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Data Base Management Systems Panel

Third Workshop Summary

Jose L. Ureña
Editor

July 15, 1981

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Space Administration

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FOREWORD

The Third National Aeronautics and Space Administration (NASA)/Office of Space and Terrestrial Applications (OSTA) Data Base Management Systems (DBMSs) Workshop was held at the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, on December 10 to 12, 1980. The workshop was sponsored by the Data Systems Branch, Communications and Information Systems Division, OSTA, NASA, and was coordinated by the Jet Propulsion Laboratory (JPL). The chairman of the Workshop was Dr. Guy M. Lohman of JPL.

The purpose of the workshop was to review and analyze activities using DBMSs within NASA/OSTA and related organizations. The objectives of the workshop were:

(1) To discuss and summarize the status and use of commercial DBMSs for scientific data management by NASA and other government agencies.

(2) To review the report drafts and the overall direction of the OSTA Applications Data Base Management System (ADBMS) task at JPL.

(3) To develop a coordinated perspective of DBMS-related efforts within the various NASA Program Offices.

The three-day workshop consisted of six working sessions. This report is organized into sections that correspond to each of these sessions. A summary of the results of the workshop and a list of recommendations have also been included in Section I.

ACKNOWLEDGMENT

Many individuals contributed significantly to this report and to the success of the Third DBMS Panel Workshop. The editor especially wishes to thank Dr. Guy Lohman for his continuing support and help in completing this report and for the coordination and chairmanship of the workshop and to thank Dr. Al Ferrari, Karen Posey, and Dr. Tom Renfrow for reviewing a preliminary draft of this report. Karen Posey and her group provided the local logistics at the Goddard Space Flight Center, and Regina Sylton and Mary Reph gave logistical support during the days of the workshop. Ralph Bernstein made available to the members of the panel an early version of portions of the CODMAC (Committee on Data Management and Computation) report of the National Academy of Sciences. The Information Extraction Division of the Goddard Space Flight Center graciously hosted the workshop. Finally, we wish to thank all members of the panel for their time and contribution.

ABSTRACT

This report summarizes the discussions and results of a review by a panel of data base management system (DBMS) experts of various aspects of the use of DBMSs within NASA/Office of Space and Terrestrial Applications (OSTA) and related organizations. The topics discussed included the present status of the use of DBMS technology and of the various ongoing DBMS-related efforts within NASA. In particular, it included a review of the report drafts of a study that seeks to determine the functional requirements for a generalized DBMS for the NASA/OSTA and related data bases. The discussions also covered future problems and possibilities with the use of DBMS technology, and included a list of recommendations for NASA/OSTA Data Systems.

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SECTION I

SUMMARY OF RESULTS OF THE WORKSHOP

The Third National Aeronautics and Space Administration (NASA)/Office of Space and Terrestrial Applications (OSTA) Data Base Management Systems (DBMSs) Workshop was a valuable forum for the exchange of information among the widest representation ever assembled of the NASA data base community. Those attending the workshop are listed in the Appendix. The areas covered were:

(1) Benefits versus costs of DBMS technology.

(2) Existing data base related efforts.

(3) Future DBMS-related technologies.

There was a general agreement on the following issues:

(1) NASA should continue to explore the utility, benefits, and costs of applying DBMS technology to the NASA data environment.

(2) NASA is presently at a transition point in the overall cycle of data management. It is leaving the computer management phase and just entering the data resource management phase. At this transition point, management plays a particularly important role in facilitating a smooth evolution of data systems towards maturity.

(3) NASA/OSTA should make greater use of the resources of universities that are doing work in data management.

(4) NASA/OSTA should find ways to increase user involvement in the design process of its data systems.

(5) The implementation of DBMS prototypes is a very valuable tool for proof of concept.

(6) Because the various NASA centers have taken different approaches to meet the specification requirements for data base systems, each center should benefit from the others' experiences.

There are significant technical problems in and limitations to the present methods of accessing, distributing, reducing, analyzing, and archiving space-derived data. The following are technical problem areas of concern to the NASA/OSTA DBMS Panel:

(1) Disappointing DBMS performance at the time large data bases are loaded may be due to a limitation of the minicomputers used, and to other limiting factors such

as secondary storage architectures (disk I/O speeds) and the traditional DBMS approach to structuring the data base (delays caused by the need to reformat data and/or create pointers, indices, etc.).

