertaining to a specific mission with the interest of compiling, digesting, repackaging, or otherwise organizing and presenting pertinent information and/or data in a form most authoritative, timely, and useful to a society of peers and management."

Furthermore,

> "in applying this definition to develop standards of reference for selecting the centers to be included as information analysis centers, the following criteria have been formulated:

6. A Critique of the SATCOM Report. Lee G. Burchinal, Director, Division of Information and Technology and Dissemination, U.S. Office of Education.

- The key activities are the analysis, interpretation, synthesis, evaluation, and repackaging of information for the purpose of enabling users better to assimilate the information or numerical data of a specific field.

- An information analysis center uses subject specialists to perform the analysis, evaluation, or synthesis.

- An information analysis center produces new, evaluated information in the form of critical reviews, state-of-the-art monographs, or data compilations and usually provides substantive, evaluated responses to queries.

- An information analysis center provides assistance to a community of users and not just assistance to "in-house" personnel.

  Excluded from consideration for this directory are the following types of information services:

- Management information services.
- Holders of raw data files.
- Conventional scientific or technical libraries.
- Abstracting, indexing, and accession services.
- Document depots.
- Mapping and charting activities.
- Regional and State information services (e.g., technological or agricultural utilization services)."[7]

Rationale to the Problem

A well-known, respected company uses the slogan "Progress is our most important product." No one doubts that knowledge and wise utilization of knowledge is the very cornerstone of enlightened progress. If civilization is to achieve noble goals and progress, then mankind must make effective and efficient utilization of the avalanche of knowledge engulfing it. The wisdom to use knowledge properly can be considered a pearl of great price, and mankind would be well-advised to treasure the proper use of knowledge. A system to manage information for the benefit of mankind should take top priority in the legislative bodies of our country, if not the world, and in the director groups of our professional and technical societies.

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7. Directory of Federally Supported Information Analysis Centers. COSATI-70-1, L.C. 73-606266, PB-189-300, 1970, p. iii.

The environment for the system is established in terms of time; anticipates technological and sociological change; characterizes users, processors, sources, and administrative alternatives; and establishes a charter for the system. Growth factors, problems, and phased planning are considered. On a world-wide basis, all sources, processors, and users of data could not be identified; however, definite patterns or groupings are self-evident. For any IMS to be truly worthwhile, the needs of the ultimate user must be given prime consideration. As an example, consider the following general identification of user groups: (1) the public, (2) the educational community, and (3) the scientific community.

There will be some user overlap in these three user categories. However, individual users will have different requirements, both as to what information is needed and how the information is presented. The layman may only want encyclopedia-type information about a given subject, whereas the researcher may wish an exhaustive literature search or an in-depth analysis on a particular subject area. The layman may be satisfied with a two- or three-page narrative, while the researcher may want an extensive report including a typed analysis, an exhaustive cross-referenced bibliography, microfiche, hard copy, CRT displays, interaction with an on-line computer system, etc.

There will be alert, intelligent citizenry in each of the three general groups who will use whatever information system is developed. These acknowledged leaders (whether they be politicians, statesmen, industrialists, educators, engineers, scientists, doctors, lawyers, businessmen, labor leaders, civic leaders, etc.) will take advantage of available information systems, but even they can benefit tremendously from a properly designed and managed information system.

The somewhat unmotivated, yet intelligent, citizenry needs to be challenged and stimulated if information systems are to serve him effectively. This should not seem surprising since the primary role of the educator is to use every means at his disposal to stimulate his pupils to study and learn. An information management system should not accept a lesser challenge.

Indeed, should not the goal of a really effective system for information acquisition and dissemination be to upgrade, worldwide, the educational opportunities for every world citizen? Perhaps the most efficient way to realize this altruistic goal is to work through the currently established and operating educational institutions. Continuous education of educators is of primary importance since they are, for the foreseeable future, responsible for seeing that appropriate knowledge is presented to the young and impressionable segment of society. In addition, educators should continue to exercise their responsibilities in offering continuing education to all segments and all levels of society.

In developing an extensive IMS, several factors need to be considered:

1. The system should not be subject to any arbitrary constraints that are of a vested-interest or politically motivated nature.

2. The system should be financed largely on a national or international basis. Users should be charged a modest fee for any and all requests simply to avoid or minimize trivial use being made of the system.

3. The system should be easy to use. Pamphlets explaining how to use the services provided by the system should be distributed to all potential users free of charge. No segment of society should be left in the dark as to how to use the more sophisticated search, retrieval, and analysis aspects of the system. The higher fees levied for these more extensive services should effectively limit users from abusing the system.

4. The system should have an established set of priorities in the event of user overuse. Hopefully, delays in use of the system can be held to a minimum.

5. The management of the system should be provided with a clearly understood charter, and proper authority and funding should be given the management to carry out the goals and purposes set forth in the charter.

A review of the Report of the National Goals Research Staff[8] is revealing. Some of the problems facing our nation — population growth and distribution, environment, education, basic natural science, technology assessment and consumerism — are discussed. The striking feature of the report is that information management is not discussed explicitly. This is amazing considering the emphasis given to this problem by SATCOM, COSATI, and others. It is certainly evident that the problems discussed in the report will require and interact and be a part of an information process. Furthermore, technology assessment is an impossible or incomplete task without information management that takes raw data, analyzes these data, and converts the data into information that is readily available.

The need for information management should not be ignored.

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8. Toward Balanced Growth: Quantity with Quality. Report of the National Goals Research Staff, U.S. Government Printing Office, 1970-0-400-107, July 4, 1970.

CHAPTER I
INTRODUCTION

CHAPTER I. INTRODUCTION

". . . , we've got a problem." Man is in trouble on the planet earth. Wise use of resources will be needed for survival. There is better than an outside chance that man can make it; man must learn better to understand nature throughout the universe and man must see more clearly his position in it. Man must have ideas and must apply them well. Information for appropriate decisions must be made available to those who need it. The future is in jeopardy, and the time to act is now.

Information is a precious resource. How does one assure that this information that man so dearly needs is reliable and that man is applying it well? This is a real challenge and man had better find the answer soon enough to do us some good. The financial cost is likely to be high; but, can the nation really afford not to solve the problem? Can one afford to sit back with eyes closed and hope that the problems will go away or solve themselves? Survival, indeed the attainment of a noble civilization, is the reward for solving these problems.

In decades past, there was a time when science and technology had a comparatively insignificant role in determining the affairs of mankind. From the first recorded information depository of ten thousand clay tablets in Nineveh in 4000 B.C., to the fifteen plans reviewed by Carter et al. [I-1], which proposed solutions to this very acute national problem of information management, it is concluded that there is an inherited massive problem. The problem apparently has always been with man, is still with man in even greater proportion, and one may even extrapolate to the conclusion that it will always exist. The problem is aggravated in Kozmetsky's [I-2] description of the fabulous 5- to 10-year doubling effect of knowledge and documentation of information over recent years. The professional journal structure threatens to collapse under the sheer weight of the documentation onslaught. In addition, new generating capacities of 10^9 to 10^{12} bits per day from each of several orbiting laboratories in our initial exploration of space are planned. Hacker [I-3] points out that men are perhaps so sophisticated that they cannot be governed, and are too undisciplined to be controlled. It has been alleged that if the needed concept costs less than $100 000, it is less expensive to redo the experiment, or rediscover the wheel, than to look up or seek out the information.

On the national level, Dr. Dubridge, Dr. Weinberg, et al. expressed concern [I-4], which is also registered in Congress, about the growing amount of knowledge and the lack of practical utilization of this knowledge for improving our living standard. The 1970 President's National Goals Committee [I-5] has mentioned in the "Education Section" of their report that "the society of today is one changing so rapidly that skills and information become outmoded, and traditional values are under challenge. . . . as well as the mass media is so large. . . . what is needed is a framework within which to sort out the diverse values to which the public is exposed." Moreover, as Stafford Beer [I-6] has stressed, "Society has become a complex organism, and it needs a nervous system. Managing the development of informational science and technology is all about this task — there is no other message than this." Consequently, the need for a management system for information has become more apparent each year as President Nixon [I-7] has emphasized:

> "The essence of preventing duplication of effort, and the consequent waste of money, lies in rapid dissemination of information throughout the world.
>
> "Our government should encourage efforts to establish a clearinghouse for all federally supported research information and should set up regular procedures for widespread exchange with other countries."

There also is a lack of training of persons who can adequately handle scientific and technical information. Consequently, persons must be trained that are able to handle a system that takes into account the whole management process from the generation of the initial stimulus data to being sensitive to all segments of users from identifiable sources to the specific person or machines. An IMS must be integrated and yet be a flexible system such that it incorporates at appropriate levels centralized and decentralized functions operated by trained personnel throughout its organization.

The lack of and cost of storage facilities as well as staff to analyze certain data and/or information are compounding the information management problem.

The information explosion has overflowed the entire information network of the world, and man has found himself knotted in the information entanglement. Considering the rate at which new information is being gathered, the only solution seems to be to challenge the entire concept of information management. Because of the present shift in emphasis away from fundamental research to the application of present knowledge, the state of the present information systems becomes a serious hindrance to progress. Except for a few experimental developments, most fundamental research has not been considered for application to man's situation on earth. If ideas for application have been considered or worked out, they have most frequently failed to reach the people who can use them.

There are a number of efforts today within various government agencies, technical societies, and private research institutes to develop information systems and data analysis centers. The government agencies are also attempting to look jointly at the information problem and have presented some ideas. As yet there appears to be no concerted effort to spend the time and money attacking the information problem on a national basis.

NASA has one of the most advanced information systems for areas of aerospace technology; but even within the NASA system, the information dissemination is very limited, and very little has been done in the area of information analysis. Those scientists and engineers who are associated with the major universities are provided with any and all information often without special requests. The majority of the scientific community and other people, such as educators, who could use the information produced through government contracts as a result of research done by government agencies are never placed on the dissemination list for information. Very little effort is made by the information sources such as NASA to find out where the results of their research efforts could be utilized in the world. There are probably a sufficient number of "spin offs" from the space program alone to keep NASA busy for years researching the possible applications for the benefit of mankind and for getting the information to where it can be used. As an example, the developments in controlled environments for space vehicles undoubtedly have direct application to the earth's pollution problem. This information must be made available to people who can use it and in a language that they can understand. Another example is the systems approach to solving problems, which has been successfully used by NASA.

Our country, as well as the world is saturated with problems. Why cannot this systems approach be used in looking for solutions to some of these problems? Because of financial pressures, NASA and other groups within the scientific community are emerging from their isolated environments. These organizations are attempting to remedy the information breakdown. They are becoming more aware of public sentiment and are looking for ways to aid mankind's survival.

Whether or not the scientific community survives is not a function of how much their discoveries aid humanity, but rather a function of how involved the scientific community becomes in showing a concern for the useful application of discoveries, in regulating the applications to maintain our environment, and in communicating willingly with society as a whole.

NASA, because of its inherent data-gathering function, its non-secretive nature, and its managerial skills, is in a unique position to be the leader in the proper development of an IMS. The wealth of data and information that has and will come from space-related experiments and projects can be of tremendous benefit to mankind only if the information is properly disseminated, analyzed, or otherwise utilized. NASA could provide a valuable service to other agencies or governments by developing an IMS that could be emulated by others.

UNISTAR

To solve the alarming problem of how to use effectively, efficiently, and economically our great and growing natural resource termed "information", it is proposed that UNISTAR be established. UNISTAR is an acronym for User Network for Information Storage, Transfer, Acquisition, and Retrieval. The purpose for establishing UNISTAR is to create a management system for scientific and technological information under the executive branch of the United States Government. The system is to be fully operative no later than 1975 with prototype systems to be established earlier.

The criteria for the UNISTAR system are:

- To provide a wide range of services that satisfy user priority needs.
- To be evolutionary — UNISTAR must possess the ability to grow, adapt, and provide for feedback.
- To be technically effective and economically feasible.
- To be integrable with existing systems.
- To provide the information, personnel, and relationships to facilitate effective decision making throughout the system.

In the analysis of the UNISTAR system, four elements of the information cycle have been identified and studied. Although the actual boundaries that constitute an IMS are somewhat less than the total cycle, the elements themselves include: the information user, the processing and distribution of data and information, the data sensors and information generators, and a management or administrative structure. In addition, an all-pervasive policy should guide the behavior and development of each of these elements.

The development of the four elements are presented in roughly the form of the following outline in successive chapters with their respective introductions and rationale:

II. Information Users

Identification of Data/Information Users

User Needs

User Responsibilities

Dissemination of Information

Education of User

III. Information and Data Processing

Information and Data Transmission

Information and Data Reduction

Information and Data Storage

IV. Data and Information Sources

Active Sources

Passive Sources

V. Management Analysis

Development and Analysis of Alternate Plans

Interpretation of Elements

Administration Analysis

VI. Policy and Plans

Although UNISTAR is a national system for handling all scientific and technical information, a prototype UNISTAR system is proposed to establish a national information management system for handling earth resources information.

President Nixon made the promise, "We are determined that the decade of the seventies will be known as the time when this country regained a productive harmony between man and nature." If the President's statement is to become a practical mandate, it is imperative that the successful management of information be realized.

Even though this study is concerned with only one of several broad segments of the totality of information (i.e., scientific and technological information), the successful implementation of an information management system such as UNISTAR could serve as a model for future systems. In the words of Carter et al. [I-1]:

> "This book is confined to the scientific and technical information and documentation system. In some ways the limitation is unfortunate and since there is so much other information and so many documents that form a traditional part of the communication and documentation world. The book does not deal with material in humanities, the law, the arts, or commerce. Traditionally, the formal knowledge, a part of which involves publishers and libraries, has not separated one branch of knowledge from the other as deserving special and preferential treatment. In recent years however the federal government has recognized the great importance of science and technology to the general welfare and has given this area unusual and generous support. Scientific and technical information and documentation has played a part in this new emphasis and because of the central position in transmitting knowledge it has been singled out for special attention. Although this is only natural, it is to be hoped that appropriate attention will be given to the documentation and library problems in other fields of knowledge and endeavor."

It is hoped that the conclusions and recommendations reached in this report will complement the work of others, particularly that articulated in the COSATI and SATCOM reports.

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CHAPTER II
INFORMATION USERS

CHAPTER II. INFORMATION USERS

INTRODUCTION

It has been stated previously that one of the requirements of an information system is that user audiences be considered. Many organizations have designed information storage and retrieval systems, but few have specifically designed a user-oriented system. Perhaps this is a result of the belief that a user, if he really wants the material, will actively seek it. To provide a successful, meaningful information system as opposed to another bureaucratic network, which most existing mechanisms unfortunately are, means that certain requirements must be met.

These requirements from the user's point of view are fourfold:

1. Direct and indirect users of an information system must be identified.

2. Various needs and responsibilities of users with regard to the system must be identified.

3. Modes of disseminating information to users must be identified.

4. An education program must be developed with the aim of optimizing consumer use of information.

Ideal standards that should be considered to meet these requirements are as follows:

For the identification of users, their needs, and responsibilities, the system must be:

- comprehensive when identifying users.
- realistic when determining user audiences to be served.
- responsive to user's needs.

For the dissemination requirement, the system must be:

- evolutionary. A system that is allowed to become outmoded is worse than no system at all.

- capable of interfacing with present information systems used by governmental agencies and professional societies.

- efficient; employing the latest state-of-the-art techniques.

- economic in operation with a minimal cost to the user.

- interactive through provision of an oral, informal mode of operation. This type of mode is necessary for users who do not have the capability or ability to use sophisticated information retrieval operations.

- flexible with only minimal guidelines or constraints. If all users were of the same mold, a highly-structured system would be deemed desirable.

- comprehensive in the compilation of worldwide generated source materials.

- able to provide the user with a channel to express his needs or wants.

- straightforward to use. Users tend to shun systems that are complex.

- able to provide brochures indicating step-by-step procedures.

For the education requirement, the system for all users must be:

- convenient.

- innovative.

- dynamic.

The importance of studying users and their needs as a requirement for an information system is cited in a document published by Herner et al. [II-1]. This document deals with a feasibility study for a New England technical information referral service. Over 500 New England manufacturing firms that could apply scientific and technological information to their operations were surveyed. The survey was performed to discover the problems encountered in information acquisition. A large number of the firms had used one or more of the sources of information shown in Table II-1.

TABLE II-1. INFORMATION UTILIZATION

Source of Information	No. Firms Using Source
1. Suppliers and vendors of technical information	> 90
2. Information centers and libraries	30
3. Clearinghouse for Federal Scientific and Technical Information	13
4. New England Research Applications Center	< 1
5. Meetings and trade shows	90
6. Technical sources	34
7. Consultants	30
8. Library or information personnel	29

The difficulties encountered by these firms in obtaining information were as follows:

- Concept of "technical information" — Vendors and suppliers of information tended to disguise or suppress the fact that technical information was being used. They dealt with ideas, products, etc., but not with technical information.

- Information was disseminated to firms with full awareness that the recipient did not have the scientific background necessary to comprehend the material.

- Instead of receiving directly applicable answers, the firms generally were issued lists of references of academic solutions.

- Literature references often were incorrect or irrelevant.

- Consultants tended to present excessively general or "recherche" approaches to solving problems.

- Existing information mechanisms were often more concerned with methods of asking questions rather than information dissemination.

- Quite often information was not obtained, because the firms were not able to pose the right question. The informal mode of information transfer commonly used by the firms did not interface with the formal modes employed by information systems.

These difficulties could have been eliminated, or at least minimized, if the information system had considered the user as the essential requirement for their system instead of an ubiquitous group eager to absorb information and competent to utilize it.

In the next five subsections, an examination and amplification of user requirements and criteria presented will be made. The intent is to define alternative approaches to satisfy the stated requirements.

IDENTIFICATION OF DATA/INFORMATION USERS

Although we are concerned with a data/information management system in terms of the individual user, we are inevitably concerned also with various publics of users. When an individual person generates his own data and subsequently processes and uses the resulting information, problems related to managing that process may be serious one intra-personally for the individual, but at least the process is uncomplicated by the act of sharing that data in a public, interpersonal sense. The fact that the broad data/information area of our concern is the scientific/technical one is incidental to the problem of how to identify data users in the most effective and efficient manner.

The identification of individual users and homogeneous groups of users beyond the first level of data processors (Fig. II-1) often becomes extremely difficult because of the myriad combinations of formal and

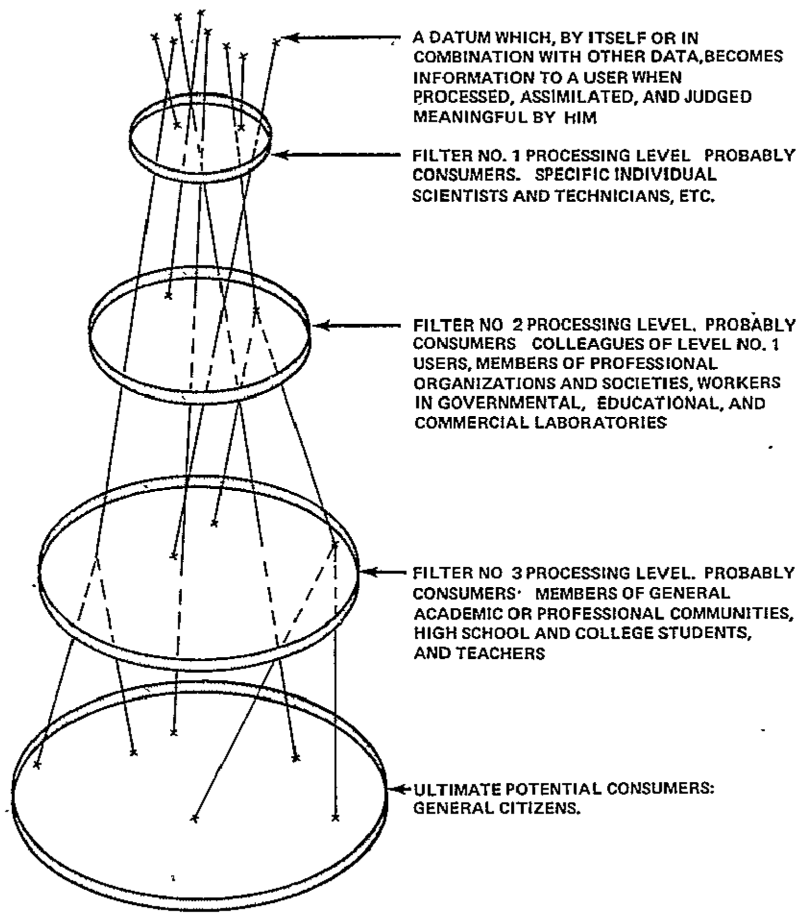


Figure II-1. Data/information diffusion model.

informal channels employed in the data diffusion process [II-2 — II-4]. Whenever data are processed and transformed into information by a particular user, that information is filtered and usually changed to some degree before being projected to another user, who in turn receives it as data and presumably transforms it into meaningful information for himself. Such a process may continue, within and between levels, almost indefinitely.

However, there are at least two broad approaches for identifying user groups: (1) those who take some degree of initiative in specifically seeking data, and (2) those who fortuitously discover data that subsequently prove pertinent and useful.

In the diffusion model depicted in Figure II-1, a data/information management system at Level I would be concerned almost exclusively with users who take strong initiative in seeking data to satisfy their particular needs. As a result, these "special interest" individuals and groups tend to be self-identifying [II-5]. They make demands upon the system that reflect the functional needs of raw data acquisition and mechanical processing (storing, transforming, transmitting). After the users at this level have processed and evaluated the data, the system may be called upon to further manage the data/information by further processing/disseminating it. Thus, the terminal user of the raw data very often is not the terminal user of the refined or interpreted data. It is axiomatic that the first-level users must be disabused of the notion that the data/information system is designed and exists exclusively or even primarily for their benefit. By the same token, the system has a responsibility to facilitate the dissemination of the first-level user's output to additional user levels.

The needs of the first-level users make the data/information management system policy very "content-dominant"; i.e., concerned with specialized, sophisticated subject matter [II-6]. At subsequent levels, the policies become much less oriented to specific content needs and subject matter specialities, and much more concerned with information applications, implications, and generalizations.

Level I Users

Because of their self-identifying, highly focused search behavior, Level I users are easily identified. Level I users, a highly specialized group, comprise the total sum of individuals who are the initial receivers of the raw-data needed for life support and maintainance activities (e.g., the crew of a space vehicle), or for research purposes (e.g., the "principal investigator" and his staff). The system does not seek out these people, so much as these people seek out the system.

Level II Users

At the second processing level, the mix between those users who initiate requests for data and those who do not becomes more apparent, although the former are still by far the most numerous. Individuals at this level typically include the refiners and sophisticated interpreters of the data and summaries of research reports, and implications for further research are the inputs to users at this level, typically through direct transfer via individual conversations and professional/technical meetings or indirectly via recorded specialized publications, oral and visual [II-7].

The users at Level II can often be characterized by high subject-matter content sophistication, plus an increased awareness of the application/generalization dimensions of the data [II-8]. The management system at this level reflects the individual, discrete needs of users, but it must simultaneously be capable of coping with a much broader base of user individuals and groups as the data/information receives broader exposure and visibility.

Level II users are identified in terms of the company they keep. Personal professional colleagues of Level I users are the likely members of this group and can be found by (1) examining lists of Level I users' laboratory and faculty colleagues, (2) identifying members of the subject-matter subdivisions of professional/technical societies of which the Level I user is a member, and (3) to a lesser degree, examining general membership lists of pertinent professional societies. Specific subgroups within various governmental agencies and commercial enterprises also are likely Level II users, with proprietary information unlikely to get below this level.

Level III Users

Level III users are characterized by less subject matter sophistication, and tend to serve increasingly as interpreters and relayers of data/information identified and processed by the Level II users. At Level III, increased strain is imposed on the system in terms of dissemination of recorded materials; since by this time virtually all the raw data have been processed and filtered by at least one other person, and very little direct transfer of data/information is likely to occur. Most public school and college undergraduate students (and some graduate students) in our educational system are representative of Level III users.

Increasing attention is also paid at this third level to identification of users in terms of the media techniques they employ. An increasing use of various mass-media technologies is characteristic of this level, as is the large time-lag that typically develops between it and the preceding two levels. Level III users can be identified by membership in general professional/technological/educational societies, and specific subject matter subgroups within the formal education population. Membership in pertinent avocational (e.g., flying, "ham" radio, etc.) or service (e.g., Cerebral Palsy Foundation, Heart Association, etc.) groups will also suggest likely users at this level.

Level IV Users

The Level IV user group is potentially the most frustrating to manage, yet the most critical in terms of need. In an information system supported by public funds, not only the system itself but the system's referent activity is at the mercy of the level of public support [II-9 — II-11]. Since it is often assumed (and frequently demonstrated) that a positive correlation exists between the public's level of knowledge and pressure for financial support of a program, the effectiveness of the data/information management system for users at this fourth level is of critical importance.

A major complication for satisfying user needs at this last level is that the user is typically not self-motivated to seek data. He benefits only peripherally (and often unknowingly) from the system's recent activity. The efforts to make information transfer beneficial for this level of user are therefore quite different than for the users of the higher levels. For example, although the scientific and technological applications spin-off from our nation's aerospace program has been substantial, the awareness of such spin-off by the general population has been minimal [II-12].

Typically, the management of data/information systems at this fourth level has employed a shotgun technique in terms of both content and dissemination. The extensive and convenient techniques of the mass media, both sight and sound, have been employed extensively to make the passive user into an active one. In addition, the thousands of people who visit public facilities (e.g., the Kennedy Space Center) and who write letters requesting information of various kinds are examples of users at this level who willfully access the system.

Level IV users represent the opposite end of the continuum when compared with Level I users. As noted in the U. S. Senate Report of the Subcommittee on Science and Technology to the Select Committee on Small Business [II-13], for many potential users the obligation for identifying technological transfer areas must lie with the originator source. Once the data/information are visible to this level of users, a degree of user identification will be possible. The "browsers" of recorded information (typically mass-media viewers, listeners, and readers) can be identified through typical market analysis procedures. Additional identification of users at this level can be accomplished through a systematic program of providing information and educational materials for the vast spectrum of primarily social or social/service organizations (e.g., Rotary International, women's clubs, etc.).

It is clear that the classification of users by levels as described above is not a mutually exclusive one. It is entirely possible that a given individual may be a user of a given system at more than one level, or perhaps at all levels. Nevertheless, the identification of data/information users by the levels described provides a systematic way of examining the total user population. It also suggests how the characteristics and needs of users differ and offers some corresponding implications for managing a pertinent data/information transfer system.

USER NEEDS

General Requirements

An information system that pays little or no attention to the needs of its users is obviously no information service at all. The system must be continuously responsive to the needs of its users, since the satisfaction of these needs is the only rational basis for the existence of the system.

The system should possess the following capabilities [II-14]:

- Ability to handle an increasing number of users.
- Serve a wide range of users; scientists, technical personnel, scholars, industrial and government employees, administrators, managers, legislators, and the general public.
- Provide a wide variety of services to fulfill specialized needs of its users.
- Be easy to use from the user standpoint.
- Be capable of fast response to user requests.
- Be responsive to user feedback that would lead to appropriate changes in the system.

Types of Requests by Users

The types of requests made by users may be summarized as follows [II-15]:

- Requests for specific documents necessitating an adequate collection of bibliographical reference works to insure accurate references. Such documents must also have the flexibility, legibility, and convenience of the printed page plus the dynamic quality of the oscilloscope screen.

- Demands for specific data such as properties, formulae, etc., in a broad range of subject areas.

- Retrospective searches that would find all relevant references. This requires an excellent collection of abstracting, indexing, and patent compilations.

- Current awareness information, which necessitates a good collection of current periodicals plus a selective dissemination service provided by the system itself.

- Critical reviews and data compilations that filter, review, and consolidate the primary literature systematically [II-16].

- Referral service that tells the user where the information may be found. There should be a flexible wide band interface with other information systems in industry and government [II-17]. Access to this body of knowledge should be through convenient procedural and discipline-oriented techniques.

- Analysis of data and information by specialists in various disciplines.

- Requests from the public for general knowledge such as descriptive pamphlets, pictures, etc.

The SATCOM report [II-18] discusses many of the aforementioned types of user requests. In the area of critical reviews, emphasis is placed not only on their preparation but on fostering greater awareness among potential users of the existence of such reviews. Indexing, abstracting, and bibliographical services sould be broadly based upon specific disciplines. In the case of literature, the basis should be formal archival journals. Moreover, semiformal communications (report literature, preprints, newsletters) should be circulated to people with an interest in the subject area, and some provision should be made for selective bibliographic referencing of such material.

Conrad [II-19] points out that scientists and engineers need help in browsing which is limited by the time that is available. With regard to browsing, current awareness help can make the browser's time more useful. When scientists and engineers are working in industrial research or development, they want specific answers too. These answers relate to prior work on a problem, knowledge of what has not been done, fruitful and negative results, competitive workers, possible applications and their manufacturing costs, plus any patent or other constraints.

In a mission-oriented forecast of the research and development for a new product, the plan of data flow might be as shown in Figure II-2 [II-20]. The type of data required determines the selection of the areas to be exploited. The researcher draws on a variety of information sources to assist him in generating new experiments. Such sources include telephone and personal contact with others, published work, handbooks, and vendor literature.

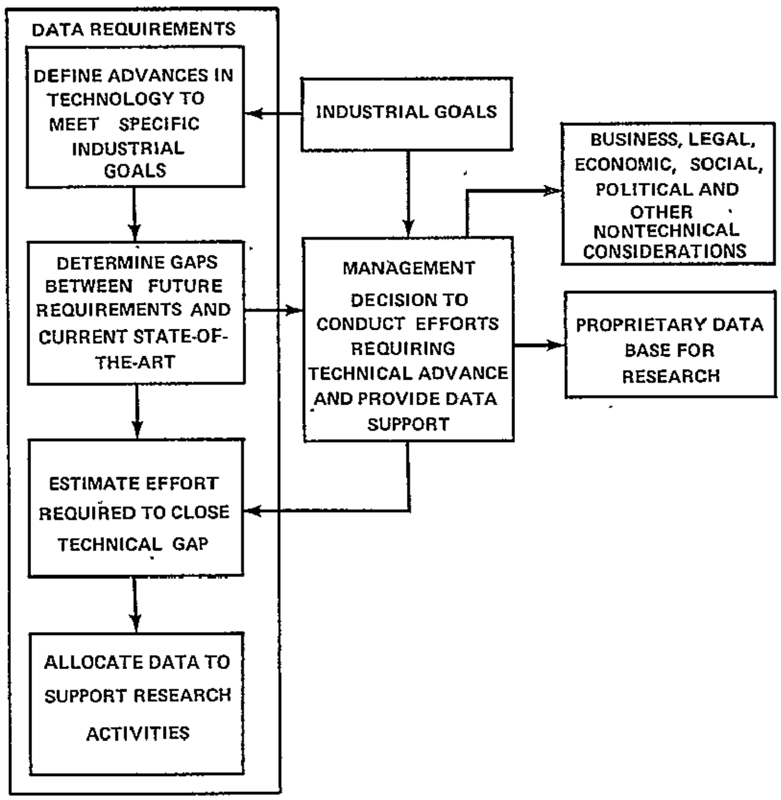


Figure II-2. Planning data flow.

In the commercial area, users are particularly interested in having information with a profit potential distributed simultaneously to many possible users. This widespread equal time sharing of valuable information prevents any one group from having special advantage.

In the case of raw data from the Earth Resources Technology Satellite, some users would like access on a quick-look or near real-time basis. This could be quite important in the prediction of possible large scale disasters. Other users of ERTS data might like to experiment in an interactive or online mode with such things as spectral band combinations to bring out contrasting geographical features.

While some researchers obtain all their own information, their numbers are declining [II-21]. Instead, because of increasing information demands on them, scientists and engineers are turning to the Information Analysis Centers, which possess extensive capabilites and full time professional staffs. Such centers analyze data, prepare summaries and compilations, and make critical and state-of-the-art reviews. Thus, for the user the IAC can answer such questions as: Who is doing what, where, and how? IAC can also answer the question, what is going on in a technical speciality? Basically, the IAC would serve the user in two areas: (1) highly specialized important short range problems, and (2) critical areas of long term significance that have a high degree of interest.

The timeliness with which data and information are made available is very important to the user. A study has shown that in engineering most information requests should be satisfied in a short time [II-22]. In fact, one day is the limitation for about 20 percent of such requests. If the user is not satisifed quickly, he will resort to more readily available information that can lead to more expensive and often poorer designs. It therefore behooves an information system to incorporate modern electronic and mechanical equipment to supply information as rapidly as possible.

As indicated in Table II-2, the Earth Resources Observation Satellite program has identified five broad classes of data users, and their time requirements, that will be supplied by the NASA Earth Resources Technology Satellite program [II-23].

Users of remote sensing data have different requirements with regard to the speed with which they must receive data. This depends on the use to which the data are applicable. Thus, geologists can wait several months for their data, but traffic control experts dealing with a dynamic situation must have information almost immediately. A time scale [II-24] for utilization of remote sensing data is shown in Figure II-3.

The characteristics of the data required by engineers and scientists are shown in Table II-3. Such data have a timeliness factor in that any user organization, government or industrial, must keep abreast of new developments via data and information acquisition if it is to maintain a sound competitive position.

TABLE II-2. ERTS DATA UTILIZATION

User	Time Frame Needed for Data	Type and Format of Data	Method of Dissemination
Scientists	1 week to 1 year	Raw and processed	Mail
Resource planners	1 week to 2 months	Interpretive, maps, extracted information	Telephone, plane, mail
Policy people	1 month to 1 year	Interpretive, maps, extracted information	Mail
The public	1 to 2 days	Raw data plus quick interpretations, sequential comparisons	TV, newspapers, radio
Educators	1 year	Maps plus interpretations	Mail

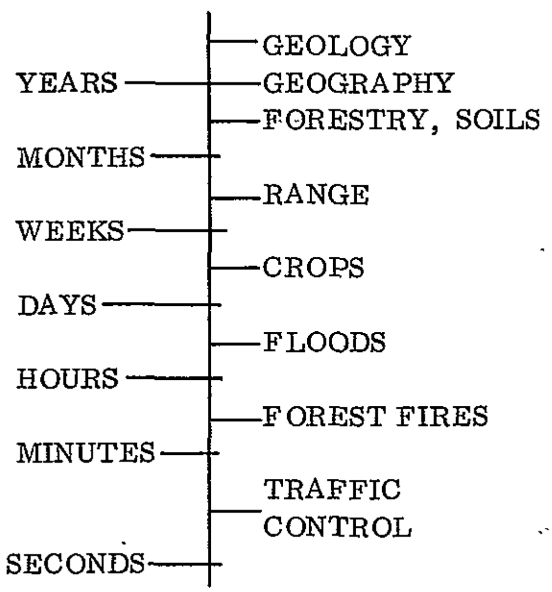


Figure II-3. Time scales for different information types.

Some Specific Examples of User Needs

Cartography is undergoing rapid change, because photographs taken from earth-orbiting satellites are far superior and cheaper than aircraft photography. Broader geographical coverage is needed because most of the world's maps are obsolete or inadequate [II-25, II-26]. The user specifications for such maps require the satellites and photographic equipment to have these capabilities:

- Ground resolution capacity of 100 to 200 miles.

TABLE II-3. DATA CHARACTERISTICS CHART FOR ENGINEERS AND SCIENTISTS

	Type of Data	Volume	Degree of Refinement and Technical Sophistication	Orientation	Value	Useful Lifetime
Engineering Data	Performance requirements	Low	Very low	National goals	Prerequisite low competitive position	Varies with magnitude of requirement
	Functional specifications	Moderate	Moderate	Moderately mission-oriented	Essential to project	Short
	Hardware specifications	High	High	Highly mission-oriented	Valuable for proprietary rights	Varies
Science and Application Data	Science	Initially high in data flow	Initially low	Universal	Varies, but usually limited to the science community	Of timeless value to historical analysis, but usually superseded by new data
	Application	Initially high in data flow	Initially low	Practical needs	Great potential	Very short

- Format of 100 square miles.

- 1-year useful life with repetition semimonthly.

- Sun synchronous orbit.

The types of maps [II-27] that could be prepared are listed below. They would prove useful to nearly every United States citizen.

- Urban and rural land use for planning.

- Hydrologic for water and snow distribution to assist in municipal water supply, hydroelectric, irrigation, and waterfowl management.

- Effluent discharge for pollution abatement and shellfish industry.

- Wilderness for conservation of national parks and seashores.

- Range condition for cattle grazing.

- Earth structures for mineral exploration.

The oceanographer is another example of a user with special needs for broad extensive data requirements, because he deals with a dynamic medium, the ocean. The kinds of data needed, the information gained therefrom, and the applications are shown in Table II-4.

A third application of information lies in the area of agriculture. The constantly changing environment makes repetitive recording of data a necessity to users. They differ widely as far as the types of information needed, its timeliness, frequency, and format. All these requirements have a direct economic effect on the national agricultural picture. The types of information [II-24] needed by non-governmental users regarding agricultural crop plantings are shown in Table II-5.

Some ways in which this agricultural information might be applied are as follows:

Crop yield — International commodity brokers are interested in a worldwide basis while a grain elevator operator is concerned only with his own delivery area. In general, crop estimates are of most interest to people furtherest from the prime producer, who can do little to remedy a crop failure. Predictions are helpful in planning for adequate storage and transport. If accurate, the predictions help to prevent violent price fluctuations, since crop shortages can be modified by shipment from other areas.

TABLE II-4. OCEANOGRAPHIC DATA UTILIZATION

Application	Information Gained	Data Needed
1. Shipping	Sea state	Wave height
	Currents	Temperature (gradients and surface) and water color
	Hazards (icebergs)	Water/ice interface
2. Fisheries	Upwelling	Surface temperature gradient
	Currents	Surface temperature gradient, water color
	Bottom topography	Wave refraction and color tones
	Oil slicks	Vapor identification
3. Coastal geography	Shoreline topography	Land/water interface, color tones and contrast
	Effluent and sediment transport	Water color tone
	Sea levels and slopes	Surface elevation
4. Marine biology	Bioluminescence, red tides, plankton, fish schools, algae	Color tones

TABLE II-5. NON-GOVERNMENTAL USER INFORMATION REQUIREMENTS ON PLANTED FIELDS

Type of Information \ Users	Farmers	Elevator Operators	Traders, Brokers, *Chicago* Board of Trade	Millers Users of *Grain*, Feed Lot Operators	Fertilizer and Pesticide Manufacturers	Farm Equipment Manufacturers
Plowed acreage					Spring	Spring
(Planted acreage)		Late spring	Late spring	Late spring	Late spring	Late spring
Planted acreage by crops	Early summer	Early summer	Early summer	Early summer	Early summer	Early summer
Soil moisture/temperature	Early summer 2-week/summer				Winter/spring 2-week/summer	
(Soil nutrients)	Winter/spring				Winter/spring	Winter/spring
Plant moisture/temperature	1- to 2-week/summer				2- to 4-week/summer	
Plant nutrients	2- to 4-week/summer				2- to 4-week/summer	
Crop yield estimate	*Monthly*, then weekly	*Monthly*, then weekly	*Monthly*, then weekly	*Monthly*, then weekly		
Harvested acreage		Daily at harvest	Daily at harvest	Daily at harvest		
Damage assessment and control	As needed	As needed	As needed	As needed		
(Crop row distance)						Late spring
(Time/temperature integral)	Continuous	Continuous	Continuous	Continuous		

NOTES 1. Types of information in parentheses may be beyond the present state of technology.
2. "1-week/summer" means the information is desired every 1 or 2 weeks during the summer only.

Cattle — Decisions must be made by cattlemen in the autumn as to whether to carry cattle through the winter on feed or to sell. The decision is influenced by a knowledge of range conditions, feed prices, availability of other ranges for leasing, and future cattle prices. The capacity of the range for nourishing cattle depends largely on plant growth and soil moisture. An accurate information system can do much to assist cattlement in their decisions.

Canning — Perishable crops are contracted for and nonperishable crops are purchased on the open market by canners. Accurate information on harvest and delivery scheduling would be most helpful.

Fertilizer — Logistics are important for profitable operations because shipping and difficult storage (fertilizers are often hygroscopic and corrosive) account for a high fraction of the selling price. The fertilizer manufacturer needs better forecasts of plowed acreage to permit him to make major savings in operation, freight, and storage charges.

Studies of User Needs

Users of information are slow to change their habits of acquiring information [II-17]. Therefore, suppliers of information must make every effort to overcome the "least resistance behavior pattern" of users by providing imaginative new and improved services. This tendency of people to expend as little energy as possible in seeking information must be overcome by optimizing the information system so that the data sources (documents and people) are in the desired form at the right time for the user. Also, when changes are made in the information system, the user's resistance to change must be considered. This means that changes should be evolutionary rather than revolutionary unless a critical change is necessary to facilitate better use of the system.

Users must be able to utilize oral techniques to converse with the system through a human intermediary, to formulate requests for information, and to respond to them. The system itself should be able to respond to the user at his level of sophistication. Terse, streamlined modes of access are desirable for experienced users working in their area of expertise. On the other hand, slower methods are needed to guide neophytes seeking knowledge to reduce the complications introduced by a diversity of language, terminology, and jargon.

The quality of information available to the user often exceeds his capacity to absorb or handle it. Thus, there is a need on the part of users for better quality data, condensation of information, and some purging of material [II-29 — II-31]. In the case of a large scale aerospace data and information system, there is a large volume of generated data that is highly redundant [II-32]. Much of the data is perishable and its value deteriorates rapidly unless promptly used. This dictates pushing the data processing as close to the input end as possible in the case of satellites; this is accomplished with prescreening, digestion, and partial compression to prevent bad or redundant data from entering the system.

The quality of service rendered by the information system is sometimes disappointing to the user [II-33 — II-35]. To rectify this situation, the system should strive for competent qualified personnel by using periodic reviews of position descriptions and the number of personnel, and through training programs. The system must also provide for an internal check to measure the quality and efficiency with which it performs its services as they relate to the needs of users.

Research programs to determine user needs often suffer from limited funds, poor planning, and a failure to recognize their basic importance in guiding the development of an information system. Indeed, programs for a systematic study of user patterns in most information systems are nearly nonexistent [II-34, II-36 — II-38]. The system should therefore include a broad research program directed at determining user needs, satisfaction, and behavior. Adequate funds should be provided for the program with participation by scientists and engineers who combine imaginative insight with abundant experience in using the information system. The studies should attempt to evaluate various combinations of accuracy, completeness, discrimination, and timeliness. User response to new or specialized information services should be carefully investigated. For academic and industrial personnel, exchange or leave programs on a monthly or summer-long basis would provide opportunity for familiarization with the system. This should result in benefits both to the system and the visitors.

There are a number of ways in which an information system can determine whether it is serving its users adequately and providing the kinds of service needed [II-15]. The field study method is simply to observe how a user goes about the process of interrogating the system for information. Although this is time-consuming on the part of the observer, it necessitates no additional effort from the user. Usually this method is satisfactory only for narrowly defined searches. Another method is the diary technique in which users seeking information record in diaries what they are doing at specific time intervals. Other methods include oral direct interviews with users, sending questionnaires periodically to users, holding professional seminars or conferences, and examining scientific proposals.

Feedback to the system which comes unsolicited from the user is very important in gauging the quality of service. While most comments will be of a critical nature, many will be justified, and some may even include constructive suggestions. The feedback, which may be either oral or written, should be encouraged, and, if possible, the commentator should be informed of the action that was taken. Feedback is likely to decline rapidly to zero if the feeling prevails that the system depreciates or ignores recommendations from its users.

USER RESPONSIBILITIES

The degree of responsibility that rests upon the various users of the system depends to a large extent upon how closely they are associated with the operation of the system. User responsibility in this case extends to individual scientists and engineers, groups such as government agencies, scientific societies, private industry, academic institutions, and the general public. Naturally, users who play a dual role as sources and receivers of information have a greater responsibility for contributing to proper development of the system. However, all users of a large information network must carry out their responsibilities if the system is to operate efficiently.

The responsibilities that must be met by users are:

1. Maximize personal use of data/information.

2. Prompt reporting of findings.

   a. To other interested users within a reasonable time.

   b. Dissemination of results, conclusions, likely implications, and other fruitful areas of research and methodological spin-off.

   c. Dissemination of what was learned about the experimental method and need for the desirability of change.

3. Participate in continuing education and systems improvement seminars.

a. To disclose fully one's experiences in working within the system.

b. To discuss the limitations in the data, the experimental method, and the equipment used.

c. To identify promising opportunities for further research, exploration, experimentation, and the possible implications of extending existing studies.

d. To identify needs for changes in the system and to develop alternative approaches for meeting those needs.

4. Public information.

a. Share the excitement of scientific discovery with the public through various public media.

b. Dissemination of research method, objectives, and potential gains.

c. Consideration in developing experiment proposals directed toward user-defined needs for specific new knowledge.

As an illustrative example of user responsibility, the PI who participates in the space program will be considered. The PI who has experiments aboard a spacecraft has the greatest responsibility for assuring proper use of the taxpayer dollar with regard to the experimental plan of the space program. Probably the most important obligation that the PI should immediately face is that of proper design of the experiment and equipment to be placed in space. It appears that a number of PI's do not realize the difference between performing research in a laboratory on earth and performing research in space. On earth, the parametric considerations of laboratory space, time, and number of individuals involved are often neglected because of the ability to repeat an experiment until the desired quantitative result is obtained. In space, however, these variables are generally constrained, and the failure to design an experiment carefully can result in needless waste of time and funds. In the proper design of an experiment, several questions are posed. These are:

1. What is the most effective way of performing the experiment?

2. How should the facts be assembled?

3. How does one arrange the facts in an orderly fashion?

4. How can creativeness be improved?

5. Will the experiment design affect other experiments that are proposed for the space lab?

The fifth point is one that a number of scientific investigators would not ordinarily consider because of the isolated, provincial nature of research. Established investigators are the least willing to adapt to teamwork methods [II-39]. Hopefully, this will soon be a relatively rare social phenomenon. Failure of a regulatory body, such as NASA, to cope with this situation has caused a further alienation of qualified space scientists and a perpetuation of the "prima donna" concepts.

The answers to the other questions that have been posed are a recognition and adoption of the scientific method. While most researchers are aware of the method, few actually practice it fully when doing research. The trial and error, or serendipity, type of research seems to be more commonly practiced. While reasons for this are manyfold, the two most prominent are (1) financial affluence in the last decade, and (2) no well-defined research goal. The latter statement implies a research approach of "Let's do this and see what happens."

The basic tenets of the scientific method are [II-40]:

1. State the objective.

2. Assemble the facts.

3. Organize the facts.

4. Propose a likely solution.

5. Test the solution.

6. Take action.

Tenet 5 is most often not used properly or completely, and as a result, the experimental conclusions are seriously affected. There are a number of considerations in solution testing such as:

- Every effort should be made to make the experiment as quantitative as possible within the limits of the equipment used. The more quantitative the experiment is, the greater the chance is of getting useful results.

- Variance analysis should be used to determine the effect of critical or controlling variables.

- Experiments should be designed to be independent of the size and nature of equipment and made as simple as possible. Flexibility in equipment size is especially important in spacecraft experiments.

The amount of data generated is directly affected by the results of the previous stated considerations. In a system where the amount of data generated is of no concern, this presents no major problem. However, the spacecraft experiment presents enormous problems to an information system if excess or redundant data are transmitted and creates a load greater than the system can handle. Therefore, unless an experimenter can find the lowest data generation method without sacrificing quantitative determinations, an experiment may have to be canceled because the data cannot be managed.

The last step in the scientific method is responsible reporting of research results. Currently, NASA allows the principal investigator 1 year to analyze the transmitted data before placing the material in the public domain. There is no guarantee that experimental results will be made available by publishing in primary journals. There are numerous cases where data have never been examined. In addition, once the data are placed in the public domain, the data are seldom used, mainly because their availability is simply not reported to the scientific community. This lax approach to the reporting of experimental results is probably a result of the way in which the Office of Space Science and Applications operates within NASA. Basically, OSSA adopts a "hands off" policy with respect to the PI. OSSA considers itself primarily responsible for the experimental package and the published results. Another NASA organization, the Office of Advanced Research and Technology, requires that the NASA center which subcontracts the experiment be responsible for the reporting of experimental results. This method has merit and should definitely be strengthened to assure better use of tax dollars.

With regard to this space example, the other users of an information system would have the responsibility of demanding technological reports for spin-off value. Recent events indicate that the public may have decided that space programs are not as worthy of fundings as welfare programs. This lack of understanding is probably a result of the failure of users of the space program to inform the public properly of technological advances that have benefited them indirectly. In the future, more emphasis must be placed on ascertaining the delivery of technological spin-offs to the general public.

DISSEMINATION OF INFORMATION

Since the user audience of scientific and technological information is such a large heterogeneous group that cannot assimilate all the information, it is best to treat a discussion of information dissemination according to types of users.

For convenience of discussion, the first and second filter groups as defined in a previous subsection on user identification will be combined. The third and fourth filter groups will be combined in a similar fashion. Scientists and technologists comprise the bulk of individuals in the first combined group, while the latter contains educators and the general public.

The former group, made up of scientists and technologists, uses journals, abstracts, bibliographies, and selective dissemination reports from information centers to acquire knowledge, as well as direct unrecorded methods (conversations, professional conferences, etc.). Libraries generally perform an archival task for this group.

The second group often lacks the capability to fully understand or appreciate science and technological information and is not aware of where the information is located. Thus, they rely on organizations and other individuals to acquire, store, analyze, and repackage information to fit individual needs. This group uses libraries, information analysis centers, newspapers, magazines, and commercial vendors to acquire information.

Because of the disparity between the groups, the ensuing discussion will be divided into two sections. The first section will deal primarily with information dissemination for scientists, while the second section will emphasize information dissemination to other users of science and technological information. Obviously there is overlap in these two discussions.

Introduction

Attempts to disseminate information and problems associated with dissemination are not of recent origin. Archaeological data indicate that a fairly structured library existed in Nineveh about 3000 B.C. [II-41]. This library contained approximately 10 000 clay tablets, which must have presented a large storage and retrieval problem.

Initial problems in information transfer began in the 15th century with the advent of printing; by the 16th century, the number of books had multiplied enormously. During the 17th century, distribution of books began to slow the flow of information. At this time, scientists began to charter scientific societies for the purpose of introducing new methods for dissemination of information. Proliferation of these societies continued throughout the 18th century with increasing emphasis placed on informal modes of information transfer.

In the 19th century, the use of journals was advanced because of the need to disseminate information to an ever increasing number of scientists and to provide better ways to archive information. Continued proliferation of journals in the 20th century, with little change in the method of disseminating them, has caused a tremendous burden on information systems [II-42].

The dimensions of the information retrieval problem have changed considerably since 1900. Before 1950, one could feel fairly certain that continual reading of current literature would keep one abreast of the field of endeavor. Today, the rapidly expanding number of publications that are the result of technological progress make it almost impossible to keep up with a field unless one specializes in an extremely narrow area. Traditionally, specialization has been the individual's defense against this rapid growth.

Kent [II-43] has outlined the reaction of the user of formal media information and appropriately titled it "The Reader's Dilemma" (Fig. II-4).

Recently, the trend in scientific research has been away from specialization to one of multidiscipline activity. This complicates the information acquisition problem, because the reader must identify more organizations to help him in the retrieval of needed information.

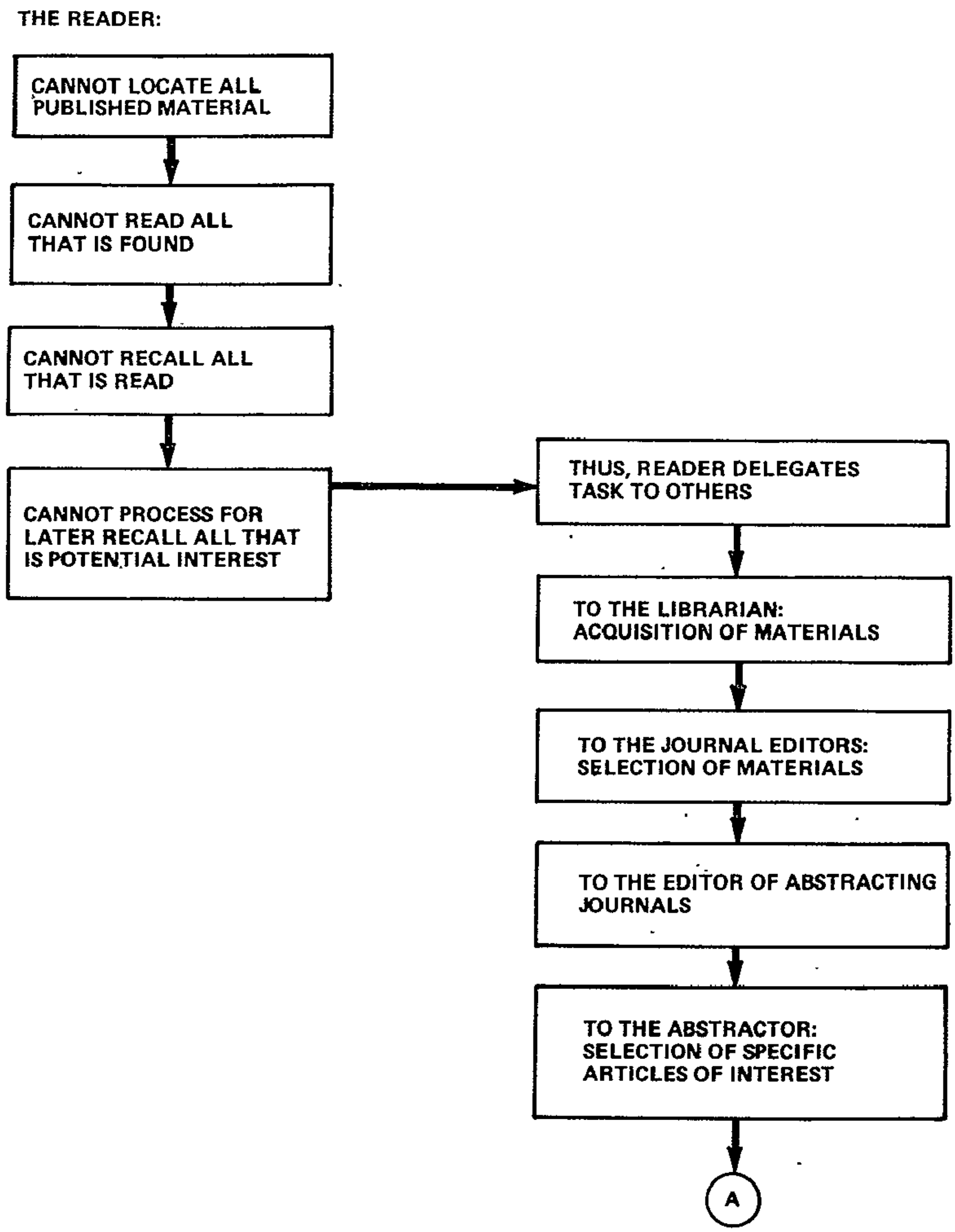


Figure II-4. The reader's dilemma [II-43].

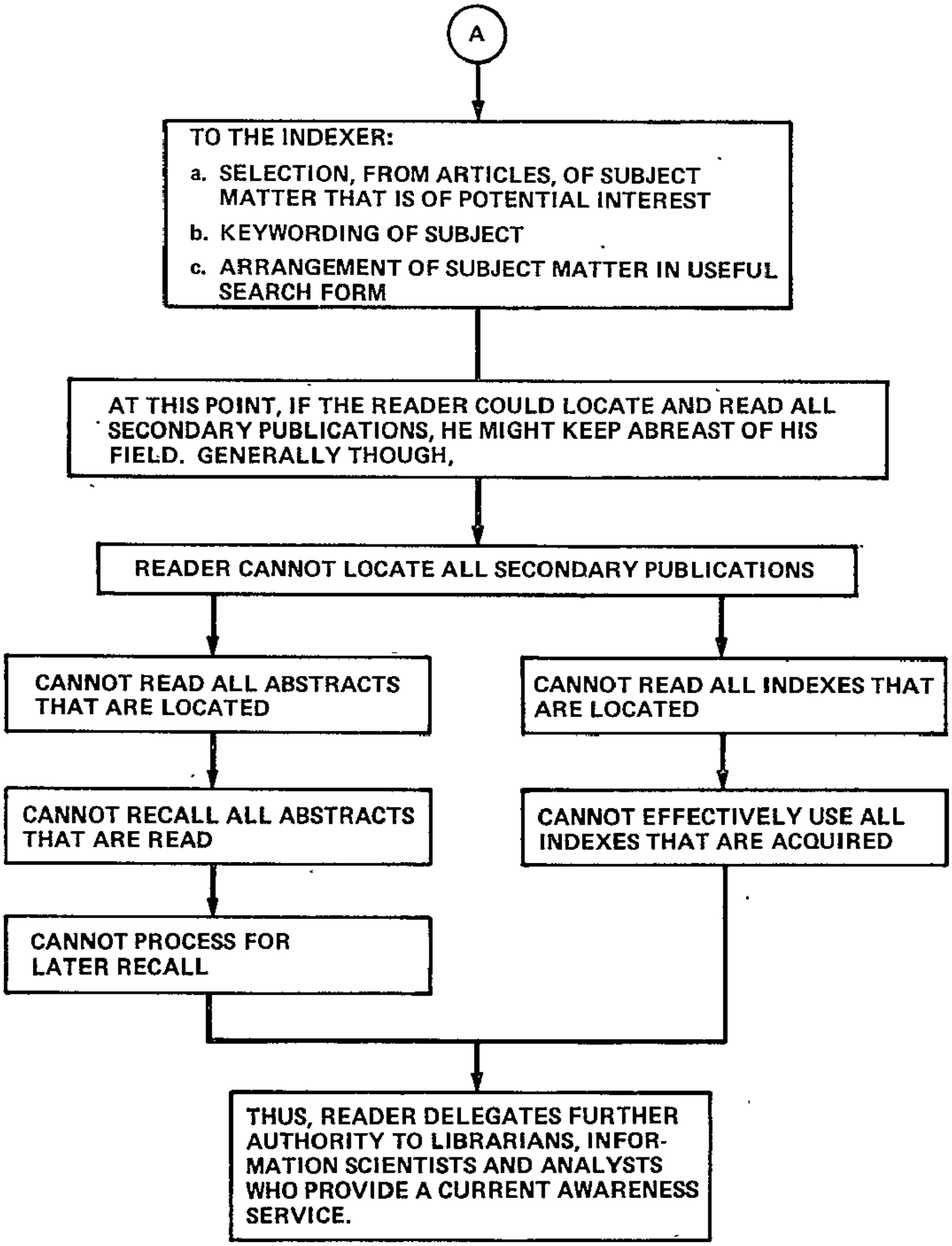


Figure II-4. Concluded.

Before proceeding further, it is best to note that the user has obtained information as a result of the confrontation approach. This type of approach is often stated, "Here it is, come and get it!". The solution to this problem is the adoption of a different or interactive approach; namely, "I've got a problem, can we solve it?". Reasons for adopting the latter approach can be identified when the various user-system interfaces are examined. A general model of information transfer to bear in mind while discussing different interfaces is found in Figure II-5 [II-7].

Dissemination Interfaces

If the concept of user-system interface implies that the user is an outsider and not an integral part of the system, then there is little chance that the user will be able to affect the operation of the system. In a number of systems though, such as that of The American Chemical Society, the user is identified and asked for his requirements. The chemist is intertwined with the system.

An information system contains the following elements:

- Originator of information.
- Medium: oral, written.
- Depositories, data banks, libraries.
- Processes: classifying, indexing, abstracting, translating, announcing, disseminating, analyzing.
- User

There are a number of user interfaces that result in the flow of information. In Table II-6, various modes for media dissemination of scientific and technological information are presented. The simplest type is that of man-man interface where the medium consists of conversation. This informal mode, while especially beneficial to those immediately involved in the interaction, cannot be documented easily for the benefit of others. The man-man interface, such as occurs at conventions, is generally disseminated to the rest of the community only if the host professional society makes an effort to transcribe the proceedings. Informal contact between scientists is facilitated in this country by such operations as the Science Information

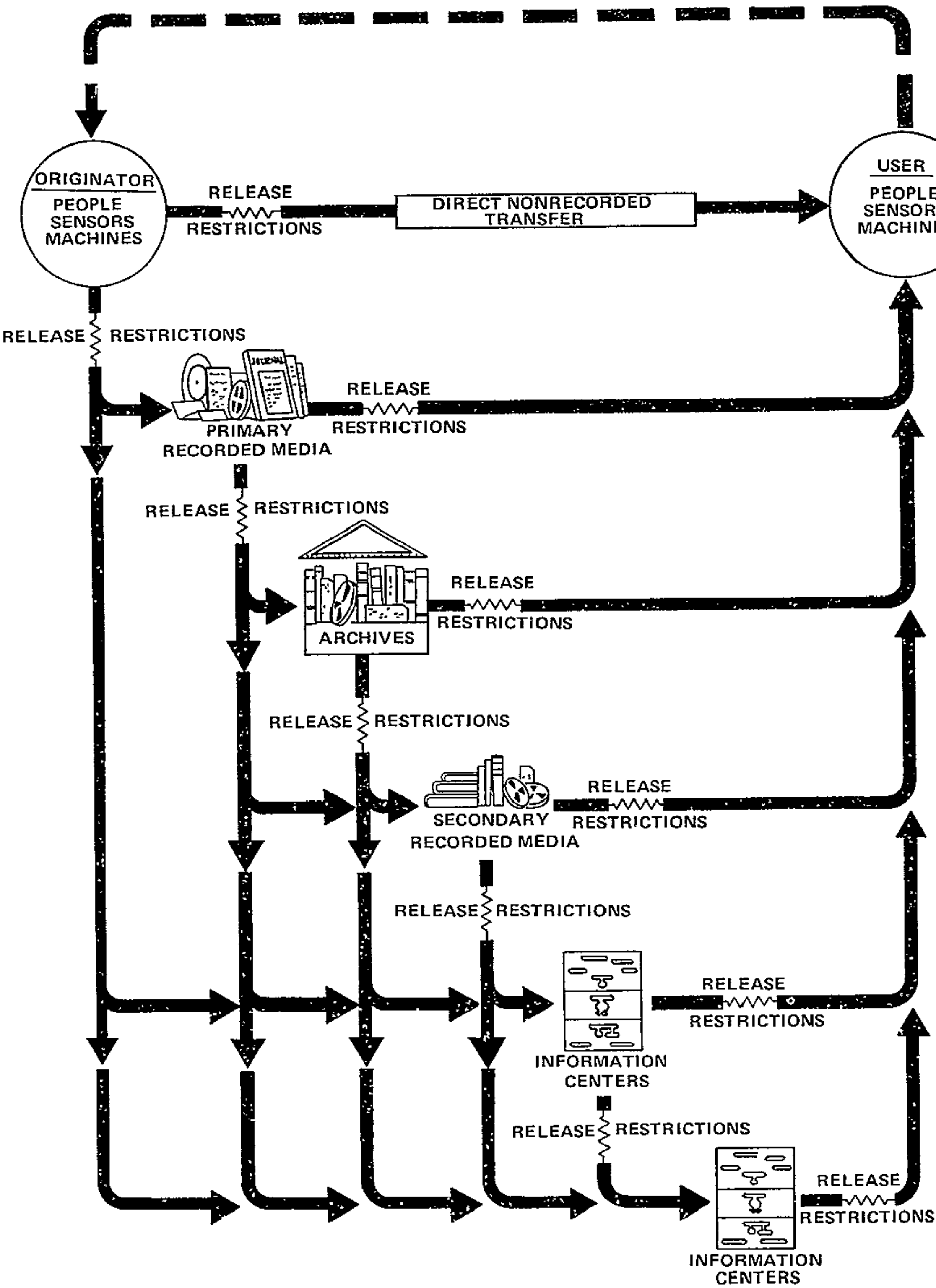


Figure II-5. General model of information transfer [II-7].

TABLE II-6. MEDIA USED FOR DISSEMINATION OF INFORMATION

Written Information	Oral Information
Semi-informal and Informal Media	
Technical reports	Colloquium
Manuscripts	Seminar
Copies of meeting papers	Special conferences
Preprints	Meeting presentations; local, regional, and national
Formal Media	
Journals and books	Lectures
Reprints	Public speech
Reviews	
Abstracts and indexes	
Current awareness media	
Meeting presentations; abstracts and presentations for regional, national, and international meetings	
CFSTI, SIE, NRCST, and other government publications	

Exchange, which is operated by the Smithsonian Institution, and the National Referral Center for Science and Technology, which is a division of the Reference Department of the Library of Congress. SIE maintains a registry of current applied-basic and applied-research projects with primary emphasis on non-DOD efforts supported by federal funds. A directory is published every 2 years in the following four subject areas:

1. Physical Science and Engineering

2. Biology

3. Social Sciences

4. Federal Government

NRCST identifies and catalogs information resources of all kinds. In addition to providing referral services to such resources, specialized directories are published. The subject areas covered are physical, biological and social sciences, engineering, and technology.

Informal methods of information transfer enjoy a favored status in science and technology because they offer specific advantages over more formal methods. These advantages are [II-44]:

- Promptness — Belonging to the scientific grapevine places one at a distinct advantage over the reader of formal publications, especially in scientific and technological areas that are in early stages of development.

- Information is routed — Scientific news is directed to individuals to whom it is relevant. This subtle operation is approved by those privy to it and strongly disapproved by "outsiders".

- Screening, evaluation and synthesis — Colleagues often make great contributions in these three areas. Some ideas are accepted easier if they can be distilled and presented in terms that both the communicator and receiver understand.

- Implication of scientific idea — Translation of ideas into action terms is a tremendous service offered by this system.

- Transmission of ineffable concepts — Journal policy often does not allow ideas to be transmitted that require extensive explanations. In general, the "fruits of experience" are left out of journal publications for this reason or for selfish desires.

- Instantaneous feedback — The questioning involved in this process helps to hasten the adoption and understanding of ideas.

- Special role of chance information — Information from beyond the area of specific interest is quite often relayed by the informal mode.

This probably accounts for the prominence of the browsing activity that is employed by many. The serendipity approach often advances the search for knowledge. Another facet of chance information is the double exposure to ideas or the revival of ideas. Quite often, initial exposure to an idea does not result in its acceptance, mainly because of concern with more immediate problems. "The rate at which an idea penetrates any population varies with the effectiveness of dissemination of the idea" [II-45].

Formal publication is the user-paper interface that is commonly used to gain information. In this mode, the user generally has little chance to affect the nature or the way in which the information is presented to him.

Projections for the number of primary and abstract journals are nearly a linear function of time as shown in Figure II-6 [II-46]. The mass of journals has been estimated to be increasing at 15 percent per annum with the top quality journals increasing by about 3 percent. The latter rate is lower because of greater selectivity by journal editorial staffs. In 1963, Gottschalk and Desmond reported that about 35 000 titles were being published.

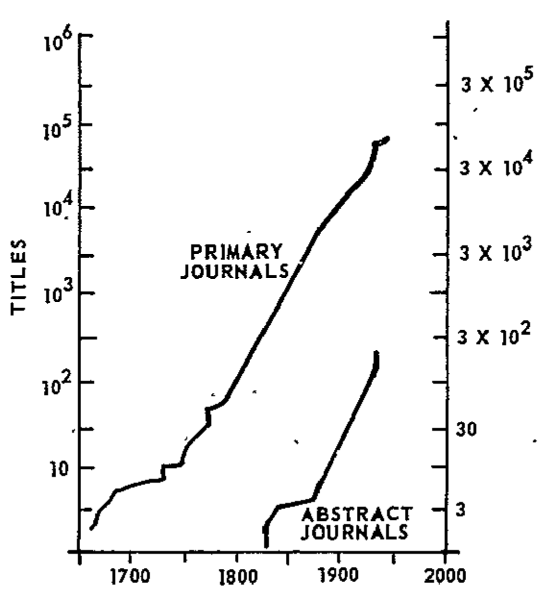


Figure II-6. Increase in the world's total number of scientific journals [II-46].

The Library of Congress is estimated to contain over 2 million titles in the area of science and technology. This is about 30 to 35 percent of their current holding. It should be emphasized that only in the area of technical reports does the Library of Congress have a custodial responsibility. Contrary to popular belief, the Library of Congress does not have a copy of everything published and has no intention of initiating such a policy. All copyrighted materials end up in the Library to be recorded, not stored. It is estimated that only about 65 percent of research materials are found there.

The National Library of Medicine reports that it has doubled its book collection every 25 years since its founding.

A projection of the information explosion has been made by Kozmetsky [II-47]. In 1900, the weekly stack of published material would be 5 feet high, 1 foot wide, and 1 foot long. In 1960, the weekly stack of published materials would be 5 feet high, 1 foot wide and 60 feet long. By the year 2000, the weekly published stack will be 5 feet high, 15 feet wide, and 60 feet long. In a century, this amounts to a 1500-fold volume expansion of published information.

The professional journal since its inception has served as [II-48]:

1. A means for recording information.

2. A means for disseminating information.

3. A means for gaining prestige and recognition.

In Table II-7, the functions of scientific journals are presented in more detail.

The dissemination function via journals is accomplished primarily by selling journals to members of the scientific community and to archival institutions. Journals have certain advantages and disadvantages when compared with the informal mode of information transfer.

The advantages of journals are:

- They afford priority and recognition to authors. The informal mode normally does not allow the author of information to gain recognition unless it is done at a conference or meeting.

- They function as a means of quality control. Filtering and referring processes reduce redundant and erroneous information.

- They archive scientific information.

- They give good distribution. Scientific information disseminated in the informal mode is often not identified by scientists.

The disadvantages of journals are:

- They provide extremely limited opportunities for source-user dialogue.

TABLE II-7. FUNCTIONS OF SCIENTIFIC JOURNALS [II-48]

1. Recording information (official public record)
   a. Control of quality (formal validation)
      Editor/referee (new; correct; non-trivial; appropriate; intelligible; referenced)
   b. Storing of information (scientific archive)
      Educational and historical resource
      Archive for scientific scholarship (data compilations; reviews)
   c. Establishment of priority (prime motivation)
      Support for claims; patents
2. Disseminating information (communication medium)
   a. Scientific information
      Tentative information (scientific dialogue)
   b. Pedagogical and historical information
   c. Information about science
      Scientist and institutions (news)
      Equipment and facilities (news, advertising)
   d. Contents of literature (information retrieval)
      Scanning journals
      Secondary journals
3. Conveying prestige and recognition (social institution)
   a. For authors (prime reward)
      Career advancement
      Visible progeny
   b. For institutions (status)
      Evaluation of personnel and programs
   c. For editors and referees (primary reward)
      Visible progeny
   d. For subscribers (visible credentials)
   e. For publishers (prestige and profit)

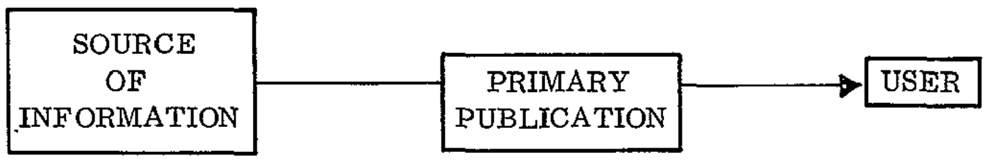
• They are slow, inefficient means of transmission of information. The main purpose of primary journals is to provide prompt publication of information. It is not unusual, though, for scientific information to be published 6 months to 1 year after the paper was received by the publisher.

• There is not enough effort made to compact information. The current problem with primary journals is their size and their near exponential growth that cannot be handled by abstracting services, libraries, and scientists themselves.

Formal Dissemination Systems

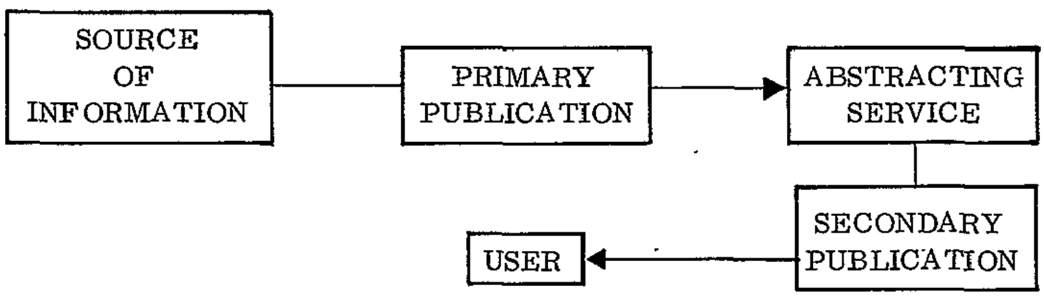
The traditional channel for dissemination, which is simple and widely used, is based on the following scheme.

System I



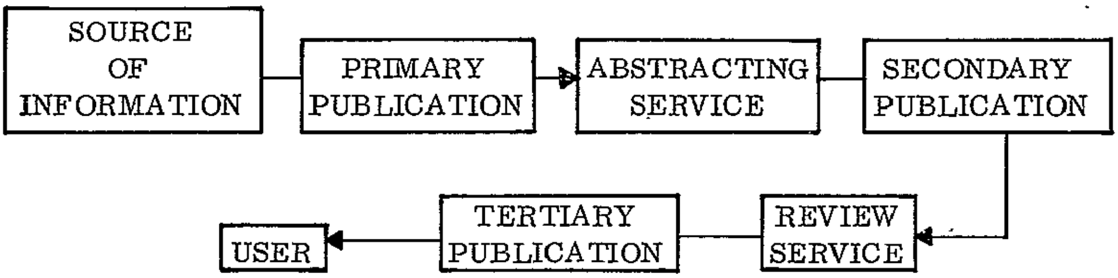
About 50 years ago, the first abstracting services were developed providing the user with a relatively rapid literature scanning system. The abstracting service produces a secondary publication that appears in the above scheme as:

System II



This system worked fairly well until the science and technological explosion occurred. Since then, there has been inserted into the system another service, which is mainly one of review, producing tertiary publications.

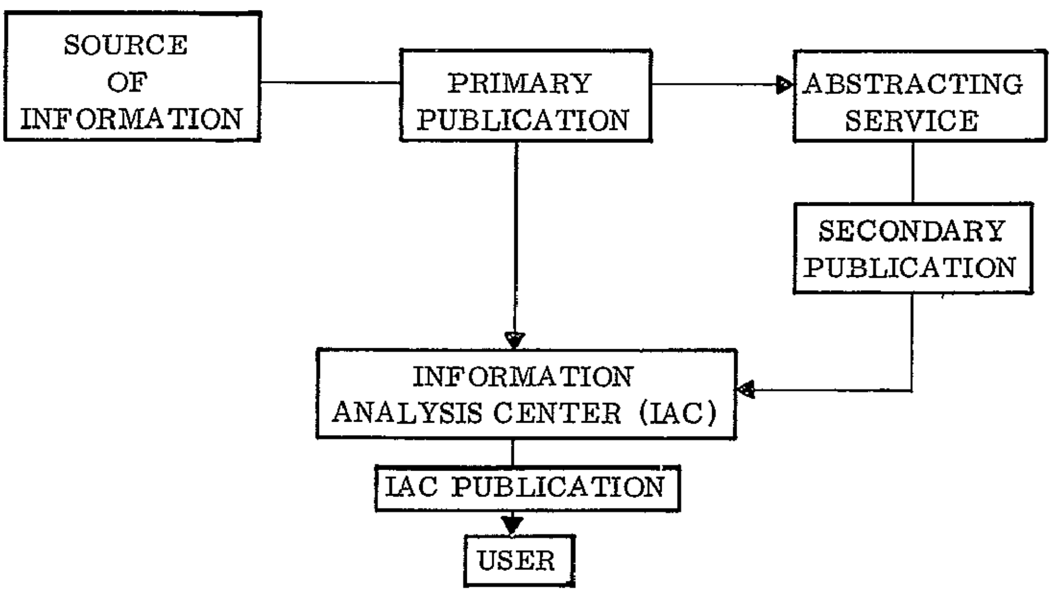
System III



The tertiary journal is of a specialized nature; namely, topic oriented.

More recently, since it has been realized that a researcher cannot successfully scan the literature himself either because of time or cost, the Information Analysis Center has been inserted into the path between the originator of information and the user [II-49, II-50]. This is shown as:

System IV



At the IAC, the scientific literature is screened by experts. The primary functions of the IAC are shown in Figure II-7.

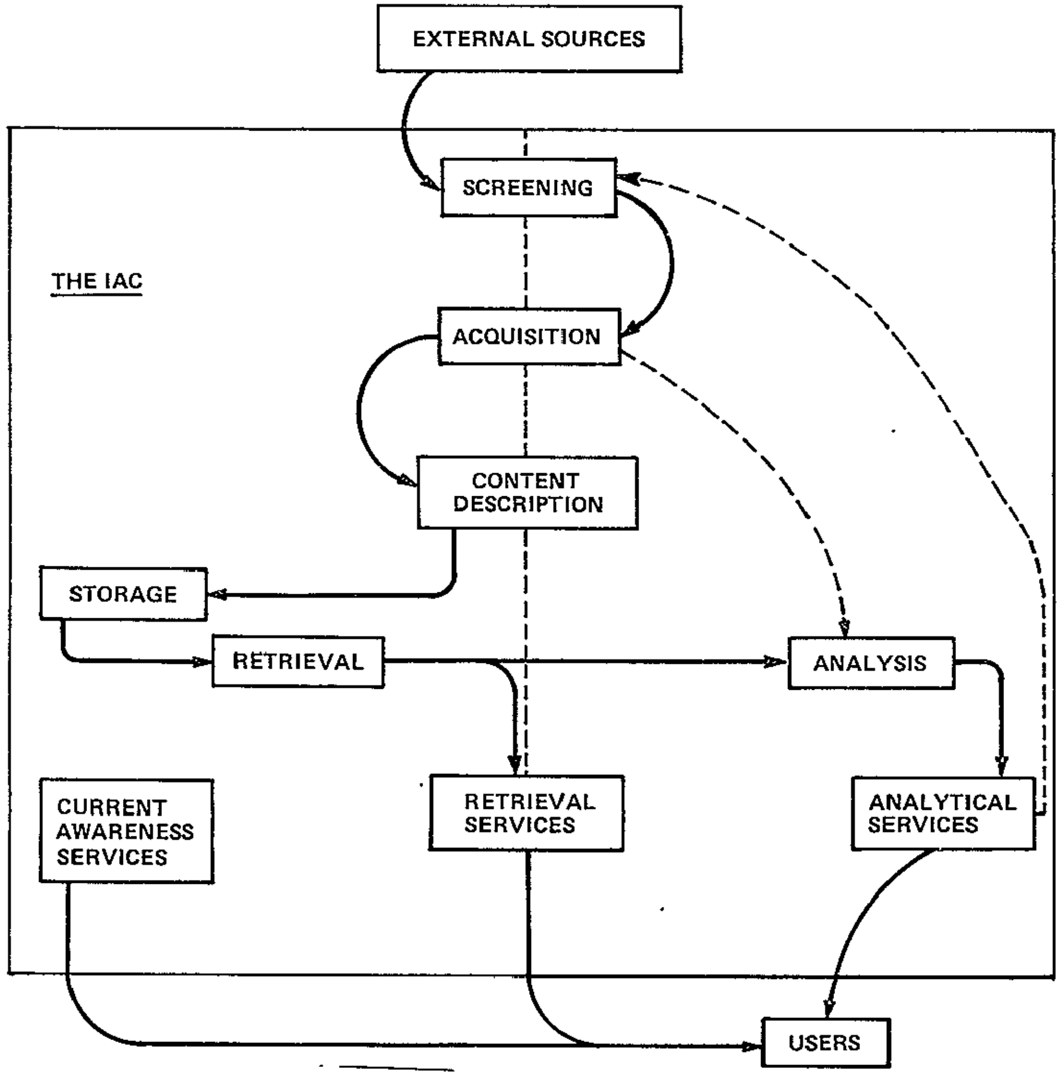


Figure II-7. Functions of an Information Analysis Center [II-49].

The advantages of using an IAC are: (1) the vast bulk of scientific literature is condensed by selection and clearly structured so that the user has an unambiguous path to the information he wants and (2) the selection process provides increased reliability of information [II-51].

At present, there are also several disadvantages. Two major disadvantages are: (1) identification of which IAC has the desired information is not an easy task, and (2) the cost for the use of their services is extremely high. With greater use and some form of government subsidization, the cost to the user could be lowered to the point where it is reasonable.

The type of material in primary, secondary, and tertiary journals is shown in Table II-8. Other formal dissemination systems are those originating with the government; e.g., CFSTI, NRCST. These two organizations issue directories identifying information resources.

TABLE II-8. TYPES OF PUBLICATIONS

1. Primary
a. Archival
b. News
c. Short notes
d. Comment
2. Secondary
a. Abstract and index
b. Bibliography
c. Current awareness titles
3. Tertiary
a. Reviews
b. Compilations

Methods For Improving Formal Information Dissemination

There are three general areas of formal information dissemination to consider for improvement. These are (1) scientific meetings, (2) publications, and (3) information centers. The latter two areas will be treated together because of the effect information centers have on publications.

SCIENTIFIC MEETINGS

Scientific meetings are an excellent idea for those in attendance. However, for those individuals who must rely on information disseminated from the meetings, they present a major problem in finding out what has taken place. The suggested idea of expanding abstracts only delays solution of the problem. Bulky compilations of abstracts are definitely undesirable. Recent meetings of the American Chemical Society and the Biology Federation have produced large collections of abstracts, which probably are not fully used by most scientists.

The suggestion of having smaller regional meetings instead of national meetings is a step in the right direction. At least more scientists can attend a meeting and get much needed exposure to new ideas. However, the problem still exists for those who cannot attend.

One solution, which has not gained much acceptance is videotaping of the sessions. These tapes could be distributed on a loan basis. The cost to an individual would be only a fraction of what it costs to attend a national meeting. ACS has recently produced tapes on various chemistry subjects and sold them outright to institutions. Acceptance of these tapes has been so good that current plans are to produce more tapes and disseminate them to a wider audience. It would appear that the time has come to experiment with this method of dissemination.

PUBLICATIONS AND INFORMATION CENTERS

There have been a number of proposals for improving the publications problem. One of these is to use preprints, which would accelerate the transfer of information and still give the author a publication priority. Detractors of the plan state that the time lag in getting information to the scientific community would be reduced at the expense of quality control and the facileness of archiving [II-52]. A publication, such as a scientific newspaper, could be used. The newspaper could be read and discarded, not archived. An investigator's priority for future publications could be established by an abstract or extract publication that would be of the secondary publication type. A feasibility study indicated that an initial investment of $10 million and a distribution to 500 000 subscribers at a cost of $15 per year would be sufficient to keep a science newspaper operating at a profit [II-45]. This study dealt with a general science publication that could be disseminated to anyone with a science background.

The time to propose different methods of dealing with the preprint problem is now. Failure to deal with this problem will eventually make current awareness of the literature in a very limited subject field a problem of the greatest magnitude.

The technique of selective notification or the development of "personalized" notification services for an individual at an academic institution or for a research group in an industrial setting has been well developed by libraries. If done properly, selective notification can be a real asset to an information system. Often, however, inconsistent selection and an excessive volume of announced materials have limited its acceptance.

Selective dissemination of information (SDI) has been effectively used in a number of science and technological areas. This concept of personalized service was formalized by Hans Peter Luhn of IBM [II-53]. It consists of the selection and announcement of current documents having a high probability of interest to the individual user. To obtain this service, the user must submit an "interest profile". NASA has used an SDI system since 1963 [II-54]. The system, which is one of the most extensive, contains the following three elements:

1. A standard form for presenting selected announcements to the user.

2. A method for conveniently requesting a copy of an announced document from a local library or from a central operation of the SDI service.

3. Routine feedback by the user to indicate satisfaction.

Of key importance is the use of a controlled vocabulary. In an SDI service, user interests and documents are indexed; whereas service, documents, and requests are indexed in a retrospective search. It is then of paramount importance that a commonly sought unit of subject matter always be labeled in the same manner and in the same terms [II-4].

Since SDI does improve the availability of information, it is quite desirable. To the backers of the journal concept, however, it poses a serious threat. SDI systems would purchase archival copies of journals and then repackage the subject matter for interested groups or individuals. If the SDI system was centralized, obviously an economic hardship would exist for publishers. The following concerns are also expressed [II-48]:

- The literature quality would be lowered.

- There is no assurance that the information would be archived in accessible places.

- Dissemination of separates is of unproven practicality.

- It is uneconomic.

These concerns will be discussed later when considering an information analysis center.

In discussing the journal of the future, Herschman [II-48] proposed an imaginative information system that might not be as far away as some might think (Fig. II-8). The system consists of terminal hook-ups that would provide service to six types of users as detailed in Table II-9. At present, such a system appears to be unfeasible because of lack of technology and the need for a universal coupling of systems. The technological advances needed for this system are presently being studied. Online computers in libraries, such as the Redstone Scientific Information Center, now satisfy the transmission link. In addition, current research at Morrow Laboratories of Redstone Arsenal on retrieving hard copy from stored information banks indicates that if a good method of processing hard copy from a video image is found, it will be possible for an individual in his laboratory or office to retrieve information stored in a computerized storage system.

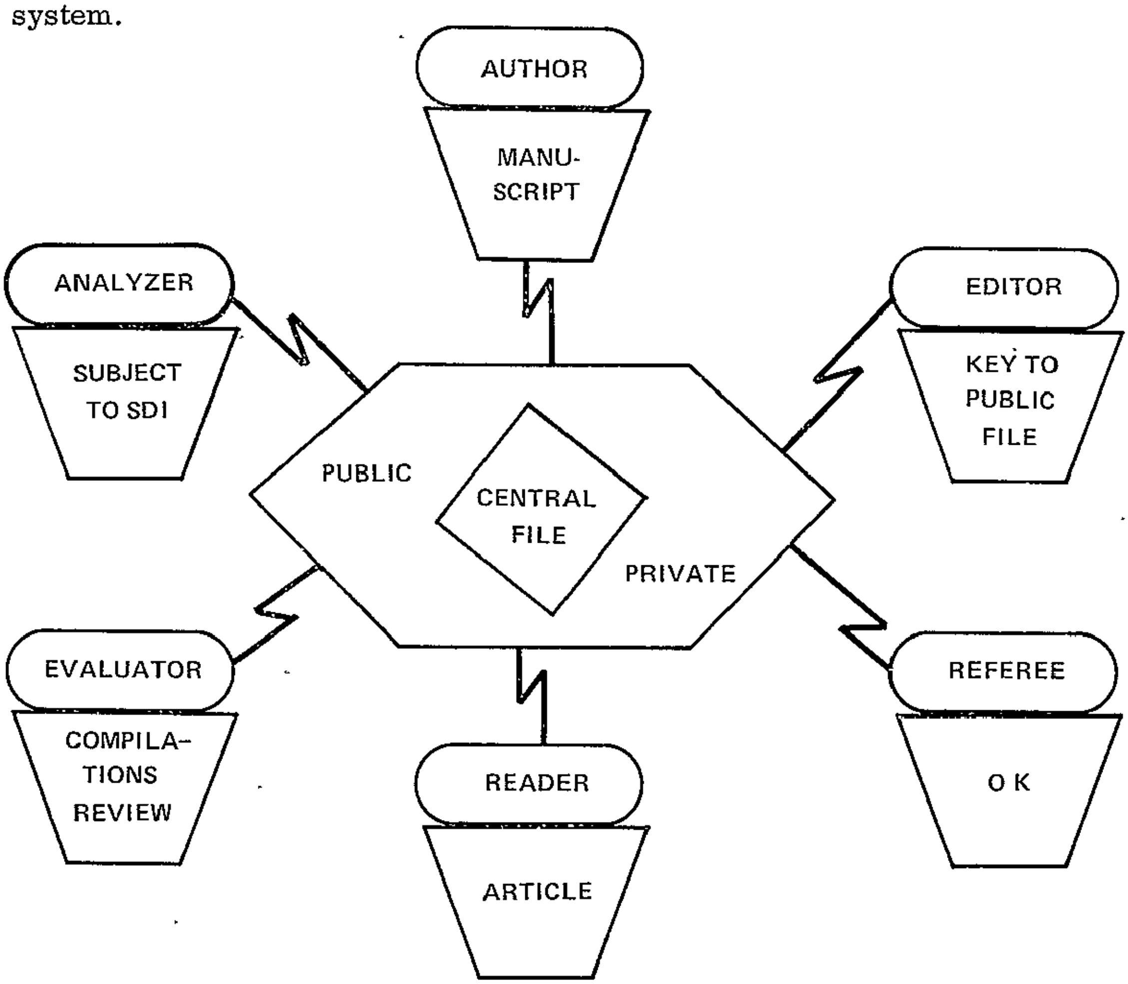


Figure II-8. The online university [II-48].

TABLE II-9. USERS OF ONLINE UNIVERSITY SYSTEMS

Type of User	Functions
1. Author	Transmits manuscripts to editor
2. Editor	Receives and transmits manuscripts to referee
3. Referee	Referees and transmits manuscripts back to editor
4. Analyzer	Transmits specialized information into various SDI channels
5. Evaluator	Compiles and transmits new material to editor for publishing
6. Reader	Assimilates material

The function of a library in these systems has been mentioned only in passing. Libraries play an important function in the areas of archiving and selective notification. Another service that has been glossed over is that of the IAC. Its function was briefly defined with respect to formal dissemination systems.

Both of these services will now be examined while considering the information flow to the casual user of science and technological information up to the most eminent engineers and scientists.

Information Dissemination To All Users

When considering the acquisition of information by the general public, one is faced with a plethora of paths. Some of the paths are to be expected. Others are subtle and often hidden to the nondiscerning observer. The existing paths or systems maybe broadly defined as:

1. Libraries — local, country, college and university, industrial and national

2. Information Analysis Centers

3. Newspapers and Magazines

4. Product Vendors

5. Extension Service

6. Government Publications

7. Television and Radio, live or taped

8. Consultants

9. Educational Institutions

LIBRARIES

Ever since Carnegie donated funds for setting up libraries around the nation, there has been a conscious effort to have one in every town, college, etc. Man's fascination with these structures would be more easily explained if they were used to their maximum utility. However, on any given day, it often seems possible to fire a cannon shot through one with little fear of injuring anyone.

These structures exist because of two beliefs:

1. The need for a place to store information.

2. The need to disseminate information in a given geographical area.

The first need seems adequately fulfilled. Every librarian in this country must be in a perpetual race to fill shelves, although not necessarily with books that the user always wants. The second need is not so adequately fulfilled. This may be good or bad, depending on whom you talk to. For the librarian, it is good because of his inability to handle a large influx of users. According to one national librarian, 90 percent of the American public does not use libraries. If the public did use them, the system would collapse. This is the reason generally offered for providing poor service. It has been found at the National Agriculture Library (NAL) that 85 percent of the material in a given year is not used [II-45]. The Library of Congress has a current circulation of about 750 thousand out of 8 million books. The National Medical Library has found that 50 percent of their material is irrelevant (by user definition) and that 50 percent of the material is never retrieved. It is known that people tend not to use libraries unless they are readily available. For a research library, a distance of half a mile is too far to go [II-45]. These examples are all applications of Moore's Law: People tend not to use information to the extent it is inconvenient to them.

Libraries in the United States are not used simply because the public is often unaware of services that could be provided. Part of this problem is because of the librarian's attitude of providing books but not service. The other factor is the behavioral pattern of the public. The public likes to use "hot" information media rather than "cold" media [II-55]. Libraries apparently must become more aggressive in their approach to serving users.

INFORMATION ANALYSIS CENTERS

The Information Analysis Center has been defined by COSATI as follows [II-18]:

> ". . . a formally structured organizational unit, specifically (but not necessarily exclusively) established for the purpose of acquiring, selecting, storing, retrieving, evaluating, analyzing, and synthesizing a body of information and/or data in a clearly defined specialized field or pertaining to a specified mission with intent of compiling, digesting, repackaging, or otherwise organizing and presenting pertinent information and/or data in a form most authoritative, timely, and useful to a society of peers and management."

There are presently about 225 commercial and governmental IAC's operating in this country. Most of these organizations are mission-oriented and provide, in general, excellent service to government-funded research groups. Another large group, estimated to be about 70 in number, is the academic IAC. Comparisons of various IAC's are found in Table II-10 [II-56].

It should be noted that the objectives of the three IAC's listed in Table II-10 are not the same. One of the major criticisms of the operation of the existing IAC facilities is the frequent use of personnel lacking expertise to make value judgements upon the worth of information and to classify it into various areas. However, at least one IAC has experimented with the use of highly skilled and active researchers operating in a referral capacity on a part-time basis. According to Liston [II-50] of the Battelle

TABLE II-10. COMPARISON OF UNIVERSITY, INDUSTRY, AND GOVERNMENT INFORMATION ANALYSIS CENTERS [II-56]

Aspect	University	Industry	Government
1. Location	Usually located in one geographic location. Physically, people and facilities are in one place.	If decentralized, can have several divisions in different locations.	Can be regional or continental U. S.
2. Orientation	Education (conserve, transmit, analyze, disseminate), advance learning; emphasis on education with broad background so individual is useful to university and society.	Profit. Training programs available to develop skills to make individual more useful to organization. Such programs may be restricted.	Service
3. Personnel	Students (pre- and post-doctoral), educators, researchers. Free contact with people all over who are available for consultation.	No students. Researchers.	No students. Researchers.
4. Facilities	Experts, large libraries, computing centers.	Narrower group of experts, more restricted libraries.	Some experts, large libraries.
5. Products	Available to world.	Usually restricted to internal use but can include patents and publications written for profit motives.	Some.
6. Funding	At one time there would have been a difference in source of funds. This is hard to generalize now. Government funds to some extent support university and industry. Industry funds to some extent support university and government.		
7. Flexibility	Most.	Some.	Some.

Memorial Laboratories, 20 percent of the expert's time was all that was required for reading and reviewing all of the pertinent material in his field. To conserve the time of the reference expert, it was necessary to back him up with a group of experts and with a library technician to supply supportive background and current information. As employed by Battelle, the expert is required to read and review all the publications of his specialty. These reviews are coded into an in-house computerized retrieval mechanism. By means of this personalized dialogue with the user, experts can determine the volume of data or information needed. In setting up a national information network, the broad range covered by these organizations would be well suited to meet the various needs of users. At present, however, these centers are often inaccessible to the general public. The only probable exception is the user who is near a university setting. Plans for an information network subsequently will be shown, wherein the IAC can play an extremely important role.

NEWSPAPERS AND MAGAZINES

The greatest portion of the science and technology information acquired by the general public is through reading newspapers and magazines. In a sense, the reader gets an analysis of what is happening in science. However, a real problem exists here because of a lack of qualified science writers. The importance of this form of media cannot be overstated. The public is not fully aware of the benefits of space research.

However, the medical profession seems to get fairly good news coverage. A study might be made on how the medical profession gets their results published often long before they ever come to fruition. It is suspected that the publics innate desire for any information that might solve a health problem is a driving force in publication of medical information. A general science newspaper might be an excellent approach to getting the information to the general public. The Wall Street Journal, which is a specialty newspaper, operates quite successfully by disseminating economic information to a limited audience.

PRODUCT VENDORS

In the New England Study and in other studies performed by the Herner Company, it was found that product suppliers provided a wide spectrum of information services [II-1, II-57]. Salesmen visiting various firms were either capable of handling user problems or they identified people, in their or other organizations, who could be of service. This highly successful service has been provided for years by large numbers of vendors and should be emulated by future information systems.

It is not unusual for a user to call a manufacturing firm for information even though other sources of that information may be close by. Two possible reasons for this are:

1. Lack of trust in information services that the individual has not dealt with.

2. Application of the principle of least effort.

EXTENSION SERVICE

The agricultural extension service in relating science and technology to farm applications has performed a valuable function. Few farmers exist today who do not use pesticides, herbicides, and commercial fertilizers. Although some people have dismissed the extension service as just another bureaucratic organization, to the farmer it is a useful aid in competing with other labor forces to produce a livelihood. The extension service is a decentralized operation under state control. Each state has at least one land grant college, and a force of county agents, who perform research, education, and analysis tasks for users.

GOVERNMENT PUBLICATIONS

This form of disseminating information has not been utilized fully. A primary reason for this is a noticeable lack in advertising the existence of government documents. The distribution of government catalogs describing the availability of information should be upgraded and expanded. Every library should become a depository for these catalogs, and the public should be made aware of this fact.

In recent months, however, with the rise of environmental and drug problems, a more conscious effort has been made to let the general public know of available publications that may be obtained.