(2) Commercially available DBMSs do not, in general, fulfill NASA's requirements for handling space-derived data.

(3) A dichotomy in the functionality of DBMS between the data-driven "front-end" data base loading and user-driven "back-end" data retrieval has been identified and unresolved.

(4) The role of the DBMS in the overall End-to-End Information System has not been specified in any detail.

(5) Data base software performance may have reached its limit. Further hardware developments and innovative uses of existing hardware architectures may be necessary to keep up with the ever increasing requirements of NASA's current and future data base systems.

Management concerns of the panel were the following:

(1) There is a need for a coherent, long-range approach to understanding and meeting the data systems' needs within OSTA, supported with appropriate funding levels.

(2) There is an urgent need for high-level planning of the data resource function within NASA, and for the creation of a Data Administrator role. It was agreed that the Data Administrator should operate at a very high level of responsibility.

(3) NASA should increase the efforts of cooperation and coordination not only between its own centers, but between itself and other government agencies.

(4) NASA has difficulty recruiting competent computer science and MBA graduates. It is suggested that present NASA recruitment procedures be reviewed to make employment with NASA more remunerative and challenging.

(5) NASA should improve its visibility in the data-base community and in such activities as conferences and user groups' meetings. If NASA were to make its special needs known, vendors could then be more

responsive to those needs. A related problem is the lack of travel funds to attend those kinds of activities.

The following areas have been identified as subjects for possible further investigation:

(1) Special purpose hardware for the handling of data base tasks, such as data base machines and intelligent controllers.

(2) Utilization of parallel processors for data access and data processing.

(3) Telecommunications and the interfaces between teleprocessing programs and the DBMS.

(4) Distributed data bases.

(5) Interfaces between DBMS and other system components.

(6) Benchmark tests of existing systems and modelling of DBMS performance and trade-offs.

(7) Modelling of the DBMS as an integral part of the overall End-to-End Information System.

(8) Random-access mass storage and archiving media.

(9) User-friendly human interfaces.

(10) Standardization.

NASA/OSTA planners expect from such groups as this panel of the workshop recommended directions for OSTA data systems thrusts. To that effect, a list of recommendations based on the results of this workshop was approved by the panel. The workshop also initiated a joint JPL/Goddard Space Flight Center effort to come up with a set of technical recommendations to be used for a 10-year plan for NASA's OSTA Data Systems.

The panel agreed to include in the list of recommendations the calendar, format, and scope of future versions of this workshop.

SECTION II

RECOMMENDATIONS OF THE THIRD WORKSHOP

At the end of the sessions of the Third NASA/OSTA Data Base Management Systems Workshop, the members of the panel generally agreed upon the following recommendations:

(1) The role of a Data Administrator or Information Resource Manager should be created in NASA/OSTA as one means to coordinate all planned and existing data base related activities across all NASA centers. For this new role to be effective, it must operate at the highest level of responsibility. This will provide the leadership power necessary to cut across organizational and institutional boundaries.

(2) NASA/OSTA should have an integrated and coordinated near-term and long-term (10 to 15 years) plan at all levels for its data base related activities. A duplication of efforts and an inefficient use of resources are some of the problems that have arisen in OSTA due to the lack of effective planning.

(3) The following are some of the areas that need further investigation:

   (a) Research the problems related to very large scientific data bases of remotely sensed observations including imagery.

   (b) Investigate the utility of "mainframe" computers (as opposed to minicomputers) for the handling of such data bases.

   (c) Investigate the use of DBMS technology only for the back-end (archiving and distribution) system.

   (d) Investigate alternative DBMS architectures (including special purpose hardware) and techniques (e.g. parallel processing).

   (e) Further investigate how DBMS technology can and should be applied to NASA's data problems.

(4) NASA/OSTA should:

   (a) Utilize the resources of universities with expertise in data management in NASA/OSTA research and development efforts.

(b) Supplement the intercenter and interagency communication in matters related to data base systems, with more frequent reviews of DBMS activities in NASA.

(5) The panel agreed on the character and calendar of future versions of this workshop:

(a) The change of the name of the panel to "Panel on Data Management" will indicate that DBMS technology should be addressed within the much broader context of the total data storage/retrieval/management problem and that the panel should broaden its view to encompass this larger context.

(b) The workshop should be held annually, preferably in the early fall, to allow enough time for its results to be included in the following year's budgeting and planning.