TELEVISION AND RADIO

With respect to the coverage of some scientific/technical information (e.g., aerospace missions), this industry has done an excellent job in selected areas, such as manned space flights. In other areas, little or no information is ever transmitted. Often, programs that are presented are scheduled at a time when little viewing or listening takes place. An unanswered question is: Is this coverage an example of over-controlled information flow by the medium?

CONSULTANTS

Small and large firms often employ consultants to solve specific technological problems. Often, the firms could get the answer at less cost if they know who to contact or where the information was available.

EDUCATIONAL INSTITUTIONS

A large amount of information stored by the 5- to 30-year age group has been acquired in the formal educational process. The amount is dependent on such external factors as quality of instruction, number of years of exposure to ideas, and specific subject area of interest. Suggestions for improving information flow will be presented in a subsequent subsection on education of the user.

Future Information Dissemination Plans

Problems in setting up a network(s) for disseminating information, assuming that constraints (e.g., financial, political, technological) can be dealt with, include:

- Size of the system.
- Degree of decentralization.
- Ability to advertise the product or service.
- Degree of personalization.
- Ability to evolve.
- Cost to the user.

Some of the points to consider in resolving these problems are:

- As the size of the system increases, it will become more difficult to manage.

- The number of projected users may determine the size, depending on available funds.

- If the number of users is small, decentralization may not be necessary.

- A highly centralized system may not be able to:

    1. Have personalized interactions.

    2. Identify its users.

    3. Advertise its services adequately.

- A large system, without prior consideration, may not have evolutionary characteristics.

- In solving the other problems, costs may skyrocket for the user.

A general system that might be adaptable and serve the needs of users is shown in Figure II-9. In this system, the IAC processes all information produced, and the current awareness center identifies it for the user.

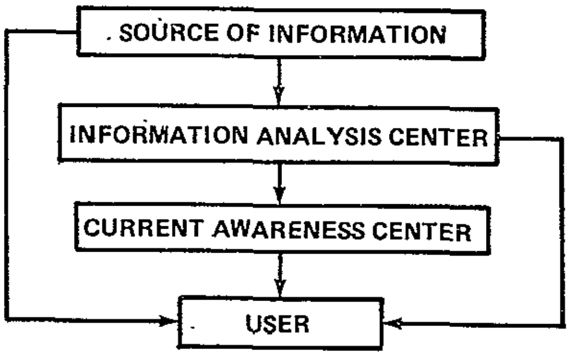


Figure II-9. Information system.

An expanded diagram of this system is shown in Figure II-10. Lines of information transfer exist along all boundary lines. An explanation of the areas in Figure II-10 is found in Table II-11. Before any more delineation of such a system could occur, specific information on constraints, technological state of the art, government policy, funding, personnel, and facilities would have to be known.

In the near future it is expected that professional societies will want to participate in a national system. Duplication of services would be reduced, lowering costs as well.

For the user, the IAC's and CAC will be answering the question: Who is doing what, where, and how? While more and more scientists and

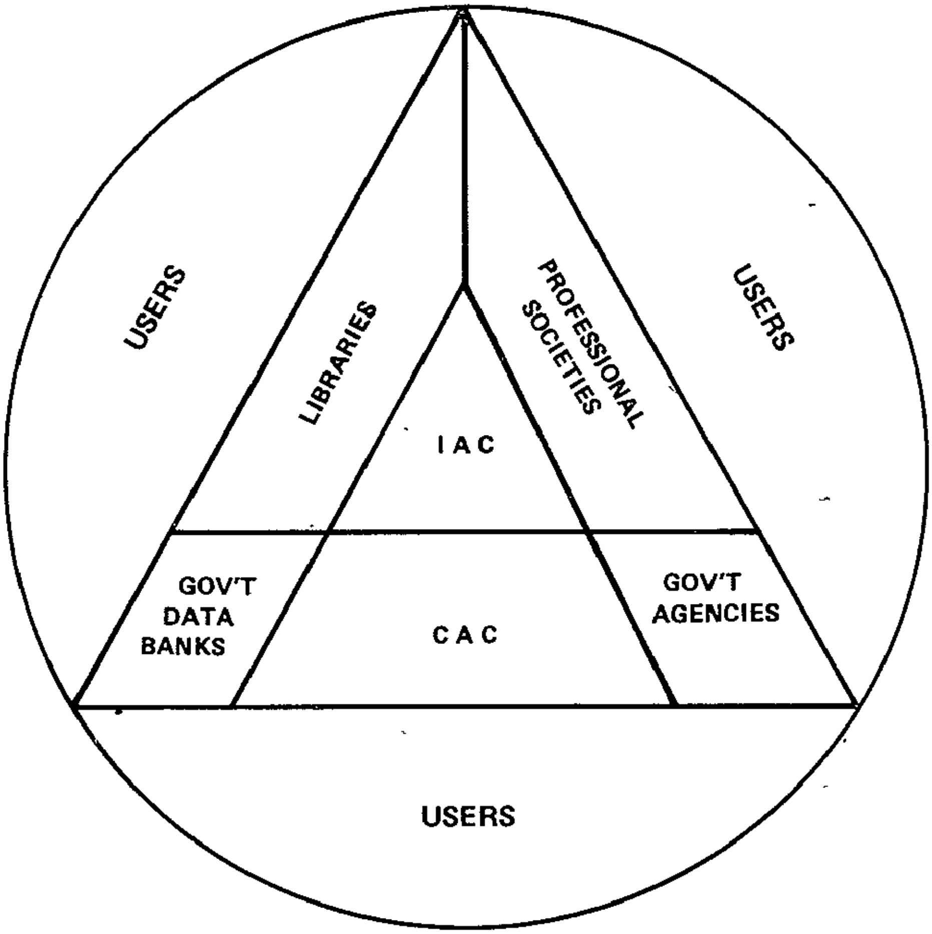


Figure II-10. Information dissemination model.

engineers are using IAC's, some still feel they can do it alone. Nevertheless, an increasing number of users are accepting the premise that information specialists and competent scientists in IAC's can provide precise, timely, and authoritative information.

It is clear that if we are going to meet the information problem, we must meet it head on, fully realizing that a major overhaul of our present system is in order.

TABLE II-11. EXPLANATION OF AREAS ILLUSTRATED IN INFORMATION DISSEMINATION MODEL

Area	Examples
User	Scientists, engineers, technologists, associate professional societies, government agiencies, new media, general public
Government agencies	Department of Defense, Department of Agriculture, Department of Commerce, Department of Interior, NASA, NSF, AEC
Government Data Banks	National Space Science Data Center, National Weather Record Center, NASA — Goddard Space Flight Center, Weather Bureau network
Professional societies	American Chemical Society, American Institute of Physics, Engineers Joint Council, American Society for Engineering Education
Libraries	Library of Congress, National Agriculture Library, National Library of Medicine, National Archives, university, private, public, and special libraries
IAC	Government, academic, commercial
CAC	Decentralized operation (projected)

EDUCATION OF USER

Introduction

Since change is inevitable in our society, one must be creative and evaluative when proposing educational programs. McMurrin [II-58] suggests that the proper function of schools is to be the chief agent of progress, whether it is: (1) the advancement of academic endeavors, (2) the social conscience in institutional organization and administration, or (3) the attainment of large visions for the future. The quest for excellence in education between 1945 and 1959 created some negative side effects in that it sought out good young minds, and most of these gifted children were found amoung the well-fed and fair-skinned [II-59]. No longer can education center on one select group.

As we enter a new decade, some of the basic assumptions delineated by previous generations of educators are being challenged. Kozmetsky [II-47] identified seven transitions that are occurring in educational settings.

1. Education is becoming a universal necessity rather than a privilege.

2. Schools are accepting, stimulating, and nurturing students rather than grouping, sorting, and screening them.

3. Education's role is becoming one of service to society rather than remaining separated from the real world.

4. Public and private enterprises are becoming educative forces and are supplementing the efforts of traditional schools.

5. Educators and students are becoming associates in learning rather than only a transferral agent for knowledge from older to younger.

6. Much informal learning is occurring outside the classroom through mass media and on-the-job training in addition to formal processes.

7. Learning devices are being utilized rather than considering the teaching-learning environment as primarily a batch-process involving teacher and students.

During the last phase of the 20th century, institutions (public and private) face the challenge of educating future leaders in the use of the technical and intellectual resources of our nation [II-47]. A current or future manager should be able to:

- Deal with emotional, behavorial, and technical changes.

- Communicate with and manage scientists, engineers, accountants, and artists.

- Use sophisticated tools for effective planning and decision making.

- Understand and implement the social and individual value systems of the populace.

These capabilities indicate that leaders or managers of the future will need to be multidisciplinary and that they must utilize new methods and techniques. When preparing for a postindustrial society, the requirement for a vast expansion in learning must be remembered [II-60]. Rather than organizing education for its value to work, work itself will need to be organized for its education value.

If the cultivation of knowledge skills is provided through diverse training and practice, individuals will be able to market their talents in a broader sphere [II-60]. Therefore, in the future, multiple careers will probably be encouraged. Similarly, multiple paths for graceful exit into other careers will offer relief from frustration or blocked advancement. No doubt, the possibility of multiple career pursuits will necessitate competence in the utilization of a broad scope of information. Green [II-60] has described one's ability to perform in this manner as "functional literacy". Although he predicts that the social demand for education as it exists now will decline, he believes that the forms in which education takes place will be greatly expanded. This expansion is expected to involve shorter spans of time devoted to education at any one point but the education will be spread over the entire lifetime of the individual.

Requirements and Criteria

Although information scientists are being trained to bridge the gap between the librarian and the scientist, the need to educate the user with respect to literature and information in his areas of interest still exists. Therefore, the user education requirement that was mentioned in the introduction to this chapter becomes the focal point for discussion in the remainder of this section. The requirement under consideration is:

> "An education program must be developed with the aim of optimizing consumer use of information."

To accomplish satisfaction of the above requirement, the following aspects of the educational program should be considered:

- To provide an education program — Provisions must be made for various organizations to educate personnel to provide for continued operation of the system.

- To provide a training program — A simple, well defined program is necessary so that all users can use the information system.

- To provide personnel and facilities to educate users.

The ultimate value of the various aspects of an educational program will be determined by how well they satisfy predetermined criteria. These criteria should serve as the quality standards against which the characteristics of educational programs are evaluated. The following set of criteria is appropriate for the various aspects of an educational program:

- Convenient

- Innovative

- Dynamic

Since each of these criteria deserves further elaboration, each standard will be discussed individually in the subsequent paragraphs.

A convenience of an educational program will have a definite influence on the number of participants who use the program, as well as an influence on the attitude that the participants may have toward the program. The need for convenience may be more pronounced among small to medium sized institutions or industries. A survey of New England firms has indicated that small firms made less use of information services and that they were less well represented at professional meetings and trade shows than were larger firms [II-1]. Regardless of the offerings of an educational program, convenience must be maintained to assure the effectiveness of the program. People do not use systems if they are inconvenient. The needs of the user must be determined and satisifed if any IMS is to be truly useful.

Secondly, educational programs will need to be innovative in the presentation of information and in the utilization of instructional techniques. Innovative instructional methods such as modular scheduling and individualized instruction are being experimented with at the university, secondary, and primary levels. Innovative curricula offer an appropriate mode for assisting users to learn about some new sources of information, as well as providing experience in utilization of the sources of information. Historically, the use factor of libraries has not been high. Therefore, a concerted effort should be made to arouse user interest in information services through innovative educational programs that have appeal and promote user participation.

Finally, the educational program should possess dynamic qualities. A number of characteristics that may contribute to the dynamic nature of an educational program are:

- Interactive — An interactive educational system is needed to replace the system of passive availability that exists now. Experiences that utilize information services and provide user interaction with sources of information are likely to be more beneficial than traditional methods. Licklider [II-61] has stressed the need for more interactive teaching techniques and has suggested that lectures are an inadequate technique for teaching about existing information systems.

- Appropriate — The relevance of an instructional program is highly dependent on its appropriateness for a specific audience. Unfortunately, in many instances, educational systems meet the needs of leaders in the field rather than providing learning opportunities for less well-informed or motivated users. Individualized instruction techniques may be necessary to insure that appropriateness is achieved.

- Communicative — Regardless of its elaborate nature, if the educational program is not focused on the effective transfer of information to the users, the communicative capability of the program will be lost. Involving users in a learning experience contributes to the communicative nature of an educational program. Also, the vocabulary and terminology employed should be appropriate to the audience being addressed.

- Involves a variety of senses — Educators realize that the effectiveness of an educational effort is directly related to the number of senses involved in a learning experience. Therefore, instruction in information management is facilitated by involving more than one sense. An example of an effort to involve more than one sense in a learning experience is the "Audio-Visual Guide to the Use of the Chemical Literature," which was accepted for instruction at Michigan State University [II-62]. This approach utilized an audio taped commentary synchronized with visual displays of 2 by 2 inch color slides.

- Involves various domains of learning — In addition to involving a variety of senses, educators recognize the need to involve various domains of learning when developing instructional programs. The cognitive, affective, and psychomotor domains should be included in the learning experiences of individuals. Education in the cognitive domain will permit the user to know about, comprehend, apply, analyze, and evaluate information services as well as his information needs. Hopefully, the user will then be able to synthesize additional uses that he could request from the information service. Education in the affective domain will encourage the user to assess the worth of information services, to value them, and, hopefully, become committed to their utilization. Experiences gained in the psychomotor area will provide users with confidence since the experiences are concerned with skill development in the utilization of information services. Psychomotor training will become more important as remote terminals and other hardware developments become available.

- Evokes desired behavorial response — Little would be gained if the audience is not motivated to have a positive behavorial change in its attitude toward and utilization of services that are available. Instructional objectives for educational programs should be constructed carefully so that they accomplish desired behavorial changes through an active rather than a passive program.

A combination of the six preceding characteristics will contribute to the dynamic nature of an educational program for the utilization of information services. Since these characteristics are general, they are suitable for use when evaluating a variety of approaches for user education.

In summary, the use of any information service is a selling job, according to Dr. Edward Bartkus of the Du Pont Information Center [II-63]. It was pointed out that information has an associated cost; but, whether free or with an appropriate charge, the tendency is not to use the services usless they are available locally and are appealing.

User Orientation and Continuing Education

Complex schemes for information systems necessitate orientation so that the user can understand the system with regard to what it can and cannot do. Information analysis centers realize that users need assistance in stating questions to get the information they desire. Apparently, users do not know how to be specific when requesting information, even when they know that information services exist. The need to stay up-to-date exists in all professions; however, in scientific and technical areas, the need for current information is particularly acute.

In addressing the North Atlantic Treaty Organization (NATO) Advisory Group for Aerospace Research and Development (AGARD) Conference, E. Liebesny [II-64] stated that the need for academic specialization by users and information suppliers has grown over the years. The information supplier has developed consequently into an information scientist but little has been done to train the user. However, Liebesny insisted that in training a user to deal competently with the documentation of his special subject field, it would be unwise to aim at such a high degree of professionalism as to render him an information scientist. Since the user's training can be initiated at various stages, the characteristics of these stages should be investigated. While Liebesny indicated that university undergraduate programs are often too crowded to include courses in documentation, he neglected to consider incorporation of the use of information services into existing courses through the problem approach. With regard to training at the postgraduate stage, Liebesny assumed that the recipient is more mature and more aware of his needs with respect to documentation and, therefore, would be expected to be in a proper frame of mind to accept training. Regardless of the advantages of training at each stage, the need for training at both stages exists.

SATCOM explored the need for training in the use of information systems and recommended that the U. S. Office of Education support a broad program in library education [II-18]. Such a broad program would (1) train more students for careers in information management systems and (2) train all students as well as faculty in the use of the increasingly complex array of existing library and information services.

Specific requirements for the amount and technical level of familiarization will differ from user to user, but the following educational considerations will apply to the majority of users.

1. Introduction to the nature of the system

    a. General information concerning system

    b. Description of data currently available

        (1) Reports on findings

(2) Experimentation in progress

(3) Sampling currently underway

c. Description of scheduled projects

2. Compatibility requirements

a. Formatting specifications

b. Remote acquisition methods

c. Feedback instructions

d. Procedure for implementing systems changes

e. Availability of technical assistance

f. Procedure for initiating experiments

g. Procedure for dissemination

3. Methods of familiarization

a. Introductory descriptive literature distributed through professional societies, universities, news media, etc.

b. Seminars of minimal length in various geographic areas

c. Use of mass media, particularly ETV

d. Published descriptive manuals

e. Prerecorded detailed instruction

(1) Programmed learning material

(2) Film presentations

(3) Video tapes

(4) Computer-aided learning

Continuing education programs for users of information systems will need to address themselves to the problems of data management, innovation in information processing and hardware, and the capability of the system. In the area of data management, users should be provided with instruction that will assist them in designing experiments or requests so that they obtain only that data or information that is pertinent to their needs.

Taylor [II-65] has suggested that seeking information consumes a large portion of an engineer's working time. The conference on Information Services, Systems, and Media in Engineering Education has considered a long range program directed toward education in information management. This proposed program allowed for a study of the methods most suitable for teaching information management with the expectation that innovation in educational procedures will occur. Although the program's objective was to improve search and acquisition, both during formal education and afterwards during professional practice, emphasis in the educational program was placed on underlying ideas more than on hardware.

The Curriculum Panel of the previously mentioned conference proposed that actual teaching of information management be directed at the following classifications of students and professionals in the order mentioned:

1. Lower division undergraduates
2. Upper division undergraduates
3. Graduate students
4. Engineers at their professional threshold
5. Engineers requiring retraining
6. Productively employed engineers
7. Secondary school students

The panel also recommended that the problem approach be employed as a teaching technique, since it is most likely to result in desirable behavior patterns. Investigation of the systems approach as a teaching method was proposed also.

Several dilemmas which face educational efforts have been identified by Kozmetsky [II-47]:

- Educational administrators must establish a basis for educating students for an industrial society that is rapidly changing.

- Channels must be kept open to transfer the flow of technical information and innovation to the students from industry and government.

- More qualified teachers must be obtained at the college and secondary school level.

- Adequate measures for evaluating teaching effectiveness must be developed.

As educators attempt to face these dilemmas, computer utilization will become more commonplace in business and education. Furthermore, multidisciplinary exchange will become essential for both research and teaching. Alternative approaches for educating the user should be considered after identifying problems and the environment in which they exist.

Alternative Approaches

Alternative approaches for education of the user that will be considered in this subsection may be divided into two major categories. The first category will explore possible approaches for providing educational and/or training programs; the latter category will deal with various approaches for providing personnel, materials, and facilities for educating the user.

EDUCATIONAL PROGRAMS

Educational programs may range from those that satisfy the educational need of the masses to those that meet the needs of only one individual. Alternative approaches are:

- Short courses conducted at regional and/or state centers

- College and university curricula

- Field worker programs

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- Secondary school curricula
- Professional society courses
- Vocational institute curricula
- Consulting firms
- In-house instruction
- Individualized instruction

Subsequent discussions consider the potential of each of these approaches.

Short Courses Conducted at Regional and/or State Centers. Residencies are a technique that have been used by the Aerospace Research Applications Center for user orientation [II-66]. For a system that has one headquarters location or various regional locations, residencies may be useful to satisfy curiosities of the users and give them a better frame of reference for the operation of the system. These short training sessions may also be conducted as an internship period. Herner [II-67] has developed and tested a 1-day course for training federally-employed scientists and engineers in information gathering. The topics covered by this experimental course were:

- Information about information
- Information on ongoing research and development
- Current research and development results
- Past research and development results
- Major american library and resource collections
- Organization of personal index files
- Relationship of the scientist and engineer to his information tools and mechanisms

A portfolio of demonstration materials and a text entitled "A Guide to Information Tools, Methods, and Resources in Science and Technology" were prepared to accompany the course syllabus. This course was developed at the request of COSATI and received financial support from the U. S. Office of Education.

Tours of a facility are another alternative for acquainting users with the operation of an information center after it has reached an operational phase. Tours provide flexibility in an educational program since they can be arranged at a time that is convenient to individual users.

Opportunities to take courses "on the road" and "into the field" should be sought since inertia and lack of interest may prevent some users from participating in courses offered at centers [II-1]. Adequate logistic support in literature searches (without irritation and frustration) tends to generate appreciative support by users for an information center [II-68]. Public relations policies employed by centers are another factor that will influence their utilization.

College and University Curricula. Graduate and undergraduate curricula offer possible approaches for providing training in the use of various information services. Instruction can be provided through formal courses in information acquisition and library use. Alternatively, regular course assignments that necessitate use of the periodical literature, as well as bibliographic tools and techniques, may be used [II-69]. Regardless of the approach employed, training of this type insures (1) an information system that is responsive to the needs of users and (2) a user group that knows how to use the system. A survey of teaching practices with respect to chemical literature has revealed that a small decline in chemical literature courses may be ascribed to a faculty preference for integration of chemical literature into other courses [II-70]. Incorporation of information gethering techniques with other teaching goals is a good way to teach information retrieval and should be encouraged in all disciplines.

Licklider [II-61] has suggested that education in the use of technical information systems be integrated into graduate project work. However, if an opportunity for utilization of information services exists at an earlier stage in university training, it would be highly desirable to take advantage of the opportunity.

Field Worker Programs. Purveyors of information who work in the field offer a third approach for education of users. This technique utilizes an approach associated with Smith, Cline, and French Laboratores and the United States Department of Agriculture Extension Service. These specially trained individuals put a link between users of information and storage centers [II-13]. Although dissemination services associated with information analysis centers are being introduced, prospective users will still need points of entrance to information systems. A referral agent, such as has been suggested for transfer of technology, might offer a point of entrance to the information system by guiding individual users into the system at a point where they have competence and understanding. At best, users will need to devote serious attention to learn how to interact efficiently with an information system.

In the medical profession, purveyors of information entitled "Continuing Education Specialists" have been proposed to make up for negative forces that exist, because medical practitioners do not utilize libraries to the extent that those in academic areas do [II-69]. These continuing education specialists would:

- Inform practitioners of the existence of information of direct use to them in their work.

- Acquaint them with useful information tools and techniques.

- Attempt to define and help practitioners to find solutions to information problems.

- Perform continuing surveys of clients' information needs and use patterns.

The concept of the Continuing Education Specialist has been modified for use in the New England Technical Service in such a way that specialists staff "Industry Desks" and facilitate technology transfer [II-1].

Secondary School Curricula. Secondary school curricula provide another approach for training potential users in the skills required for efficient information acquisition. A priority listing for teaching information management prepared by the Curriculum Panel of the Conference on Information Services, Systems, and Media in Engineering Education placed secondary school students lowest on the list [II-65]; however, this position may be unfortunate since any training that the student has prior to entering college provides an ultimate advantage. A number of innovative schools exist currently and provide a natural setting for introduction of information utilization techniques. Previously, when educators became concerned about training in science and mathematics, emphasis was placed on all levels of primary and secondary schools. Perhaps similar concern should be demonstrated with respect to the need to educate information users.

Professional Society Courses. Professional society symposia, technical exhibits, and trade shows provide an alternative approach to acquaint users with available sources of information. Several professional societies have had sessions on information and documentation in recent years. Unfortunately, these sessions do not appear to be as well attended as concurrent sessions that deal with discipline-oriented topics.

Evidence indicates that larger firms tend to be represented to a greater extent than small firms at scientific and technical meetings [II-1]. Typically, the information obtained by representatives at these meetings deals with (1) specific discipline topics and (2) methods and procedures. Nevertheless the professional society maintains a strategic position for educating users. Required continuing education has been implemented in professions such as dietetics and may be expected to follow in other professions in either a formal or informal manner.

Technical exhibits at professional society meetings are being utilized to acquaint users with various sources of information. Attractive displays offer instruction to the viewers and provide commercial suppliers with immediate evaluations of their services [II-68].

Trade shows are attended by a wider range of representatives from industries than are scientific and technical meetings [II-1]. Information acquired at trade shows generally deals with equipment and industry trends. These gatherings provide an ideal possibility for acquainting the industrial users with available information services.

Members of learned societies and associations offer prime targets for education. These memberships are capable of cutting across the barriers of individual firms, government agencies and separate colleges [II-71].

Vocational Institute Curricula. Vocational-technical institutions offer a mechanism for training users who have little scientific training. In this educational setting, emphasis should be placed on information retrieval for the nonscientist. Publications that describe the spin-off value of scientific developments are available from agencies such as NASA and AEC. These publications offer information needed by smaller firms or industries for utilization of technological developments. Since the graduates of vocational programs are usually associated with these small industries, their familiarization with the availability of information of a slightly technical nature is especially vital in insuring the future of small enterprises.

Consulting Firms. Consulting firms represent a source of information, as well as a means for education of users. A survey of New England industries revealed that larger firms tend to use consultants to a greater extent than smaller firms [II-1]. Although services provided by consulting firms are commonly limited to specific goals in an attempt to solve perceived problems, consultants can be sources of information or they can direct users to available sources of information. Consultants may assist users in refining their data or information management techniques.

In-House Instruction. In a survey that explored the potential market for continuing education in engineering, Landis [II-72] found that most engineers overestimated the likelihood of their taking college courses and underestimated their participation in company-offered courses. One would expect a similar situation to exist in other professions. Landis identified the "homogenization" process as a major problem in continuing education, since participants are most often at many different levels of competence. Most of the engineers who were surveyed expressed interest in offerings that would help them immediately and that were related to their current job. According to Landis, "skill training" is the way to enlarge the continuing education market among engineers. Skill training requires compartmentalization of knowledge into small modules. In addition, he suggested that there must be an apparent payout function that is job-action related. Landis identified partial programmed instructions as a natural technique for accomplishing compartmentalization of knowledge. Another problem to be considered is that a relatively high average age will reduce participation in continuing education. The climate, which continuing education induces, as well as what is actually being taught, will influence the success of a continuing education program.

Individualized Instruction. Methods that can be used or adapted for the education of individuals range through the spectrum of prerecorded tape recorders, individual projectors for slide strips, and microfiche all the way to a man/computer preprogrammed instruction. Cassette or cartridge audio recordings for use in the automobile may fulfill the orientation needs of individuals who spend considerable time commuting between their home and business and wish to use their time profitably.

Since cartridge television is expected to be available in the future, familiarization of users with the complexities of information systems may be accomplished by supplying informative television cartridges to the user at his home or office [II-73]. Video tapes and telephone lectures associated with educational television networks offer other possibilities for user orientation. Although cathode ray tube (CRT) terminals are not as widely distributed now as they may be in the future, CRT displays are likely to provide a mechanism for user orientation without requiring the user to travel away from his office or institution. Individualized instruction has the benefit of providing training when or where it is wanted. Networks that utilize remote terminal access possess the potential for injecting new life into programs of continuing lifetime education in a wide variety of academic areas [II-74].

EDUCATIONAL PERSONNEL, MATERIALS, AND FACILITIES

To offer an effective educational program, adequately trained personnel, acceptable materials, and convenient facilities are required. Greater emphasis is being placed on the training of information scientists in an effort to bridge the gap between the scientist and his literature [II-68]. Individuals who function as purveyors of information must maintain a state of readiness in the scientific or technical fields. Likewise, the manager of an information system needs to keep up to date; however, he will probably place greater emphasis on breadth rather than on depth of knowledge [II-75]. Although educational institutions can assist in providing training programs, many will need equipment, financial assistance, and further training for some of their faculty before they can function in this role.

Consideration should also be given to training science writers so that they can relate technical findings in an understandable fashion. Skilled science writers will be in demand to prepare informational materials for use in technology utilization programs undertaken by vocational/technical institutions, government agencies, professional societies, and commercial firms.

Personnel for information services will need to be trained in the use of computerized equipment as automatic information retrieval and bibliographic search techniques come to the forefront. Individuals interested in working in the field of information retrieval should be reasonably meticulous in working out details and be creative when developing new approaches for information acquisition [II-68]. Furthermore, they will need to develop the ability to identify users' needs.

Materials and equipment become an integral part of an educational system. Although mailed announcements have been the standby for many types of services, evidence indicates that interested individuals may not be included on the mailing lists; or when the announcements are received at an institution, they may not be communicated down through the hierarchies to all the interested users. Therefore, mailed announcements need to be supplemented by some other type of orientation method whenever possible.

Handbooks that describe techniques for using data collections and services will become another material for use when educating the user. These handbooks should include (1) instructions for using the publications, (2) instructions for processing data, and (3) a manual documenting the programming language. selected as a standard. Handbooks of this type are expected to be in greater demand as large quantities of data become available for further analysis (spaceflight data, earth resources data, etc.). These manuals should be attractively formatted and widely distributed. At the outset, frequent revisions of the handbook should be issued to clarify points that confuse readers.

Since technological advances permit evolution in hardware and information processing procedures, periodic instruction or orientation will be needed to acquaint users with new developments, as well as to obtain feedback regarding user acceptance of technological innovations.

The use of certain media, notably various microforms, has not received wide acceptance in the scientific community. Not only are many copies blurred and hard to read (being no better than the original), but people with eye problems have difficulty with the viewers. The current emphasis on microimages has been pursued by information specialists without adequate consideration of how satisfactory they are to the user. Evidence concerning the use of microfiche indicates that when users were consulted, approximately one-half of the individuals surveyed were dissatisfied with either the microimage or the reader [II-76]. By the same token, a high resolution television picture with a 2000 to 5000 line raster is mandatory if TV is to achieve its full potential as a learning aid. Acceptability by the user must be remembered and planned for as much as possible, while keeping in mind that technology seems on the verge of many more usable innovations. Education of the user for acceptance of other innovations will also be required to insure consumer satisfaction and utilization of the information management system.

Facilities constitute a final requirement for an educational program. These facilities need to be strategically located so that they demand minimal effort from the users. Government agencies and commercial organizations utilize booths at professional meetings to distribute samples of their publications and to emphasize technical services offered. In this way, the agencies and organizations provide convenient facilities to attendees. The foregoing considerations are appropriate regardless of whether the education services are provided by high schools, colleges and universities, vocational/technical institutions, government agencies, professional societies, national library systems, or consultants.

In planning an agricultural sciences information network, the National Agriculture Library (NAL) has assumed that the state land-grant libraries are natural nodes for interconnecting users with desired information [II-77]. Proponents of the agricultural sciences information network acknowledged that the user's awareness of and use of the network must be encouraged. Direction of users to their closest point of entry into the network was delineated as an operational duty of the NAL and its information network.

Summary

The success of an educational approach will depend on the communication and working relationship that is established between the users and the information management system. Individualization of the program is encouraged to increase its appeal and interactive characteristics. Users will need to be made aware of services and tools that are available to them and how to use them profitably.

Initiation of innovative methods should be reserved for individuals who are receptive to new techniques; Bartkus [II-63] refers to these individuals as "movers". Dynamic individuals, as well as dynamic instructional methods, should be employed when developing an educational program for information users. Also, the convenience of the instructional program for its intended audience is of prime importance.

Generally speaking, the primary reasons for the failure of potential users to optimize their interaction with the information system are that they either were not aware of the system's content or they were unable to enter the system as either a principal investigator or simply as an active user. All users of the system will need some degree of system orientation in order to participate effectively in the information interchange. As a general rule, those most dependent on the system will naturally require the highest level of familiarization and, in some cases, training in the optimization of man/system interface.

SUMMARY

The development of any information system must be predicated on the needs of the user. The identification of user needs is a difficult process. The user himself cannot articulate these needs in every case.

The answers to this dilemma are multifold. Factors that should be considered are:

- Education of the user for the purpose of articulating his needs.

- Education to prepare more disciplined, responsible individuals.

- Behavioral studies to determine what kind of system the user audience will use.

- Recognition that these are several levels of users with each level having unique requirements.

From the user's point of view, it would appear that current systems have not been designed with his interests considered. Planners who disregard the social and behavioral factors of mankind are playing the role of "suboptimizers". They are designing a beautiful system that nobody wanted in the first place.

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CHAPTER III
INFORMATION AND DATA PROCESSING

CHAPTER III. INFORMATION AND DATA PROCESSING

INTRODUCTION

The function of processing in an IMS is to perform the required transmission, reduction, and storage of information and data between specified sources and users. A successful processing system must meet the following criteria:

- It must satisfy the users.
- It must process information and data supplied to it and requested from it.
- It must be evolutionary; i.e., it must possess the capability to adjust its functions and size.
- It must be economically feasible.

Some of the implications, problems, design variables, and components of a processing system that will satisfy the above objectives and criteria will be presented. The considerations will be more conceptual than detailed in nature in that they will speak more to philosophies and methods than to specific detailed components of a system.

An IMS has three areas of responsibility — sources or generators of data, processing of data, and the utilization of data or information by appropriate users. Figure III-1 is a pictorial diagram showing the relationship between these areas in the most general sense. There is a fourth area of management analysis, which overlays, permeates, and coordinates the other areas. Management is considered to be an integral part of the other areas and is not shown here as a distinct entity.

Information and data processing can be subdivided into the three functions of transmission, reduction, and storage. The transmission link extends from the sources of information and data to the users. It thus serves as a means for identifying the system's scope (area of influence) and for tying together the IMS. Reduction and storage occurs in varying degrees at many points along the transfer path, as illustrated in Figure III-1. The greater amount of information and data will flow from the source to the user. A lesser

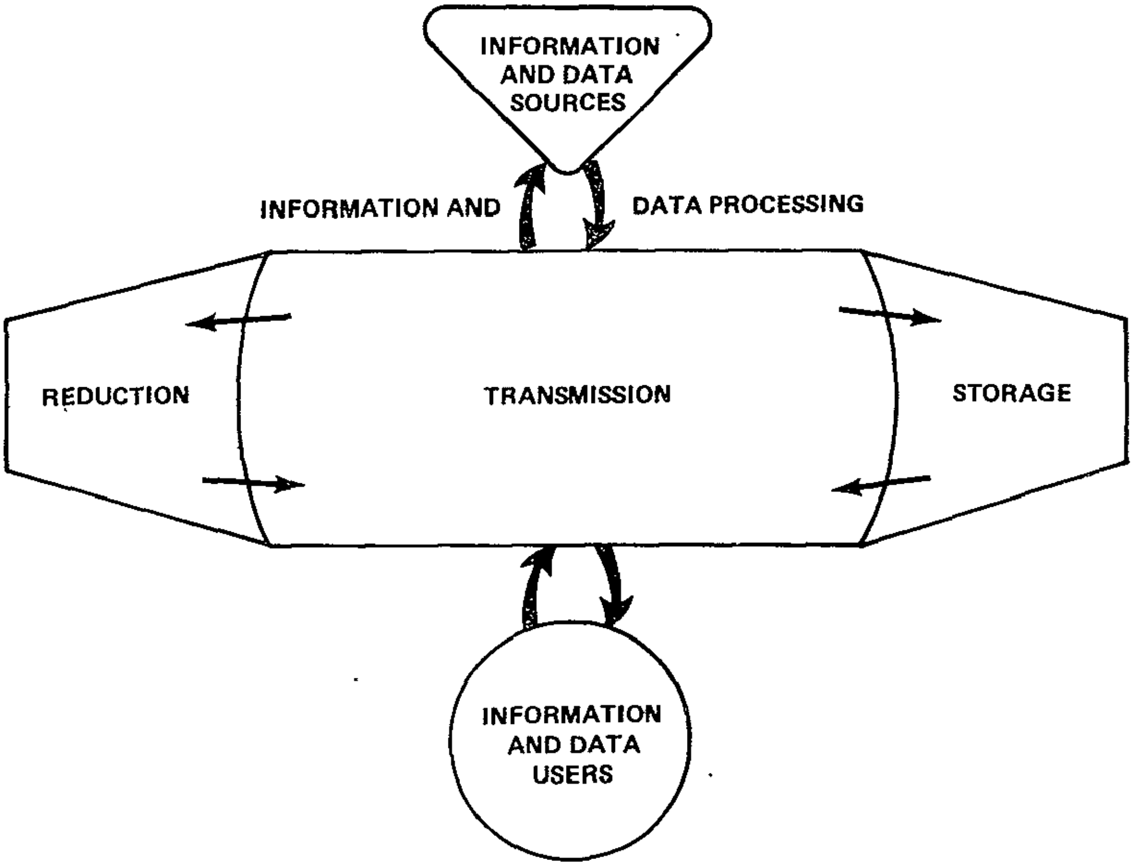

Figure III-1. A block diagram of an information management system.

amount in the form of user requests, control signals, system operation data, and feedback information will be transferred in the reverse direction.

One of the most important keys to a successful IMS is the level of understanding and trust that the individual user has in the data processing. The user must, therefore, be completely informed as to the internal mechanisms used to "manipulate" the data. He must, likewise, be educated in the state-of-the-art technological constraints and the economic feasibility constraints. This understanding will aid the user in making reasonable requests of the system in terms of the amount, form, and delivery time of available information and data.

The areas of transmission, reduction, and storage will now be discussed with a view toward considering further the overall design of an information and data processing system. Attention will be focused on particular concepts, system variables, and problems.

INFORMATION AND DATA TRANSMISSION

Introduction

Man has long strived to master his environment and has succeeded in most instances. One of his most notable failures, however, has been his attempt to establish rapport with an information transfer system. The man-system interface has posed a problem from the standpoint of both the user and the system. The degree of success enjoyed by any system depends ultimately upon the acceptance of the system by the user. In this context, the information transfer process will be viewed from the standpoint of both the technical aspects of the system and from the system expectations of the user. To obtain and identify the system variables, the question as to what requirements must be imposed upon the system to elicit full user acceptance will be addressed. It is of fundamental importance that the system (1) operate on the principle of least effort and (2) produce usable and timely results. The above requirements produce two system variables. These are (1) the user-system interface and (2) the transmission link.

The functional relationships and characteristics of these variables will be discussed, and an example will be presented illustrating trade-off parameters.

Characterization of System Parameters

The user-system interface will be characterized according to available and projected hardware. The various input-output devices will then be tabulated on the basis of information capacity as a possible trade-off parameter.

The transmission link is defined by the transmitter-receiver locations. The trade-off items are identified, tabulated, and examined with several examples presented.

Several input-output devices are listed below, and pertinent characteristics are discussed.

User-Information Specialist. Experimental evidence suggests that neither the information system specialist nor the nonuser subject specialist is very successful in assessing the relevance of information to specific user requirements. Therefore, it would seem that in the operation of any information system, the user should preferably be the only arbiter of "information relevance" to a specific problem.

User-Computer. There is sound rationale to justify the necessity of computers in an information transfer process. One only has to examine the literature to verify this contention. A study by Hough [III-1] projects information transfer volume for the 1970 to 1990 time span. A summary of these cataclysmic projections is presented in Table III-1. Concomitant with these predictions is a definite need for more information processing capacity. In the year 1965, the amount of machine information processing capacity that was available amounted to not much more than one-tenth of all available human processing power. Hence, we are still in an era where electronic information processing capacity is relatively scarce. Since the human population has neither the time nor the inclination to process all of the data generated during this 20-year time span, it is mandatory that we automate the ingestion of these forthcoming data. The mass production of giant automatons is not the total answer. Experience has shown that, however modern, the computer can never make critical judgements or interrogation of the data it handles. It is therefore assumed that direct contact between individuals will continue to play a major role in communications.

Remote Sensing Terminals.

Typewriter. This mode of communication is straightforward and easy to operate (assuming a knowledge of the system thesaurus). The input is slow, depending upon the user's skills, and the output is relatively slow (15 characters per second).

Picturephone. This service provides the capability to instantaneously display the output in video form. If hard copy is necessary, special peripheral equipment could provide the desired service. Picturephone service is soon to be introduced on a regular basis in several cities. It is possible that these devices could (1) provide a means for mass dissemination of information, (2) augment the NET, and (3) provide special service to the scientific community.

TABLE III-1. SUMMARY OF DEMAND TREND PROJECTIONS

Service	Units	1950	1960	1970	1980	1990
Voice						
Telephone	calls/year × 10^9	62	105	174	286	482
Video						
Video telephone	calls/year × 10^6	0	0	1	36	1000
Television transmission	hours/year × 10^3	11	11	14	32	72[a]
Record and Data						
Telegraph	messages/year × 10^6	180	125	80	53	35
Stolen vehicle information transfer	cases/year × 10^3	160	320	820	1950	4600
Stolen property information transfer	cases/year × 10^3	430	880	1720	3500	7000
Facsimile transmission of "mug shots", fingerprints, and court records	cases/year × 10^6	2	3.5	7	13	25
Motor vehicle registration	items/year × 10^6	49	74	110	164	245
Driver's license renewal	items/year × 10^6	38	48	60	75	90
Remote library browsing	accesses/year × 10^6	0	0	neg.	5	20
Remote title and abstract searches	searches/year × 10^6	0	0	neg.	8	20
Interlibrary loans	books/year × 10^6			neg.	40	100
Remote medical diagnosis	cases/year × 10^6	0	0	20	60	200
Remote medical browsing	accesses/year × 10^6	0	0	20	60	200
Electrocardiogram analysis	cases/year × 10^6	0	neg.	20	60	200
Patent searches	searches/year × 10^6	6	6	6.5	7	7
Checks and credit transactions	transactions/year × 10^9	11	25	56	135	340
Stock exchange quotations	transactions/year × 10^9	0	0	1	2	4
Stock transfers	transactions/year × 10^6	290	580	1200	2500	4900
Airline reservations	passengers/year × 10^6	19	62	193	500	1400
Auto rental reservations	reservations/year × 10^6	0	neg.	10	20	40
Motel/hotel reservations	reservations/year × 10^6			25	50	100
Entertainment reservations	reservations/year × 10^6			100	140	200
National Crime Information Center	transactions/year × 10^6	0	0	6	20	70
National Legal Information Center	transactions/year × 10^6	0	0	neg.	5	30
Written						
Mail (first class and airmail)	letters/year × 10^9	25	35	50	70	100
Books (remote printing)	new titles/year × 10^3	11	15	34	60	105
Newspapers (facsimile transmission)	number of newspapers using service	0	1	2	10	20

a. Assumes the projection to 20 networks in 1990.

Television. Used in conjunction with the telephone, a duplex scheme could be devised for a large population of users. Hesselbacher [III-2] has proposed a television broadcast satellite system for the general public with a maximum cost to the user of $150.00 per receiver. To date, the transfer of information via video link has not been successful in satisfying the user's requirements. The main complaint stems from the poor resolution and quality of the picture. Dr. K. H. Powers, RCA Laboratories, Camden, N.J., states that the current state-of-the-art in video presentations employs 1000 line per inch resolution on a 5-inch screen. Preliminary experimental evaluation has shown that this resolution has the capability of satisfying even the most demanding user. This high resolution television system could still be designed such that it is compatible with existing home receivers.

Present plans for a National Medical Library video information retrieval service are being formulated for early implementation and operation. Dr. Ruth Davis, Director, Lister Hill National Center for Biomedical Communication, is presently active in the design of the above system that will service medical personnel in medical universities throughout the nation.

Table III-2 represents a compilation of various input-output devices with which the user interacts. These devices are characterized by the bandwidth required for transmission of various types of data.

THE TRANSMISSION LINK

The reliability of the data transfer process is a direct function of the information transmission link employed. Three basic transmission links exist. They are:

1. The terrestrial link.

2. The earth-space link.

3. The space-space link.

To illustrate the important design parameters upon which trade-offs are based, the terrestrial link will be analyzed and discussed. The propagation link is characterized by frequency and is enumerated along the ordinate of Table III-3. The abscissa lists many design parameters upon which trade-offs are made. Table III-3 addresses the electromagnetic form of data, and Table III-4 addresses the material form of data. The rationale required to make the trade-off is a function of a specific system, which, in turn, is identified by user requirements.

TABLE III-2. TABULATION OF INPUT-OUTPUT DEVICES AND THEIR ASSOCIATED BANDWIDTH

Type of Data Interface Device	Required Bandwidth			
	Narrow Band, 150 to 300 Hz	Voice Band, 4 kHz	Broad Band, 48 kHz	Video to 6 mHz
Alphanumeric Data				
Teletypewriters	X			
Printers		X		
Punched paper-tape	X	X	X	
Magnetic tape			X	
CRT display		X		X
Facsimile		X	X	
Static Graphic Data				
Electrowriters		X		
CRT display		X		X
Facsimile		X	X	
Telemetry Data				
Sensor/controls	X	X	X	X
Dynamic Graphic Data				
EXG — analog signal		X		
Televisions				X
Voice				
Telephone		X		

A primary design parameter was purposely eliminated from Table III-3 on the premise that it was sufficiently important to warrant special consideration; i.e., the choice of analog as a function of digital data encoding.

TABLE III-3. HARD COPY GROUND-TO-GROUND LINK

Type	Perishability Factor	Ease of Shipment	Mode of transport: Ground	Air	Sea
Photographic plate	Very fragile	Easy	X	X	X
Films	Fragile	Easy	X	X	?
Microfilm	Durable	Easy	X	X	?
Texts	Durable	Easy	X	X	X
Magnetic tapes	Durable	Easy	X	X	X
Material objects	Varies	Varies	?	?	?

Analog data represent the most desirable form of data from an observable event to the extent that it contains the maximum amount of information. Unfortunately, when transmitting information over a radio-frequency link, the analog form of transmission is degraded by random atmospheric perturbations to a much greater extent than the digital form.

Although conversion of analog information to digital information degrades the resolution of the data and consumes more bandwidth, it is necessary many times to perform this conversion of these data in the interest of more accurate and reliable communications. To emphasize the difference between analog and digital transmissions, time was selected as the basis for comparison. Table III-5 illustrates the various transmissions times involved in transporting different forms of information to the user. The calculations supporting Table III-5 were made on the assumption that a single channel of a RELAY series communication satellite is used to transmit the information at a data rate of 1.152 kilobits per second.

It seems appropriate at this point to discuss the impact of the laser upon existing and future communication systems. The laser, although promising tremendous innovations in the communications industry, will find limited application when applied to a terrestrial link. Research is being performed by

TABLE III-4. ELECTROMAGNETIC GROUND-TO-GROUND DATA LINE

Frequency	Antenna Size	Propagation Loss	Mode or Device	Data Rate	Probable Error Rate	Reliability	Desired Buffering and Process	Transmitter Facility	Receiver Facility	Information Content Bandwidth	Atmosphere	Hard Line
Very low frequency < 30 kHz and Low frequency 30 to 300 kHz	Very large	Minimal	High power vacuum tubes	Very low	Very low	Excellent	None required	New	New	Very low 3 to 30 kHz	Yes	Yes
High frequency 3 to 30 mHz	Medium	Low	Solid state or vacuum tubes	Low	Low to high	Varies from 50% (poles) to 90% (equator)	May be desirable	Existing	Existing	Low 3 to 30 mHz	Yes	Yes
Very high frequency Ultra high frequency	Medium	Medium	Solid state or vacuum tubes	Medium	Low to high	Varies	Desirable	Existing	Existing	Medium to 50 mHz	Yes	Yes
Microwave to millimeter wave	Small	Medium to high	Magnetrons or klystrons	High	Medium to High	Varies	Desirable	Existing	Existing	High	Yes	Yes
Visible	Small	Low to high	Laser	Very high	Low to high	Varies	Highly desirable	New	New	Very high	Yes	Yes

Note: The propagation distance and transmitter power are assumed to be constant.

TABLE III-5. SUMMARY OF TRANSMISSION TIMES

Form of Data	Transmission Time
Typed page	20 seconds
High resolution photograph	Digital — 100 hours Analog — 15 hours
Low resolution photograph	Digital — 10 hours Analog — 1.5 hours

RCA to establish the feasibility of utilizing lasers to propagate high data rate information, in excess of 250 megabits per second, over a path of several miles during adverse weather conditions. It is felt, however, that the main utility of the terrestrial laser will be found in a guided mode application. The value of the laser in the earth-space link is questionable, but the potential of the laser in the space-to-space link is unlimited. The portion of the radio frequency (rf) spectrum that promises continued future gains in the field of communications is in the millimeter-wavelength regions.

The trade-off criteria are determined by the order of importance assigned the two main system variables. In the trade-off it is assumed that, in order to be effective, the system must be subordinate to the user and will therefore be defined (directly and indirectly) by the user.

Example. It should be realized that no configuration of transmission paths or determination of capacity can be proposed seriously until the mission of the information management system is defined. A large number of alternatives are possible in communications design, and abstract exercises are of questionable value. Thus, to gain appreciation for the requirements of a transmission system, the following example, extracted from work performed by the General Electric Company and funded by NASA (Contract NAS 3-9708) will be presented for consideration.

This report presents the results of an evaluation of technological and cost factors associated with television satellite systems. The services to be provided by the systems are shown in Table III-6.

Three potential user groups were selected as representative of the range of technical and service requirements.

TABLE III-6. POTENTIAL SPACE TV SERVICE

Name	General Description
	Special Services
ITV	Instructional television for formal classroom use
"Medical" TV	An instructional service for medical or other postgraduate training
TV distribution	To distribute TV signals for retransmission by terrestrial broadcast stations
	Broadcasting Services
TV broadcast for the Americas	To broadcast TV signals to the continents of North and Sourth America
RTV	Provide TV service to rural, fringe, and low population density areas
GTV-D/E	General television for developed areas
Urban TV	To provide TV service to urban areas
UN-TV	Worldwide system for dissemination to UN, UNESCO, etc.

1. A community distribution service to India

2. A direct service to Alaska

3. Educational service to the U.S.

These three groups were examined in detail to define the common system variables and their interfaces. The results of the study are summarized in Table III-7.

TABLE III-7. TVBS CONFIGURATION SUMMARY

	TELEVISION BROADCAST SATELLITE SYSTEMS		
	Case I Community/Distribution Service to India	Case II Direct Service to Alaska	Case III Instructional Service to U.S.
Satellite weight, lb	752	2043	983
Booster (capability, lb)	Atlas E/Agena D/Kick (910)	Titan 3B/Centaur/Kick (2260)	Atlas E/Agena E/Kick (1150)
Satellite description			
No. solar cell panels	2 at 72 ft^2	4 at 171 ft^2	2 at 145 ft^2
Total cell area, ft^2	124	621	259
Power level after 2yr, kw	1.1	5.5	2 3
Antenna			
Type and size	2 concentric parabolas 21 ft (8 GHz), 2 ft (8.4 GHz)	Elliptical segment of paraboloid 29 ft × 80 ft	4 parabolas 2 at 1.4 ft; 2 at 2.25 ft
Construction	Deployable (umbrella) and rigid	Inflatable wire grid	Rigid
Gain and HPBW	Both 4.1° circular/32 dB	1.1° × 3.1°/39 dB	4 1° circular/32 dB, 2 5° circular/ 36.3 dB
Beam pointing (0.05° accuracy)	Antenna electrical axis using rf interferometer	Feed translation using rf interferometer	Orbit inclination for elevation control, rf interferometer for azimuth positioning
Transmitter type	CFA TWT	CFA (separate video and audio)	TWT
Avg rf power output CH, w	416 20	505	70 (max)
Overall efficiency of transmitter system, %	58 35	42	34
Attitude control type	3-axis active-momentum wheel	3-axis-momentum wheel (flywheel augmented)	3-axis active-reaction control system augmented with pitch flywheel
Performance			
Satellite ERP CH, dBw	58 45	70	50 (max)
Field strength, μv/m	122 18	420	24
(Req'd/act.) coverage area, 10^6/mile^2	1.1/2.3	0.6/≈1.2	3/≈7.6
Picture quality (TASO grade/S/N)	2/39.5 dB CCIR relay/ 56 5 dB	2/39 5 dB	1/50.5 dB
Audience size	0.5 × 10^6 100	10^5	10^5
Ground station cost ($)	50 2885	100	1100
Cost comparison — total 10-yr program			
Satellite ($ million)	87	155	95
Terrestrial ($ million)	151	325	1284
Terrestrial to satellite ratio	1.7	2.1	13.5

Note: Information provided courtesy of the General Electric Co

In particular, a cost effectiveness study was performed to compare the three approaches. The result was that the satellite approach was less expensive than the terrestrial approach by a factor of ten. Although no specific means of financing were recommended, the individual user would be expected to finance his portion of the system either on a buy basis or on a rent basis.

The consideration of two extremely important parameters seem to be lacking in the design of an information transfer system. The first, and most obvious, is a quantitative definition of user needs. The second is the interfacing problem existing between the new system and present means of communication.

The technical problems associated with the transmission of information are many, but are not considered unresolvable. As the potential user becomes more aware of the benefits to be derived from a system predicated on his needs and desires, many of these problems will disappear.

INFORMATION AND DATA REDUCTION

Introduction

Data reduction can be divided into two major categories, transformation and compression. This subsection will concentrate on a discussion of these categories, identification of data reduction system design variables, the interrelationship between these variables, and some system design alternatives. The analysis will be kept on a general, functional basis and will be slanted toward the needs of the user.

Since the advent of the digital computer in the 1940's, technology has experienced a computer explosion and a proliferation of computer applications. Today computers have the responsibility for carrying out the vast majority of data reduction functions. People have become so dependent on the computer, in fact, that it is almost a foregone conclusion that any system of significant size requires at least one central unit and various pieces of supporting equipment. Thus, it is tacitly assumed that these media to some degree will be available.

Historically, users have approached the data reduction function with a lack of understanding that has alternated between blind confidence in all that the computer reports and unyielding skepticism and mistrust. Furthermore, users who don't comprehend the workings of the system are dependent on programmers, systems analysts, and operators to implement their requests. Very often communication is less than perfect because of the divergence of interests of the parties involved. Usually, programmers and systems analysts are not skilled in the areas of interest to the users. Operators are trained as technicians and are not expected to be engineers or scientists. The user is often dissatisfied with the services he gets and is sometimes unjustifiably resentful. Problems like these are somewhat typical. Occassionally, this situation has led to calamitous results. There are cases on record in which the user was so completely oblivious of what was to be received that no significant use of the data occurred. Instances like these should be avoided.

Design Variables for a Data Reduction System

The remarks of the previous paragraphs serve to indicate the required sense of responsibility toward the user. The needs of the user are considered to be one of the design variables. This variable is a function of:

- What the user wants to accomplish.

- When it is to be accomplished and by what time.

- What mode of output is acceptable so that the data received can be most effectively used to yield the greatest amount of information for his purposes.

The second system variable is the available equipment (including personnel). The equipment is generally a function of:

- Funds for the project.

- Existing state of technology.

- Location (referring to places where equipment will be housed).

It is quite apparent how funds and location influence the technology. Perhaps a few words should be said about location. This can be accomplished easily with an example. Suppose that the task is to perform a reduction on data generated from an experiment carried out in a satellite. To accommodate transmission devices and ground facilities, it is decided that some data compression on board the satellite is advisable. However, the search for reliable, durable computers with the speed and memory to do the job reveals that physical size and weight severly limit the choice. In fact, for smaller unmanned flights, the disadvantages are so great that it is probably better to abandon this course of action altogether. Thus, location has considerable influence on the second variable.

The system design variables listed previously are intimately related. It is apparent that if the available equipment is fixed, then the range of services accessible to the user are limited. Similarly, if we set priority on the needs of the user, then we may be forced to expand the equipment variable.

In practice, neither variable is initially fixed. Since the data reduction system is merely a subsystem of the IMS, we must work toward integrating it into the whole. To accomplish this, a process of iteration and trade-off takes place in which our initial estimates serve as goals. Compromises take place. We insist that the user be aware of these compromises and participate in making them to whatever extent is possible. By this means, the user will develop confidence in the system. This is essential if he is to fully utilize the output.

The following example is used to illustrate the points made above. Some degree of onboard processing to control the volume of data received from earth satellites is very appealing. Suppose that while designing the IMS for a satellite carrying scientific experiments, it is decided that an onboard computer to do some data reduction might be advisable. Should one be arbitrarily designed before consulting the experimenters whose data will be served by the device? Not if we want the highest probability for success of the experiments! In fact, a number of authors [III-3 — III-5] support the opinion that the experimenter should participate in the design of this equipment. Even in the design of onboard computers to do a variety of tasks [III-6, III-7], user needs have been adequately taken into account.

In the next subsection, the data reduction functions are discussed. In the section following, the topic of the equipment variable is resumed. If the reader desires more information on user needs, it is suggested that he refer to Chapter II, User Needs.

Transformation and Compression

The analysis of the data reduction process will be done on a functional rather than hardware basis. Although data reduction invariably requires the use of a computer, these machines will not be discussed here.

As indicated in the introduction, data reduction can be divided into two classes. These are:

1. Data transformation — changing the physical form of the data.

2. Data compression — reducing the physical amount of the data.

Each of these will now be discussed in more detail.

DATA TRANSFORMATION

A clear undertanding of data transformation will be achieved through the answers to the following three questions:

1. Why is it necessary to transform data?

2. Where should transformations take place?

3. How often or how much data transformation should take place?

Why is data transformation necessary? Although hard data might not have to be transformed to transmit or transport it, it is frequently desirable to do this. Transformation is a little more important in the hard copy area where storage is involved. Frequently, microfilming, or some other means of reducing size, is absolutely necessary if hard copy is to be stored. In the case of electronic data, transformation is frequently necessary to transmit the data. That is, the output of the sensor may be in a form that cannot be transmitted electronically. Probably the most important reason for transforming data is that frequently the output from the sensor is in a form that is not comprehensible to the user. That is, the input must be transformed before the user can analyze the data.

In the area of transformation, the major technical problem that arises is how to maintain the integrity of the data in the transformation process. In other words, how much information contained in the original data is lost in the transformation process? To work on this problem, one has to ask the additional question, how much of the information in the original data must the user have? In other words, is the loss of some information permissible? There is no need for elaborate transformation procedures to save certain information if that information is not going to be used.

One of the problems that people face in the area of data reduction is the education and cooperation of the user in the determination of what is usable information and how much it is worth. Data reduction people must educate, or inform, the user of the transformation process, its reliability, how much data is lost, and also the costs involved. In this education process, one must seek and obtain the help of the user for the user to have faith in the data. This is absolutely essential, if he is expected to use it effectively or at all. However, the user should be a responsible individual and not require more data from the system than he will actually use. For example, the U.S. Post Office in their study of electronic mail has come up with some results that should be applicable to this situation. They say that if you want to be able to read a page, 100 cuts or bits per line will be needed to make it understandable. If you want to reproduce a photograph with reasonable high resolution, 5000 cuts per line may be needed for the resolution desired. The 50 to 1 ratio between the bits for a photo and bits for a typed copy illustrates the point that if one is to be cost effective or conscious of the need to keep the operating cost of the system to a minimum, the user should be required to request only the information that he will use.

Where should data transformation take place? Should it take place at the source of the data, or should it take place at the outlet or sink? Should it take place at both, or should it take place in the middle? Sometimes, it is necessary to transform the data so that it may be transmitted. Then, the answer obviously will be to transform it at the source of the data. Another example is the case in which the data are very important and contain a lot of information. Then, transformation might only take place after the initial use of the data.

How often should data transformation take place? The answer to this question is obvious. Because it is possible to lose some information every time the data are transformed, transformation should be held to a minimum. This is not to imply that one may not transform data back and forth many times. However, if we have the data transformed for instance to machine language and the user is going to store it in a machine, there is no reason to print it out or change it and then transport hard copy to the user. The user can take the data in machine language that was transported and use that data in his computer without additional transformation.

DATA COMPRESSION

Because of the amount of data that is expected to be generated in the future, data compression (i.e., a reduction in volume) will be essential. The one problem to be solved is how to reduce the volume without loss of information. The criterion for data compression is similar; i.e., no loss of information. This is a relatively simple process if data are redundant or if the data contain no information. The simplest data compression technique is the discarding of data. For example, if two cameras take the same picture at the same time and both the cameras have identical resolution, as well as film, there is, or seems to be, no need to keep both pictures. Thus, one may be discarded. In a similar situation, in trying to take a picture and if for some reason the lens cover is not taken off, there seems to be no reason for keeping the picture since it contains no information.

Miniaturization. Another method of compressing data is by reducing the physical size. The classical examples of microfilm and microfiche show this very well. As our technology advances, better methods of placing the same amount of data into a smaller form will be developed. For example, in the microfilm area, improvements in reduction from 20 to 1, to 40 to 1, to about 250 to 1 have been accomplished. According to Dr. Ruth Davis, our technological advancement in this area will continue to improve, and at some future date, reduction in size will continue until eventually it disappears. This might take care of many of our storage requirements, or archiving requirements. However, in the process of reducing physical size, it must be remembered that reduction in size is of no value whatsoever if the information cannot be retrieved.

Sampling. Another type of data compression is sampling. In the area of statistical sampling, the word random sample is frequently used. The term random really means that it cannot be predicted in advance. Thus, the random sample is a function of chance. The important thing about a random sample is that the sample to some degree represents the parent population. However, it is not an exact miniature.

It has been demonstrated that in random sampling as the sample size becomes larger, the characteristics of the sample approach the parent population. Thus, by obtaining a large enough sample size, one may, to any degree of exactness needed, make the sample to resemble the parent population. In fact, if a sample size of 100 percent is taken, the parent population is obtained. There are other sampling procedures such as function of time or stratification that will also represent the parent population. Although sampling procedures provide information in a condensed form, the user must be cognizant of these techniques and be satisfied with the information that the sample contains.

Modeling. The development of a mathematical model will permit the condensation of reams of data into one mathematical equation. The mathematical model basically is a representation of the real world by a mathematical formula, and it should be emphasized that since it is only a representation, there will be some error involved. Some people are apprehensive when they learn that a mathematical model contains error, and thereafter are opposed to the use of them. Thus, the first requirement of the use of mathematical models is an educational process to demonstrate to the user that the results obtained are satisfactory.

There seems to be no easy-way at present to educate the user. It appears that the only logical way to proceed is to give the user, which in this discussion is the experimenter, all the data he requests. If a satisfactory model is developed, instead of storing all the data, the storing of the mathematical model with its appropriate parameters is all that is necessary. After a mathematical model has been determined, sampling can be used to estimate the parameters of that model. By using sufficient statistics in estimating the parameters of the model, all the information in the sample will be obtained in the estimated parameters. Thus, it is possible to take data, regardless of the amount, and reduce it into estimates of the number of parameters and have all the information that the sample contained.

Control Charts. Frequently, in scientific investigations or even in operations of systems, another type of data exists. These are called "controls." Certain variables that are not under investigation are kept constant. To maintain a check on the experiment, periodic measurements of the controlled variables are taken. There is no interest in the exact measurement of these, except that they must remain constant to a certain degree. Therefore, when the experiment is finished, the only thing that is important is whether or not the variable was in control. A very easy technique for this is the quality control chart. Usually, when one talks about control limits, one is interested in two variables, one is the average of the measurements and the other is the range between the lowest and the highest variables or the variation of the data. This brings up the concept of a sliding window in which certain data are kept (a history of data is kept for a certain period of time), and as new data arrive the oldest data are discarded. The length of time this history is kept is an engineering judgement on how much past history is necessary to determine the cause of a process that has gone out of control.

Purging. Finally, the need for purging information should be considered. All of the previous discussion on compression was centered on how to reduce the amount of data with little or no loss in information. If this is done, there will be much more room to store information. However, in time, information itself will clog up the system and, therefore, there must be some form of purging of information. Two criteria for the purging process are:

1. Obsolescence of information; that is, when new experimentation has made this information so obsolete that it is no longer valid, it should be purged.

2. The probability of the information being useful sometime in the future determines its archiving value.

In addition to the probability of being used, one also has to consider the cost of replacing lost information. If information is purged and at some later date is needed, then what would be the cost of repeating the experiment and obtaining the same information again? The lower this cost is, the higher the probability of use is that one may accept in the purging process.

COMPUTERS

The prominent role of computers in data reduction functions justifies a short review of the process used in their selection. There are three questions that require answers.

1. What type of computer? — There are two broad classes. Special purpose computers, such as digitizers, are usually designed to perform a specific task. Therefore, a change in task requires a change in computers. These are usually hand-wired devices. A general purpose or programmable computer can be changed to perform different functions by a change in program. These are usually larger than special purpose computers and more expensive.

2. Where is the computer placed? — Should the computer be near the source, the storage area, or the user? Is it better to have one computer at a central location or to have several computers dispersed?

3. What capacity should the computer have?

In answering these three questions, two criteria should be considered; namely, evolution and relative costs.

Evolution. The computer must perform the jobs of today and the future, as far as can be predicted. In addition, it must be modularly expandable so as to be adaptable to new functions when unpredictable changes occur.

Relative Cost. Relative cost includes the initial cost, the continuing cost of operation, and the cost of incorporating change.

The evolutionary criterion indicates that general purpose computers should be used even for simple one-step functions. Thus, as sensors or data sources change, the computer can easily be adapted to new inputs.

The answer to the second question, location, contradicts the answer obtained to the question about type. Because of different function requirements, some data transformation will occur at different locations. Therefore small, cheap, special purpose computers seem to be the answer. The criteria of evolution and cost effectiveness must be used simultaneously to provide an optimum solution. This might be the development of small, cheap, programmable special purpose computers.

To determine the capacity of the computer, all that is necessary is a knowledge of the functions. However, unforseen changes in capacity requirements raise a question, does one over-build initially or does one try to build a modular computer? The modular concept seems to have some merit. With the modular concept, as requirements change, the capacity of the computer can be changed by addition or subtraction of modules. The modular concept will also permit the dispersion of some computer functions to different locations.

SUMMARY

To design a data reduction system that would be compatible with user needs, one must be aware of what the user hopes to get from the system. There is no reason to build a system whose output is entirely unsuitable to the user! Although this is a completely logical statement, it is often inconsistent with current practice. There are numerous complaints associated with "adapting to the system." The individual doesn't like to feel compelled to submit to the machine or system, and if it gets to be too much trouble, he simply won't use it! Of course, this defeats the purpose of the system; i.e., to serve the user.

It is far too idealistic to insist that every user be given what he wants. People are more flexible than machines, and on occasion it is reasonable to expect people to exercise their flexibility. This is especially true when it comes to general purpose devices that were designed to serve a wide range of users. However, when we are designing a special purpose system to serve a small community of users, perhaps it would be best to start with these users and continually solicit their advice throughout the design process. For example, if we are trying to design a computer system to perform some preprocessing of data onboard a satellite [III-3 — III-5], then it would be wise to work with the investigators who will be served by the system. To clarify further this remark, consider the following situation.

A particle count experiment is proposed for a satellite. It is known that certain experiments of this class are notorious for generating enormous volumes of data. Suppose that the computer people devise a system that can process the data and preserve accuracy (within the context of their meaning of accuracy). Suppose that the investigator neither requires nor desires this accuracy. In addition, suppose that he does not desire the volume of data that has been generated. Upon receipt of the results, he realizes that he does not have the capability to analyze the data and extract the information he wants. He now faces the prospect of an expensive and time-consuming reprocessing of the data. This simple misunderstanding has produced a monumental headache for all involved. Further, this hypothetical example is not far-fetched. There are several cases known in which this sort of thing has actually happened. On more than one occasion the results of the experiment were completely compromised.

INFORMATION AND DATA STORAGE

Introduction

Information and data storage is concerned with methods of creating and managing collections to facilitate the recovery of pertinent information/data as it is needed.

Most information management systems of real utility and functional value to the user have a storage process; however, none fulfill user needs completely. Criteria imposed on efficient storage systems that are responsive to the user are that the information/data stored must:

- Be useful — It is desirable to have as nearly complete coverage of science and technology as possible by obtaining significant domestic and foreign documents. Periodic review of holdings should allow purging of active files based on usage or potential value. Criteria, processes, and techniques should be developed for minimizing unnecessary redundancy in the system.

• Have minimum volume and weight — Efficient compression techniques can be used to reduce the amount of data received from active scientific research while retaining all the significant information. Recent research has contributed greatly to advancing microform processes such as microfiche and video film.

• Have maximum longevity — After acquisition, the system should provide for long term preservation and retention of documents and other information/data form holdings. The purging of unused or out-dated information/data and the accurate retention of that of value are of equal importance to the successful system.

• Be accessible — That which is stored is of no value if it cannot be obtained when needed. The system should be easy to use and should be capable of fast response. It should provide efficient methods for conducting searches, processing requests, and disseminating information/data.

• Be accurately retrievable — It is important that the user be able to retrieve a particular document or portion of a document and also that the retrieved information/data be correct.

• Be reproducible in desired form — The system should be able to provide such forms as conventional page copy, microfiche, and magnetic tape as well as video images.

Fundamental Operations of Information and Data Storage

The fundamental operations of information and data storage are:

1. Indexing — methods of recognizing, selecting, identifying, and arranging information/data to facilitate organized storage, searching, and retrieval.

2. Storage — methods of maintaining information/data to facilitate its use and preservation.

3. Retrieval — methods of extracting required information/data from storage.

Each of these three operations will now be discussed.

INDEXING

Indexing is the task of structuring information/data so that succeeding manipulation can be accomplished. The major function is to evolve coded forms so that computer programs and other techniques may select an item of information/data for retrieval or to specify distinct pieces of usable information/data. Indexing may take two forms to determine selections, intellectual analysis or a parameter search. The latter technique can result in automatic indexing. The former, at least in the foreseeable future, cannot be automated.

Classification, as used for indexing, means that a decision must be made for every item in the collection. Most classification schemes such as the Dewey Decimal classification are highly disciplined, while others are spur-of-the-moment categorizations. According to users, alphabetically arranged subject headings or titles are most convenient for those who can precisely name the subject of search, using the same terminology as the system. This is why subject headings are often used for cataloging technical data, engineering standards, and commodities. Technical know-how of the users enables them to use the index.

Another procedure for indexing is "Basic Keyword Coordinate Indexing." The indexer familiarizes himself with the document or item by studying such introductory information as the abstract, foreword, summary, table of contents, and conclusions. Prior to referring to the body of information, the trained indexer is able to sense the intent of the author and the purpose of the item. He is now able to identify concepts treated. While the material is fresh in his mind, the indexer writes those terms that most concisely and accurately describe concepts. Adequacy of the terms selected are dependent on the indexer's viewpoint, qualifications, and competence. The indexer next examines the body of the item to confirm the validity of his selected terms and to identify missed or lesser concepts. It is desirable for a second indexer to examine the item briefly and check the selected terms.

A form of automated indexing is the permuted KWIC index, a form of concordance generally used to index documents by the words in their titles. A computer reads all of the words in all of the titles and alphabetizes these words. Then it prints out these words for all the titles in alphabetical order on successive lines, but keeps the context of the titles and a code for locating the full information with these words. No attempt is made to associate synonyms. A computer will search for a given word with great success, but it will not select a synonymous word or phrase, because computers are still notoriously deficient in the ability to recognize concepts.

Coding makes it possible to transform information/data so that machines and techniques can be used to manipulate the information/data of a given index. The procedure takes selected words and, either as a part of the index function or later, reduces these words to codes and organizes the codes for system input either manually or by machine. Coding facilitates the identification and retrieval of desired information/data. It reduces indexing time, reduces the volume of the index, speeds retrieval, and therefore reduces cost. Coding is the application of transformations in the form of alphabetic, numeric, and binary characters to English words to change them to more systematic machine-manageable equivalents [III-8, III-9].

STORAGE

Storage is the accumulation and preservation function in information management. In many instances, a large delay line (not obtainable directly in transmission) is required, which means that storage is needed. Storage, both temporary and permanent, may be accomplished by various types of media. The heart of information/data storage systems in bygone days was the outdated conventional library with row-upon-row of hard copy documents and drawer-after-drawer of catalogue (index) cards. Two current techniques include the use of computers and microfilm.

Computers. The key to present and future storage systems is the digital computer. The "new computer generation" can perform logical, clerical, and arithmetical instructions at a rate of 5 to 10 million operations per second. New technological developments have made it possible to contain as many as 4 million characters of data in central computer memories and as many as 16 million characters in high speed auxiliary memories (transferring a single character within 8 microseconds). Since the average English word length is approximately 5 characters, these memories can contain 0.8 million and 3.2 million words, respectively. Slower, random-access auxiliary computer storage subsystems are in operation with a capacity on the order of billions of characters. This greatly increased random-access storage capability is particularly important for computer-based information management activities, since it allows more rapid processing of documents than current systems that use magnetic tape storage media.

Computer input and output devices for the acquisition and dissemination of information/data include telecommunication equipment and such computer-oriented media as punched card, magnetic tape, and printing equipment. The current state-of-the-art will allow hundreds of magnetic tape units (containing as many as 20 million characters each) to be attached to a central computer.

Current computers can receive as many as 150 000 characters per minute from a punched card reader, many of which may be attached simultaneously. Electromechanical printers can be attached to a computer for direct printing of information in a formatted form. A printing rate of 1100 lines per minute, each of 132 characters of data, is within today's state-of-the-art, and is equivalent to 20 000 English words per minute.

No comprehensive software has yet been developed for large-scale computer-based document-handling systems. The most extensive operational software package is probably that of NASA. Computer programs are indispensable in the utilization of computers. Yet it is sometimes not fully recognized that the writing of computer programs is often a very difficult, costly, and time-consuming process. Such recognition is important in planning for storage systems. It should be emphasized that computer equipment selection for a document-handling application should feature storage elements and instruction repertoires best suited to document processing. That is, such equipment should be capable of rapid direct storage, retrieval, and processing of textual data on a character-by-character basis. This capability allows optimal sorting, transfer, and comparison of data, which are the key operations used in manipulating documentation files.

Microform. Microform devices are widely used as document storage vehicles. Two primary uses may be distinguished: (1) reduction of volume and (2) permanent retention of documents that otherwise would be lost because of the deterioration of the paper on which they are printed. Some typical microforms are:

- Microfiche — Microfiche is essentially a special format of microfilm. A page image is reduced to a 16-millimeter microfilm size, and a number of these images are grouped together on a flat rectangular format. The standard microfiche format of the National Microfilm Association (and approved by COSATI) contains 58 page images on a 4 × 6 inch microfiche.

- Aperture card — The aperture card is a microfilm image inserted into a punched card. An aperture-card image may contain one to four "page" images. Aperture cards are particularly attractive as a means of storing engineering drawings.

- Opaque microcard — Opaque microcard devices generally use media other than transparent microfilm. This group of devices includes highly reduced printing of document pages on special forms of paper, as well as other special techniques.

• Video film — Video film is a tape-recording medium, prepared by scanning and transcribing a TV camera image. Six to eight 8 1/2 × 11 inch page images may be stored on 1 linear inch of video tape. Reels of video tape are made in 3600- and 7200-foot lengths. The maximum announced storage capacity is 500 000 images per 7200-foot reel.

• Other — A recently announced microform technique that uses laser beam recording, is being researched. This technique claims to offer the possibility of recording the entire holdings of the Library of Congress on a format approximately the size of a page!

As stated above, the saving of storage space is an obvious objective of the use of microforms, but it is one that should be approached with caution. Although extremely high reductions are possible, they have rarely been economical because of the penalties of higher filming and projecting expense and the difficulty of handling tiny images [III-8 — III-10].

RETRIEVAL

Retrieval is the ultimate response of an information/data storage system to the request of the user. Retrieval of information/data is intimately associated with storage. Indexing and retrieval are input and output, respectively, while storage is the transfer function.

The same techniques that can be applied in sorting and in indexing information/data items by computer can be used in searching a collection of machine-stored items. If the computer can recognize in an information/data item the specific code (word or phrase) called for by the search request, it can seek out the pertinent information/data. It may then list them, copy them, compile them, or cause them to be physically retrieved or transmitted. In discussing computers earlier, a print capability of approximately 1100 132-character lines per minute as a normal rate was mentioned. More rapid types of electrostatic printers are available; however, they usually do not print a standard page image. The use of current computer prints for preparation of finished copy, suitable for publication, is not yet an economical process. This is due in part to the technical problems of economically providing suitable ribbons and paper and of computer-printer design that prevents optimal use of the space on the paper. Consoles and display devices have a significant potential use as a means of interrogating computer-stored bibliographic tools and document files. The new generation computer configurations include inquiry consoles with cathode-ray tube displays and manual keyboard input units.

The fact that records on microfilm can be duplicated more cheaply than the full-sized originals is probably more important than space saving to many present users. Microfiche, which are distributed in quantity by such federal agencies as the AEC, NASA, and DDC, cost only a few cents each to duplicate (full- size copies may be produced as needed). The saving in weight that results from microfilm is also important when transportation of documents is a consideration. One shortcoming of microfiche to date is that it has not been accepted very well by users for sustained viewing on present viewers.

Just as computers have been developed to select and retrieve records that exist in the form of punched cards or magnetic memories, a variety of computer-like devices have been developed to select and retrieve microform items. One such machine, produced by Image Systems, Inc., is approximately 19 × 18 × 25 inches deep and will store 750 microfiche (45 000 document pages) for quick-viewing and identity for reproduction. Other systems are the Recordak Microcode for 16-millimeter microfilm reels and the Ampex videofile for video film [III-8, III-9].

Example of an Information and Data Storage System

NASA has pioneered in automating the storage, retrieval, and dissemination of aerospace information and data. The NASA Scientific and Technical Information Facility, in College Park, Md., receives hundreds of documents daily. These are promptly checked to avoid duplication, examined for relevance, and cataloged descriptively. Each document accepted as a potentially valuable addition to this information bank is then given an accession number and, if appropriate, is recorded on microfiche. The accession number serves as a unique identification tag for the document, and both compact and full-size copies of every page can be made from the microform for storage and distribution as needed.

Professional indexers examine each item when it is deposited in the system, document the bibliographic data that accompanies it, and select terms under which it is listed in subject and other indexes. Trained abstractors read the abstracts submitted with the documents, sometimes editing and condensing these abstracts, and write abstracts of documents that have been received without them. Then, after further reviewing, complete bibliographic records are placed in the memory of a high speed electronic access to the citations of all documents for all users.

From the day a document is acquired, it can be located quickly by its accession number. This number can be ascertained from other bibliographic information in the computer. A searcher need only know the corporate source, the authorship, the subject, the number assigned to the document in another U.S. Government agency's information system, or the number of a contract under which the work was performed, to be directed to a report he needs.

The NASA information bank now contains more than half a million documents. Thousands more are added every month [III-11].

Summary

Information and data storage and retrieval are concerned with methods of creating and managing collections to facilitate the recovery of pertinent information/data as it is needed. Ideally, the user would like to have both access to large amounts of potentially useful information/data and the ability to retrieve rapidly and accurately particular information that pertains to each of his specific needs as they arise. Computers and various other means of storing information in highly reduced form are making libraries and other facilities more efficient, but the goal of providing instant access to almost any desired information/data remains in the future.

Exceptional progress has been made in providing high speed access to carefully defined and limited stores of information/data. With progress, however, has come the realization that the ultimate goal is far more difficult to achieve than it would seem. It involves not only the development of systems and techniques for storing and manipulating the information/data, but what is probably more difficult, methods for gaining access to the information must be developed. Two different strategies can be followed in operating an information and data storage and retrieval system. One is to analyze and organize the collection with great precision in anticipation of the questions. This is usually done by means of indexing so that when a question arises, the pertinent information can be retrieved rapidly and routinely by means of index entries. The second strategy is to avoid any unnecessary prior processing by making a complete search of the collection when a question is received. In practice, virtually all systems employ a blend of both methods.

Advances in technology have produced widespread use of automatic data processing equipment, often in association with computers, to accomplish routine clerical tasks. Techniques and machines that were evolved to handle tasks in industry are being adopted generally in the larger libraries and in many other specialized information storage and retrieval systems. The ability of data processing equipment and computers to generate new data and reproduce existing information is extremely useful. When numerous index entries are to be derived from a single packet of information, the use of data processing techniques can make it unnecessary to create each index entry manually. The same techniques that can be applied in sorting and in augmenting records by computer can be used in searching a collection.

Other important technical developments have been made in techniques for copying records and making microphotographic images. Many systems now provide copies of records in preference to lending the originals. Self-service and automatic copying privileges have, in general, been eagerly accepted. The microfilming of records has produced the microfiche, a transparent film card that contains several rows of images, and the aperture card, which is a standard punched card for data processing machines in which one or more microfilm frames have been embedded. These can be handled and filed easily and offer a saving of storage space and more rapid access to contained information. A variety of computer-like devices are being developed to store, select, retrieve, and reproduce information in this microphotographic form.

Some typical information and data storage devices available for various techniques are compared in Table III-8. In Table III-8 storage media are compared by storage density and other characteristics. Microfiche, for the most part, have been stored in file drawers. They must be manually retrieved and manipulated for viewing and reproducing. One of the few effective devices for dynamically storing microfiche for use has recently been developed by Image Systems (CARD: Compact Automatic Retrieval Display). Aperture cards are usually stored in large open bins called tub files. A tub file, 26 inches wide and 16 feet long, will hold about 50 000 cards. If the file is well organized, a hand search can retrieve a given card at random in less than 10 seconds. To extract the same card by machine search of a small batch of cards will often take much longer. The IBM system is the only one listed that provides automatic random access to a complete store of records. A module of 2250 plastic cells, each containing 32 film chips, can store nearly 600 000 documents. The system can be expanded to seven modules, providing storage space for more than 4 million documents [III-12].

TABLE III-8. ALTERNATIVE INFORMATION AND DATA STORAGE DEVICES

Characteristics \ Media	Microfiche (General)	Image Systems Card Microfiche	Aperture Cards	Recordak Miracode	IBM 1350 System	AMPEX Videofile
Normal Storage Configuration	4 × 6 inch sheet film in paper jacket	4 × 6 inch sheet film	35-mm film frame in 3 1/4 × 7 3/8 inch card	100-foot reel 16-mm film	1 3/8 × 2 3/4 inch sheet film in plastic cell	7200-foot reel 2 inches wide
Size of Storage Container	30 jacketed sheets per inch	19 × 18 × 25 inches deep	125 cards per inch of file	4 × 4 × 1 inch	32 sheets in 1 1/2 × 3 × 1 inch cell	16 × 15 × 3 inches
Storage Capacity 8 1/2 × 11 inch Documents (Reduction Ratio)	60 per sheet (18 1)	60 per sheet (18.1) 750 sheets	up to 8 per card (24 1)	2000 per reel (24 1)	256 per cell (24 1) modules of 2250 cells	250 000 per reel (1,280 lines per frame)
Maximum Documents per Cubic Inch	75	5	42	125	57	350
Sequential Search Rate	(manual)	15 random accessions per minute	up to 33 cards per second	200 documents per second	(1000 random accessions per hour)	1050 documents per second

CONCLUSIONS

Many processing systems today are failures because they fail to satisfy the user. While modern technology, when appropriately financed, provides sophisticated solutions to complex problems, these solutions are notably divorced from the human user. As such, they have failed to instill in the user a sense of confidence in the system. This is a complex problem, and advanced technology offers only a superficial solution.

Solutions that are directed toward user needs are a more attractive prospect. It is recommended that in the design of any information processing system:

1. The user participate in the design of the system to whatever extent is possible.

2. The designer develop a complete understanding of user needs.

3. An efficient feedback (evaluation) mechanism be designed into the system.

4. The user be educated as to the potential benefit and capability of the system.

5. The system be as evolutionary as possible allowing reasonable time for changing procedures with the least interruption of service.

6. The system be reliable.

It is felt that the implementation of these recommendations will constitute a great step toward the development of a successful IMS.

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CHAPTER IV
DATA AND INFORMATION SOURCES

CHAPTER IV. DATA AND INFORMATION SOURCES

INTRODUCTION

Generators/sources are defined as points from which data or information originate or emanate. The identification of a given source, by definition, is a function of the user; e.g., a library book may be perceived as the source of information by the book's reader, while another user who talks to the author of the book about the author's original ideas contained in the book perceives the author himself as the source. In neither case are the respective users inaccurate, but the difficulties in identifying and classifying generators/sources are compounded as a function of the user's entry into the system.

Nevertheless, broad categories of generators/sources are identifiable according to the following system:

1. Active sources — those individuals or machines that generate data (ideas, sensory observations, etc.) which are original with them and that make these data and information available to other persons or machines. Examples of such active sources are light sensing equipment on spacecraft and the individual who generates ideas and draws conclusions in the laboratory.

2. Passive sources — those individuals, machines, and institutions (man-machine combinations) that have nonoriginal data and information in storage which are retrievable by users. Examples of such passive sources are libraries, computer data banks, and most adult humans.

Both active and passive sources can be further classified in terms of:

1. Physical/spatial location (e.g., subterranean/ground/atmosphere/space-based, surface/subsurface-based).

2. Related subject matter areas and/or disciplines [e.g., life/natural/technical sciences (including psychology, physics, engineering, etc.), liberal/fine arts (including literature, music, etc.)].

3. Function or service provided (e.g., traffic-control, weather prediction, archival repository, etc.).

Classification 1 above is primarily useful for "first step" source identification by users, while classifications 2 and 3 are primarily useful for specific topic-oriented search procedures by users.

Active human sources (who are also inevitably passive sources) in scientific/technological fields tend to be clustered in communities of individuals with common disciplinary interests (e.g., the universities) or in common project interests (e.g., a computer industry or a space agency facility).

The recorded results of these active data sources tend to be much more broadly distributed geographically as passive sources and are themselves the partial result of the information system's processing and disseminating procedures.

This chapter is concerned with sources, active and passive, as either an integral part of the information system or as an external input to the system and discusses both aspects. In discussing active sources, the tremendous amounts of new data and information that are being generated and that will be generated are illustrated by a discussion of the astronomy program. Passive sources are discussed and a listing of some of the facilities that constitute these sources is given. Examples are given of a system for which the sources must gather specific data as required by the system at specific times (The National Meteorological Center) and of a system that exerts no influence over the data and information that are generated (The National Space Science Data Center).

CRITERIA

The criteria as listed in Chapter I are given in very general terms. In this section, the criteria for evaluating the information system with respect to the sources are considered. Such criteria are as follows. The system:

- Has flexibility to accept input from sources of a widely different nature.
- Effectively utilizes existing sources.
- Is readily adaptable to accept new sources.
- Exercises efficient control of sources where applicable.

Many sources will simply serve as inputs to the system, while some sources may actually be controlled by the system. In either case, the information system should provide feedback to the sources so that the data and information that are being generated will have the highest potential for use.

ACTIVE SOURCES

The active sources were defined as those sources that are currently producing new data and information. These active sources may be people, sensors, and/or machines and may be found in many locations and organizations. One interesting facility, the Information Analysis Center, may find itself in the role of both an active source and a passive source.

As classified by location, active sources are subsurface-based, ground-based, atmosphere-based, and space-based. Whereas in the past most new data were generated on the ground, one has witnessed a phenomenal growth in the amount of data generated in the other areas.

Man's interest in the depths of the seas has led to such projects as Sealab and Tektite. Here, experiments are performed and human physiology and psychology are studied. These projects are adding to the wealth of new data being generated. In close relation to these projects, are the nuclear submarine development and operation projects.

The ground-based active sources of scientific and technological data and information are found in such places as industrial research facilities, universities, research institutes, governmental laboratories and research centers, etc. These sources cover all disciplines and generate data in a widely diversified form. The data and information usually enter the field of scientific knowledge through primary recorded media such as technical journals.

Aircraft, balloons, and sounding rockets are examples of active data generators that are atmosphere-based. Pictures contain much information, with the amount depending upon the resolution. (For example, a commercial television picture may be described by a number of digital bits on the order of several million.) Since much of the data generated by atmosphere-based sources is in the form of imagery, these sources are usually producers of large amounts of data.

Beginning with the orbiting of Sputnik I in 1957, the space-based sources of active data have produced increasing amounts of data. The Skylabs are projected to be producing from 10^9 to 10^{13} bits per day of data to be sent by electromagnetic means, plus 1000 to 1700 pounds of hard data each 3 months. As David Keller points out in discussing the ERTS program, which will be capable of producing more than 1000 times the amount of data that the Nimbus Spacecraft produces, one must be selective in the acquisition of data [IV-1].

Astronomy — Illustrations of Active Sources

Astronomy employs ground-based, atmosphere-based, and space-based active sources. Since this subject illustrates many of the characteristics of active sources, a discussion of the astronomy program, as an illustrative example, is included in this section.

The Astronomy Missions Board was chartered by NASA in September, 1967 to advise on the planning and conduct of all NASA missions to create and operate astronomical experiments in space. The scope of the Board's activities includes: development and review of the scientific objectives and general strategy for space astronomy and associated ground-based astronomy, formulation of guidelines and specific recommendations for the design of space astronomy missions and for the various experiments and auxiliary equipment to be developed and used on these missions, and continuing examination of policies relating to the operation of these space observatories once they have been made operational and available for use by the scientific community [IV-2].

The mechanics of mission definition as carried out by NASA rely heavily on the recommendations of the Astronomy Missions Board. There also exists a Lunar and Planetary Missions Board with specific responsibility for scientific exploration of the moon and planets from a close vantage point.

The selection of experimenters to develop specific scientific packages for use on board the various satellites is carried out by proposal evaluation. The proposals submitted to NASA are evaluated by an experiments selection board composed of both NASA and non-NASA scientists. The details of the selection process fall within the scope of system management.

The problem of what to do with the experimental data resulting from an astronomy experiment is initially the concern of the responsible scientific investigating team who developed the particular experiment. However, once the experimenters have completed their analysis of the data, provision must be made for its dissemination on a much broader scale, both in its original raw form and in its final analyzed form. The former task involves a multiplicity of details not directly related to the particular experiment, such as data storage, retrieval, and distribution in a form that can be used by the recipient.

The National Space Science Data Center at Goddard Space Flight Center performs the vital function of preparing and preserving space science data (which includes astronomy data) for use and further study. The operation of NSSDC is discussed at length later in this chapter.

The dissemination of scientific data in its final analyzed form is accomplished primarily by publishing an article in a scientific journal after initially presenting the results at a professional society meeting.

Following the Astronomy Missions Board, one can divide the field of astronomy into subdisciplines as follows: (1) high energy astronomy, (2) optical astronomy, (3) infrared astronomy, (4) low frequency radio astronomy, (5) solar astronomy, (6) planetary astronomy, and (7) fields and particle astronomy. Within each of these areas, we will consider mainly data generators located in space or the atmosphere. No attempt to identify all ground-based generator/sources in astronomy is made here.

HIGH ENERGY ASTRONOMY [IV-3]

Within this subdiscipline, the following three areas of interest can be identified:

1. X-rays of energy less than 15 keV.

2. Gamma rays of energy less than 10 MeV.

3. Gamma rays of energy greater than 10 MeV.

This breakdown is based mainly on similarity in production mechanisms and detection techniques within each group. A further breakdown can be made into balloon experiments, rocket experiments, and satellite experiments.

In 1969, the rate of X-ray rocket flights was about 12 per year. Workers in this field of astronomy feel that this rate should be increased to 18 flights per year to satisfy the growing needs of existing groups.

About 30 discrete sources have been resolved to date. Almost all of the data have been obtained from either sounding rocket flights or balloon flights.

Three categories of immediate experimental objectives for X-ray astronomy can be listed. These include surveys in selected regions of the sky, detailed studies of individual objects, and long term monitoring of certain sources. This program will be supported by means of the Small Astronomical Satellite (SAS), X-ray detectors on Orbiting Solar Observatory-H (OSO-H) in 1971, and the High Energy Astronomy Observatory (HEAO) scheduled for launch in 1974. The latter satellite will also be employed for study of gamma ray and cosmic ray sources. Data generation is projected to be at the rate of 25 kilobits per second for HEAO. The baseline experiment package for HEAO includes the following experiments:

1. Large area X-ray detector.

2. Low energy gamma ray detector.

3. Medium energy gamma ray detector.

4. Gamma ray telescope.

5. Primary cosmic ray electron detector.

6. Cosmic ray calorimeter.

Gamma ray astronomy at energies below 10 MeV has been carried out mainly from balloons, although OSO-III will provide the spectrum of some 20 objects over the 7.7- to 200-keV range. The highest energy gamma rays (several hundred keV) yet detected from discrete objects are from the Crab Nebula and Cygnus XR-1.

The diffuse or background X-radiation observed with rockets has been extended to higher energies by the Ranger spacecraft observations. These observations have been confirmed by balloon observations to form a continuous spectrum from several hundred electron volts to several million electron-volts. Further balloon-borne experiments will be carried out to detect gamma rays in the 0.3- to 10-MeV range. Other experiments may be flown on SAS, OSO, and HEAO, as well as on Aerobee rockets.

Three small astronomy satellites are presently under development. The first mission, scheduled for launch during the second half of 1970, is designed to survey the celestial sphere for X-ray sources with the aim of compiling a catalog of X-ray sources to serve as the basis for follow-up detailed observations by SAS-C. The SAS-B mission scheduled for 1971 is being designed to search systematically for celestial gamma ray sources. A joint U.S.-British satellite, UK-5, scheduled for a 1973 launch, will carry five X-ray experiments.

Gamma rays of greater than 10-MeV energy must be studied from satellite-borne instruments, since the diffuse atmospheric background flux prevents significant measurements at balloon altitudes. Rockets are not useful

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because of their limited payload weight and short exposure times. Recent OSO-III results have established a diffuse gamma ray flux at these higher energies. To explore this problem further, the SAS-B will provide a sky survey in 1971.

At the present time, there is no positive evidence for the existence of gamma ray radiation at energies greater than 10 MeV from discrete sources, but balloon and satellite flights of spark chambers are planned by several groups. The HEAO payload will probably include this type of experiment.

A 12-man orbiting space station facility scheduled for a possible 1978 launch will carry two high energy astronomy experiments. An X-ray telescope will be used to locate X-ray sources in the 1- to 10-keV energy range to 0.1 arc second. A high energy stellar survey experiment containing two grazing incidence X-ray telescopes with associated spectrometers and imaging systems will enable high resolution measurements to be made of X-ray sources. A spectrometer, consisting of lithium-drifted detector crystals and a collimator, will search for gamma ray sources. The anticipated data generation rate for the X-ray and gamma ray experiments is of the order of 10^{10} bits per day.

OPTICAL ASTRONOMY [IV-2, IV-4, IV-5]

1. Sounding rockets.

   a. Stellar UV spectrographs.

   b. Testing of miscellaneous small scale instrumentation.

2. Small satellites.

   a. Broadband UV photometer and polarimeter.

   b. UV sky survey.

3. Orbiting Astronomical Laboratory — six telescopes.

   a. OAO-A2 — University of Wisconsin package and SAO package, in orbit.

The Wisconsin Orbiting Astronomical Laboratory experiment package consists of three separate instruments; a stellar photometer, a nebular photometer, and a scanning spectrograph. The primary objective of this experiment is to study the energy distribution of the light emitted by several thousand stars of all types in the spectral range from 900 Å to 3000 Å. Since its launching on December 7, 1968, the OAO-A2 satellite has been extremely productive. During its first year of operation (1969), the Wisconsin experiment package obtained scientific data on over 705 celestial objects during nearly 2300 observations. OAO-A2 has also made UV spectral scans of Jupiter, Mars, and Saturn as well as performing UV filter photometry. The SAO experiment package contains four high resolution telescopes, four filters, and four image-forming Uvicon tubes. Its purpose is to image sections of the sky in four spectral ranges to provide a map of ultravioletly bright objects in the sky. The experiment is not presently operational because of degradation in the response of the UV imaging tubes. The data transmission rates were of the order of 10^4 bits per second with a daily accumulation of around 10^8 bits. After 1 year of operation, the SAO experiment had taken almost 6000 pictures containing data on an estimated 19 000 stars. The success of the OAO-A2 mission has resulted in the introduction of a guest observer program, for which 14 different investigations have been approved and programmed for execution. In this way, space astronomy has taken a big step in the direction of a national orbital facility for astronomical research [IV-4].

b. OAO-B — Goddard package, UV scanning spectrometer, 2-Å resolution for stars and emission nebulae; to be launched in November 1970.

The Goddard experiment package will carry a 36-inch telescope with a grating spectrograph attached to perform precision UV spectrophotometry of various kinds of stars. The spectral resolution of 2 Å, which will be refined to 0.05 Å later in the mission, will permit fairly detailed knowledge of the energy distribution in stellar spectra to be determined in the ultraviolet region from 1050 Å to 4000 Å. Some 14 000 celestial objects will be observed per year. This facility will be available to scientists with sound research programs.

c. OAO-C — Princeton package, UV scanning spectrometer with 0.1-Å resolution for interstellar absorption lines and stellar spectra; to be launched in 1971.

The Princeton experiment package will contain a 32-inch telescope and a UV spectrograph to investigate interstellar absorption lines and stellar spectra with a spectral resolution of about 0.1 Å over the spectral range from 750 Å to 3000 Å [IV-4].

d. OAO-D — national facility for UV observations in space; proposed for 1973.

e. OAO-E — general-purpose instrumentation, plus special-purpose polarimeter and wide-band UV spectrophotometer operating with a 40-inch telescope; this would be a national space observatory; proposed for 1975.

f. OAO-F — similar general-purpose instrumentation as on OAO-E; special-purpose, high-resolution instrumentation, 40-inch telescope; proposed for 1976.

g. OAO-G — large aperture telescope for infrared work and UV operations after cryogenics expended; early all-up test of the 120-inch space telescope; proposed for 1978.