(c) The format of the workshop should consist of a plenary session, and of parallel sessions on technical and managerial issues.

SECTION III

SESSION 1: "WHY ARE WE HERE?"

The first session of the workshop addressed the issue of the justification of Data Base Management Systems. In the computer community there are some misconceptions about the justifiability of DBMS use that are due, to a great extent, to a lack of information about this new technology.

The purpose of this session was to prove the advisability of the DBMS efforts within NASA, in general, and within the OSTA Data Systems Program, in particular, and to show how DBMS technology can help in the solution of many of the problems that have been identified in NASA's information systems today.

The program for this session was as follows:

Report on National Academy of Sciences Committee on Data Management and Computation	Ralph Bernstein
Comparison of Generic User Data Management Requirements vs Applicable DBMS Capabilities	Guy Lohman
Evaluation of Performance, Economic Costs, and Payback of DBMS	Alfonso Cardenas

Mr. Ralph Bernstein, as chairman of the Committee on Data Management and Computation (CODMAC) of the Space Science Board of the National Academy of Sciences (NAS), presented the preliminary results of a study of the NASA Data Management problem undertaken by this committee. A report will be published by the NAS in the near future.

The objectives of CODMAC are to examine the management of existing and future data acquired from space and associated computation in the areas of space and earth sciences, and to recommend improvements from the point of view of the scientific user.

One of the major findings of the report is that there are real problems and limitations in the present methods of acquiring, distributing, reducing, analyzing, and archiving space-acquired data. The report analyzes these problems and includes a study on present and future requirements for data/information systems. A separate panel of CODMAC made, in parallel, a study of technology trends. Taking all this information into consideration, the committee has issued a series

of recommendations to improve the management and efficiency of space science data systems.

The report finds that scientific involvement is essential in mission planning, data acquisition, software development, and data analysis, utilization, and archiving. The committee also reports a lack of overall planning as to how new NASA systems will interact with each other. Several ongoing data systems study activities exist without adequate central direction. A limited use draft document of the report is available (Ref. 1).

The rest of this session was dedicated to discussing the capabilities of DBMSs, how NASA's data systems can benefit from DBMS technology, and the management issues relevant to the adoption of this technology by an enterprise of the size and complexity of NASA.

Dr. Guy Lohman explained the general capabilities of DBMSs, and how these systems can be mapped onto a subset of the problems and inefficiencies that can be identified in OSTA Information Systems. His study, which can be found in Ref. 2, shows, in the form of a table, which of the identified problem areas are covered, in different degrees, by one or more of the described DBMS capabilities.

Dr. Cardenas, in his talk, stressed some of the benefits of DBMSs, such as the reduced software development time and maintenance costs that can be expected with the adoption of DBMS technology. He pointed out that performance and efficiency are not the only parameters to consider when evaluating the use of DBMSs. Very often a decrease in the efficiency and performance of the computer resources is argued by DBMS detractors to justify their position. A fair evaluation of DBMS technology must take into account all the benefits that this technology can bring, and weigh them against the cost. The usual result is that DBMS technology brings more gains per dollar spent.

According to Dr. Cardenas, NASA presently finds itself at a transition point in the development cycle towards maturity in managing the data resource function. Typically, an enterprise evolves from a stage where the computer is treated as the resource that has to be managed, to a stage where data is considered the resource. Figure 1 illustrates this evolution. The transition point is very critical and important, and requires a change in outlook. It is here where management has a particularly important role in allowing a smooth evolution of data systems towards maturity.