The OAO program has been funded only for OAO-A2, B, and C. The follow-on missions are recommendations of the OAO Project Office. A major advantage of the approach adopted for the OAO-D and later proposed missions is the integrated principal investigator/general purpose instrumentation philosophy that retains the advantages of the principal investigator approach while simultaneously satisfying the broader needs of the astronomical community.

Skylab, a manned orbital laboratory scheduled for launch in the 1972/1973 period, will carry an ultraviolet stellar astronomy experiment. The purpose of this experiment is to obtain spectra of early type stars and photographs of the Milky Way, using a Schmidt camera to obtain ultraviolet spectra.

Two optical astronomy experiments are among the candidate experiments for the proposed space station. One of these is a stellar astronomy module containing a 120-inch telescope equipped with videographic, spectrographic, and photometric instruments to observe individual faint stars, galaxies, and stellar clusters in the 900-Å to 10 000-Å spectral region. The second optical astronomy experiment being considered is a 12-inch ultraviolet Schmidt normal-incidence telescope to photograph objective grating stellar spectra in the 1000-Å to 2000-Å spectral range with a spectral resolution of 2 Å or greater and to obtain moderate resolution for UV direct photographs of selected objects. These experiments will generate data at a rate in excess of 10^{10} bits per day.

INFRARED ASTRONOMY [IV-2, IV-4]

The early exploratory observations in the infrared spectral region do not require satellites but can be conducted with telescopes mounted in high flying jet aircraft. At present, astronomers are using a Lear jet and plan to fly a 36-inch telescope on a C-141. In addition, balloon flights and sounding rocket flights can be applied to infrared astronomy work.

The Astronomy Missions Board has recommended that NASA devote a small astronomical satellite to IR observations, but no such mission is presently scheduled.

One of the proposed space station experiments is an infrared stellar survey. A cryogenically cooled 40-inch telescope equipped with a mercury-doped germanium detector will be used to conduct a sky survey for IR source at wavelengths of more than 20 microns. This experiment has a data generation rate of around 10^9 bits per day [IV-6, IV-7].

LOW FREQUENCY RADIO ASTRONOMY [IV-4]

Radio Astronomy Explorer-A (RAE-A) was launched in 1968. It is the first satellite devoted exclusively to radio astronomy, as well as the largest spacecraft ever orbited (1500-foot antennas). RAE-A has generated a wealth of low frequency radio data from which a model of the distribution of galactic ionized gas can be inferred, as well as a model of coronal streamer density and temperature out to 0.60 solar radii.

NASA is planning an RAE-B mission for 1972 to provide measurements of galactic and solar radio noise of increased resolution and discrimination by utilizing the moon for occultation, focusing, and aperture blocking.

SOLAR ASTRONOMY

Since 1962, six Orbiting Solar Observatory satellites have been launched, and four more are planned through 1975. By this method, the solar spectrum has now been completely surveyed down to a wavelength of 1.8 Å in the X-ray region with sufficient resolution to show its bright line character, and with wavelength determinations accurate enough to permit the identification of nearly a thousand lines. However, much work remains to be done to improve the absolute photometry in the far UV region, obtain time sequences of spectra in all the UV and X-ray wavelengths (especially in active centers), measure line profiles for the quiet sun, and so on.

In addition to the Orbiting Solar Observatories, sounding rockets, aircraft, balloon observations, and ground-based observational and theoretical work have an important impact on the solar space program.

Skylab will contain five solar astronomy experiments. The following experiments will be carried on ATM-A: (1) white-light coronagraph, (2) UV coronal spectrographs, (3) X-ray spectrographic telescope, (4) UV spectrometers, (5) X-ray telescope and (6) a hydrogen-alpha telescope. ATM-B, the follow-on mission, is slated to carry the following experiments: (1) photoheliograph, (2) X-ray spectrographic telescope, (3) UV scanning polychromator spectroheliometer, and (4) hydrogen-alpha telescope. Both TV and film cameras are under consideration for use as the medium for data generated on ATM-B. The majority of the data from ATM-A will be recorded on photographic film, which will enable the collection of large quantities of high resolution data. This mode of data collection will require extravehicular activity by the astronauts as well as the need for return of the film cannisters upon the conclusion of each mission. The real-time data transmission rate is about 10^4 bits per second for the solar experiments. TV imaging systems represent a potential improvement in operational capability and real-time monitoring of experiments and require no extravehicular activity, film return, or resupply. Planning for ATM-B is based on TV data recording rather than film. If the TV system does not prove feasible, film cameras will probably be used [IV-8, IV-9].

The space station will probably conduct a solar astronomy program. Typical instrumentation may include a 40-inch UV photoheliograph, an 8-inch far UV spectroheliograph and spectrometer, a large-aperture coronagraph capable of observing out to 30 solar radii, and a 20-inch X-ray grazing-incidence telescope with direct imaging and a spectrometer. The solar experiments are very prolific data generators with rates in excess of 10^{11} bits per day. These high rates are attributable to the high spatial and spectral resolutions of the observations [IV-6, IV-7].

PLANETARY ASTRONOMY

Interplanetary probe missions will play a role of increasing importance in this area of astronomy. The current (FY 1971) approved NASA space probe program includes the following missions [IV-10]:

1. Mariners H & L (1971) — to orbit Mars and conduct photographic reconnaissance at a resolution of 1 to 2 miles.

2. Pioneers F & G (1972/1973) — to investigate space between Earth and Jupiter and take photographs and make in situ measurements of Jupiter during close flyby. Thirteen scientific experiments have already been selected to be flown on these missions.

3. Mariner Mercury (1973) — to flyby Venus and get gravity assist for Mercury flyby to perform scientific investigation of Mercury. Pictures of Mercury's surface will be taken, the temperature characteristics of the surface will be recorded, and a search for a Mercurian atmosphere will be made.

4. Mars Viking Mission (1975) — to put a package into Martian orbit and dispatch a lander to the surface for analysis of surface material and conduct meteorological, seismological, and soil mechanics measurements. The payload will contain 25 experiments.

The information yield from unmanned lunar and planetary missions has already been enormous, including the Ranger, Lunar Orbiter, and Surveyor missions to the moon and the Mariner missions to Mars and Venus. As an example, the Mariner 6 and 7 flights to Mars in 1969 yielded over 200 photographs and more than 5000 UV and IR spectra of the planet. The NASA FY 1971 budget line item for data analysis has been increased to permit the detailed analysis of the Mariner 6 and 7 data in order to maximize the investment made in these missions.

The success of OAO-A2 has permitted the introduction of a Guest Observer Program. A special planetary group has been formed and observations of Mars have been made with OAO-A2 that have confirmed the presence of ozone in the Martian atmosphere, the ozone first being detected by Mariners 6 and 7.

FIELDS AND PARTICLE ASTRONOMY

From 1964 to 1969, six Orbiting Geophysical Observatories (OGO) carrying 130 experiments were successfully orbited and operated for over 100 000 hours. They logged over 1.5 million hours of experiment time and generated a large portion of the daily data input to the Goddard Space Flight Center. The last OGO was launched in 1969. Several OGO's are still generating useful data.

Although enough of the acquired data has been processed and analyzed to meet initial mission objectives, the unexpected long lifetime of these systems and the continued performance of much of the scientific instrumentation produced an amount of data somewhat beyond the existing capability of the ground-handling facilities. These data have value for special events and long term studies and are now being stored in a data band for selective processing at a later time.

Present emphasis is on the smaller Physics Explorers (PE), of which three were launched in 1969 and five more will be launched in 1970 and early 1971. These satellites study the various phenomena related to the earth's radiation belts. In addition, the Atmosphere Explorers (AE) will study the earth's lower atmosphere in the altitude range between 90 and 150 miles. AE-C will be launched in 1973, with AE-D and AE-E to follow in 1974 and 1975, respectively. Finally, the joint U.S. West German Helios mission in 1974 will send a spacecraft some 10 million miles inside the orbit of Mercury to explore the interplanetary medium. This is NASA's largest cooperative international project to date [IV-10].

A wide variety of experiments in atmospheric physics, auroral phenomena, radio and X-ray astronomy, and solar physics can be conducted with sounding rockets. In 1969, NASA launched 83 sounding rockets and plans to do the same in 1970. There were 56 NASA-sponsored balloon flights in 1969.

A cosmic ray physics laboratory is being considered for the space station. This experiment will contain a large liquid hydrogen target, a central ionization spectrograph, a superconducting magnet, a spark chamber, and an assortment of counters for detailed analysis of cosmic rays. The data generation rate of this experiment will approach 10^9 bits per day. An ionospheric plasma experiment to investigate the wake generated in the ionospheric plasma by a spacecraft moving through it has also been proposed for the space station. This experiment would have a data generation rate of around 10^{10} bits per day [IV-7].

Summary

It is quite obvious from the preceding discussion that astronomy and space physics alone will be two tremendous generators of scientific data during the decade of the 1970's. To derive the maximum scientific benefit from this expected torrent of data, proper attention and funding must be directed to the development of more efficient and rapid means for analyzing such data and incorporating the resultant information into the mainstream of scientific knowledge. It makes little sense to spend hundreds of millions of dollars to generate new data and then skimp on the funds required to carry out the data processing, analysis, and the dissemination of the final results to all interested users. There should be a careful matching of the data handling capacity to the data generation rate to reduce the lengthy time delays that mark the present system in most cases. Since the results from a current space experiment might very well have a major effect on the design of an experiment package slated for a later flight, rapid processing of the data and dissemination of the results could have an important economic impact in addition to their scientific impact.

PASSIVE SOURCES

The sources to which a user turns for stored data and information are defined as passive sources. The role of the passive sources is of substantial importance to an information system. Passive sources would be found both within and without any information management system of which one could conceive. Much interfacing with passive sources must be accomplished by the infromation system to direct the user to the most likely source of the information he desires.

Examples of Passive Sources

As stated in the introduction to this chapter, passive sources may be people, machines, and institutions that have in store information that is not original with them. Quite possibly one's first idea of a passive source is the library. Saul Herner [IV-11] gives pertinent information on some 44 major American libraries and resource collections dealing with scientific and technical information. In addition, he lists and describes the various publications that compile and describe papers, reports, textbooks, abstracts, etc. Information Analysis Centers, which are discussed in some detail in Chapter II, are playing an increasing part as a passive source. There are over 200 such centers of which some 119 were listed as federally supported in January, 1970 [IV-12]. An example of passive sources data bases can be found in Table IV-1, which is representative of the types of passive sources that might be available to a user. The space-based and atmosphere-based sources would apply only if pertinent data were stored on board, either in men or machines.

Relation to Active Sources

Although a thin line often divides the active from the passive source, the latter is distinquished by a greater use of recorded data sources. Although mainly a passive source, an Information Analysis Center can, through the analysis of a number of related sources, synthesize this material into original ideas. Figure IV-1 defines schematically the passive sources of a network [IV-13].

TABLE IV-1. ILLUSTRATIVE DATA AND INFORMATION SOURCES

Systems Area: Scientific/technological data and information

Focus Area: Aeronautical and space-related data and information

Specific Topic: Earth resources data (academic areas of possible application include agriculture, forestry, hydrology, geology, oceanography, meteorology. Service areas include urban development, transportation control, and weather forecasting.)

Space-Based		Atmosphere-Based		Ground-Based	
Manned	Unmanned	Manned	Unmanned	Manned	Unmanned
1. Gemini missions 2. Apollo missions 3. etc.	1. ESSA 2. NIMBUS 3. etc.	1. P3A 2. E130B 3. RB57F 4. etc.	1. Weather balloons 2. etc.	1. Work location of individual researcher (for direct, non-recorded data transfer) 2. Recorded data points a. Earth resources research data facility at MSC b. Technology applic-ations center (NASA) c. Information/research centers d. Libraries (general and specialized) e. etc.	1. Rain guages 2. Insect traps 3. etc.

Note: Methods of access to a given topical data source will be a function of the user's needs in terms of (1) nature and level of data sought and (2) cost in terms of time, energy, and money.

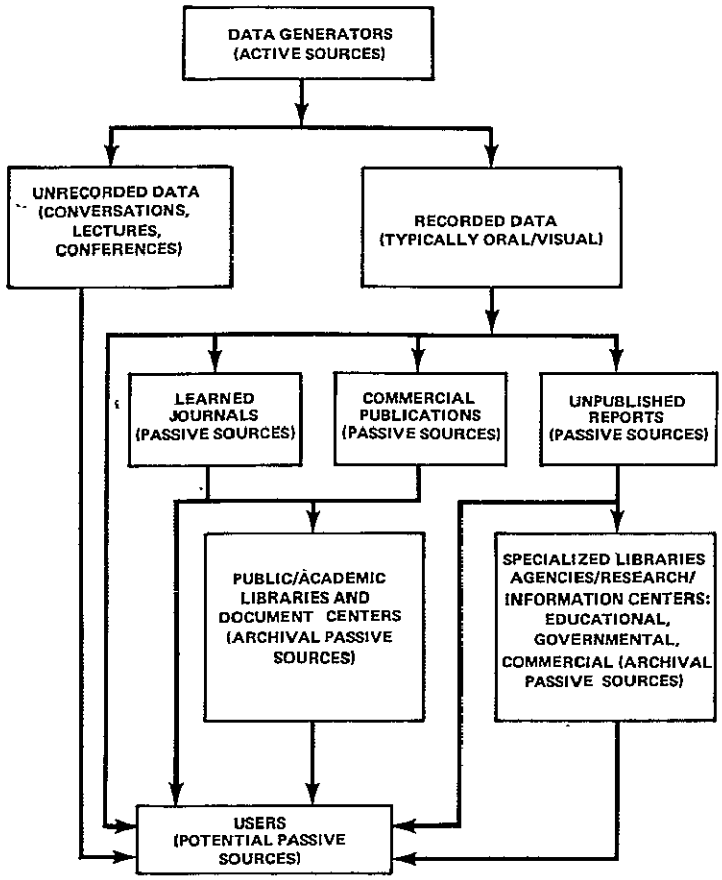

Figure IV-1. Data and information flow.

In those situations where a human being is both generator and user, the processing path typically bypasses the "recorded" step. When the user is the first receiver of data that is sensed mechanically or electromagnetically (e.g., a radiometer recording digitized data on tape), the data are recorded but may not be archived until after treatment. Any user has the potential for becoming, and often does become, a passive source.

Summary

The vast amount of stored data must be an effective and usable source. The information that is to be stored in these sources has greater potential for future use if standard input formatting such as a technical report standard title page is used.

Data sources require visibility in direct proportion to their potential usefulness, whether the source be a man, machine, or institution. Therefore, they must themselves be either spatially dispersed, or, perhaps more desirable economically, access points to their materials must be dispersed, in conjunction with fast time retrieval operations. There is much need for information experts to be strategically located in research areas in order to promote the needed interface between the researcher and the great body of recorded information.

EXAMPLES OF FUNCTIONING SYSTEMS

In this section two systems, the NMC and the NSSDC, are discussed. The former has responsibility for making weather analysis and predictions; therefore, the system requires very specific data input in a timely fashion. The system must then exert some control over the sources. In the latter case, the system has large amounts of data and information in many forms being funneled into it from many diverse sources, and the system seeks to make this data available to potential users.

The National Meteorological Center (NMC)

The NMC provides an example of an existing information system that is organized to provide a specific service [IV-14]. This service is to supply weather information daily to all parts of the United States. The NMC also provides weather information to many other parts of the world.

Figure IV-2 shows the world wide meteorological network of which the NMC is an integral part. The basic structure of NMC is also shown in Figure IV-2. Data are transmitted to the Center from two to four times daily from aircraft, various ground-based stations around the world, a world-wide weather balloon system, and the weather satellite system through the National Environmental Satellite Center. The data are then processed and prepared for dissemination to the 50 district Weather Bureau Forecasting Offices, to military users, and to other countries. The district forecasting offices send the information along with their additional inputs to the local Weather Bureau Offices. The local Weather Bureau Offices in turn provide the weather information to the general public.

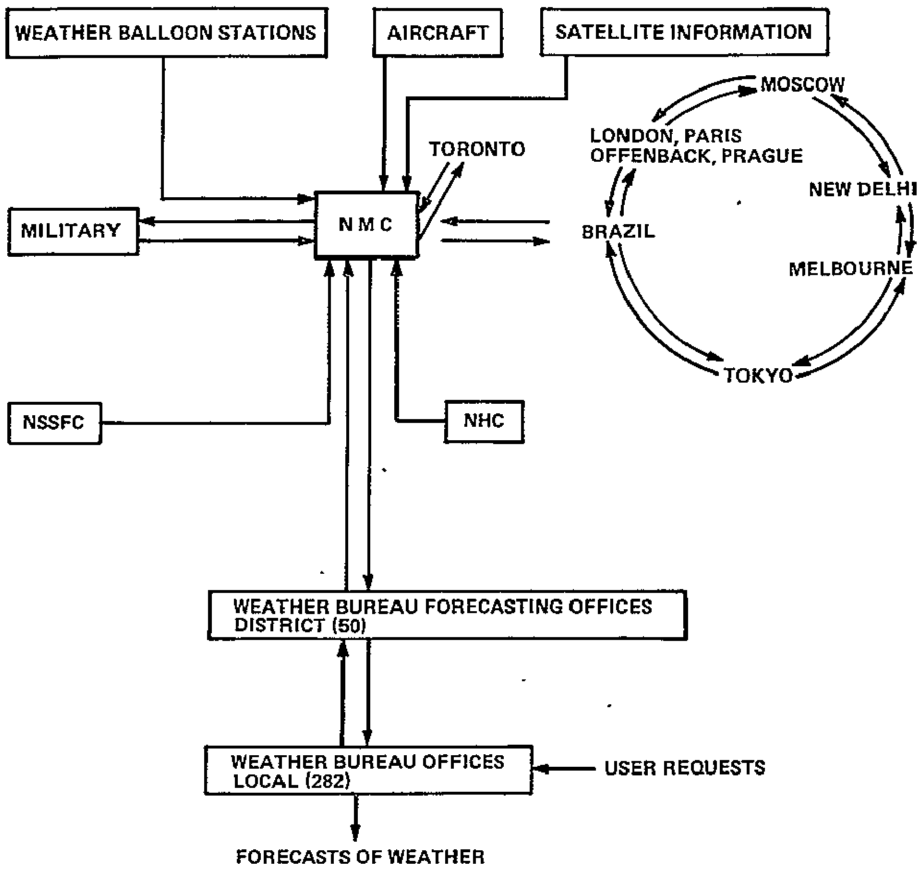

Figure IV-2. Weather forecasting information system.

According to its charter, the NMC is required to perform the mission of weather analysis and predictions. The sources required for accomplishing this mission have responsibility for providing the raw data. Some of the sources from which the NMC would desire input are exterior to the system. For example, many of the international sources are not part of the system and do not always provide timely data. The result is that the analysis suffers without these additional inputs.

National Space Science Data Center (NSSDC)

The rationale behind the operation of the NSSDC is to make the data from space science experiments available to a wider user group than the original investigating team responsible for a particular experiment.

It might be in order at this point to indicate the specific category of space data for which the NSSDC is responsible. We can speak of four major categories of space data:

1. Scientific experiments.
2. Engineering measurements.
3. Applications satellites.
4. Biomedical experiments.

The NSSDC is concerned with most of the scientific data generated by space probes, satellites, sounding rockets, stratospheric balloons, and high altitude aircraft. It is responsible for the acquisition, organization, storage, retrieval, announcement, and dissemination of the resulting data and information [IV-15, IV-16].

NSSDC was established by NASA in 1965 as an outgrowth of the existing data center activity at the Goddard Space Flight Center. The scope of NSSDC's operations extends to the national level, since space science data generated by all agencies and research groups are collected. The resulting data bank is available to all requesters.

To understand the operation of the NSSDC, one must first have some idea of the origin and overall flow of space science data and information. Let us consider an orbiting spacecraft as a typical example of a generator of space science data and trace out the procedure necessary to convert this data into useful information that can be understood by a larger group of users. The diagrams presented in Figures IV-3 and IV-4 show the steps involved [IV-16].

It is interesting to note that the majority of experiments are performed by a PI who has sole responsibility for the design, construction, and calibration of the instrument to be flown as well as for the initial interpretation of the resultant data. In fact, the PI usually controls the availability of the data to others for a period of several years after the experiment is flown and usually has exclusive rights to its use. The PI's may be located in universities, government laboratories (such as the Naval Research Laboratory), NASA field centers, or in private industry.

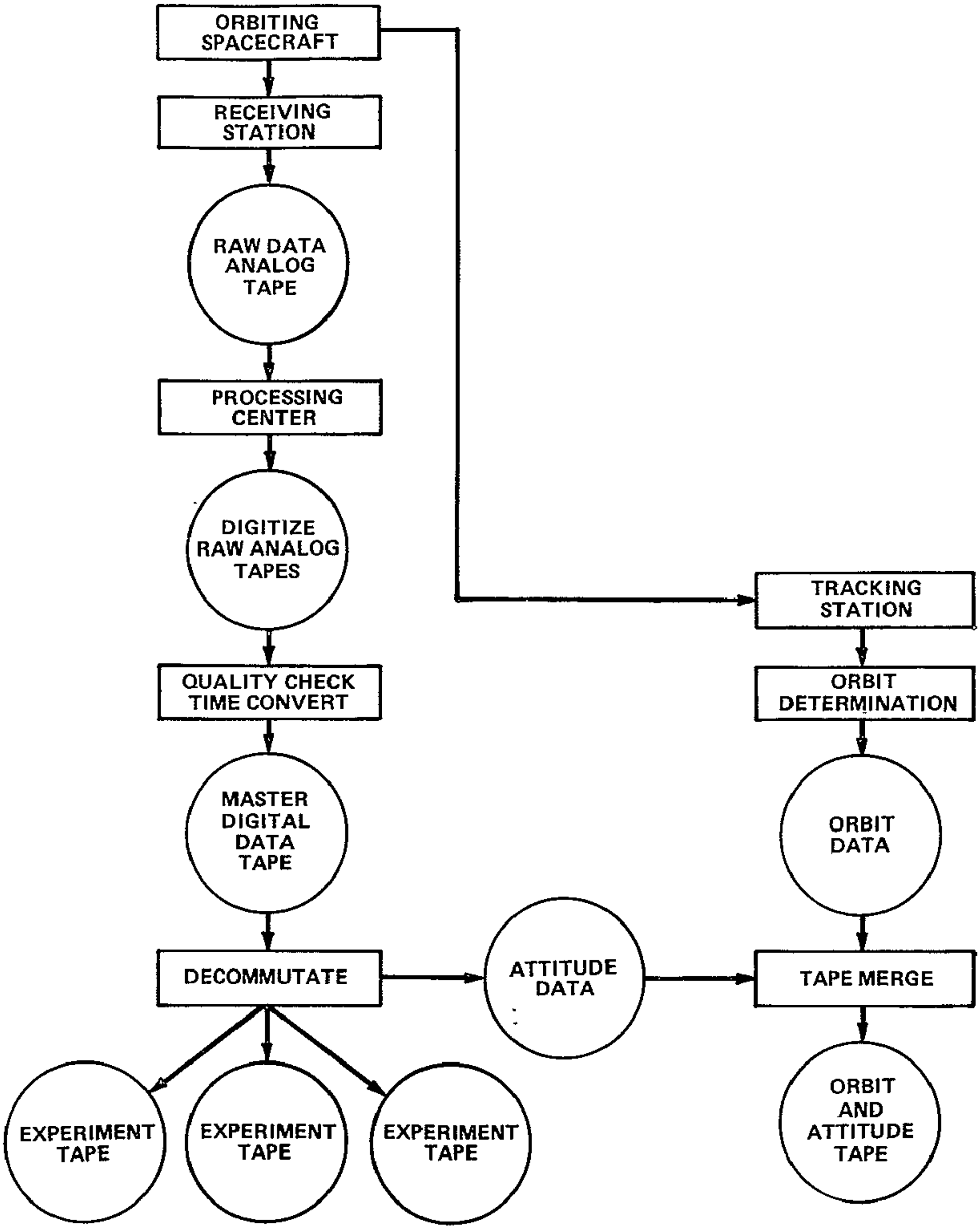

Figure IV-3. Diagram of satellite data flow from orbiting spacecraft through central processing facilities [IV-16].

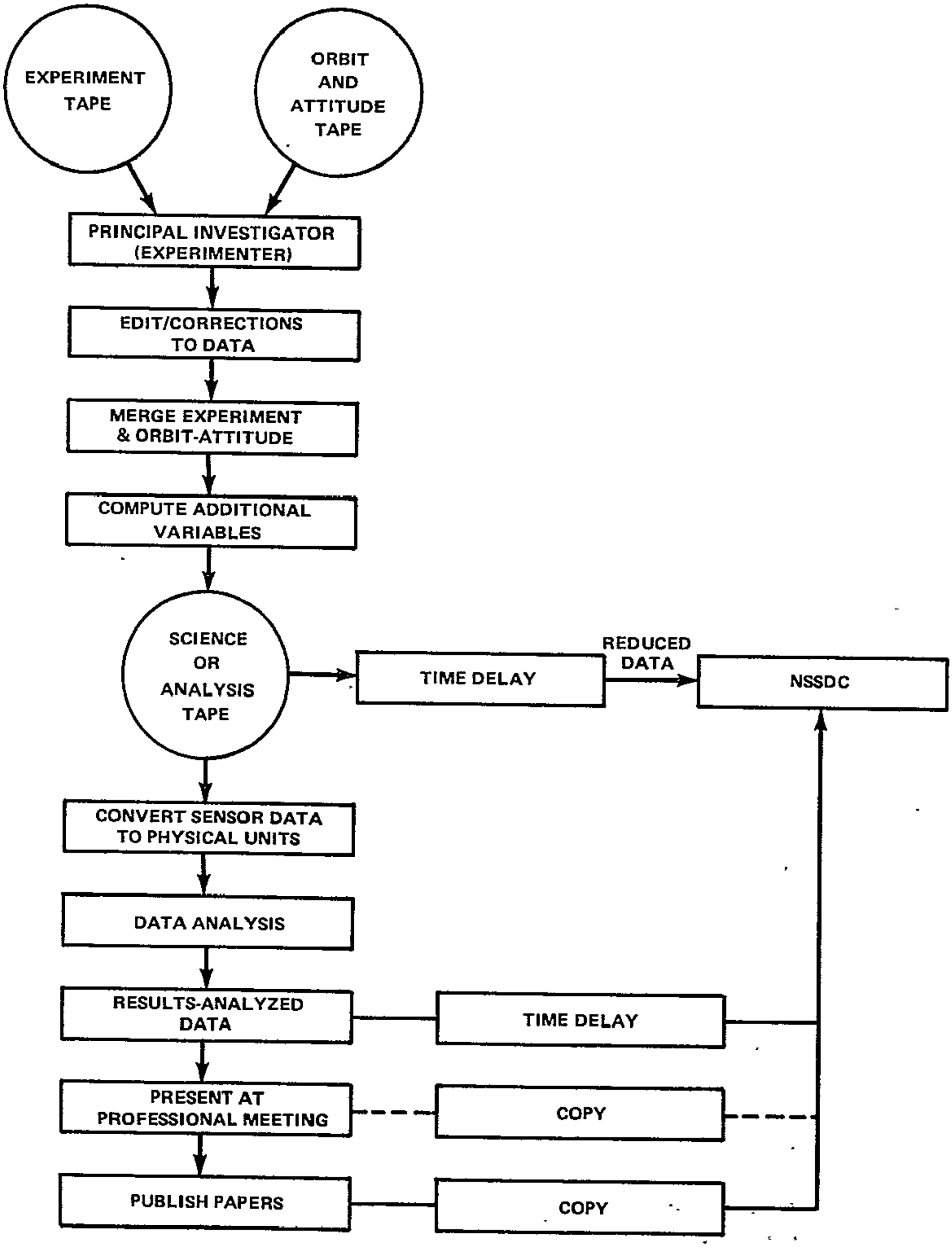

Figure IV-4. Diagram of satellite data flow from experimenter through analysis to final publication (phases when data are collected by NSSDC are shown) [IV-16].

After the science or analysis tape is generated (Fig. IV-4), the PI can undertake the interpretation of his experimental results. The NSSDC attempts to collect the reduced data contained on the science or analysis tapes so that other scientists active in the same field can, given the instrument characteristics, independently interpret the data for their own purposes. There is usually a time delay of 2 to 3 years from the time the experiment is flown until the reduced data are made available to the NSSDC. In the case of picture-taking satellites, the photographs are available to NSSDC several months after launch, and the negatives are considered the reduced data for such experiments.

After the PI completes his interpretation of the reduced data, he usually presents his results at a professional meeting and publishes them in a scientific journal. These results, called analyzed data, are also included in the NSSDC files because of their usefulness to other scientists.

The activities of the NSSDC are illustrated in Figure IV-5 [IV-15], in which the various inputs to and outputs from NSSDC are depicted. The raw materials fed into the NSSDC are space science data and ground-based correlative data. The latter are usually obtained from other data centers.

To encourage the dissemination of the data available at NSSDC, catalogs containing cumulative listings are published on a semiannual basis. In addition, a Data Users' Note is compiled by the NSSDC staff with documentation supplied by the PI to provide key information important for the use of the data by other scientists. NSSDC also provides the facilities for visiting scientists to perform their studies on-site or to select those data sets that they wish to have sent to them at their home institutions for further study. The NSSDC response to user requests results in the generation of magnetic tapes, pictures, microfilm, or hard copy for distribution.

An important characteristic of NSSDC is its capacity to handle large varieties and amounts of data. The NSSDC staff has estimated that within the next few years, NSSDC will receive annually about 10 000 magnetic tapes, 150 000 linear feet of roll charts, and 2000 100-foot rolls of microfilm. It is probable, according to NSSDC, that more than 10^{12} bits of space science data will be fed into their system each year [IV-17]. The present NSSDC data base is about 5×10^{11} bits. It is presently estimated that this will grow to 5×10^{13} bits within 7 to 10 years [IV-18].

To improve the efficiency of its operation, NSSDC has developed a request accounting status and history file that keeps tabs on the internal processing function of the organization. RASH is designed to display up-to-date

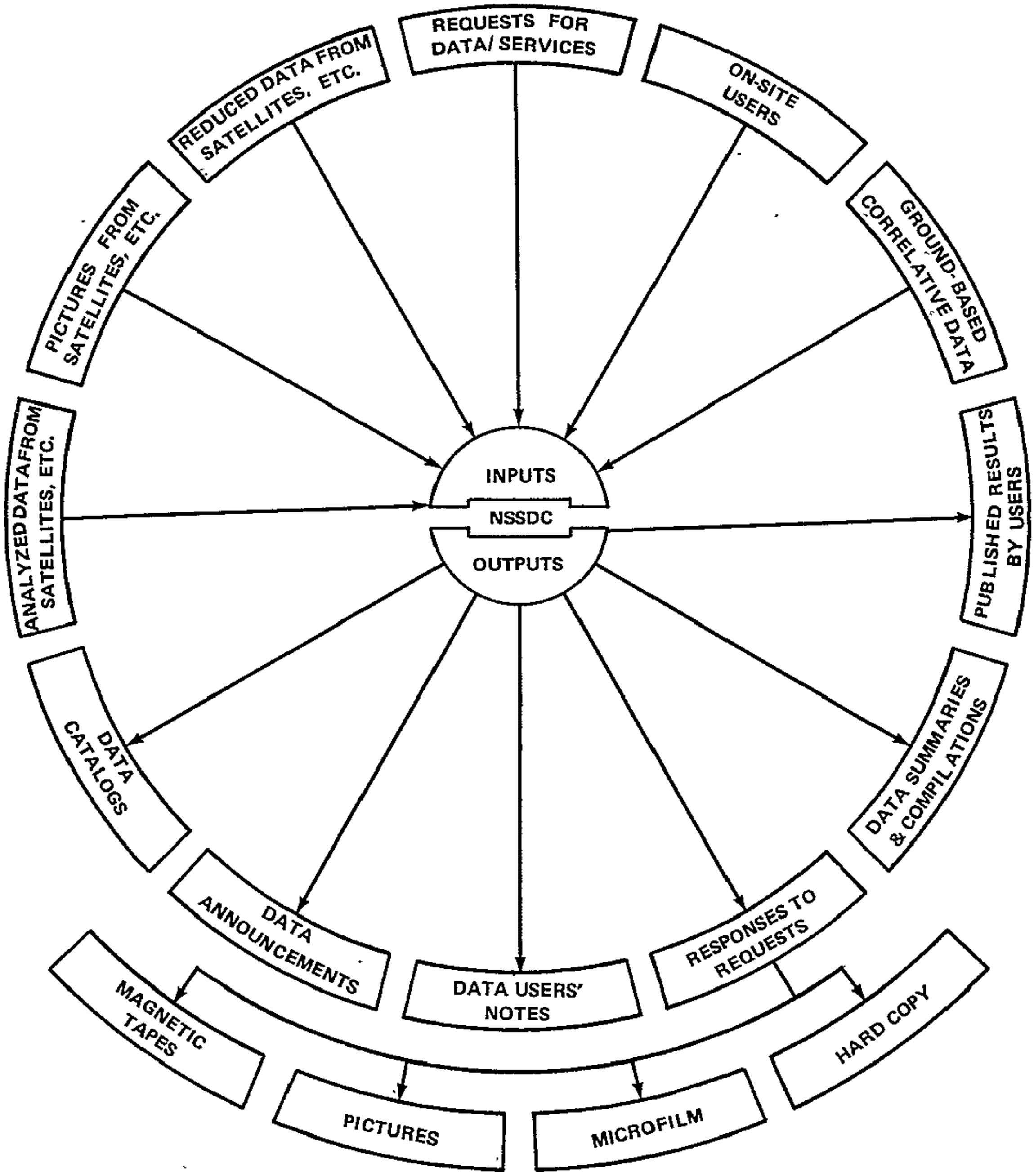

Figure IV-5. Activities of the National Space Science Data Center [IV-15].

information regarding the number of requests, their status, estimated and actual costs, processing time, and necessary action reminders. By using the RASH system, the staff of NSSDC is supplied with important information on the user community, types of requests and responses, and data sets most likely to be used.

This latter point raises the question of what can be done to control the size of the data base with which NSSDC must work. Figure IV-6 shows the yearly generation of space science data by satellites through 1969 [IV-16]. In 1969, one is speaking in terms of about 10 000 reels of magnetic tape entering the NSSDC file each year. This figure makes it obvious that attention has to be given to the efficient packing of the digital data on the tapes to minimize their number. In addition, NSSDC has given thought to retiring from the active data base or compressing that data that is not being used. Thought has also been given to the use of higher density storage techniques that utilize photographic or metallic film.

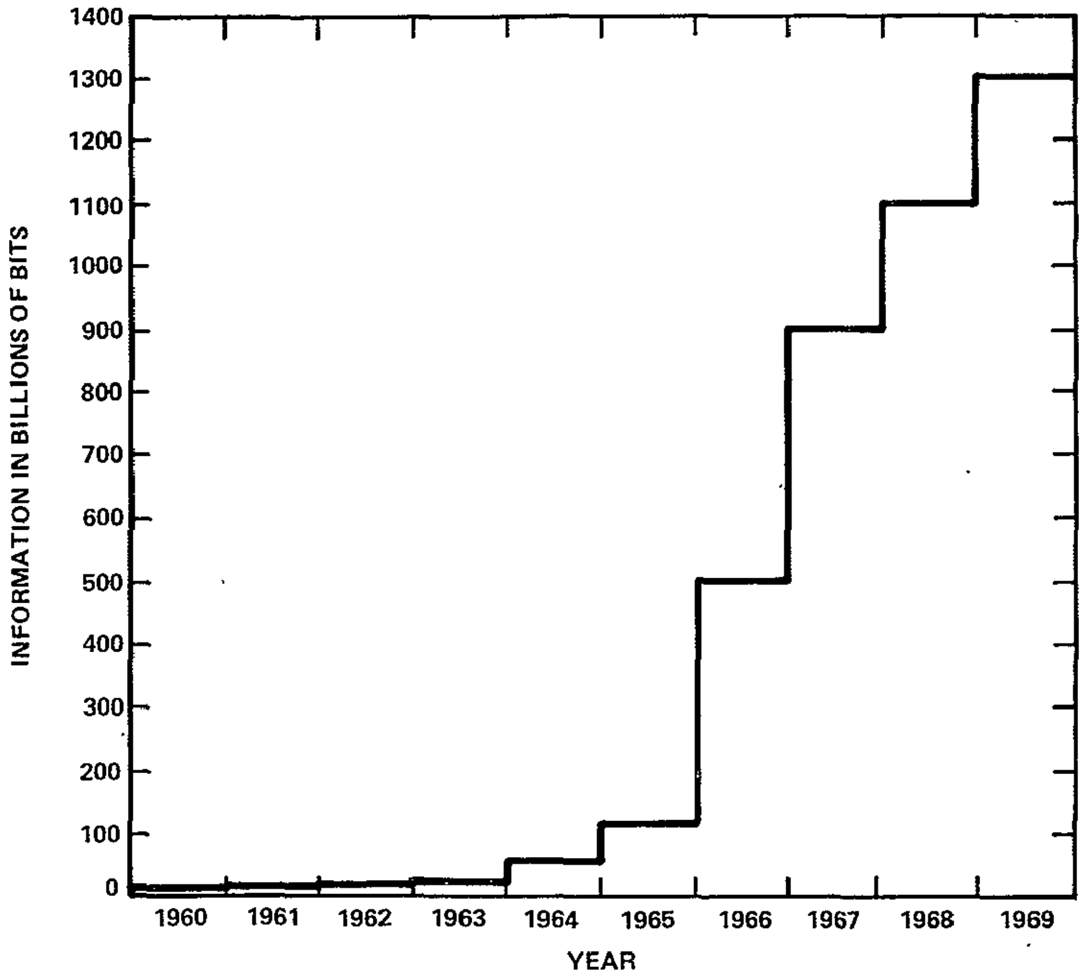

Figure IV-6. Yearly generation of space science data by satellites (totals do not include data from pictures) [IV-16].

The NSSDC philosophy of data compression envisions the occurrence of several steps. The first step would involve the retirement of alternate forms of the data and retaining the most useful form. Next, this most useful form of data could be subjected to the removal of derived variables calculated from the basic positional and attitude information for the particular spacecraft on which the experiment was flown. This would permit the later recalculation of these variables if it proved necessary. Since the derived variables that accompany the basic data average about 10 times as many bits as the sensor measurements themselves, their removal would result in a reduction of one-tenth of the amount of stored digital experiment data. At this point, no loss of basic information content has occurred. This procedure does have one drawback; namely, that if one wishes to use this data, more time and resources have to be utilized than were necessary prior to the removal of the derived variables. What one is doing, in effect, is balancing this cost against the maintenance cost of keeping all these data in the active data base. There will obviously be a break-even point that will be a function of the frequency of data usage.

There is another possible approach to data compression. Most of the space science data can be split into two categories. One category is the ambient, quiet-time, background information; the other category is the disturbed-time, discrete-event information. There are a large number of different discrete events such as magnetic storms, solar flares, comet appearances, novae, etc., that are of great interest to scientists. However, background information accounts for the majority of the space science data accumulated since the advent of the space age. As newer instruments of greater time, energy, or spectral resolution become available, the fine details of the older background data will become of historical interest only. Time averaging of such outdated background data could be carried out for time periods of hours or even days in some cases. Such time-averaged data would still be useful to scientists for the study of long-term changes. A sizable reduction in the number of bits for a given data set can be achieved by such a process without compromising the usefulness of such data for future studies.

Comment should be made on the type of personnel required to successfully operate an organization such as NSSDC. The data center must have professionals in the space science disciplines to (1) acquire the data in the proper form from the experimenters; (2) maintain the appropriate interface with the scientific community; (3) provide the proper entities for the storage and retrieval system; and (4) translate the data into forms useful to the scientific engineering and management communities.

Another important area is the financing of the NSSDC operation. The estimates of the NSSDC staff indicate that if 1 to 2 percent of the budget available for the research areas that produce the original data handled by NSSDC is given to the data center, then an adequate facility can be developed to handle the complete data needs.

It should be stated that the NSSDC serves a unique function in the space science field. Operating procedures and proposed future approaches developed by NSSDC can serve as a model for the management of information within many other areas of science and technology.

Summary

These examples illustrate a number of features that could be incorporated into an information system. They also point out the fact that financial resources must be allotted for the proper acquisition, processing, and retrieval of information. Also, in order that these functions be effective, there must be qualified personnel who are trained in both the scientific field and information field.

CONCLUSIONS

The sources of data and information have been viewed from the user's viewpoint; therefore, many of the passive sources will be viewed as users by other generators of information. The discussion in this chapter has, however, approached these sources in their role as sources rather than considering their role as users. The consideration of the user aspects of these sources is discussed in another chapter of this report.

This chapter has pointed out the ways in which the active and passive sources could interrelate with an information system. Consideration was given to systems that actually exerted control over the sources and to systems that accepted whatever output a group of sources gathered.

The growth in the amount of data being produced and the capacity to increase this amount greatly has been indicated by several examples. It is evident that the capacity of the users to utilize these data efficiently must receive careful consideration in the designing for the acquisition of data and in the daily operation of generating data.

A key to the efficient use of the sources lies in the development of people who will become "information scientists". These people will find themselves in industry, universities, research centers, and government where they will interface with the literature and other researchers. Writers who can converse with scientists and engineers and then report in laymen terms on the work being done will serve to bridge the gap in communication between the disciplines. The work of William R. Corliss in the NASA EP series is an excellent example of this type of reporting [IV-19].

To provide efficient use of the wealth of information available and the data being generated, resources for utilizing the data and information must be balanced with the resources alloted to performing research.

Sources have the capacity to flood us with data and information. Efficient use of these sources is mandatory.

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CHAPTER V
MANAGEMENT ANALYSIS

CHAPTER V. MANAGEMENT ANALYSIS

INTRODUCTION

The IMS requires an organization or framework for the integration and administration of the system, otherwise it is only a collection of components. Without this requirement, the IMS does not have the capability to meet the criterion of being evolutionary.

In this chapter, the needs of the system are analyzed. These needs are organization, integration, and administration to fulfill the system's mission goals and meet the criteria. This chapter begins with an analysis of the needs; it presents a framework for the generation and evaluation of alternatives, and then presents an example of an organization that meets the criteria.

This discussion strives to analyze the full range of potential alternatives from the most centralized to the most decentralized form of organization. It attempts to include and integrate into the system as many of the existing organizations and facilities as possible. An analytical method is proposed, using the decision as the unit of analysis to evaluate the full range of alternatives. (See Appendix V-A for an example of the process used in this management approach.)

Several approaches are utilized to spawn alternative organizations that could integrate and administer the proposed IMS. These alternatives are evaluated in terms of the criteria specified in Chapter I and in terms of their ability to execute the decisions required to operate the system. The criteria for this system are that the system must:

- Provide a wide range of services that satisfy user priority needs.

- Be evolutionary — it must possess the ability to grow, adapt, and provide for feedback.

- Be technically effective and economically feasible.

- Be integrable with existing systems.

- Provide the information, personnel, and relationships to facilitate effective decision making throughout the system.

This evaluation results in an example organization that is a composite of the alternatives, meeting the objectives and the criteria of the mission. In the conclusion of this chapter this example organization is discussed in terms of the objectives and criteria.

REVIEW OF SELECTED PREVIOUS REPORTS

Analyses of the requirements for the organization, integration, and administration of the information management system are important components. The SATCOM report [V-1], which deals with information management, places emphasis on this function, devoting over half of its recommendations to the topic.

As mentioned in earlier chapters, a review of 15 of the most familiar plans for national document handling systems for science and technology was prepared by Carter in 1965. The majority of the plans included in Carter's study included the organization aspects, but most of them ignored the technical aspects of the organization. They provided general guidelines, as did the Tripartite Committee Report and the SATCOM report. (See Appendix V-C for an example of an analysis of this latter report.) They outlined the responsibilities of the proposed governing bodies but gave no plan specifically defining the internal organization structure and did not spell out its functional responsibilities in the detail necessary for effective operation.

Harrison, Brockman, and Sommers analyzed an aerospace data system [V-2]. They drew the following conclusion:

> "Some division of labor between humans and machines is required. Most often, the human belongs in a network other than the primary one. . . . The human is most effective working in a secondary, smaller control network, monitoring data acquisition, transfer, processing and transformation."

The control network will be mentioned and the interface between its decision and information requirements is developed in the following pages in the analysis of the management of the system.

ORGANIZATIONAL GUIDELINES OR CRITERIA

A set of organization guidelines is presented in Table V-1. Preparation of the list forced the group to acknowledge its assumptions — a formal presentation reduces the likelihood that a conclusion will be based solely on such a prejudgment. Secondly, the list served as a guide in the development of a plan

TABLE V-1. ORGANIZATIONAL DESIGN GUIDELINES OR CRITERIA

1. That administration be limited to the minimum needed to fulfill the mission objectives.

2. That the organization be limited in structure to the minimum needed to provide the needed degree of administration.

3. That decision making be decentralized. The responsibility for a given decision should be placed at that point:

   a. Which is closest to the point of execution.
   b. Where the maximum amount of information relevant to the decision is available.
   c. Where personnel are available who are best equipped to apply the relevant decision criteria.

4. The system must be designed so as to provide all of the required information for each decision.

5. Each decision maker should be charged with responsibility to the system above all other responsibilities and is limited to the criteria specified.

6. Everyone affected by each decision should be notified as to who has the responsibility and what criteria will be applied in making that decision (full disclosure).

7. The organization of the system should be independent of the data and the uses to which the data are put. The organization should minimize detracting interference within the system.

8. The fewer the number of "gatekeepers" along the path are, the more likely it is that unmolested data will reach the user.

of analysis to assure that the range of alternatives considered was as wide as possible. Each of these guidelines is developed from and/or supported by some combination of studies of organizational processes and management experience.

No a priori concept of organization or development approach exists that will permit one to synthesize or deductively determine the appropriate structure or mode of organization best suited to a given definition of system objectives. A series of alternatives must be examined and evaluated against a set of criteria. These alternatives range across a wide spectrum, from a highly centralized single agency all the way to a highly decentralized system with the responsibility for all decision making placed on the user or person closest to the need.

DECISION – BASIS FOR ANALYSIS

To perform a logically consistent analysis of the organization, administration, and integration of the system, the "decision" was taken as the basis of analysis. The reasons for this base of analysis and evaluation are listed in Table V-2.

TABLE V-2. DECISION AS THE UNIT OF ANALYSIS/EVALUATION

Reasons for using "decision" in the analysis of management requirements of the system:

1. Smallest unit of analysis that still includes or interacts with all elements of the system.
2. Bridges, or is not limited by structural elements of the organization.
3. Occurs in large numbers throughout the system.
4. Is affected by (or constrained by) the structure of the organization.
5. Is an important aspect of the evolution of the organization.
6. Is readily identifiable in operational terms.
7. Covers a long time span; bridges the personnel changes and other modifications of the organization over time.
8. Is susceptible to rigorous, methodical analysis using network and systems techniques.

ANALYTICAL DECISION FRAMEWORK

To analyze the IMS in such a manner that the whole spectrum can be considered, it is necessary to look at each of the decisions in detail. (See Appendix V-B, Tables On Analysis of Planning Decisions, for an example of this process.) This requirement is dictated by the consideration of the alternative of a decentralized system where each decision could conceivably be made by a different individual or group. Analyzing the problem in broader terms would risk overlooking or foreclosing the alternative of a decentralized system. It would tend to limit the ability of the system to incorporate existing information systems, which are smaller, into the total system.

The analysis proceeds according to the six-step framework shown in Figure V-1. Step 1 is the identification of each of the decisions required in the operation and the continuing, evolutionary planning of the system. These are called "decision nodes" for the purposes of this analysis. "Decision node" includes all the aspects of the decision that are required to clearly identify and delineate the decision; the personnel and materials affected, the place where the decision has its effects, information channels feeding into the decision process, and so forth. In a block diagram of the system, the decision nodes will appear as blocks with two or more arrows coming from them.

One method of identifying the decision nodes is to develop a detailed block diagram of the IMS. The block diagram must devote careful attention to those relationships that involve more than one subsystem or portion of the block diagram. Identifying a decision node is like picking up a fish net by one of the knots; the relationships tying it to other activities are the tendrils hanging down. An example of a decision node is shown in Figure V-2.