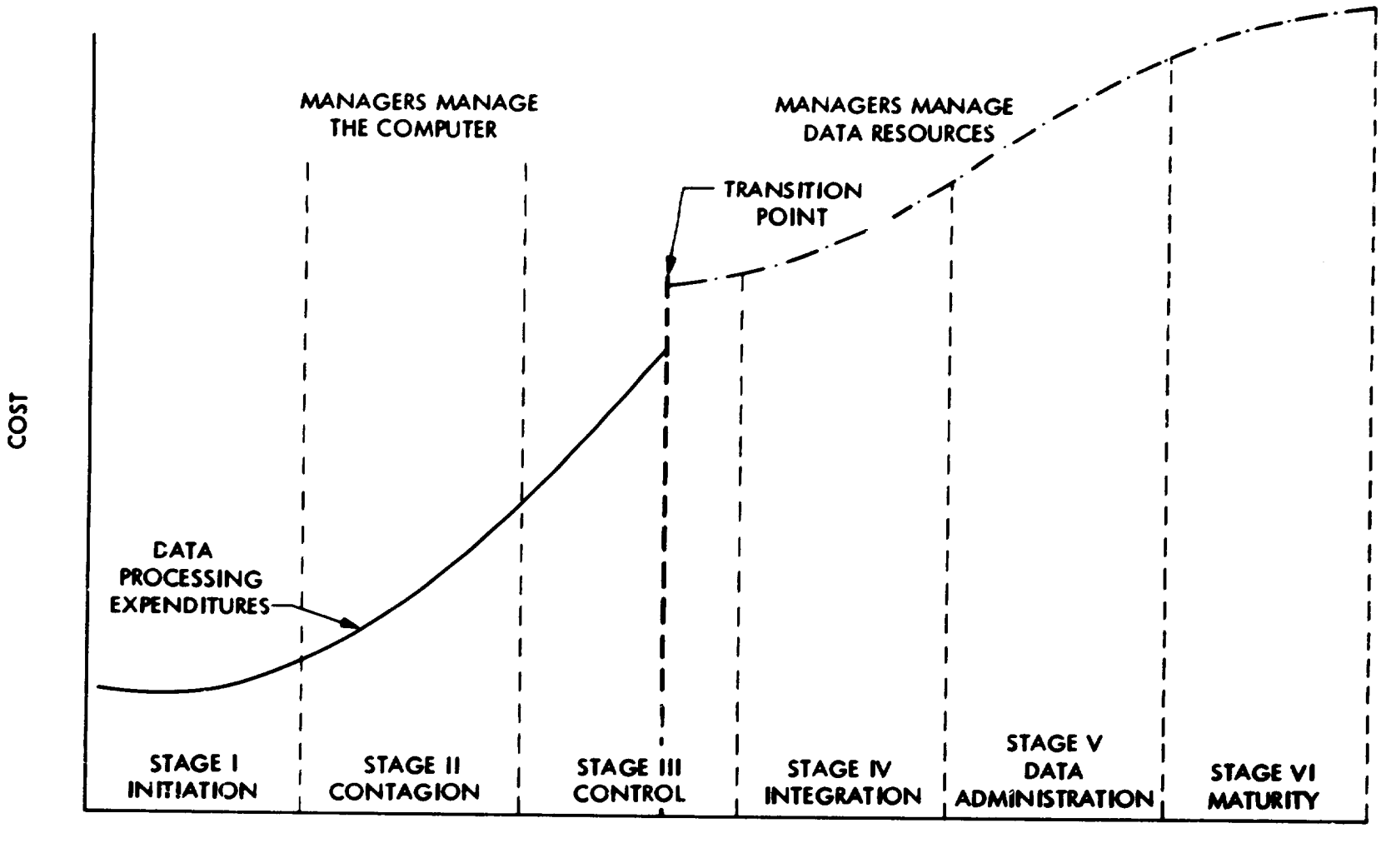

Figure 3-1. Six Stages to Maturity in Managing the Data Resource Function

SECTION IV

SESSION 2: "WHAT IS BEING DONE?"

The first session of the workshop showed the potential of DBMS technology in solving many of the problems that have been identified in NASA's data systems. During the second session, the members of the panel explained the approaches used for programs they represent to make full use of this potential.

The session consisted of a series of short presentations by the members of the panel, and of the exposition of the plans and programs of OSTA and the Office of Aeronautics and Space Technology (OAST) of NASA.

The program of presentations for this session was the following:

Overview of OSTA Data Systems Program	Pete Bracken
Overview of OAST NASA End-to-End Data System (NEEDS) Program	Lee Holcomb
Applications Data Service (ADS) Pilot Systems	J. Patrick Gary Loren Meredith Janeth Heuser
ADS Standards	Barbara Walton
NEEDS Integrated Data Base Management System (IDBMS)/Pilot Climate Data Base Management System (PCDBMS) and Archival Mass Memory (AMM)	Doug Thomas Karen Posey
Transportable Applications Executive (TAE)	David Howell
OSTA (Oceans) Catalog and Inventory Development	Karen Posey
USGS Efforts: Earth Science Information System	Ted Albert
National Oceanographic and Atmospheric Administration (NOAA)/Environmental Data and Information Service (EDIS) Efforts	Newton Page
Applications Data Base Management System (ADBMS)	Guy Lohman

NASA Office of Space Science (OSS) Data Records System Prototype	Ed Records
Theoretical DBM Investigations	Walter Truszkowski
Geocoding Models	Al Zobrist

Pete Bracken, chief of the Data Systems Branch of NASA's OSTA, presented the status of the OSTA Data Systems Program. A plan for 1982 and beyond is presently being prepared, and the final version is scheduled for release by March 1981.