Step 2 is the identification of the alternative outcomes for each decision node. This step naturally follows from step 1. In many cases the alternative outcomes will be logically apparent, given the delineation of the decision node. For the example shown in Figure V-2, the alternatives are: Yes, the subject is a user; and No, he is not. Those decisions for which the alternative outcomes are less apparent must be developed using informed judgment.

Step 3 is the identification of the criteria that are appropriate to each decision node. These criteria must fulfill the objectives of the system; they must emphasize the role of the user and the welfare of mankind. The list of these criteria was developed by a brainstorming process. The list then had to be reviewed in detail for logical consistency. Table V-3 illustrates these criteria, using the same example as before.

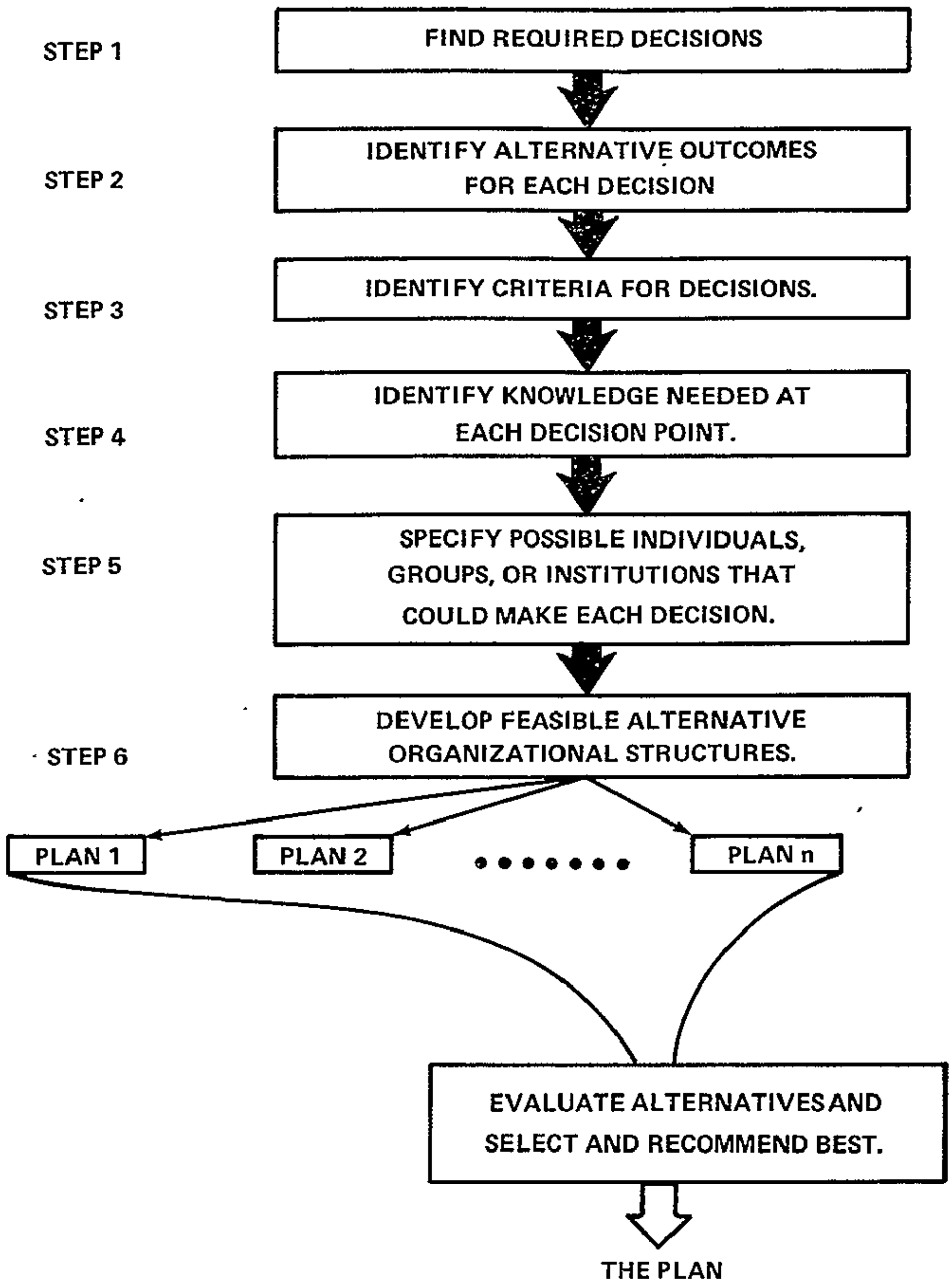


Figure V-1. Management analytical framework.

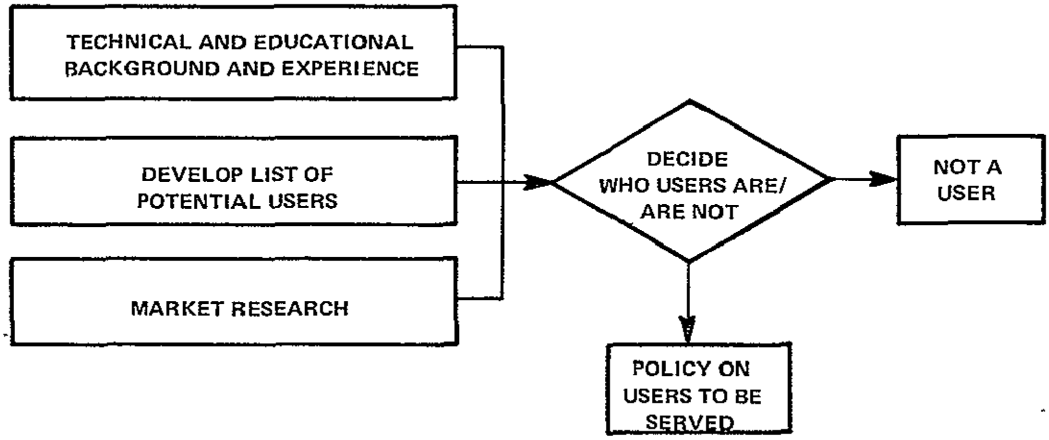


Figure V-2. Example of indentification of decision node.

TABLE V-3. CRITERIA FOR EXAMPLE DECISION

Demonstrated use of the system (established users, on mailing lists or membership lists).
Expressed willingness or desire to use the system.
Potential value to be gained from the system.
Probable rate of usage.
Degree to which proprietary needs are met.

Step 4 is the identification of the knowledge or information needed at each decision node. This is the information needed to apply effectively the criteria so as to reach the optimum decision under the conditions that prevail at the time. The information needed can thus be defined by the individual charged with the responsibility for that decision, within the framework of the criteria specified above. In most cases, this information is effectively defined by the criteria.

To define the information needed, the investigator must assume the role of the decision maker, empathize with him, assume his environment, and then review the decision criteria. The information needed to apply each of the criteria effectively should then be apparent by inductive logic. Again, a circular process involving review and amendment by the broadest group with the widest possible view is needed to avoid limitations because of tunnel vision or incomplete background.

Many of these information needs will represent arrows on the flow chart moving from one subsystem element to another. These represent the feedback flows of information, aside from the main flow of data from source to user. The identification of these information needs serves the important purpose of defining many of the interrelationships within the system. Many of these interrelationships take the form of subsidiary communication channels.

Step 5 is the identification of possible individuals and/or groups or institutions that could make each decision most effectively. Step 5 begins to define alternatives for the organization. Step 5 can be performed by brainstorming sets of alternatives and then evaluating their ability to acquire the necessary information and to apply the appropriate criteria. The larger the number and scope of participants engaged in this brainstorming is, the greater the number and the range of alternatives will be.

It is appropriate to engage in a checking process, to insure completeness and consistency. The sets of decisions from step 1 and the knowledge from step 3 were arrayed in matrix form (Tables V-4 through V-7). The matrix is reviewed to insure both completeness and consistency. The most striking result that emerged from this process was the role of educational background and experience. When educational background and experience appeared on the matrix, the sets of decisions were reviewed to see whether or not this source of information was required. It was concluded that it was an important information input for about half of the decisions. However, almost none of the proposed or existing plans for information centers include educational background and experience as a component of the system.

Step 6 is the development of feasible alternative organization structures. Most of the published studies of information systems base their recommendations for the organization of the system upon a set of undefined predispositions or upon the examination of a limited set of alternatives. This study is committed to the examination of as wide a range of alternatives as possible.

Several approaches were used, as described in Table V-8 to generate the wide range of alternatives. The primary goal in step 6 is to consider the full range of alternative structures that can conceivably represent the relationships between the various elements of the system.

TABLE V-4. ANALYSIS OF PLANNING AND REPLANNING DECISIONS

Knowledge Area: Breadth for High Level Planning and Replanning

Decision Area: User's Distribution

Decision / Knowledge Required	Policy Decision on Proprietary Needs	Decide Who Users Are/Are Not	Decide User Needs/Wants	Design Dissemination System (Channels)	Design Index System	Design Archival System	Design Format Procedure	Design Training Programs for Users	Establish Public Relation Policy	
Performance and Cost Studies	1	1	1	1	1	1	1	1		

TABLE V-5. ANALYSIS OF PLANNING AND REPLANNING DECISIONS

Knowledge Area: Breadth for High Level Planning and Replanning	Decision Area: User's Distribution				
Decision / Knowledge Required	Decide Who Users Are/Are Not				
Broad Technical Knowledge and Experience	1				
Educational Experience	1				
Market Research	1				
User's Feedback and Evaluation	1				
Established Users	1				
Performance and Cost Studies	1				
Forecast on Future Data Sources	1				
Master Plan of Data Sources	1				
Alternative Sources of Economic Support					
Alternative Sources of Aid and Employees					

TABLE V-6. ANALYSIS OF PLANNING AND REPLANNING DECISIONS

Knowledge Area: Detail of Present Operating System and Policy									
Decision / Knowledge Required		Decide Who Users Are/Are Not							

TABLE V-7. ANALYSIS OF PLANNING AND REPLANNING DECISIONS

Knowledge
Area: Detailed in Depth in Specific
Technical and Operating Areas

Decision / Knowledge Required		Decide Who Users Are/Are Not							

TABLE V-8. INDIVIDUALS, GROUPS, OR INSTITUTIONS CAPABLE OF MAKING EACH DECISION

Alternative Plans for Identifying the Possibilities
Micro Approach — Based on Decision Nodes Brainstorming possibilities after reviewing the total set of decision nodes and information requirements.
Macro Approach — Based on Deductive Method Application of "models" of organizations to the system.
For example:
National Meteorological Center as a model for an information management system.
National Space Science Data Center as a model.
Generalized organization models of other types in practice or proposed.

Step 7 is the evaluation of alternatives in terms of established criteria to select the one, or ones, that best fulfills the objectives of the system and best meets the criteria and constraints. Evaluation of alternatives can be fully documented, with the evaluation according to each of the criteria fully documented, and the basis for each trade-off described. Such documentation enables the reader to benefit from the foregoing analysis. This enables him to build upon it, although he may arrive at different conclusions by assigning different weights and values to the alternatives.

DECISION-KNOWLEDGE MATRIX

The set of relationships most useful for the purpose of building an organizational structure is the interrelationship between decisions and knowledge. The decision is dependent upon the set of information needed. The knowledge needed for a decision defines the organizational level of the decision maker. The time horizon of the knowledge defines the time horizon needed by the decision maker. The decision-knowledge matrix defines the communication network of the organization. Therefore, an IMS requires a management information system.

The decision-knowledge matrix defines the technical, administrative, educational background, and experience needed by individuals. In essence, a job description could be written from this list of information needs.

To obtain maximum value from the decision-knowledge matrix, both knowledge and decisions must be classified. From the many alternative schemes available, one was selected that seemed to facilitate the construction of an organizational structure. The decision classifications are:

1. Area
   a. User's need
   b. Sources
   c. Processing
   d. Dissemination to user
2. Type
   a. Planning and replanning
   b. Operational

The area classification corresponds to the divisions of activity normally found in business institutions. Source selection corresponds to the purchasing function. The processing is the production function. The dissemination to users is the sales function. Figure V-3 illustrates the above concepts.

The type of classification is illustrated in Figure V-4. All information management systems exist in a time environment. The conditions in which the system exists are continually changing. The planning and replanning function is to regularly redesign the system for the future environment in which it must exist. The operational decisions are concerned with operating the system; i.e., executing the plans.

PLANNING-REPLANNING DECISION

Each operational decision is associated with a particular planning-replanning decision. Both short term and long range planning are involved here.

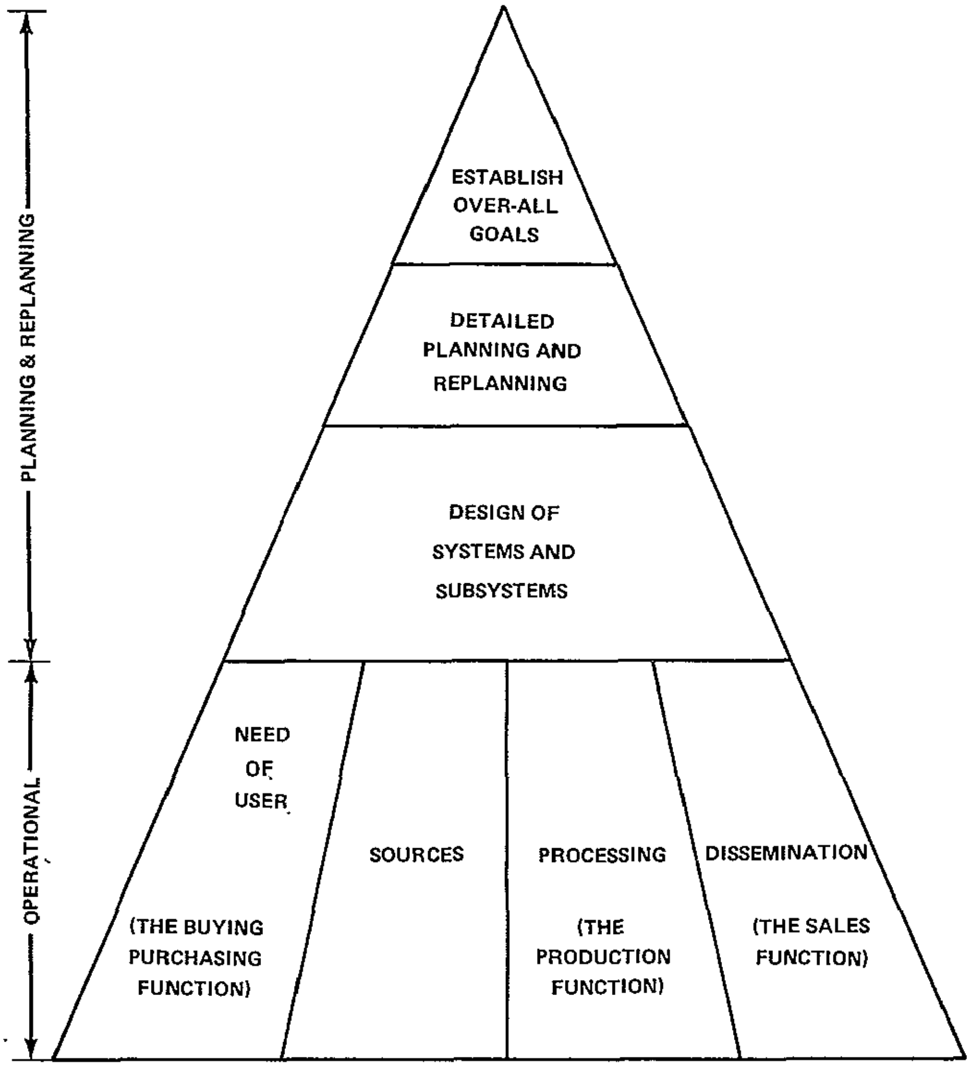


Figure V-3. Organization structure for an information management system.

The planning-replanning decision establishes a policy framework for the technical specialist to make his operating decisions. These policies are guides for operational decisions so that they are consistent with the overall goals of the system. Both Figures V-3 and V-4 are of value in visualizing the relationship.

The knowledge classification is:

1. Knowledge in breadth for high level planning and replanning.

2. Details of the present operating system and policy.

3. Depth of the technical and operational background.

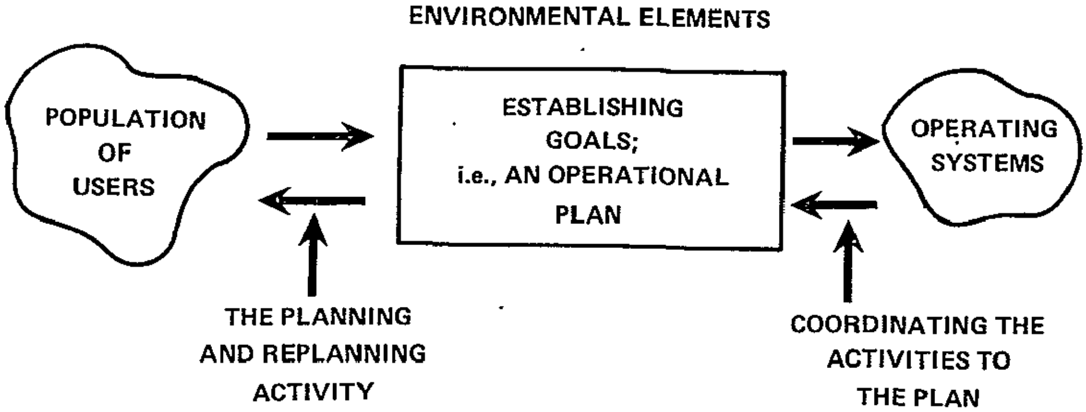


Figure V-4. Environmental elements toward a dynamic information system.

The division of knowledge was designed to separate knowledge into groups for identification with decision makers. Appendix V-B shows the detailed results. Tables V-4 through V-7 are designed to illustrate the type of information available from this analysis.

Table V-4 shows a single row of knowledge; i.e., performance and cost studies. The objective in the table is to identify the decisions in the area of planning and replanning that require the knowledge of performance and cost studies. The decisions (policy decision on proprietary needs, decide who users are/are not, decide user needs/wants, design dissemination system, design index system, design archival system, design format procedures, and design training program) all require this unit of knowledge.

Table V-4 indicates which decisions do not need this knowledge. The function of reviewing unnecessary material on a continuous basis is inefficient and confusing. The decision to establish public relations policy is the only one not requiring the unit of knowledge (performance and cost studies).

The alternative method of examining the decision-knowledge matrix is to select a column (decision) and see what knowledge is necessary to make that decision. Tables V-5 through V-7 examine the matrix in that manner. The decision examined is to decide who users are/are not. The policy on what users to seek out and those to reject will change over a time span. To make the policy decision, the knowledge needed is: broad technical knowledge and experience, educational experience, market research, user's feedback and evaluation, established users, performance and cost studies, forecast on future data sources, master plan of data sources, alternative sources of economic support, alternative source of aid, and employers. The information not required is also shown on Tables V-5 through V-7.

RESULTS OF ANALYSIS

The recognition that an information management system needs a communications network to perform its management function is an observation based on the decision-information analysis.

The decision-knowledge analysis provides a framework for the integration of existing information management systems. An information system now exists for the United States. This information system is made up of a large number of uncoordinated independent information management systems. No single administrative procedure will eliminate all the overlaps and gaps existing between independent subsystems. The decision-knowledge analysis will aid in selecting the several administrative processes that will provide the coordination of these many diverse pieces and develop others to fill the gaps.

APPLYING PROCEDURES TO THE PROBLEM

In applying the analytical procedure to the information management system, the effort focused its attention upon the user end of the information stream. Existing systems and organizations have tended to concentrate on the source end of the stream. By concentrating on the user, this project may make its greatest contribution. By emphasizing the user, this effort is best able to apply the criterion that the system be user oriented. In most existing and proposed systems, this criterion is not emphasized.

Table V-5 contains the analysis of the planning and operating decisions identified in the user portion of the information management system. The table includes a list of the decisions along with the appropriate criteria and information. The salient features of these data, from the point of view of organizational design, are as follows: there exists a strong parallel between the planning and replanning decisions and the operating decisions. For each element of the system that requires an operating decision, an element of the system charged with the responsibility of establishing the policy for that area is needed. The policy making unit must also have the means and the responsibility to detect changes in the needs of the system and in the environments within which the system resides. Any transformation detected must be reflected in changes in the policies that guide or limit the operating decision.

DEGREE OF CENTRALIZATION

One of the basic choices in the development of an organization and integration of the management information system is the degree to which the system is to be centralized. If a centralized organization is decided upon, a new organization will have to be created. No single organization exists at the moment that encompasses the full scope of an information management system of the type discussed here — spanning from the source of the information to the user. Whether such an organization were to be developed within or outside of NASA, it would be necessary to develop a set of organizational relationships that at present do not exist. No existing organization is equipped to deal with the whole set of decisions previously listed.

Since each of the existing organizations cover only a part of the system, a centralized organization would have to subsume many of these organizations (such as the Committee on Scientific and Technical Information, the Library of Congress, etc.) to meet one of the criteria. The criterion states that the system shall make maximum use of existing systems, in the interest of economy. The economy results from the possibility of starting from established units and building upon them as the system grows and evolves.

The major limitation of a centralized system is the lack of a model for the development of such a system. 1970 has been a year of reevaluation of major government organizations; for example, the Postal Department, the Defense Department, and the Bureau of Management and Budget. The major recommendations of these studies have tended to be in the direction of decentralization and increased independence of the decision making centers. The decision making process was the focus of attention of these studies as it is in this report.

Libraries and library systems seem to offer a model for the development of an information management system. Yet, libraries are notable in their failure to evolve, as well as keep current with the requirements of the universe of knowledge and the needs of the potential user. Libraries do not all meet the criterion of being evolutionary, so an information system based upon library systems as a model is inadequate.

Industrial experience has been similar. When facing major changes in the environment and objectives of the firm, such as International Business Machines' adaptation to the era of the computer, the focus of reorganization has also been toward decentralization. Decentralization has been carried out in the interests of more effective decision making and greater responsiveness to changed requirements on the business by the customer (user) or the environment.

Decentralized organizations are often challenged on the basis of the cost criterion, since there apparently is duplication in the internal communications. The problems of coordination or integration of a decentralized organization are also apparent as a limitation. However, the analysis of the decisions previously described indicates that the internal communications are not redundant, but are necessary for effective decision making. While such a process may not seem efficient, these communications are necessary in order to make the best decision. The matter of integration and coordination is served by these internal communications. As illustrated in Figure V-3, these internal communications must transmit the policies selected to the groups making the operating decisions. Moreover, they must transmit the information collected by the market research and other feedback sources to the appropriate decision making groups. Consequently, an organization that is designed to tie together existing subsystems and to provde policy making leadership can meet the criteria (see Table V-1) and fulfill the mission objective. Such an organization would be much like that used for the design of the Saturn V [V-3].

Regular mission review meetings and problem evaluation sessions would serve to provide the coordination and to reinforce the overall mission objective that the relatively independent subgroups hold in common.

The detailed design of a specific organization to meet particular mission goals follows directly from this review of the decisions required by the mission goals and the existing organizations that are involved in part of this process. The same analytical process may be used as a basis for evaluating and comparing the various alternative organizations proposed by others.

DETAILED ORGANIZATION DESIGN

The detailed design of an organization to fulfill the requirements of an Earth Resources Program must identify those agencies most concerned with dissemination if the proposed system is to meet the criterion of being "user oriented." It must include as many as possible of the effective existing organizations engaged in the transfer of information if it is to make the maximum use of existing facilities.

Other criteria are that the system be evolutionary, technically effective, and economically feasible [V-4]. The evolutionary criterion means that the system has to have built into it the mechanisms necessary to detect changes in the requirements of the user and the requirements of the environments within which the system operates (technical, manpower, social, political, economic, etc.). In addition, the system must have the ability to express these detected changes to that point in the organization where they can be evaluated and the appropriate changes in policy and action can be initiated. The criterion of technical and economic feasibility requires that the design of the hardware and software of the system be performed within the limits imposed by the criterion.

PROPOSED ORGANIZATION FOR INFORMATION MANAGEMENT

An example system is illustrated in Figure V-5. This example illustrates one of the alternative organizations possible for a major Earth Resources Program, including the operation of a space station as a framework for the sources of data.

The public is the most fundamental classification of users. The media for dissemination of information to the public are the news media, scientific journals, science museums, etc. These media are well equipped for broad dissemination, but they do not have established feedback channels that permit the user to register his degree of satisfaction or his unmet needs. These media do not have mechanisms for collecting data or responding to it. To integrate these media into an effective information management system, it is necessary to establish policies or standards of effectiveness in dissemination that can be measured. These media might develop such facilities themselves, much as industry trade associations do. There is a need also to integrate enforcement mechanisms as a necessary part of this system.

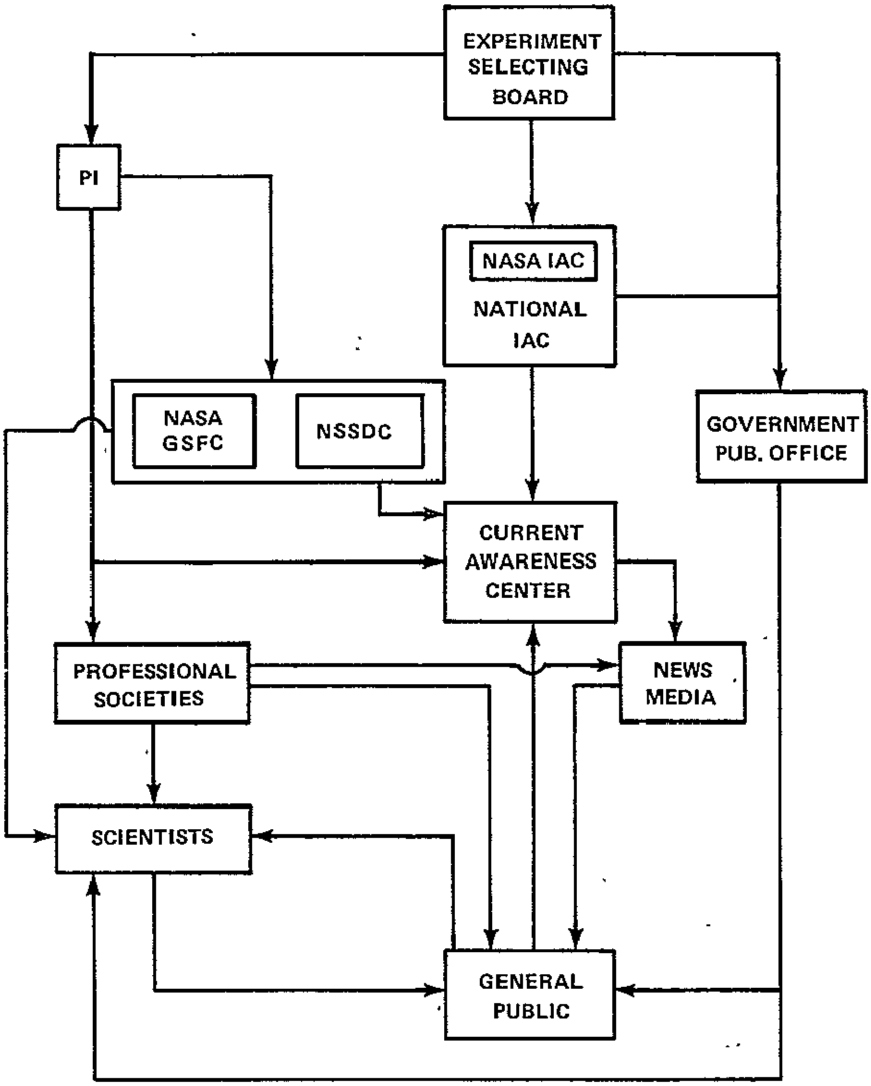


Figure V-5. Proposed functional organization for information management.

Libraries constitute one of the important media for disseminating information. Herner has analyzed the needs of the system to integrate the many small or nearly staffless libraries into the total information management system [V-5]. The most important aspects of this integration are the evaluation of the users' needs and wide publicizing of the services the system can offer.

COORDINATION OF SYSTEM ELEMENTS

The scientific community already possesses an effective information and coordination subsystem in the form of professional societies. Coordination, communication, and integration between the societies is lacking. The Current Awareness Center mentioned in Chapter II, can serve this function.

Interdisciplinary research is growing rapidly and promises to be a substantial portion of academic research in the near future. Formal types of integration will become increasingly important as this trend toward interdisciplinary research develops. Building the information system around discipline-based groups, such as the professional societies, can introduce barriers to such interdisciplinary research. These barriers can result from the publications, the vocabulary, and the internal communications (meetings, seminars, etc.). The CAC must also serve the function of recognizing and supporting the needs of interdisciplinary research.

Similarly, the various news media are accustomed to working quite independently, even in competition with one another. To insure that information of broad interest will be given broad dissemination, some integrating and intercommunicating agency or function is required.

The agency that could meet these requirements is termed here the CAC. This function does not exist at this time, and there is no readily apparent source of funding to establish such an agency. Since this agency would broadly represent the public, it is appropriate that this function be assumed by the national government. Similar functions within particular scientific disciplines are presently funded by the government. Charged with the responsibility of seeing that information is disseminated in an accurate and timely fashion to all users, the CAC logically would include the feedback channels and the market research function that are needed by the system. If feedback and market research are located at this point in the system, their inputs to the system can be put to the best and quickest use. Federal funding for this CAC would be consistent with these functions.

CURRENT AWARENESS CENTER

The CAC must be decentralized in structure to maintain effective contact with all of the professional societies and news media on the one hand and the wide range of potential users on the other. The closer the system can be to the user, the greater the likelihood is that the system will be used. Studies indicate that personal contact between the user and the system facilitates both the use and the customer satisfaction with the system. The information management systems at Smith, Kline, and French and at the DuPont [V-6] companies are based upon this principle. Such close contact with the user also facilitates the collection of feedback and market research data that can be used to improve the system's performance and structure.

The nature and the importance of market research to identify the needs and the changes in needs of the user are a significant component of the research and the design of the Central Office of Scientific, Technical and Economic Information (COSTEI) of Czechoslovakia [V-7]. This advanced project includes a number of scientific and systematic research projects directed toward these important variables. These Czechoslovakian findings support the importance of research and feedback in the user portion of the system. In the past, most of the research has been focused on the technical aspects of the system; i.e., the sources and the processing of data.

Another function of the CAC is the selection of information from the data banks that should be disseminated to provide the maximum service to the user. The selection of the appropriate medium for dissemination also falls within this same set of responsibilities. The CAC also can best serve to maintain close, personal contact with the user and direct the marketing of the system's user services.

SOURCES OF DATA AND INFORMATION

Such a CAC also requires an appropriate source of inputs. At present a number of agencies already exist to collect and store this kind of information. These agencies include the National Space Science Data Center and other groups. Again, what is lacking in order to integrate these various sources into an information management system is a mechanism for coordination, interagency communication, and statements of policy. Some supervisory board is needed to pull together these various sources of information, to provide a common framework and mission objective, and to provide the ability to sense the needs of the customer (the Awareness Center) and the needs of the environment within which the system operates.

ORGANIZATIONAL RELATIONSHIPS

Since these agencies operate within the same organizational framework within the government, all that is needed here is the restatement of goals and the realignment of supervisory responsibilities for these agencies to focus their attention upon the objectives of the information management system.

The relationship between the data generators and these information gathering agencies is one of the most critical portions of the system. However, this area is the most fully developed, for this relationship has existed and been reinforced to date through all the stages of the space program. This experience and the established relationships could be of great value, if they had been successful and effective. Nevertheless, there are certain flaws in these relationships that make their established channels of communication a barrier to the effective operation of an information management system.

For example, when the 19 members of the Auburn University Engineering Design Group assembled in the summer of 1970, none of them had seen or heard of the Announcement of Flight Opportunity (AFO). While these 19 are not representative of the whole scientific community, it is amazing that such a broad slice across the academic disciplines should fail to include one who had been exposed to the dissemination of the AFO.

SOURCES OF EXPERIMENTER'S DATA

An effective relationship between the PI's and the information system places requirements on several aspects of this relationship. A potential experimenter must have an awareness of the opportunities. He must also be fully aware of the criteria used to evaluate candidate experiments. To be encouraged, he must know the nature of the proposal that is required, so that he may feel that his proposal has a chance to be accepted. The more broadly this information is effectively disseminated, the greater the number of candidate experiments that are submitted will be.

This larger number of candidate experiments poses a problem of another type. The job of selecting the best from among the candidate experiments becomes more difficult, especially if they are received from the full range of scientific and neo-scientific disciplines. To select effectively from among a large group of candidate experiments requires an explicit set of evaluation criteria. Moreover, it requires a group of individuals who are widely respected for their judgment throughout the broader scientific community. Such a board must have a charter from the highest authority, preferably the President, for they must represent the users' long range needs for knowledge. A complex nominating procedure for assigning new members will be needed to assure the broad acceptance that is needed to encourage potential investigators. Such boards in the past have often been one-time assignments. However, the earth resources program is now so well established that it probably will continue into the distant future. Therefore, the mechanisms for the relationship between the PI and system must be developed for continuous, long term, evolutionary operation. Board members will retire and need to be replaced within the lifetime of the system. It will not be possible in this system to operate with an in-group, all of whom are close to one another.

With an excessive number of candidate experiments, it is no longer adequate to judge a proposal by judging the man and his reputation. The board will require some basis for judging the relative importance of each of the candidate's experiments for the long run welfare of mankind and the pursuit of knowledge. It will not be enough to determine that a proposed experiment is a "good one" or that the experimenter has a fine reputation as a researcher.

Another complicating factor that will enter the choice of the candidate experiments is the matter of funding. The board will have to consider proposals from the academic community in the U.S., from foreign governments, from private research institutions, and from industrial firms. Some proposals will be submitted with guarantees of funding while others will contain requests for government funding. Assigning the priorities to such a set of candidate experiments poses some formidable choices for the board. Selecting and administering a group who can place the long run welfare of mankind above their parochial interests is a major challenge. It is important to the system, for the board will act as a gatekeeper at the entrance to the IMS.

INFORMATION FOR DECISIONS

A detailed examination of the decision nodes in the IMS shows that the original proposal and the master schedule of experiments (the output of the Experiments Selection Board) are important source documents providing needed information for about one-third of the decision nodes in the system. These documents are particularly important for the policy or planning decisions. Uses elsewhere in the system define what these documents must contain to communicate effectively.

The proposal must be far more than a description of the experimental method. It must include an evaluation of the implications of the potential findings for the welfare of mankind, for the pursuit of knowledge, and for future research projects. It must include an estimate of the archiving needs and the useful lifetime of the data. It must include a measure of the degree of redundancy required in the data to insure valid results and an analysis of the encoding and data reduction methods that can be tolerated. For materials to be flown in space, the proposal must include a simulation plan that can be executed on the ground before flight, to establish baseline data and to insure compatibility with the system. The proposal must also include abstracts and key word index suggestions to facilitate the later dissemination of the data through the system. There are many other requirements of the system that add similar requirements to the proposal.

PROPRIETARY DATA

Deeply involved in this same area is the question of proprietary data, which pervades the whole system from PI to operation of the experiment. The proposal must include a firm commitment by the experimenter to disclose all data after a given time to prevent the system from being merely a service to the PI and a place for storing his data. It must include also a commitment from the PI to disclose his findings as of a certain date (which will, of course, vary with the type of problem being studied). The board must deal with a variety of needs for secrecy; the professional investment by the academic investigator, the competitive value of data collected by an industrial firm, security needs of experiments that have implications for national defense, earth resources data collected for one foreign country that may have strategic value to its neighbors, and so forth. Again, this is a formidable set of requirements for the board to meet. The system must be able to respond to a variety of needs to protect proprietary data, which may be different for each experiment.

CONCLUSIONS

The system proposed here is built upon existing agencies that function as information subsystems. It proposes and defines several organizational elements that do not exist at this time; a Current Awareness Center, a National Information Analysis Center, and an Experiments Review Board. These new system elements are defined by the particular decisions that have to be made to operate the system. These decisions define the relationships needed between the various functional elements shown in Figure V-6.

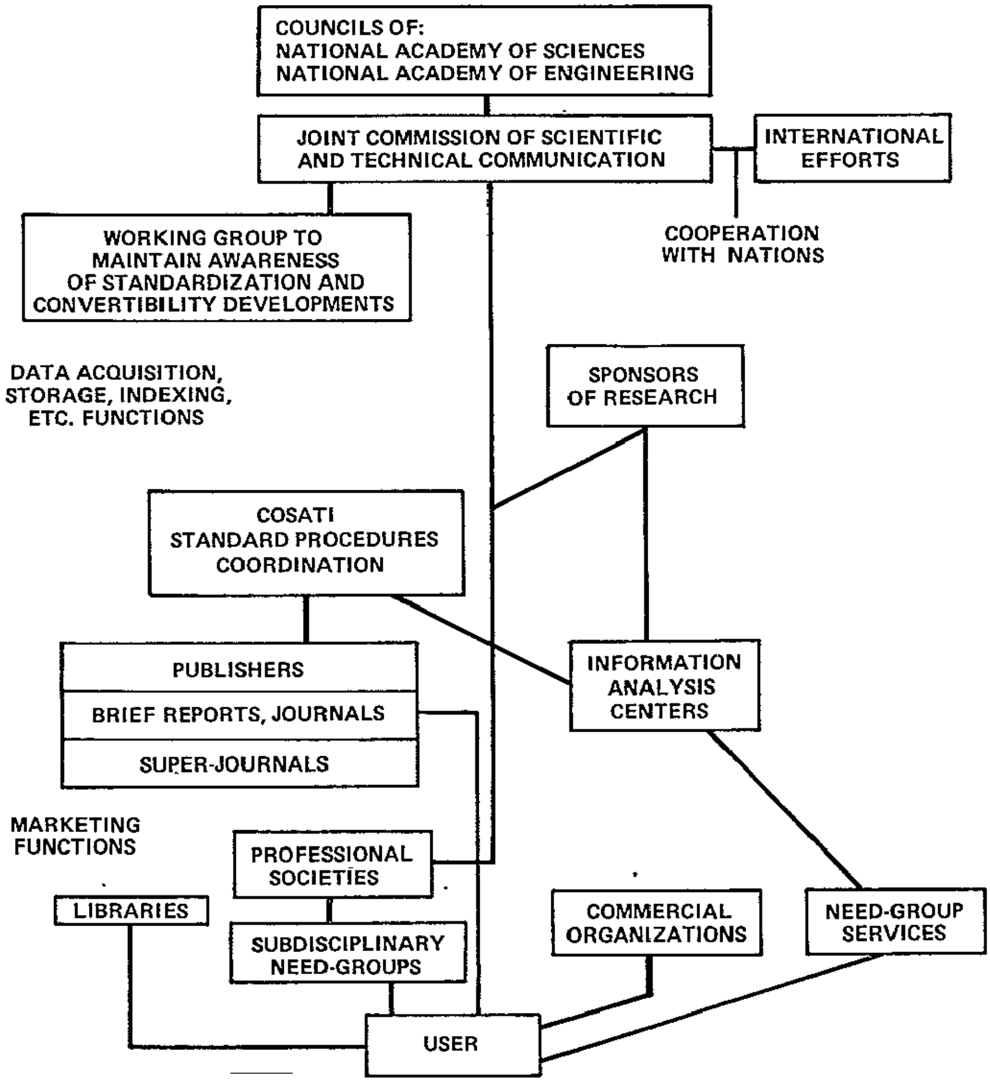


Figure V-6. SATCOM recommendations for scientific and technical information management systems.

A number of additional alternative plans for the structure of this information management system were proposed by several members of the Auburn University Systems Engineering Design Group. Most of these alternatives are not presented in this report in detail. In the process of reviewing these alternatives, their salient features were incorporated in the statements of policy, constraints, and criteria. Thus, they are reincarnated in the example organization previously given and in the analysis of the other alternatives examined.

APPENDIX V-A
EXAMPLE PROCESS CHART OF MANAGEMENT APPROACH

Statement of Purpose or Objective	Objective of Management	Requirements of System
To design an information management system for aerospace and earth related data and/or information.	To develop alternative plans for the organizational design, integration, and administration of an aerospace related information management system.	1. User group 2. Process group 3. Source group 4. Management group

Amplification of Subrequirement of Management

1. Define administration necessities, describe and identify alternative criteria, have knowledge to make effective decisions, and be alternative decision makers.

2. Evaluate integration procedure with regard to environmental constraints — internal adaptive mechanisms, environmental structure, and favorable direction of environment — long range planning function.

3. Evaluate alternative administrative plans such as those being used and those being planned, and determine the one that best meets criteria.

Policy Criteria of Management

Fulfills total system objective or statement of purpose.

Some of the necessary criteria for the management of the system are:

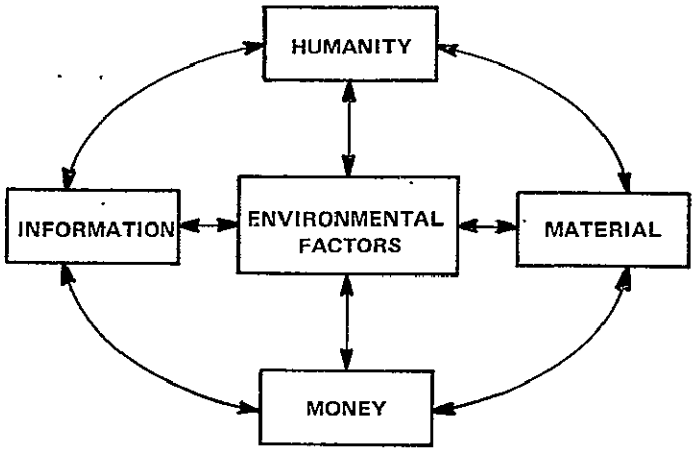
1. Provide a wide range of services that satisfy user priority needs.