There are some areas of the Data Systems Plan in which there is insufficient information or experience to specify an adequate set of requirements for a system. In those areas, OSTA has adopted the approach of sponsoring pilot programs. There are three pilot programs, at present:

(1) The Pilot Atmospheres Data System (PADS) at the Goddard Space Flight Center.

(2) The Oceans Pilot System (OPS) at JPL.

(3) The Renewable Resources Pilot System (associated with the AGRISTARS Program) at the Johnson Space Flight Center.

These and other pilots will explore ways of meeting some of the basic needs of these disciplines, ultimately tying the systems together in a distributed network for data access and sharing (the Applications Data Services (ADS) Network).

The Data Systems Branch is actively seeking input from groups such as this workshop's panel, on information systems research areas that should be pursued in the Data Systems Program to complement the Data Base Management activities during the next 5 to 15 years.

For the Office of Aeronautics and Space Technology (OAST), Lee Holcomb presented the status of the Nasa End-to-End Data System (NEEDS) Program. The NEEDS Program intends to be an answer to the problems of responsiveness and timeliness of NASA's data systems, and to the increasingly more stringent requirements and data rates. It is intended to be a technology program, not an operational program. It will provide technology for end-to-end data systems for future NASA systems.

Mr. Holcomb described in his presentation the different activities that are taking place under the NEEDS Program. The second phase of the program started in 1979, and Phase III will begin during 1981.

The NEEDS concept is described in Ref. 3, and the Program Plan for Phase II is in Ref. 4.

Mr. Patrick Gary, in his talk about the Pilot Atmospheres Data System (PADS), explained the present configuration of the pilot, with its two local processors at the Goddard Space Flight Center and a third one at the University of Wisconsin. The system will provide the user sites not only with telecommunications capabilities, but with a more uniform interface to the user and with a central directory. In the future, the system will extend to the other pilots, and the team is very actively pursuing the interconnection of various heterogeneous systems and their data management schemes. There have been many requests from several sites to that effect. The initial demonstrations of the system are scheduled for the first quarter of 1981.

The objective of the Oceanic Pilot System Project, according to Mr. Loren Meredith of the Jet Propulsion Laboratory, is to develop and evaluate an Oceanic Pilot System (OPS) with the use of advanced technologies and standards in a number of different technological areas. The project comprises three phases, the last one of which will support networked remote data acquisitions. The hardware for the project is presently being procured, and a preliminary draft of the functional requirements document will be released by the beginning of 1981 (Ref. 5).

Janeth Heuser, from NASA headquarters, gave a short presentation on the Renewable Resources Pilot System. This pilot is part of the AGRISTARS Program, which is a joint agency project involving the U.S. Department of Agriculture, NASA, and the National Oceanographic and Atmospheric Administration (NOAA). There are eight projects within AGRISTARS, each managed by a different agency. In general, each project requires its own sets of data, although some data sets are required by more than one project. The Renewable Resources Pilot System will support a Data Management Team that will develop a transportable system with a directory of data and a catalog of the sources of the data.

The objective of the ADS Standards Program is to develop standards for OSTA starting with the OSTA ADS Program. Barbara Walton, from the Goddard Space Flight Center, presented a classification scheme for ADS standards that will eventually be used to create a data base of standards, a dictionary of standards, and a reference library. A preliminary (draft) survey of standards using the classification scheme has been completed (Ref. 6). Within the next 8 months a set of requirements will be compiled through interviews with representatives of the pilot projects. At the same time, standards evaluation criteria will be developed. A workshop in May is scheduled to discuss preliminary results.

From the Marshall Space Flight Center, and through a teleconferencing arrangement, Doug Thomas presented the Data Base Management System objectives of the second phase of the NEEDS Program. Work on the different DBMS elements is handled by the Marshall Space Flight Center and the Goddard Space Flight Center. Mr. Thomas gave a description of the basic hardware configuration of the DBMS and of its component functions, as well as the key elements of the Archival Mass Memory Project, which is one of the major components of the proposed system.

Karen Posey presented a brief history of the Pilot Climate Data Base Management System (PCDBMS) and of the Integrated Data Base Management System (IDBMS). The IDBMS is a component of the NEEDS program. It will be installed in a VAX computer at the Marshall Space Flight Center. The PCDBMS will be installed in a minicomputer at the Goddard Space Flight Center. It will begin to provide interactive user capabilities, and electronic transfer during 1982 and 1983. This project has released a study on the characteristics of data sets of interest to the climate community (Ref. 7) and a System Functional Requirements document (Ref. 8). Within one month after the workshop, a hard copy catalog of climate data will be released (Ref. 9) and its format will be distributed for critique and comments. During 1980, the MITRE Corporation has been performing a study on DBMS technology in support of these two projects. In Refs. 7 through 13, a list can be found of other documents generated by these projects up to the present.

About the OSTA catalog and inventory activity, Karen Posey emphasized the need for coordination between all the projects with a similar interest. The first objective is to establish an OSTA-wide catalog/inventory development plan to arrive at a coordinated plan within OSTA. A first objective for this activity is to develop catalogs for oceans data bases, and, for those data bases that are stored locally, to also develop inventories. At the present time the initial inputs to a coordination/development plan have been reviewed with NASA Headquarters, and a set of preliminary guidelines and standards have been developed for the climate discipline.

In an effort to integrate the work in developing interactive systems in support of application projects, David Howell of the Information Extraction Division of the Goddard Space Flight Center (GSFC), explained how the concept for the development of the TAE came into existence. The goal was to avoid duplication of software development effort and to promote sharing of system and application software. The approach was to develop a single transportable software system with a common applications interface by identifying common system elements in the interactive analysis and graphics environment. A prototype is scheduled to be ready by September 1981, and Version I of the TAE

will be available by November 1982. A more complete description of the TAE can be found in Ref. 14.

Ted Albert, Data Administrator of the U.S. Geological Survey (USGS) of the Department of the Interior, described the nature and scope of the activities and the structure of the USGS. He also explained how the Data Administration Function is helping the USGS to put an end to a situation where different applications and disciplines were creating, in an uncoordinated way, incompatible data bases and systems, with the consequence of inefficiencies in the development and use of USGS information systems. The objective was to arrive at a unified representation of earth science data, and, in 10 to 15 years, have systems and data compatible enough to allow the transfer of data and multidisciplinary analyses. The approach to solve this problem included the adoption of DBMS technology. Model 204 of the Computer Corporation of America (Cambridge, Massachussetts) was chosen as the most suitable DBMS to develop the Earth Science Information System as a directory/dictionary front-end information system. Future activities include the creation of an USGS Standards Committee to work in coordination with the National Bureau of Standards on standards relevant to the earth sciences.

Mr. A. Newton Page, Manager of Systems of the Environmental Data and Information Service (EDIS) of the National Oceanographic and Atmospheric Administration (NOAA) explained the organizational structure of NOAA and presented a description of some characteristics of EDIS data bases. the short term plan (1981 to 1986) of EDIS objectives are to apply DBMS technology to create a new EDIS data management system with the use of a data dictionary system (DDS) and the consolidation of three of the present data bases from conventional observations (excluding satellite data) in a single facility in Ashville, North Carolina. Objectives for FY 1980 are to analyze the initial DDS entries, review the DDS updates and update procedures, and publish the DDS catalogs. The objectives for 1984 to 1990 include an analysis of user requirements, and an evaluation of state-of-the-art technologies for subsequent phases of the plan.

The objectives of the Applications Data Base Management System (ADBMS) task, according to its task manager and chairman of the workshop, Dr. Guy Lohman, are to develop a Data Base Management System tailored to NASA/OSTA requirements, one that has evolved from the NASA DBMS prototypes and pilots. It will be adaptable to data systems for future OSTA missions and it will be utilized as a tool for users to access observational data and information about the data. The ADBMS Functional Requirements will be completed by the end of 1981, and a development and implementation plan will be ready by April 1981. A more thorough presentation of this task was given at the 4th Session during the second day of the workshop. A list of the documents produced by

this team, up to the present, can be found in Refs. 2 and 15 through 17.