2. Be evolutionary, possessing the capability to grow, adapt, and, provide for feedback.

3. Be technically effective and economically feasible.

4. Be integrable with existing systems.

Flow Chart of Selected Management Challenges



Suggested Value Priority
(1 is highest)

1. Humanity
2. Environment
3. Information
4. Material
5. Money

APPENDIX V-B
TABLES ON ANALYSIS OF PLANNING AND OPERATING DECISIONS

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
Policy decision on proprietary concerns	Active participation and commitment by investigators Free dissemination of information to users	Technical knowledge and experience Educational knowledge and experience Market research User's feedback and evaluation Established users (mailing lists) Performance and cost studies of the system Forecast of future data sources Master plan of data sources Contact with potential new data sources
Decide who users are and are not	Demonstrated use of the system Expressed willingness or desire to use the system Potential value to be gained from the system Are proprietary needs met? Probable rate of usage	Same as above
Decide user needs and wants	Accuracy Completeness; all needs Immediacy; system responsive to the REAL user User has some legitimate use	Same as above

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
Design dissemination system (channels)	Breadth of user coverage by channel Cost per user reached Accessibility by users Interest on the part of the medium	Educational knowledge and experience Market research Users' feedback and evaluation Established users (mailing lists) Performance and cost studies of the system Master plan of data sources Awareness and evaluation of current dissemination systems
Design index system	Who might use? His vocabulary; thesauri His associations of related words and concepts Utility to dissemination system and access	Technical knowledge and experience Educational knowledge and experience Market research Users' feedback and evaluation Established users (mailing lists) Performance and costs studies of the system Master plan of data sources Awareness and evaluation of current index system Knowledge of available thesauri

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
Design archival system	Potential value for further "mining" by students and scholars Value as an example for further research Intrinsic worth; museum of basic discoveries Basis for judging further data	Technical knowledge and experience Market research Users' feedback and evaluation Established users (mailing lists) Performance and cost studies of the system Forecast of future experiments Master plan of experiments Awareness of present archival systems
Design format procedures	Format requirements for: analysis equipment analysis software dissemination medium preparation of reports archival system Users' needs and wants	Technical experience and knowledge Educational knowledge and experience Market research Users' feedback and evaluation Established users (mailing lists) Performance and cost studies of the system Master plan of experiments Awareness of present dissemination systems Awareness of present index systems Awareness of present archival systems

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
Design training program for users	Knowledge required by effective user Knowledge held by average and minimal user Number of users requiring education Degree of use of system by average user Degree of proficiency needed to fulfill expectations of user	Educational knowledge and experience Market research Users feedback and evaluation Established users (mailing lists) Performance and cost studies of the system Master plan of experiments Awareness of present dissemination systems Awareness of present index systems Awareness of present archival systems
Establish public relations activity	Need to provide justification for expenditures Editorial capability, ability to judge newsworthiness and impact Ability to judge user need to be informed, value to user	Educational knowledge and experience Market research Users' feedback and evaluation Established users (mailing lists) Master plan of experiments Awareness of present dissemination system Contact with media

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
PI's decision to apply for candidacy	Probability of being selected Probability of carrying project to completion Probability of obtaining economic support (manpower, equipment, space, and released time) Personal needs and wants Availability of help; technical, presentation, etc.	Knowledge of opportunity, selection criteria, and methodology Assurance of technical competence Availability of economic support Source and cost of help
Local endorsement of PI	Demonstrated level of professional competence Amount of involvement (space, manpower, economics) Amount of staff support required	Number and quality of publications and demonstrated ability to gain support Projection of requirements

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
Review group selects experiments	Uniqueness of proposed experiment to space Probability of successful completion National urgency of experiment Relationship to human needs Conformity to constraints (physical, cost, etc.) Development of an overall master plan	Consultation on space-related uniqueness (experts) Physical constraints National needs and urgency as defined by representative source Full definition of national space goals and the national goals of all nations involved
Time schedule for data	Relationship to other experiment (ground verification) Sun angle and other physical constraints Priority of data Availability of medium; conflict with other experiments Degree of delay imposed by system; perishability of data Targets of opportunity Power requirements Shuttle schedule	Schedule of experiments Report of technical constraints "August body" report of priorities assigned Schedule of media and of experiments Experiment proposal; report of perishability Real-time reports of opportunity Power planning chart Shuttle schedule

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
Schedule related experiments (on ground, probes, etc.)	Same as previous entry	Analogous to previous entry
Schedule shuttle	Maintain inventory of consumables on board Personnel rotation pattern Personnel emergencies Maintain inventory of unexposed film/tape Perishability of hard data Need for repair parts	Current inventory status Personnel schedule Real-time notification of emergency Current inventory on film/tape Experiment proposal; report of perishability Real-time notification of need for parts
Acceptance or selection for review group	Breadth of representation — all major scientific disciplines Acceptance by the individual's reference or peer group Effective and wide contact with his constituent group Rest of committee accepts each individual as spokesman for his specialty Priority assigned by nominating party or group	A measure of the breadth of membership of groups to which individual belongs Nomination by professional society, educators, Presidential commission, etc. Peer ratings within the membership

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
Priority of experiments	1. Operation a. Life support, physical, and mental b. Flight operations 2. Experimental — variable real-time requirement a. Biomedical b. Coordinated experiments c. Opportunistic events d. Geographic oriented experiments e. Action based on survey data f. Feedback for experimental modification 3. Noncritical unusual events 4. Delayed transmission 5. Stored data 6. News dissemination 7. Personal communication and recreation	Proposal for experiment Master Plan of national space goals
	Importance of experiments to an established national program Does experiment fit constraints (mass, power, data rate, etc.)? Risk of danger from experiment Risk of hardware not adequate Risk of no meaningful data received Need for real-time data	Master plan for long range space study Technical reports and expert evaluation

ANALYSIS OF PLANNING DECISIONS

Decision	Criteria	Information Needs
Adaptation of the experiment to the system	Total limitation of all experiments to flight (mass, power, size) Consolidation of supporting equipment where possible Elimination of unnecessary emission	Sum of all requirements of approved experiments Evaluation of possible consolidation Negotiation with affected experimenters Final hearing of all experiment proposals Knowledge of all sensor elements

ANALYSIS OF OPERATIONAL DECISIONS

Decision	Criteria	Knowledge
Decide what each user wants from the system; to what extent can they be filled?	User requests Users' undefined wants and criteria of satisfaction	Technical knowledge and experience Users' feedback and evaluation Awareness of present dissemination systems Awareness of present index systems Awareness of present archival systems Awareness of formatting procedures Awareness of training programs Awareness of public relations policy Policy on proprietary data Awareness of thesauri
Select specific medium (channel)	User coverage by channel Cost of this channel Number of users	Technical knowledge and experience Users' feedback and evaluation Awareness of present dissemination systems policy Awareness of present index systems Awareness of present archival systems Awareness of present formatting procedures
Indexing of new material	Who might use? His vocabulary; thesauri His associations of related words and concepts Utility to dissemination system and access	Technical knowledge and experience Users' feedback and evaluation Awareness of present indexing system Knowledge of thesauri Original proposal

ANALYSIS OF OPERATIONAL DECISIONS

Decision	Criteria	Knowledge
Decisions to archive specific material (form, length of storage, etc.)	Potential value for further "mining" by students and scholars Value as an example for further research Museum value Basis for judging further data	Technical knowledge and experience Educational knowledge and experience Users' feedback and evaluation Master plan of experiments Awareness of present dissemination systems Awareness of present formatting systems Original proposal
Decide on specific format from alternatives	Format requirements for analysis equipment analysis software dissemination medium preparation of reports archival system Users' needs and wants	Technical knowledge and experience Educational knowledge and experience Users' feedback and evaluation Awareness of present index systems Awareness of present formatting procedures Original proposal

ANALYSIS OF OPERATIONAL DECISIONS

Decision	Criteria	Knowledge
Decide what training user needs	Knowledge required by effective user Knowledge held by the specific user Number of users requiring this particular training Degree of system use by user Degree of proficiency needed to fulfill expectations of user	Technical knowledge and experience Educational knowledge and experience Users' feedback and evaluation Master plan of experiments Awareness of present dissemination systems Awareness of present index systems Awareness of present formatting procedures Awareness of present training programs Awareness of public relations policy Knowledge of thesauri
Decide on redundancy removal	Awareness of redundancy introduced to overcome noise in system Redundancy needed to assure experimenter data are good Redundancy needed to aid interpretation of the data	Technical knowledge and experience Users' feedback and evaluation Master plan of experiments Awareness of present index systems Awareness of present archival systems Awareness of present formatting procedures Original proposal Technical measures of redundancy Results of prelaunch simulation

ANALYSIS OF OPERATIONAL DECISIONS

Decision	Criteria	Knowledge
Selection of material for news media	Need to provide justification for expenditures Newsworthiness, impact on public Public's need to be informed Value to user	Technical knowledge and experience Educational knowledge and experience Users' feedback and evaluation Master plan of experiments Awareness of present dissemination systems Awareness of present formatting procedures Awareness of present training programs Awareness of public relations policy Original proposal Results of prelaunch simulation

ANALYSIS OF OPERATIONAL DECISIONS

Knowledge Area: Breadth for High Level Planning and Replanning

Decision Area: User's Distribution

Knowledge Required \ Decision	Decide What Each Individual User Wants from System	Select Specific Channel (Media) to Use (and How to), Film/Hardcopy/Specimens	Indexing of New Material	Specify if Stored, How, Length, etc.	Decide on Specific Format from Alternatives	Decide What Training a User Needs	Decide on Redundancy Removal	Selection of Specific Material for News Media	
Broad Technical Knowledge and Experience	1	1	1	1	1	1	1	1	
Educational Experience				1	1	1		1	
Market Research									
User's Feedback and Evaluation	1	1	1	1	1	1	1	1	
Established Users									
Performance and Cost Studies									
Forecast on Future Data Sources									
Master Plan of Data Sources				1		1	1	1	
Alternative Sources of Economic Support									
Alternative Sources of Aid and Employees									

ANALYSIS OF OPERATIONAL DECISIONS

Knowledge Area: Detail of Present Operating System and Policy

Decision Area: User's Distribution

Knowledge Required \ Decision	Decide What Each Individual User Wants from System	Select Specific Channel (Media) to Use (How to), Film/Hardcopy/Specimens	Indexing of New Material	Specify if Stored, How, Length, etc.	Decide on Specific Format from Alternatives	Decide What Training a User Needs	Decide on Redundancy Removal	Selection of Specific Material for News Media	
Policy on Criteria and Methodology									
Policy on Economic Support									
Decision on Acceptance of Review Board									
Decision of Review Board									
Present Training Program	1					1		1	
Present Position in Time vs. Schedule									
Overall System Performance Characteristics									
Data Transmission Schedule/Performance History									
Current Status of Economic Support									
Forecast if Required of Specific Projects									
Present Dissemination System	1	1		1		1		1	
Present Index System	1	1	1		1	1	1	1	

ANALYSIS OF OPERATIONAL DECISIONS

Knowledge Area: Detail of Present Operating System and Policy

Decision Area: User's Distribution

Decision / Knowledge Required	Decide What Each Individual User Wants from System	Select Specific Channel (Media) to Use (How to), Film/Hardcopy/Specimens	Indexing of New Material	Specify if Stored, How, Length, etc.	Decide on Specific Format from Alternatives	Decide What Training a User Needs	Decide on Redundancy Removal	Selection of Specific Material for News Media	
Present Archiving System	1	1		1			1	1	
Present Formatting Procedures	1	1	1	1	1	1	1	1	
Rejected Because of Inability to Handle									
Public Relations Policy	1					1		1	
Proprietary Data Policy	1								

ANALYSIS OF OPERATIONAL DECISIONS

Knowledge Area: A Depth of Technical and Operational Background

Decision Area: User's Distribution

Decision / Knowledge Required	Decide What Each Individual User Wants from System	Select Specific Channel (Media) to Use (How to), Film/Hardcopy/ Specimens	Indexing of New Material	Specify if Stored, How, Length, etc.	Decide on Specific Format from Alternatives	Decide What Training a User Needs	Decide on Redundancy Removal	Selection of Specific Material for News Media	
Knowledge of Opportunity									
Depth of Technical Competence									
Expert on How to Make Data Generally Fit System									
Statistical Experience Design-Knowledge									
Access to Data on Historical Experience									
Original Proposal			1	1	1		1	1	
Research Knowledge in Depth							1	1	
Transmission Experience									
Emergency Conditions									
Knowledge of Available Thesaurus	1		1			1			
Redundancy of Data							1		

ANALYSIS OF PLANNING AND REPLANNING DECISIONS

Knowledge Area: Breadth for High Level Planning and Replanning	Decision Area: User's Distribution									
Decision / Knowledge Required	Policy Decision on Proprietary Needs	Decide who Users Are/ Are Not	Decide User Needs/Wants	Design Dissemination System (Channels)	Design Index System	Design Archival System	Design Formatting Procedures	Design Training Pro- grams for Users	Establish Public Relations Policy	
Broad Technical Knowledge and Experience	1	1	1		1	1	1			
Educational Experience	1	1	1	1	1		1	1	1	
Market Research	1	1	1	1	1	1	1	1	1	
User's Feedback and Evaluation	1	1	1	1	1	1	1	1	1	
Established Users	1	1	1	1	1	1	1	1	1	
Performance and Cost Studies	1	1	1	1	1	1	1	1		
Forecast on Fu- ture Data Sources	1	1	1			1				
Master Plan of Data Sources	1	1	1	1	1	1	1	1	1	
Alternate Sources of Economic Support	1	1	1	1	1	1	1	1	1	
Alternate Sources of Aid and Em- ployees										

ANALYSIS OF PLANNING AND REPLANNING DECISIONS

Knowledge Area: Detail of Present Operating System and Policy

Decision Area: User's Distribution

Decision / Knowledge Required	Policy Decision on Proprietary Needs	Decide Who Users Are/Are Not	Decide User Needs/Wants	Design Dissemination System (Channels)	Design Index System	Design Archival System	Design Formatting Procedures	Design Training Programs for Users	Establish Public Relations Policy	
Policy on Criteria and Methodology	1								1	
Policy on Economic Support	1								1	
Decision on Acceptance of Review Board	1								1	
Decision of Review Board									1	
Present Training Program				1	1	1	1	1		
Present Position in Time vs. Schedule										
Overall System Performance Characteristics	1									
Data Transmission Schedule/Performance History										
Current Status of Economic Support										
Forecast of Requirements of Specific Project										
Present Dissemination System				1			1	1	1	
Present Index System					1		1	1	1	

ANALYSIS OF PLANNING AND REPLANNING DECISIONS

Knowledge Area: Detail of Present Operating System and Policy						Decision Area: User's Distribution					
Decision / Knowledge Required	Policy Decision on Proprietary Needs	Decide Who Users Are/Are Not	Decide User Needs/Wants	Design Dissemination System (Channels)	Design Index System	Design Archival System	Design Formatting Procedures	Design Training Programs for Users	Establish Public Relations Policy		
Present Archival System						1	1	1	1		
Present Formatting Procedures									1		
Rejected Data Generally Because of Inability to Handle				1	1	1	1				
Public Relations Policy									1		
Proprietary Data Policy									1		

ANALYSIS OF PLANNING AND REPLANNING DECISIONS

Knowledge
Area: A Depth of Technical and Operational Background

Decision
Area: User's Distribution

Decision / Knowledge Required	Policy Decision on Proprietary Needs	Decide Who Users Are/ Are Not	Decide User Needs/Wants	Design Dissemination System (Channels)	Design Index System	Design Archival System	Design Formatting Procedures	Design Training Programs for Users	Establish Public Relations Policy
Knowledge of Opportunity									
Depth of Technical Competence									
Expert on How to Make Data Generally Fit System									
Statistical Experience Design-Knowledge									
Access to Data on Historical Experience									
Original Proposal									
Research Knowledge in Depth									
Transmission Experiences									
Emergency Conditions									
Knowledge of Available Thesaurus						1			
Redundancy of Data									

APPENDIX V-C
CRITIQUE OF SATCOM REPORT

The SATCOM report was issued in 1969 by the Committee on Scientific and Technical Communication of the National Academy of Sciences — National Academy of Engineering. This report was the result of a 3-year study of the information explosion. The report is limited to information in science and technology and makes a number of recommendations including a recommended basic structure of an organization for a proposed information network. The organization implied by the recommendations (as perceived by the authors of this study) is illustrated by the chart in Figure V-6. The recommendations of the SATCOM Report are treated in this study as one of the alternatives.

The SATCOM Report fits the first criterion of this study, since it emphasizes the importance of the contact between the system and the user and also strongly recommends a marketing effort on the part of those institutions that disseminate information directly to the user. The report defines responsibilities of the researcher and of the agencies sponsoring research and emphasizes the steps that are appropriate and necessary to assure that the results of the research are available to other researchers and to those who would apply the findings.

The SATCOM recommendations include building upon the existing facilities of the professional societies, commercial organizations in the information business, and the present library system. Each of these units has established an effective relationship with groups of users of information. SATCOM is not satisfied with the present functioning of libraries, however, and recommends greater emphasis on a range of services and some cost/benefit analysis of the services presently offered. The Report encourages the development of additional information subsystems in those areas of research where they do not exist at the moment. They include in this area the development of information subsystems in those government programs dealing with social issues.

The SATCOM Report recommends some new mechanisms and policies for the coordination and guidance of the private information networks. These policies involve companies, the libraries, the professional societies, the various government agencies involved in information dissemination, and the agencies sponsoring research projects that are inputs to the information system.

Several important aspects of the IMS are missing from the SATCOM Report. The report recognizes the tremendous growth in scientific and technical information, the increasing complexity of concepts, and an intensifying demand for the rapid and efficient application of the information. However, it does not speak to the large questions raised by an increasing tendency of research to be interdisciplinary. Moreover, it does not come to grips with the problems imposed by the needs and desires of the investigators to maintain their proprietary interests — there is a conflict between full communication and these needs for secrecy.

The report includes policy statements and recommendations for changes in mission of many of the existing information agencies. Again, it does not deal specifically with the requirements for the organization that is needed to integrate all of these agencies into a functioning whole — a system. The report speaks to the large and growing problems of information transfer, but it does not deal with the evolutionary requirements of the system, the ability to grow and to change as the problem continues to develop further in size and complexity. Yet, the SATCOM Report has not totally ignored these considerations. They are treated in a set of recommendations for further and continuing research directed toward these and similar problems for which present institutions and technology are not adequate.

The report also fails to make provisions for the feedback of comments from the user or for carrying out market research. In this report, communication is a one-way street to the user. This situation contains the risk that the users' needs will not be filled, and the system will be unable or slow to change as user needs change. This is an important ommission in the report, because change is a major component of the trends affecting information.

The SATCOM Report also takes a more narrow view of the user than do the members of the Auburn University Systems Engineering Design Group. SATCOM focuses its attention upon users of technical information that can be identified as need groups, each numbering about a thousand individuals who have similar needs. The report focuses upon the scientific user or researcher and overlooks the general public and the large numbers of users who are concerned with the application of the information (for example, for industrial purposes).

The report recognizes great need for improvement in the area of information processing; indexing, abstracting, editing, format conversion, etc. Furthermore, it makes recommendations in terms of encouragement of further research efforts in these areas. Thus, the organization chart is incomplete in the middle, between the sources of data and the users.

SATCOM sees the roles of COSATI and the Joint Commission on Scientific and Technical Communication, which it defines in the report, as important to the process of coordination and facilitating cooperation. The Joint Committee would have broad representation, as does COSATI, to facilitate coordination and integration between the various groups that are represented. This coordination can take place by communication between the representatives and their primary organizations. This representation is used as a coordinating mechanism rather than authority or supervisory responsibility. To this extent, the chart in Figure V-6 is incomplete. Such an organization does fulfill many of the organizational needs of the system by having broad representation. What it lacks is the ability to initiate action and to detect and respond to changes in user needs and in the environment. This inadequacy is most noticeable in the failure to define policy and operating responsibilities and a working relationship between them. The SATCOM report relies upon strong self-coordination. Yet, a review of the current situation in information management does not lead one to have a great deal of confidence in this process.

In summary, the recommendations of the SATCOM Report meet the first and fourth criteria very well, but the report fails to deal with the problem in detail. The report also makes very specific recommendations for further research in depth on those matters that would increase its detailed coverage. Yet, the report deals with the user, defined in a restricted sense as "the technical researcher". It fails to deal with the evolutionary nature of the problem that requires evolutionary capability on the part of the system. The process of obtaining feedback and market research from users is notably absent. Thus, the basis for the decisions required by the system is not fully spelled out.

The appropriate next step for SATCOM is to focus upon these additional functions and integrate them into its recommendations. Then, the SATCOM Report can be a total system with a complete and evolutionary organization.

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CHAPTER VI

UNISTAR POLICY AND PLANS

CHAPTER VI.

UNISTAR POLICY AND PLANS

A national policy and plans for UNISTAR are presented in this chapter in the following sequence: Status of Information Management Problem, Policy, Proposed Plan, Flow Diagrams for User and Contributor Interactions, and Time Phase Plan.

STATUS OF INFORMATION MANAGEMENT PROBLEM

The UNISTAR study shows that:

1. A national policy must be developed to handle the information management problem and to insure economic utilization of existing data and the anticipated increase in data from all scientific and technical sources, especially earth resources.

2. Information is a key resource; research and development expenditures are only partially effective if expenditures are not made to develop information in a form that is available to all potential users and consistent with a national plan.

3. A number of useful studies have been devoted to information management without a resulting national policy or plan.

4. Every individual and every organization, in frustration over the problem, has attempted to solve parts of the problem; a number of potential models and subsystems for a national plan have resulted from these various attempts.

5. The President's Goals Report [I-5] does not explicitly address the information management problems; yet, information management pervades each of our national and international problems, and the information management problem must be solved, at least concurrently, with these national problems.

6. Earth resources must be used intelligently if mankind is to achieve a rewarding existence, and the NASA earth resources experiments in manned and unmanned aerospace systems are a key to intelligent management of the earth's resources.

7. NASA is making a valiant effort to manage information resulting from NASA programs; but, as with any other data source, these efforts cannot be successful in the fullest sense without an established national policy.

8. NASA data rates will reach unprecedented levels with an implemented Earth Resources Program, as will the data rates associated with other national objectives.

9. To be successful, a national policy and plan must be executed in an incremental fashion, and considering this study, NASA along with some other agencies or perhaps with the NAS and NAE as partners should be used to develop a prototype IMS.

10. An information management system must itself be managed.

11. There is difficulty in performing a satisfactory information search when there is no single source or staff to perform the task completely.

12. Educational institutions should educate persons who by virtue of their training would seek careers with Information Analysis Centers.

13. Any national plan must evolve without unduly disrupting present efforts.

14. The information explosion threatens the existence of scientific and technical journals.

15. Information management will create a new basic industry, and with a properly designed plan, this industry will flourish.

16. The efforts of other countries such as Japan to develop national information systems must not go unchallenged if the U. S. is to maintain a competitive posture in world trade.

On the basis of these comments and other observations made in this study, the UNISTAR participants have developed and recommended a policy and plan for a national IMS. The view and experience of professionals in disciplinary areas other than those represented in the study should expand the ideas presented in the following sections.

POLICY

It is recommended that:

> A national information management system (IMS) for scientific and technological information be developed by the United States under the executive branch of the Federal Government to begin operation no later than 1975 in its initial form with prototypes to be established by January 1972.

The IMS will have the following characteristics:

1. The President shall apoint a Director for the IMS who will report to the President. The Director will be advised by a politically nonpartisan Board of Commissioners appointed for staggered terms by the President. The Commissioners shall represent the broad spectrum of users.

2. The President shall request Congress to provide funds to establish the IMS, to maintain the IMS, and to insure growth of the IMS commensurate with information generation and usage rates and to provide a mechanism for subsidies to cooperating agencies and investment in the IMS from the private sector.

3. The IMS shall serve the widest possible user community, both U. S. and foreign. Separate fee schedules shall be developed as necessary for U. S. and foreign users.

4. A series of regional offices of the UNISTAR shall be established to facilitate and encourage equal user access. Foreign offices may be established by treaty agreement.

5. The IMS shall provide the following user services:

a. A current inventory of all available sources of scientific and technical data and information in the U. S. and abroad.

b. Retrospective search and retrieval tailored to individual request.

c. Packaging and dissemination of products upon user request.

d. Referral service.

e. Current Awareness Centers in all areas of science and technology.

f. Information Analysis Centers.

g. Personalized consultation.

6. The IMS will make the maximum possible use of existing information services and facilities and will interface with existing systems.

7. The IMS will cooperate to the maximum extent with all users to insure that maximum benefit is derived from the IMS.

8. The IMS will insure the opportunity for user feedback and user orientation to the IMS.

9 The IMS will provide for cooperative efforts with free enterprise.

10. The IMS will provide for education of qualified IMS personnel.

11. The IMS shall serve the user community through a variety of modes, including formal and informal, written and oral.

12. The IMS shall provide direct links between the user and the IMS.

13. The IMS will provide adequate orientation for the user to understand how the system operates.

14. The IMS will provide comprehensive compilation of world-wide sources of information.

15. The IMS shall be evolutionary with the capability to change size, adapt, and feedback in all areas.

16. The IMS shall employ the latest state-of-the-art technology as feasible.

PROPOSED PLAN

The plan, representing a capping agency synthesized as a result of this study, is presented in terms of a table of organization for the proposed UNISTAR and possible flow diagrams for user and contributor interaction with UNISTAR. The Federal organization and associated documentation organizations (Fig. VI-1) and the document handling institutions (Fig. VI-2) extant are presented in graphical form to provide background for UNISTAR.

Figure VI-3 shows the organization structure of UNISTAR, which has a Director appointed by the President and is advised by a Board of Commissioners and a Long Range Planning Committee. Interaction with other advisory groups such as COSATI, technical and professional societies, commercial groups, and foreign groups is provided. The Director has two deputies, one for administrative and personnel affairs and one for technology and user affairs. The Director's staff includes special assistants for (1) legal counsel, (2) legislative affairs, (3) user services effectiveness, (4) public affairs officer, (5) educational affairs officer, (6) industrial affairs officer, and (7) internal communication.

The operational aspects of UNISTAR are carried out by seven directorates; User Services, Information Processing, Information Sources Coordination, Research, Project Development and Planning, Administrative Services, and Personnel Services.

DESCRIPTION OF EACH ELEMENT OF PLAN

The responsibilities of each aspect of the system are described in the following.

Director's Office

Director	The Director is responsible to the President and the users, and manages and directs all phases of the system to provide information management, dissemination, and utilization

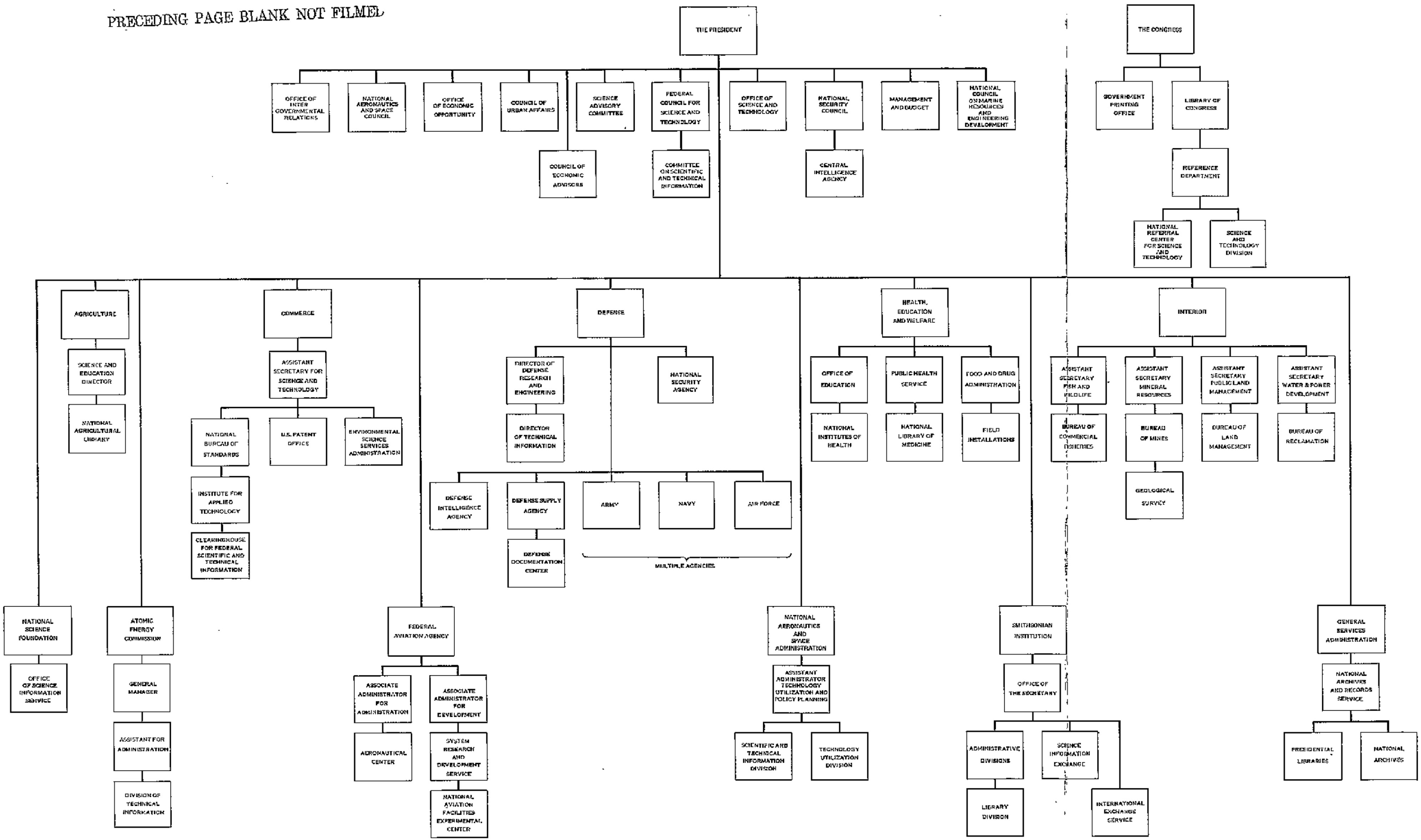

Figure VI-1. Federal organization and associated documentation organizations.

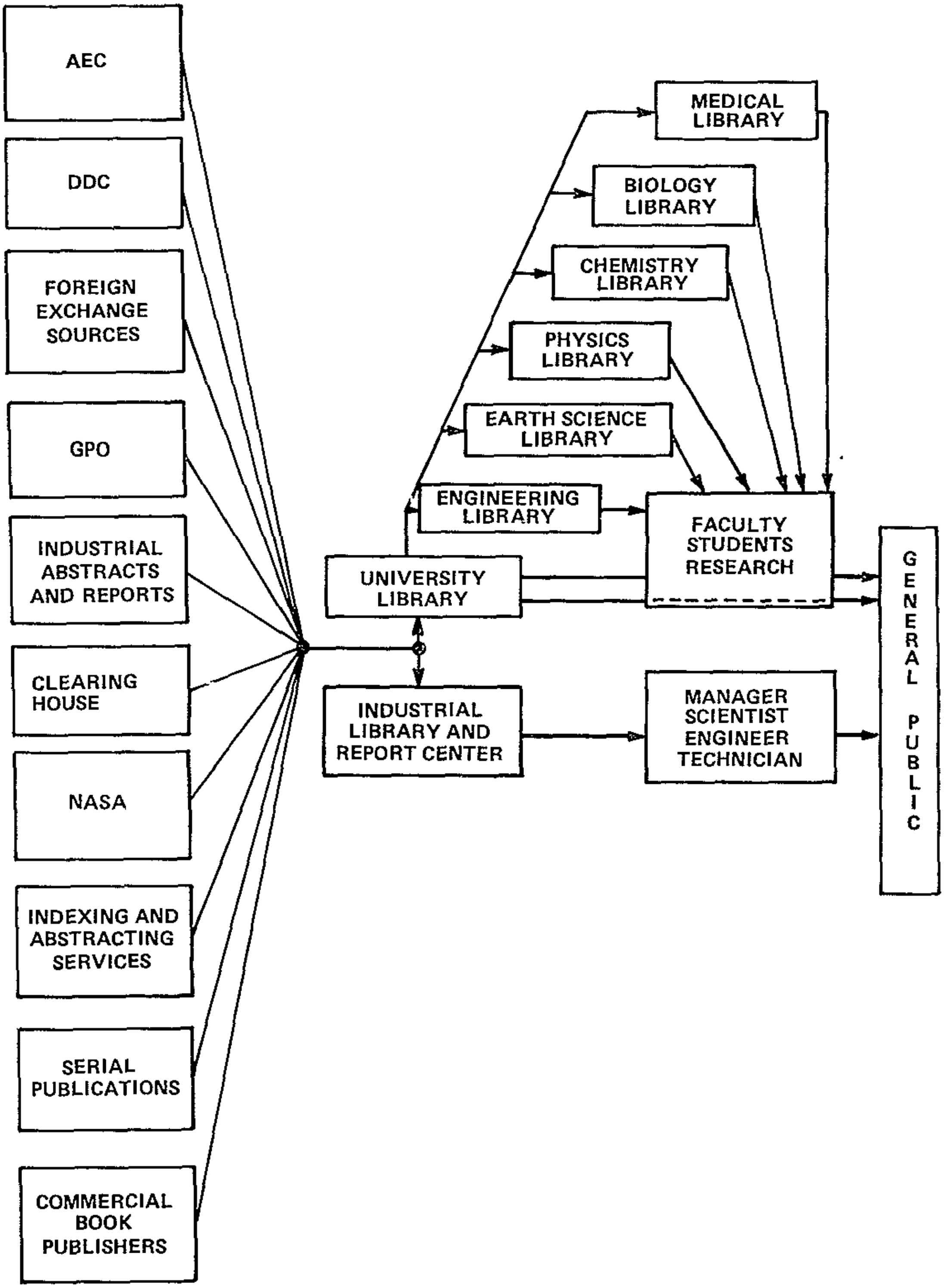

Figure VI-2. Document-handling institutions.

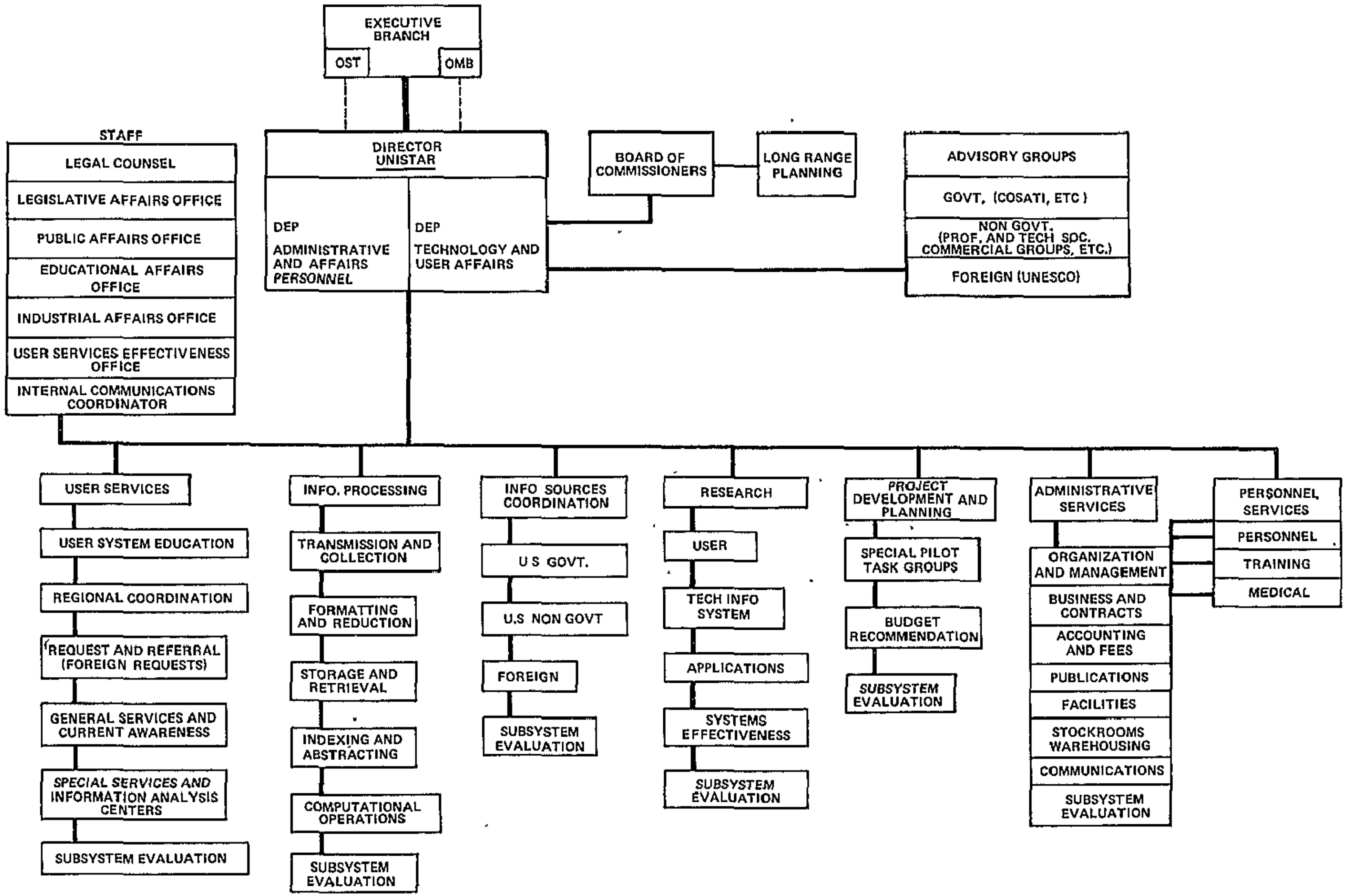

Figure VI-3. Organizational structure of UNISTAR.

Deputy Director for Technical and User Affairs	The deputy insures the success of the system in providing user services and the development of the system commensurate with data usage and growth rates.
Deputy Director for Personnel and Administrative Affairs	The deputy provides support services for the system and insures that employee services anticipate needs.

Staff

Legal Affairs Office	This office provides legal counsel and assistance for the Director and all elements of the system to insure conformance to applicable legal and policy requirements. Provides legal counsel on matters involving patents, trademarks and copyrights, trade secrets, and proprietary data.
Legislative Affairs Office	This office prepares and coordinates UNISTAR legislative proposals.
Public Affairs Office	This office plans, directs, and coordinates all public affairs activities and insures dissemination of information about the system, its services, and its use.
Educational Affairs Office	This office serves as a focal point for contact with the general academic community to insure availability of services, continuing UNISTAR awareness of research and teaching personnel in information systems, to receive suggestions from the community, and to develop cooperative arrangements.

Industrial Affairs Office	This office serves as a focal point for contact with profit and nonprofit organizations to develop cooperative efforts between industry and UNISTAR.
User Services Effectiveness Office	This office insures, by receiving suggestions from users and system personnel and studies, that the system is serving the user.
Internal Communications Coordinator	The Internal Communications Coordinator develops, plans, and coordinates a comprehensive internal communications program for the benefit of all employees of the system.
Board of Commissioners	The Board of Commissioners advises the Director on all matters concerning the system.
Long Range Planning Committee	The Long Range Planning Committee provides suggested objectives, requirements, and alternative approaches to those requirements for study and selection of a final plan for each objective by the Director.

Directorates

USER SERVICES DIRECTORATE

Administrator	The Administrator of the User Services Directorate is responsible to the Director of UNISTAR and provides for: 1. Planning, budgeting, disbursing, and controlling the financial, manpower, and facilities resources of the directorate.

2. Reviewing, analyzing, and coordinating the implications of UNISTAR policies within the directorate toward more effective user services.

3. Participating as a senior member of UNISTAR management in the evolutionary development of UNISTAR policies and programs.

Request Referral Division

The Request Referral Division develops, implements, and administers a comprehensive program for receiving, classifying, and placing all user requests, domestic and foreign, for data/information. Requests will be routed to the appropriate facility for definition, treatment, and response.

General Services Division

The General Services Division develops, implements, and administers a broad-scope dissemination program for frequently requested, stacked materials for users. Such items as prepared bibliographies, picture and chart folios, informational pamphlets and brochures, microfilm and microfiche copies, etc., are examples of the kinds of materials available for distribution. A Current Awareness Center to compile and disseminate timely information on the production, location, and services of data/information generators shall be a part of this office's functioning responsibility.

Special Services Division

The Special Services Division develops, implements, and administers a program for providing customized services for individual users. The preparation of in-depth, topical, requested literature, abstracting services, etc., are examples of service capabilities. The Special Services Division also establishes and operates Information Analysis Centers in coordination with new and existing centers.

User Education Division

The User Education Division develops, implements, and administers a program for educating users of the UNISTAR facilities in methods of accessing and employing the system. Inherent in these functions are: (1) the development of trained personnel to educate the users and (2) the training of the users themselves in employing UNISTAR services and using the data/information received.

Regional Coordination Division

The Regional Coordination Division organizes, states, and administers a system of Regional Service Offices to facilitate the servicing of user requests.

Subsystem Evaluation Division

The Subsystem Evaluation Division develops, implements, and administers a comprehensive program for systematically analyzing and evaluating the internal and external operations of the directorate. This analysis will provide the basis for subsequent adaptation of the directorate to evolving needs and responsibilities.

INFORMATION PROCESSING DIRECTORATE

Administrator

The Administrator of the Information Processing Directorate is responsible to the Director of UNISTAR and provides for:

1. Planning, budgeting, disbursing, and controlling the financial, manpower, and facilities resources of the directorate.

2. Reviewing, analyzing, and coordinating the application of UNISTAR policy within the directorate.

3. Supervising and coordinating all necessary functions associated with the transfer of information.

4. Participating as a senior member of UNISTAR management in the evolutionary development of UNISTAR policies and programs.

5. Supervises and coordinates all necessary processing functions associated with the transfer of information.

Transmission and Collection Division	This division locates, acquires and provides for the orderly and timely movement of information within the system.
Formatting and Reduction Division	This division transforms, compresses, manipulates, and displays information to meet transmission, storage, and user needs.
Storage and Retrieval Division	This division provides the secure, orderly storage of information for preservation and future use, and identifies, recalls, correlates, and reproduces required information for further processing or dissemination to the user.
Indexing and Abstracting Division	This division analyzes all acquired information, classifies and assigns standardized indexing terms and codes, and prepares abstracts for the orderly storage, timely retrieval, and content evaluation of the information.

Computer Operations Division — This division specifies the computational equipment, formulates the necessary programs, and operates the computers to perform the required processing of information.

Subsystem Evaluation Division — This division establishes necessary programs to provide feedback for evaluation of processing functions as to user satisfaction, and makes recommendations for improvements.

INFORMATION SOURCES COORDINATION DIRECTORATE

Administrator — The Administrator of the Information Sources Coordination Directorate is responsible to the Director of UNISTAR and provides for:

1. Planning, budgeting, disbursing, and controlling the financial, manpower, and facilities resources of the directorate.

2. Reviewing, analyzing, and coordinating the implications of UNISTAR policies within the directorate.

3. Compiling and maintaining an inventory of all available sources of scientific and technological information.

4. Participating as a senior member of UNISTAR management in the evolutionary development of UNISTAR policies and programs.

Government Sources Division — This division maintains an up-to-date file on all government publications in science and technology and compiles information about ongoing research in government facilities.

Non-Government Sources Division	This division functions in a manner similar to the Government Sources Division in the non-government sphere.
Foreign Sources Division	This division functions similar to the Government Sources Division for foreign-based sources.
Subsystem Evaluation Division	This division monitors the operations of the other divisions of the Information Sources Coordination Directorate (ISCD) to aid in evaluating the overall effectiveness of the ISCD.

The information on published material gathered by the Government, Non-Government, and Foreign Sources Divisions of the Information Sources Coordination Directorate would be entered into the Central Information Sources File maintained by the Information Processing Directorate. The compilation of information about ongoing research would be compiled by field men touring research facilities and from reports submitted by researchers themselves. This information would be entered into a Current Research File for accessing by the User Services Directorate. The mechanical details of these files and their maintenance would be handled by the Information Processing Directorate.

The ISCD would also act as a source of information to be used in a weekly scientific and technical newsletter published by the system to assist in alerting scientists and engineers to matters of potential interest to them.

RESEARCH DIRECTORATE

Administrator	The Administrator of the Research Directorate is responsible to the Director of UNISTAR and provides for: 1. Planning, budgeting, disbursing, and controlling the financial, manpower, and facilities resources of the directorate. 2. Reviewing, analyzing, and coordinating the implications of UNISTAR policies within the directorate.

3. Carrying out continuing wide ranging research of long time benefit. The areas must include research in use patterns and potential demands, research into new and innovative methods and technological advances to perform efficiently and effectively information management functions, discovery of ways these ideas can be applied to solving the information problem, and the continual evaluation of present operation in light of new potential.

4. Participating as a senior member of UNISTAR management in the evolutionary development of UNISTAR policies and programs.

User Research Division

This division provides for the potential needs of new areas of use, of new applications for existing users, of changing patterns of use, and opportunities of creating utility.

Technical Information Systems Research Division

This division provides investigation synthesis and creation of more efficient and more effective methodology and equipment for the handling of information.

Applications Division

This division applies improved methodology, equipment, and administration to the problem of information management.

Systems Effectiveness Division

This division sets and maintains measures of effectiveness and statistical evaluation to be used in the evaluation of the operation of the information management system.

Subsystem Evaluation Division

This division establishes the necessary program to provide feedback for evaluation of research functions as to research effectiveness and new directions and to make recommendations for needed improvements.

PROJECT DEVELOPMENT AND PLANNING DIRECTORATE

Administrator

The Administrator of this directorate is responsible to the Director of UNISTAR and provides for:

1. Planning, budgeting, disbursing, and controlling the financial, manpower, and facilities resources of the directorate.

2. Reviewing, analyzing, and coordinating the implications of UNISTAR policies within the directorate.

3. Developing potential innovations into actual operation in as many as possible of the various cooperating areas, and provide for an overall or special planning function for the information management system.

4. Participating as a senior member of UNISTAR management in the evolutionary development of UNISTAR policies and programs.

Special Pilot Task Groups Division

This division forms and supports these groups to develop the concepts for improving UNISTAR. These task groups consist of personnel who originate the ideas evaluated as desirable for UNISTAR and the personnel necessary to prepare implementation plans.

Budget Recommendation and Preparation Division	This division provides the preparation and supporting justification of budget for future plans.
Subsystem Evaluation Division	This division establishes the necessary program to provide feedback for evaluation of development and planning functions as to the effectiveness of operation and to make recommendations for needed improvement.

ADMINISTRATIVE SERVICES DIRECTORATE

Administrator	The Administrator of the Administrative Services Directorate is responsible to the Director of UNISTAR and provides for: 1. Planning, budgeting, disbursing, and controlling the financial, manpower, and facilities resources of the directorate. 2. Reviewing, analyzing, and coordinating the implications of UNISTAR policies within the directorate. 3. Insuring that all elements of the system are maintained and supported; system effectiveness.
Organization and Management Division	This division serves as the principal staff management and advisory office for the Director and other key personnel for organization management analysis of all operations and support aspects of the system, and for the planning, coordination, and securing of management support services.
Business and Contracts Division	This division develops and administers a comprehensive financial management

	plan and operating program that serves as the factual and legal basis for accountability control and use of funds. This division also plans and conducts a complete range of purchasing and contracting operations to include proposals, negotiations, awards, and administration of contracts for the system.
Accounting and Fees Division	This division performs reviews and appraisal of administrative and financial aspects of the system and establishes fees for services.
Publications Division	This division provides reproduction services for documents and the printing of materials pertinent to system operation.
Facilities Division	This division develops, implements, and administers a comprehensive facilities program encompassing the planning, budgeting, design, and construction of facilities in support of the system.
Stockrooms and Warehousing Division	This division stores supplies for management services, and anticipates storage requirements for system documents.
Transportation Division	This division provides transportation for personnel, documents, and equipment.
Communications Division	This division provides communications for the system.
Subsystem Evaluation Division	This division provides evaluation of the effectiveness of all subsystems and their interaction with the system and recommends improvements to the Director.

PERSONNEL SERVICES DIRECTORATE

Administrator	The Administrator of the Personnel Services Directorate is responsible to the Director of UNISTAR and provides for: 1. Planning, budgeting, disbursing, and controlling the financial, manpower, and facilities resources of the directorate. 2. Reviewing, analyzing, and coordinating the implications of UNISTAR policies within the directorate. 3. Insuring the safety, health, education, and well being of all system personnel. 4. Participating as a senior member of UNISTAR management in the evolutionary development of UNISTAR policies and programs.
Personnel Division	This division develops and administers the combined personnel management, personnel resources, community relations, and labor relations program.
Training Division	This division develops and administers an educational program to train information specialists for the system and the nation.
Medical Division	This division provides preventive health care.

FLOW DIAGRAMS FOR USER AND CONTRIBUTOR INTERACTIONS

Typical flow diagrams for user and contributor interactions with the system are suggested in Figure VI-4 through VI-8.

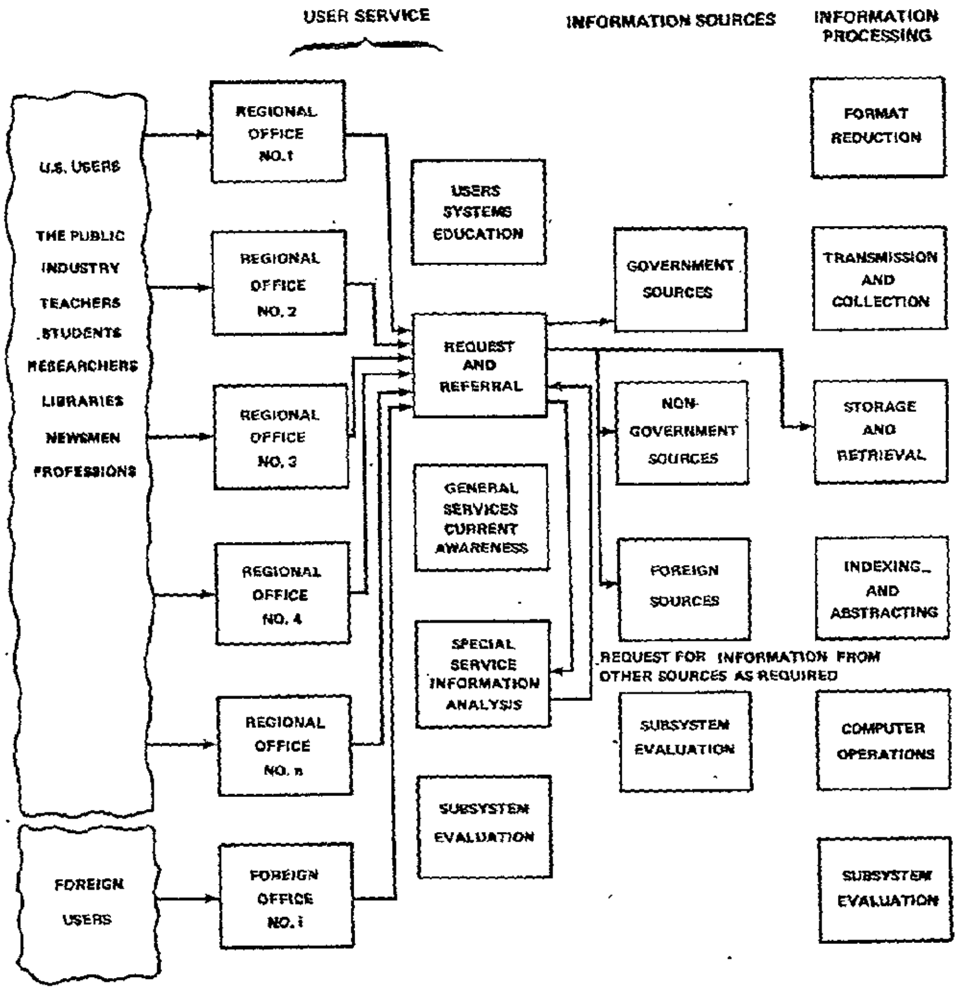

Figure VI-4. Request for information analysis, search, or information relative to ongoing research.

Figure VI-4 shows the route a special request for information analysis, information search, or information relative to ongoing research might follow in the proposed system. The user interfaces with the system at the most convenient local Regional Office and requests are forwarded through the Request and Referral Office. If it is a rush, or unusual, request, a direct contact in the Special Service Office may be made. Once the Special Service Office receives the request, it collects the necessary information to answer the question. A special service request return route of data and information from the storage center to special sources to users is shown in Figure VI-5.

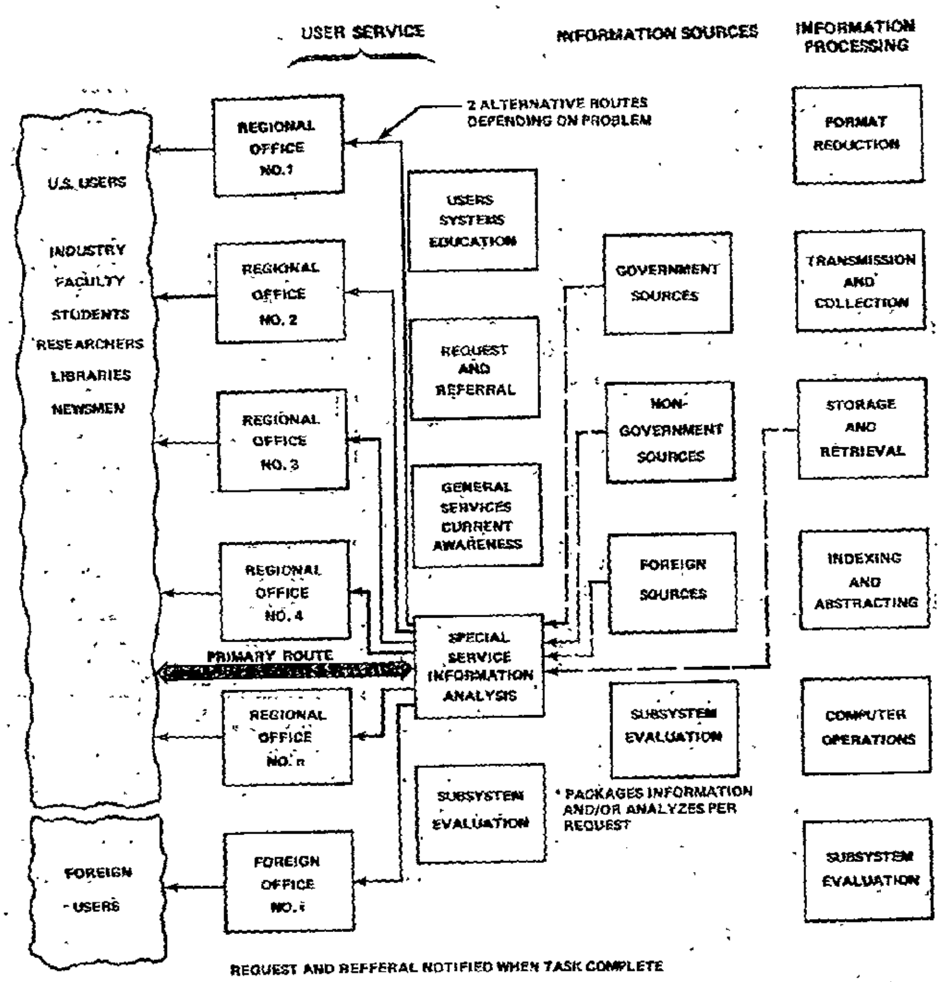

Figure VI-5. Return of results of information analysis, search, or information relative to ongoing research.

The general request flow for a specific unit of information is shown in Figure VI-6. The sequence is user to Regional Office to Request and Referral Office. Once in the office the request is sent to the most convenient source.

Figure VI-7 shows the manner in which the general request for some unit of stocked information is filled. A request is satisifed by prepackaged material if possible. (The dashed line illustrates this alternative.) The other route shown is when a storage center must be tapped.

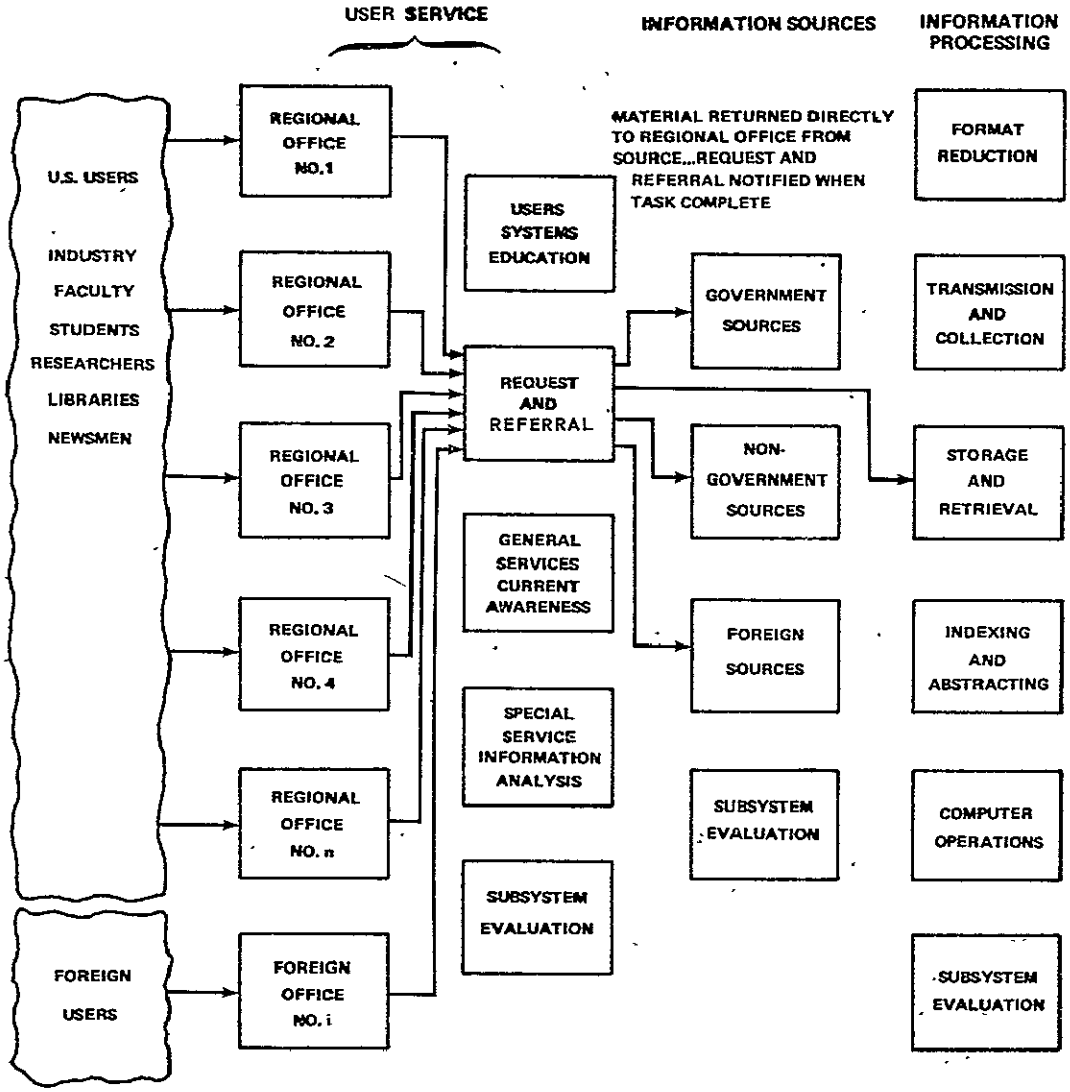

Figure VI-6. Request for specific unit of information.

The Regional Offices are designed to handle both output and input of the system. In Figure VI-8 a sequence of steps, User to Regional Office to Transmission and Collection, etc., is shown. Alternative paths from Transmission and Collection to Government Sources, Non-Government Sources, and Foreign Sources are shown for the case where the main system does not wish to maintain the information but forwards it to another part of the system. The lines to Special Service and General Services indicate the updating of the indexes associated with the input of new information.

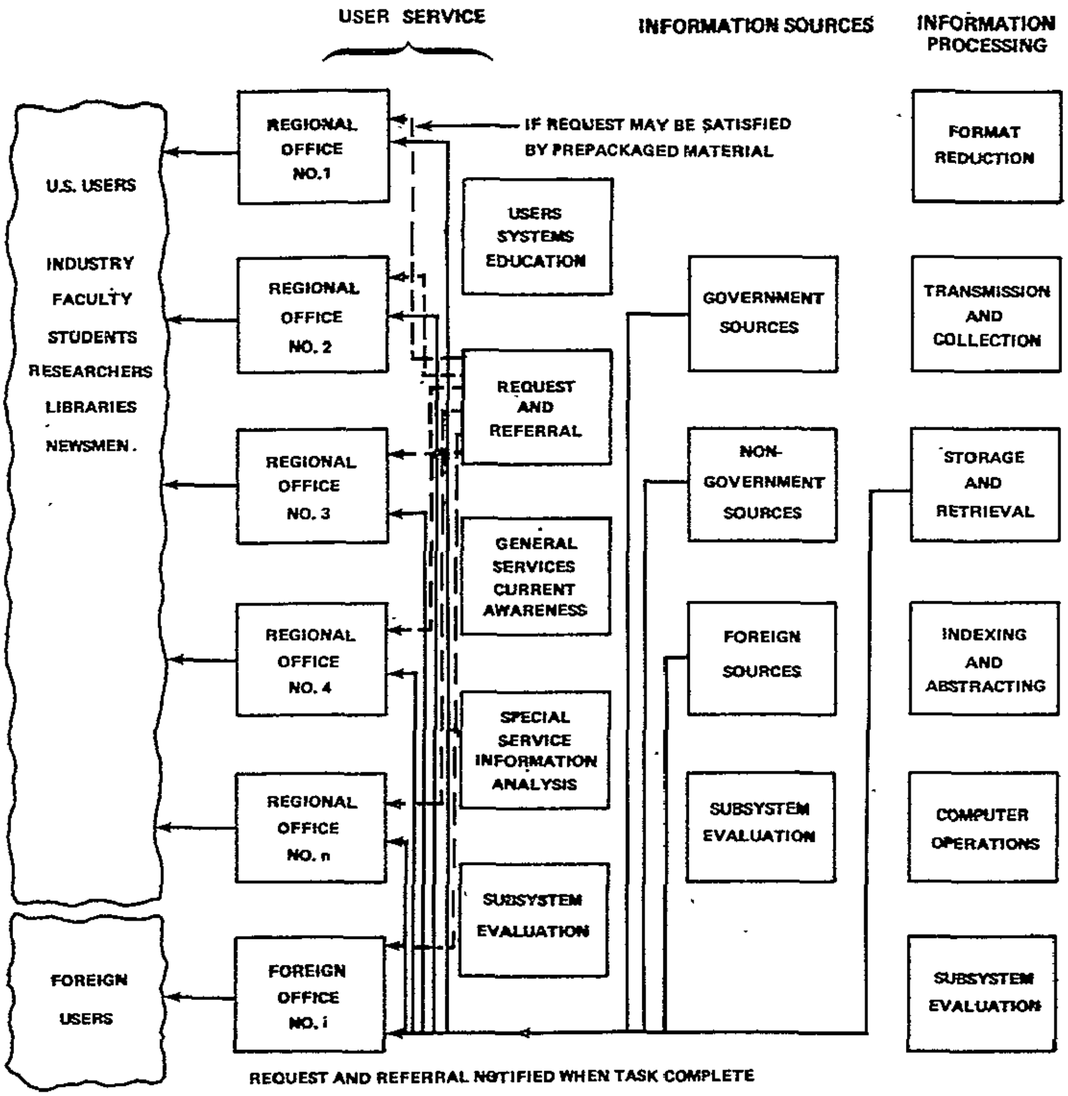

Figure VI-7. Return of a specific unit of information.

TIME PHASE PLAN

The time phase plan for the formation of UNISTAR is shown in Figure VI-9. No financial constraints have been suggested or recommended because the economic picture of the nation and world changes and economic requirements and constraints will have to be determined subsequent to the indeterminate time indicated in Figure VI-9. The earth resources example in Chapter VII indicates how the time phase plan may be shortened by initiating a prototype operation at the end of the Phase A study.

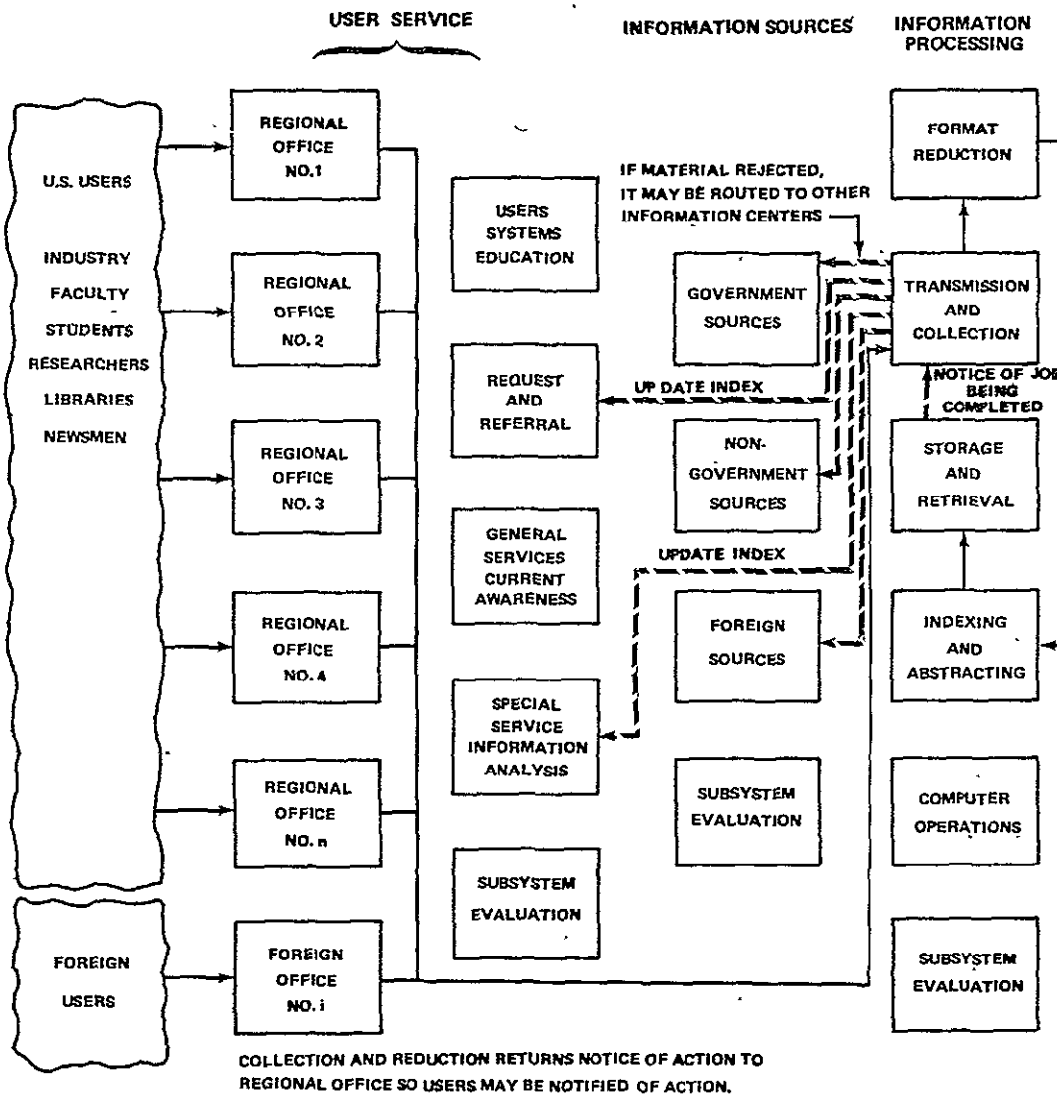

Figure VI-8. Input of data and information.

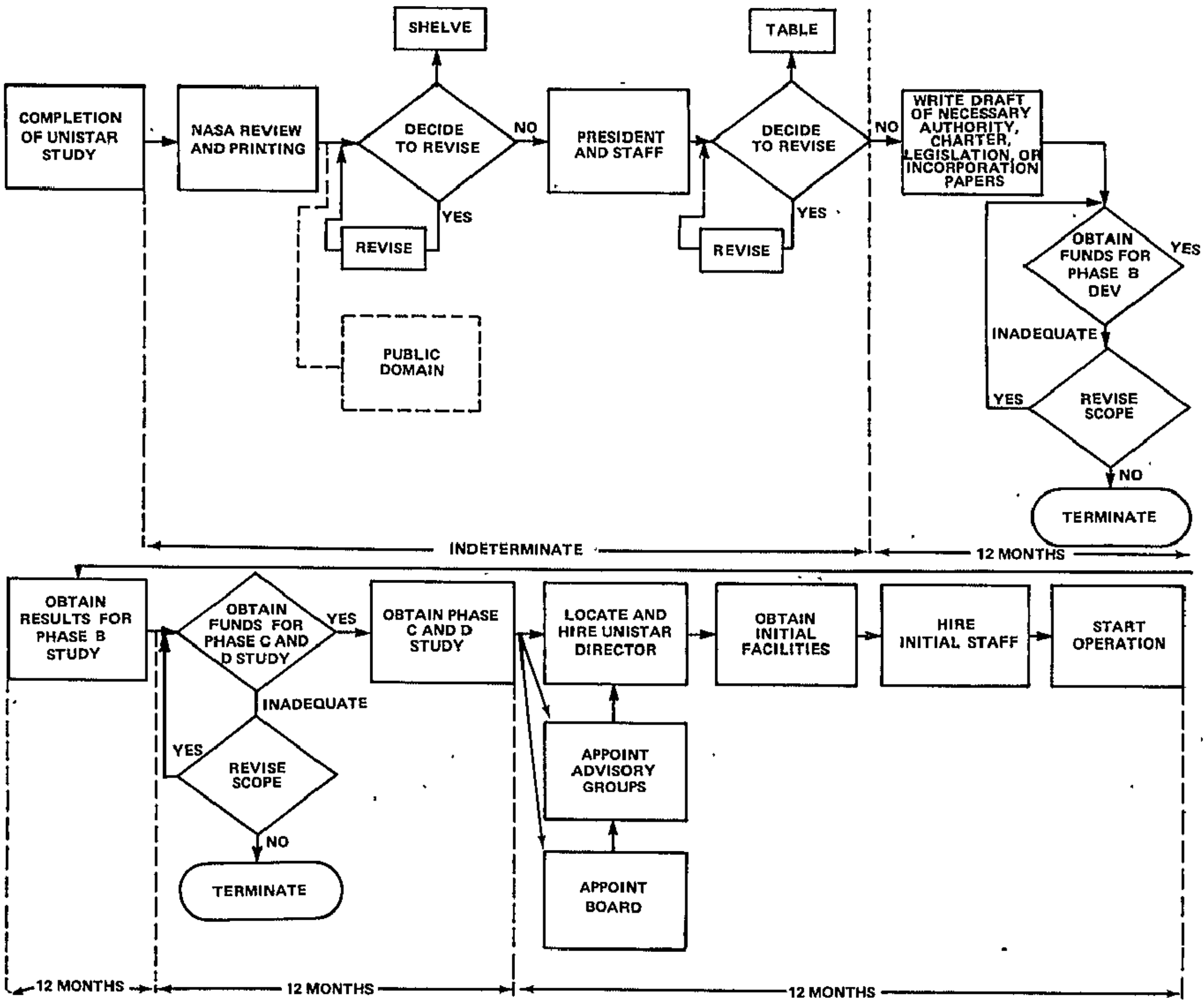

Figure VI-9. Time-phase plan for the formation of UNISTAR.

CHAPTER VII
PROTOTYPE UNISTAR SYSTEM

CHAPTER VII.

PROTOTYPE UNISTAR SYSTEM

UNISTAR is a national system for handling all scientific and technical information. The prototype of UNISTAR is a national information management system for handling earth resources information. The National Aeronautics and Space Administration is suggested as the agency for the development and administration of the prototype system.

INTRODUCTION

President Nixon made the promise, "We are determined that the decade of the seventies will be known as the time when this country regained a productive harmony between man and nature."

The earth is a system. It is dependent upon the successful functioning of its parts and man's harmonious interaction with it. The condition of the environment and the state of the natural resources of the earth indicate that man's interaction with the earth has left many scars. Today, many people feel that the preservation of the system, earth, is man's greatest challenge. If this is the challenge of our day, the ERP can be a great contributor to meeting this challenge.

In the area of earth resources, two programs stand out; first,

> EROS (Earth Resources Observation Satellite) is a Department of the Interior program to utilize resources data acquired from aircraft and spacecraft. The program is a cooperative one involving NASA, the Department of Agriculture, the Naval Oceanographic Office, and numerous other governmental and academic organizations. The EROS program is supported by research leading toward definition of observation systems to be employed from appropriate platforms and toward more effective use of the data [VII-1].

and secondly,

> The NASA ERTS system is a major national program designed to improve methods of gathering data on our resources by remote sensing from automatic, earth orbiting satellites [VII-2].

The basic objective of the EROS and ERTS programs is to develop the means of obtaining useful data about the earth from space vehicles, aircraft platforms, and ground-based sites.

If the initial phase of the ERTS program is able to establish useful applications, it will become a continuing source of data and information for man. The amounts of data that will be received from the ERP will be greater than man has ever had to encounter. The challenge will be to extract information from these vast amounts of data. The problems of dissemination and utilization of the data and information will be great because of the large number of suggested applications and users. A single program with such a large quantity of information necessary for so many applications will be a challenge for any system. (See Appendices VII-A and VII-B for a partial list of proposed applications and federal users.)

These facts place a critical requirement on the nation. Since the financial commitments for the Earth Resources Program have been made, the commitment to utilize the results of this program must also be made. An IMS must be developed that can take the vast amounts of data from the ERP, transform them into information that people can use, and be responsible for the fair dissemination of that information to people.

Col. Andrew A. Aines, Chairman, COSATI, of the Office of Science and Technology, Executive Office of the President, stated:

> "There is a growing recognition in many quarters that the large potential benefits of earth resources sensing satellites can be realized fully only if the information acquisition capabilities are matched by coherent and integrated information dissemination network capable of serving a large and extremely diverse audience with widely differing interests and requirements. The requisite network system may well be of unprecedented size and complexity. Coordination and cooperation among the numerous agencies of the Government participating in this program in planning and developing this network system is essential. . .
>
> "I am convinced that this situation poses an unusual challenge and a great opportunity for those of us in the Government who bear a share of responsibility for the effective dissemination of scientific and technical information. I believe we should move to meet the challenge and to exploit the opportunity with all deliberate haste" [VII-3].

W. T. Pecora, Director, U. S. Geological Survey, states that one of the major issues of this time is:

> "How, to whom, and in what time frame are the data from earth resources satellites to be made available to the scientific and resources communities?'
>
> "These decisions need to be made to permit data handling and dissemination systems development to proceed in harmony with satellite construction and launch.
>
> "I believe strongly that the data must be freely available to the resources and scientific communities, on a timely basis; restricted use of the data is not in keeping with the traditions of our Department. This view is shared by our advisory committee in the Academy of Sciences as expressed in their strong recommendation for making the raw data from the satellites rapidly and freely available to the scientific and resources communities' " [VII-1].

Hannessian and Logsdon [VII-4] expound on two international aspects of earth resources data and the role of the U. S. and other countries in utilizing these data.

An Earth Resources Program is by necessity multidisciplinary. A requirement of an IMS for earth resources is that it must also be multidisciplinary. The system must cross present discipline lines in the university world and cross agency and department boundaries in government. The concern for a multiagency information system to handle earth resources information is expressed by both the Executive Office of the President and the National Aeronautics and Space Council. Study groups have been set up by earth to look at the problem of the management of earth resources information. The Space System Organization of General Electric has also made a study to investigate the requirements of an IMS to handle earth resources information for a multidiscipline user. Another requirement is that national policy for an earth resources IMS be established. There is the potential for many problems resulting from earth resources information.

The selection of NASA to develop and administer the prototype system is based on the following rationale:

1. NASA has the experience in communications necessary to establish the dissemination network.

2. NASA has management experience. The NASA organization is unique. It has a phenomenal record for successfully meeting unusual challenges. It has a management team capable of dealing with problems.

3. NASA has experience with industry and the university community. In fact, teams from these two areas have worked effectively on numerous tasks.

4. NASA has the necessary research and technological experience. Through the development and successful operation of spacecraft, NASA has developed techniques for processing telemetry data.

5. The Gemini and Apollo flights and the aircraft program at MSC have given NASA a competence in remote sensing and in the analysis of earth photographs from satellites and aircraft.

6. NASA has an extensive background in information management systems and has begun a study on the dissemination of earth resources information.

7. NASA can demonstrate the continued value of the space program. The development and operation of a useful IMS for earth resources would show mankind some of the valuable contributions the space program can have.

For these reasons, it is believed that NASA is the organization able to handle the task of establishing an earth resources IMS.

USERS

Since the raison d'etre of the earth program is to provide new information so that mankind can enjoy a better way of living, it is of paramount importance that the actual users and their needs be identified. While it may be impossible to provide direct services to all users, it is imperative that their needs be identified and fulfilled by some organization.

In Chapter II the needs of various types of users were identified. While the presented list is not exhausitive, it does provide insight into the magnitude of the problem that must be faced in user identification. Any individual who is concerned with, or works with the environment directly or indirectly, is a potential user.

It would be frivolous to propose that every individual, once identified, would be sent data/information generated in the ERP. However, users must be identified so that they can obtain data/information directly or be able to have a representative who will deliver to the user processed, analyzed, and repackaged information for various users. To this end, it is proposed that a survey be implemented as soon as possible to determine:

1. Users of earth resource data/information.

    a. Government.

    b. Non-government.

2. Needs that can be satisfied by remotely sensed data.

3. Format, frequency, timing, and level of aggregation for this information.

4. Types of remote sensors needed to supply desired data/ information.

Since the ERTS-A flight is scheduled for 1972, it is essential that immediate steps be taken to acquire answers for these determinations.

User surveys made by the various organizations that currently serve the broad spectrum of users could supply most of this desired information. Various departments, e.g., Commerce, Interior, Agriculture, have already initiated user surveys to determine user requirements. A compilation of these studies should be made so that a determination can be made as to the completeness of these studies. If the studies are not complete, the ERP organization should initiate a complete study as soon as possible.

Various dissemination schemes may have to be set up to deliver data/information to the user. A proposal for accomplishing this will be presented later.

Education of the user of such a system must be dealt with as soon as funding is available. Suggestions for the education of a broad spectrum of users have previously been made (Chapter II). Implementation studies are necessary to insure that the user will be educated, so that the system will be used, and the greatest possible benefit to the user can be obtained.

PROCESSING

The processing requirements of a national earth resources IMS would be impossible to assess in a preliminary survey. To establish the detached requirement of the processing function, an analysis of the various applications and the total user community must be made. Some remarks, however, will be made concerning the general requirements for processing.

An initial processing of all data from the satellite is required. In addition, the information must be put into a form that the user can use. For earth resources work, the information from the aircraft and satellite programs will be recorded on film as photographs or on magnetic tapes. The research and development work will require more complex processing.

A number of various processing procedures for the films and photographs may be required for different applications. The production of color photographs from the multispectral images and the color enhancement of the images are useful techniques for interpreting natural environmental factors. The type and amount of color enhancement would probably vary with the application. For particular programs, transformation and rectification of the images will be required. Orthophotography will be another required process. An orthophotograph is a photographic copy that has been linearized and can be used for accurate measurements. Annotations added to photographs and the production of mosaics are types of processing that would have many applications. This is only a partial list of processes that may be required to transform the raw images into informative pictures and information. The list, however, points out the heavy requirements on the processor.

The reproduction of photographs and tapes for an expanding variety of users will also place a real demand on the processing facilities.

Finally, the processing function must provide the search and retrieval facilities so that the user can recall desired information.

SOURCES

As presented in an earlier chapter, the sources of data and information can be divided according to whether they are active or passive. In this section, the emphasis will be on the active sources. The only active sources that need special consideration here are those associated with aircraft and satellites in the ERP. These sources are new and present the real problem for an IMS.

Mercury and Gemini

Photographs taken by the astronauts during the Mercury and Gemini flights provided the first opportunity for scientists to sense the value and potential of satellite photography. Geologists, for example, were able to detect features of the earth never before seen on such a scale. The Apollo spacecraft carried more sophisticated cameras and when the results of the photographs were compred to photographs taken simultaneously by aircraft, the potential of the satellite photography was evident.

Aircraft Program

The Manned Spacecraft Center's Aircraft program has played a major role in the research and development of remote sensing techniques. Three aircraft, each equipped with a set of sensors, are used in this program. An Electra P-3a and a Hercules C130B perform at low and intermediate altitudes, and an Air Force RB-57F operates at high altitudes up to about 60 000 feet. A number of sites in the United States and some foreign countries have been studied by the remote sensors on the aircraft. Since much of this work was for the development of remote sensors, ground correlation data were gathered at these sites.

ERTS

The launching and operation of the Earth Resources Technological Satellite (ERTS) A and B in 1972 and 1973 will represent an enormous jump in the data and information generated for application in earth resources. ERTS A will be in sun synchronous orbit and will take 18 days to obtain complete coverage of the United States. The data transmitted will give

VI

complete coverage of the United States, and by using tape recorders on board, some foreign lands can be studied. The satellites and the aircraft can be used in a complementary program. Satellites obtain initial data and then the aircraft can be directed in for more detail.

Skylab

Skylab, a manned satellite mission also scheduled for a 1972 launch, will have an experimental package for the remote sensing of the earth's surface. Since the main mission of the Skylab is not to gather earth resources data, the inclination of the orbit will permit coverage of only a portion of the earth's surface. A significant quantity of earth resources data and information will, however, be supplied by Skylab.

Summary of Sensors

The sensors scheduled to fly on ERTS are a multispectral TV camera and a multispectral scanner. The TV camera will operate in three spectral regions and the scanner in four spectral regions. The sensors for Skylab are somewhat more sophisticated. A multispectral camera operating in six spectral regions and a multispectral scanner covering ten spectral regions will provide the majority of data. Skylab will also have spectrometers and microwave remote sensing equipment on board. In addition to the scanners and cameras, the aircraft carry radiometers, laser altimeters, scatterometers, side looking radar, and spectrometers.

As an example of quantity of information generated, ERTS A will deliver 200 000 images/year from the TV cameras and 250 000 images/year from the multispectral scanners.

MANAGEMENT ANALYSIS

Criteria

The system must:

- Provide a wide range of services that satisfy user priority needs.

- Be evolutionary — It must possess the ability to grow, adapt, and provide for feedback.

- Be technically effective and economically feasible.

- Be integrable with existing systems.

- Provide the information, personnel, and relationships to facilitate effective decision making throughout the system.

Proposed Organization

The organization that best meets these criteria is a composite, partially decentralized organization that fits together the many existing agencies which are already active in the information management area. The proposed organization that fits these many activities together into a functioning and evolutionary system is illustrated in Figure VII-1.

The example starts with the public, as the most fundamental classification of users. It embraces next the established media for disseminating information; the news media, scientific journals, science museums, etc. Also reflected are the scientific and technical societies, with their journals and meetings, which provide an effective medium for coordinating and disseminating the information relevant to individual fields of endeavor.

Such a broad treatment of dissemination to the user is especially important to a system designed for earth resources, because the information in this field has value in such a wide range of scientific investigation and in application to every human being.

To achieve the wide dissemination consistent with the broad utility of the earth resources data, it is appropriate to include in the dissemination portion of the system all media that have established channels of communication to users, defined in the broadest sense.

CURRENT AWARENESS CENTER

The Current Awareness Center is proposed as the organization for coordinating these dissemination media and supervising this function. The many media for scientific and technical information tend to operate independently, even in competition with one another. There is always the risk that certain information will fall through the cracks between the media. This risk is particularly great with the interdisciplinary and multidisciplinary

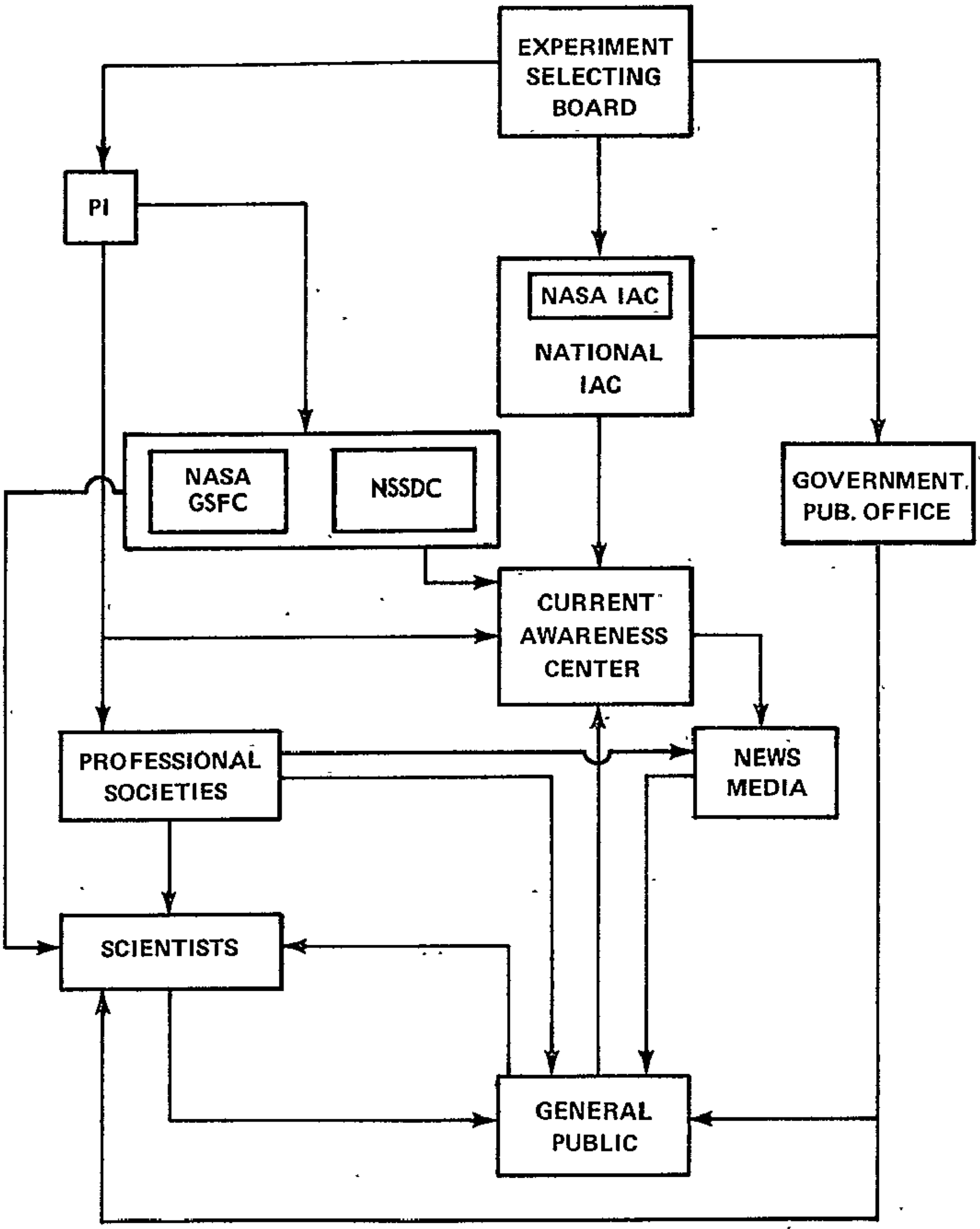

Figure VII-1. Proposed functional organization for information management.

kinds of information that will be produced by the ERP. The system should be as effective in transmitting relevant information to the man in the street as to the National Meteorological Service.

The CAC is proposed as an organization having a sufficient number of technical experts to identify and transmit through its appropriate channel each bit of information received by the system. The CAC is assigned those decisions listed in the charts of decision nodes in Chapter V that are not effectively handled by the existing agencies.

In addition, the collection of feedback and market research information from the users is a primary function of the CAC. None of the existing agencies or those proposed by others (for an example, see the SATCOM recommendations) are equipped to handle these feedback functions. Such feedback and market research are of great importance to the system if it is to have an evolutionary character, if it is to be able to grow, and if it is to adapt as user needs and the environment change.

INFORMATION ANALYSIS CENTER

The next function in the chart is the collection, storage, and processing of the data. There are many established agencies with facilities for performing these operations. There is no system to integrate and coordinate their efforts. To the extent that they can be integrated, it will not be necessary for the user to cope with the delay and complexity of identifying and then contacting the appropriate agency in its own special way. By providing a common point of contact and a common language and format, the system can facilitate use of these agencies and their capabilities. This defines the nature of the National Information Analysis Center. It serves to integrate the existing data stores and to identify earth resources data received from space. Earth resources data received from space overwhelms the existing facilities and a portion of the data fall outside of the defined areas of these facilities.

The role of the NIAC is defined by those decision nodes that are not within the pattern of the existing organizations, and it includes most of the planning decisions. The failure of existing organizations to execute these planning decisions is the reason the information problem exists. To the same extent that the NIAC can perform the planning decisions well, the IMS can deal with the problem and evolve.

EXPERIMENTAL SELECTION

The sources of the information for the ERP may be expected to originate from the scientific community in a form similar to the present PI concept, except, of course, that a PI will probably be more often a group of scientists from many disciplines rather than an individual. Effective fulfillment of the promise of the Earth Resources Program will require tapping the full range of scientific disciplines. Thus, the announcements of flight opportunity must be more broadly disseminated and promoted than they are at present.

This broad participation will create another problem: the need to select the experiments to be flown from a very large number of candidates coming from a wide range of sources. These candidates will range all the way from some with assurances of funding by private firms to those that include a request for government funding. The decisions of choice of experiments, dissemination of AFO, and how to handle funding of the projects are important enough to require an organization of their own.

An Experiments Selection Board is proposed. This board would be charged with its responsibilities by the President. This board must be both fair and credible to the scientific communities in general. The board must have wide representation, as wide as the nature of the earth resources studies and as wide as the interests of those who will utilize the data. Therefore, a complex nominating procedure is required to insure that the representation on the board is as wide as possible and that the members are widely recognized for their integrity.

Wide representation and acceptance, a Presidential charge, and full commitment to the mission objectives are important, because the board may well have to choose between a candidate experiment in oil exploration and one in air pollution.

The board should also arrange for full disclosure of the criteria by which the proposed experiments are to be evaluated. By so doing, it will increase its credibility to the scientific community and thus encourage the development of more proposals of a higher caliber.

FUNDING

The existing organizations that are integrated into the above system already have established means of funding, ranging from subscription by users to government support. It makes economic and political sense to continue such arrangements, with the user paying for services received and the government subsidizing those activities that cannot be readily observed by the user as offering utility to him. This latter group includes the collection and indexing of documents, while the user can readily perceive the logic of charging him for copies.

By this same line of reasoning the NIAC and the CAC will require a budget from the Federal Government to establish their facilities and their data banks, while the filling of requests can be treated as self-supporting. Much the same system apparently works effectively in the Bureau of Standards.

Because of its remoteness from the user, the Experiments Selection Board will require government funding to support its staff and expenses.

Any additional dissemination media that are found to be necessary to communicate to the user information that is not effectively handled by existing organizations must be funded in some composite form. Perhaps a combination of government seed money and charges to users could make it possible for such organizations to become self-supporting in the future.

CONCLUSION

The organization proposed above fulfills the mission objectives and meets each of the criteria established for the Information Management System.

ORGANIZATION STRUCTURE

The organization structure is shown in Figure VII-2. As suggested here, the director of the prototype UNISTAR system is directly responsible to NASA. He will have an advisory board that will include representatives from both federal agencies and non-federal organizations that are directly involved in earth resources work. The purpose of the advisory board is to coordinate the development of the system so that it will be of the greatest value to the numerous users. The Board of Commissioners will have the same constituency as UNISTAR. The Long Range Planning Committee as coordinated by the Board of Commissioners will maintain the evolutionary capability of the system and will direct attention to the goal, which is a

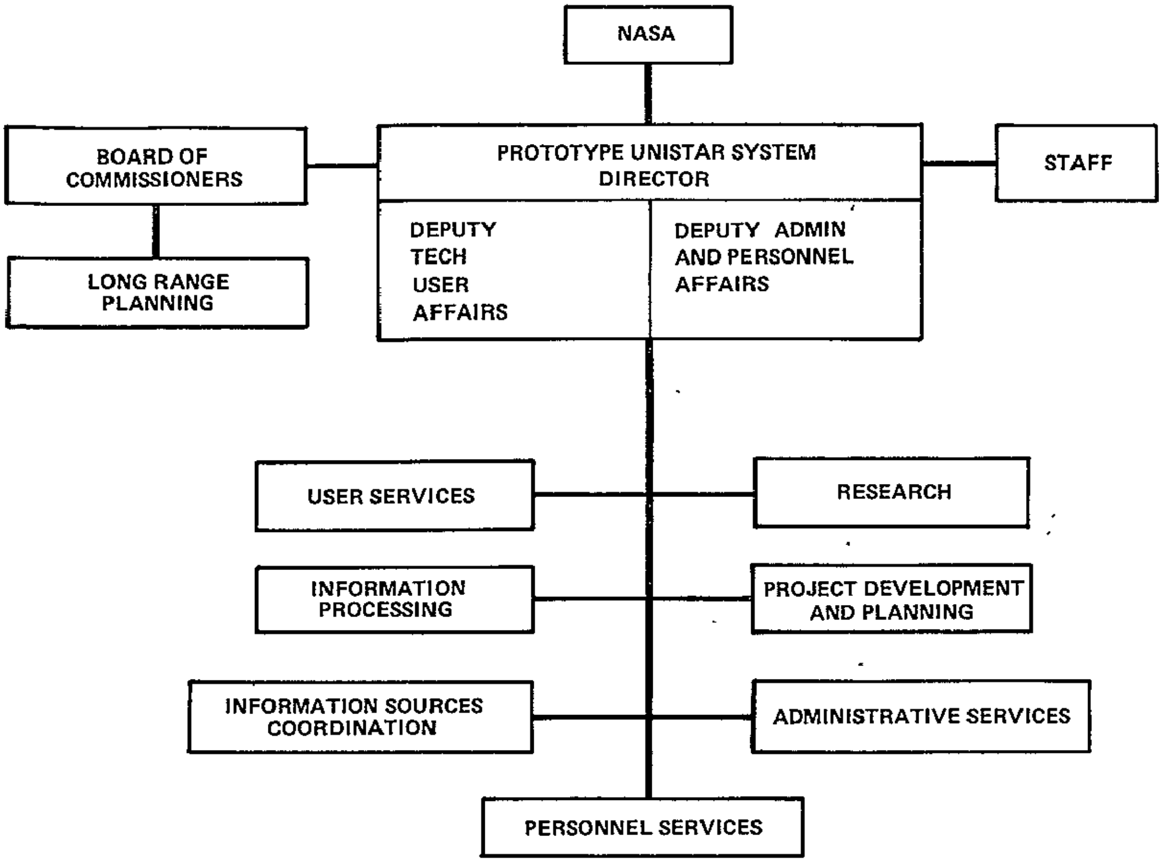

Figure VII-2. Organization structure.

national IMS for all scientific and technical information. The remainder of the organization structure is similar to that presented previously for UNISTAR.

CONCLUSIONS

Concerns

During our deliberation of the needs for a prototype UNISTAR system, a number of concerns have been expressed. There is a sense of urgency. The flow of data from ERTS will begin in early 1972, less than 2 years from now. Data from Skylab will begin shortly thereafter. The information generated from these sources is required for environmental programs. It is urgent, therefore, that the program for establishing the IMS begin immediately.

There is a concern that the user community be identified. No IMS can be effective if it is not aware of the makeup of its users. This system must not be content with reaching only the "experts" in the field. We, therefore, encourage that a study be made to identify the known and potential users of the system.

There is a concern that the best use be made of existing dissemination networks. The Department of Agriculture, for example, has a dissemination network through the land grant universities and county agents. We encourage that a study be made of present dissemination networks that could be used for earth resource information.

The scientific community had little to say about the multispectral TV cameras and multispectral scanners that are on the ERTS. The success of the ERP, however, depends upon the scientific community actively using the information. The scientific community can use the information only if a well organized earth resources dissemination network is in operation.

One would also encourage the coordination of these networks to bring the user as close to the source as possible.

The IAC is considered the key to the satisfactory functioning of the system.

In many cases the people who can use the earth resources data will have no idea of how it should be processed to obtain the information. This situation will put a real burden on NASA to develop an IAC and a processing center that will make possible the dissemination of useful information.

There is a concern that in the planning stages of the prototype, both federal and non-federal representatives will cooperate to develop a system that can be coordinated among the many interested organizations and scientific disciplines.

Finally there is a concern that the prototype be evolutionary. In its prototype form, the system would depend on the Long Range Planning Committee to look ahead to a complete UNISTAR system. Through the

Board of Commissioners, UNISTAR would begin to develop after the fashion of the prototype. All that would be learned in the operation of the prototype would be applied to the development of the UNISTAR system. As UNISTAR progressed in its development, the prototype would be phased out and incorporated into UNISTAR. Thus, UNISTAR is born.

Problems

Other aspects of this system should have been considered. Such things as:

1. Should the data and information be controlled or classified in any way?

2. What should be the international policy on dissemination of satellite pictures?

3. How should the economic advantages of satellite pictures be handled?

4. What are the problems that might be encountered as the system evolves.

For example, as the sensors are developed and their resolutions are improved, satellites could be used to monitor all events occurring over the entire surface of the earth. They could also be used for controlling human activities. One can imagine great benefits for mankind as a result of these developments. There are, however, disadvantages also. Unless humanity changes radically we must always concern ourselves with the consequences of setting up a system that can control human activities. There is always that person or group of people who seek opportunities to control the world.

APPENDIX VII-A

FEDERAL ORGANIZATIONS INVOLVED IN EARTH RESOURCES

The following federal organizations are involved in earth resources:

- Department of Agriculture
- Department of Interior
- Department of Commerce
- Department of Navy
- Department of Justice
- Department of Transportation
- HUD
- HEW
- U. S. Coast and Geodetic Survey
- Federal Power Commission
- National Park and Planning Commission
- Federal Water Pollution Control Administration
- Forest Service
- Farm Credit Administration
- Bureau of Mines
- Bureau of Census
- Bureau of Narcotics
- Bureau of Outdoor Recreation
- Bureau of Indian Affairs
- U. S. Geology Survey
- Bureau of Land Management
- Bureau of Reclamation
- National Park Service
- Bureau of Commercial Fisheries

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APPENDIX VII-B

APPLICATIONS OF EARTH RESOURCES INFORMATION

Agriculture and Forestry

Measure vegetation density
Record grass-brush-timberland interfaces
Record plant species and vigor
Measure soil quality, temperature, and moisture
Determine expected crop yields
Determine irrigation water
Assess disease and insect damage
Assess infestation patterns
Measure forest areas and timber volume
Map location of tree types
Assess forest fire damage
Police timber harvest
Monitor distribution and change in farm land use

Water Resources

Measure rain distribution and infiltration
Determine distribution of fresh water
Make water inventory of lakes, streams, and show watersheds
Water quality
Locate ground water discharge
Monitor river effluents
Locate irrigation routes

Geology

Study geological structures — regional tectonics
Study of engineering geology
Make mineral resource surveys
Study rock composition
Study stratigraphy-sedimentation

Conduct crustal-mantle studies
Predict earthquakes
Monitor volcanoes
Detect MASCONS
Study gravity variation
Predict landslides

Conservation and Recreation

Conduct land use surveys, study change in land use, and rate of change of land use
Make life studies
Take animal census
Examine forest recreation sites
Assess fossil fuel reserves
Study resources utilization

Environmental Planning

Study transportation development, control, and planning of systems
Measure population distribution
Monitor population movements
Classify land areas
Use in cartography, topography, and geomorphology
Control floods

Oceanography

Monitor thermal conditions of oceans
Monitor sea surface roughness
Map shoals and coasts
Monitor ice in the ocean
Measure sea-fresh water interface along coasts
Map sea currents

Meteorology

Predict weather
Obtain cloud pictures
Monitor storms

Obtain atmospheric temperature and humidity profiles
Measure vertical water vapor distribution
Measure vertical ozone distribution
Monitor surface temperature

Pollution

Survey air, water, and land pollutions
Locate polluting sources
Detect Eurasian Milfoil
Study patterns of thermal pollution

Miscellaneous

Discover archeological sites
Locate hydrothermal energy sources
Study geothermal anomolies in Yellowstone

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CHAPTER VIII

SUMMARY

CHAPTER VIII. SUMMARY

The study on UNISTAR was begun by identifying requirements basic to any IMS. Data pertinent to these requirements were collected and analyzed. Discussion on each requirement is reflected in the user, processing, sources, and management analysis chapters that coincide with the requirements identified.

The analysis of the general problem disclosed that there is no announced national policy or plan for information management. Furthermore, scientific and technological data rates are increasing to the point where there is a serious question as to the utility of research, because the possible user population may never have access to research results. Although the establishment of a national information system may cost 200 billion dollars or more, the U. S. must embark on the development of such a system if it is to maintain a competitive posture in world trade.

This report discusses information systems proposed by SATCOM and the Tripartite committee as well as other systems, and reflects information gathered from extensive interaction with NASA.

A national policy and plan, UNISTAR, are suggested for consideration by the President of the United States. An example of a prototype system for earth resources data is discussed, and NASA is recommended as the agency to develop the prototype. The recommendation that NASA be the developer of the prototype is predicated on the following rationale:

1. NASA has the experience in communications necessary to establish the dissemination network.

2. NASA has management experience. The NASA organization is unique. It has a phenomenal record for successfully meeting unusual challenges. It has a management team capable of dealing with problems.

3. NASA has experience with industry and the university community. In fact, teams from these two areas have worked effectively on numerous tasks.

4. NASA has the necessary research and technological experience. Through the development and successful operation of spacecraft, NASA has developed techniques for processing telemetry data.

5. The Gemini and Apollo flights and the aircraft program at MSC have given NASA a competence in remote sensing and in the analysis of earth photographs from satellites and aircraft.

6. NASA has an extensive background in information management systems and has begun a study on the dissemination of earth resources information.

7. NASA can demonstrate the continued value of the space program. The development and operation of a useful IMS for earth resources would show mankind some of the valuable contributions the space program can have.

This report emphasizes the immediate need for UNISTAR to meet the pending data rates of the Earth Resources Program involving satellite and aircraft observation.

It is realized that before the information management problem can be solved, the public in general must be made aware of the problem. Furthermore, a national IMS must serve all classes of users and must not be restricted to a select group of users. Essential to the success of a national IMS is the use and acceptance by the citizenry. It is important that a thorough study be conducted at once to determine the alternative approaches leading to the establishment of an effective national IMS.

The information problem pervades all aspects of society, and it is hoped that this report will prompt meaningful steps toward solving the information management problem. The steps taken now can mean a satisfaction of wants and needs of man today and in the future.