Ed Records, of JPL, explained in his presentation that, to keep up with the increasingly more stringent requirements of JPL's flight missions, a decision was made a few years ago to adopt DBMS technology. A UNIVAC 1181 was chosen as the mainframe, and it was decided to implement a data records prototype to find out whether the data records effort could be implemented using a commercially available DBMS such as the DMS 1100. The results of the prototype experience showed that, given a series of carefully chosen evaluation factors, the system met its objectives and it is considered a success. The full Mark IV Data Records System is presently being implemented using the education and experience that the prototype provided.

There are four different areas of theoretical data base research centered at NASA's Goddard Space Flight Center. Walt Truszkowsky of the Goddard Space Flight Center explained that the objective of the research on N-dimensional systems consists of an investigation of alternative ways to deal with multidimensional data. A proof of concept 15-dimensional data base system is presently being built to demonstrate its use with meteorological data. During 1981, an experimental data base program applied to a polar ice analysis will take place at the Goddard Space Flight Center. In 1982, an operational system will be available for use by scientists in various disciplines. Documentation on the proof-of-conept system will be available by January 1981. The other three research activities deal with software management, distributed control, and knowledge information systems with the use of artificial intelligence concepts.

Representing VICAR (Video Information Communication and Retrieval System), Al Zobrist from JPL talked about the basic uses of geocoding models; the uses are mainly two: data bank preparation, and application modeling and analysis. Mr. Zobrist discussed the data handling procedures necessary to form an image mosaic of the State of California, in what way the MARK IV file management system is used, and how a DBMS can greatly improve the mosaicking procedure given the large amounts of data that must be handled in an application of this type.

This session was followed by a discussion period among all the members of the panel. As a comment to some questions that had arisen, Dr. Cardenas pointed out that, contrary to the general belief that DBMS can talk to and have some control over a mass storage system (MSS), DBMS technology looks at an MSS as an archival area, and no relationships are established among the files that are stored in it.

Dr. Renfrow raised a question concerning the intended scope and possible extension to other agencies of the current work on standards, given that the ADS pilots will eventually communicate with other systems external to NASA, such as those in USGS and EDIS.

The focal point of the present OSTA standards effort is the ADS standards program. There are other ongoing standards efforts in other NASA offices, but the issue of the coordination of all these activities is still an unresolved issue. There have been some talks about the possibility of setting up a coordination committee with representatives from all the NASA offices involved. The issue of the coordination with other standards activities external to NASA is also an open issue. The necessity of such a coordination activity is recognized, and, as a way to solve this problem, there are some plans for a pilot coordinating team with representatives from all interested agencies working together with the pilots. At the present time, most of the standards work is strictly internal.

A question was raised as to whether the overall NASA standards efforts should capitalize on the packet telemetry concept and formats. Several comments indicated that the packet format is designed to optimize the transmission of data from the sensor aboard the spacecraft to the data base. It is not clear, at this point, what the distribution of these data is, or even what NASA office would be responsible for answering that question. The packet format may not be the most suitable format for data storage or information interchange between data bases. It was also pointed out that the possibility for a "new generation" packet format is open, if the need arises, and it is the responsibility of groups such as the Panel in this Workshop to recommend such changes if they prove necessary.

Another suggestion made by Dr. Cardenas is that NASA give more attention to commercial teleprocessing monitors, given that they are very closely related to DBMS technology. The data communication networking problem has not yet been addressed adequately by NASA considering its importance for the distribution of the data after the data have been acquired and stored in a data base.

SECTION V

SESSION 3: "WHAT ADDITIONS, ALTERATIONS, OR IMPROVEMENTS MUST BE MADE TO EXISTING SOFTWARE?"

Session 3 opened the second day of the workshop. The topic of this session was twofold: in the first part of the session, those members of the panel who had hands-on experience with commercial DBMS software packages presented their experiences and comments about the performance, problems of implementation, and use of such systems. During the second part of the session, those members who were directly involved in management issues presented their views on what are the major management concerns about the use of DBMS technology.

Because DBMS technology is relatively new, there is often a big difference in the robustness and maturity of commercial DBMS packages. Robustness is a measure of the stability of the DBMS under normal or abnormal operating conditions. Some of the more recently released DBMS packages seem to suffer, in different degrees, from a lack of maturity in regard to problems encountered in the design process of a project, as noted from some experiences presented in this session. These problems range from simple system bugs to disparity between the documentation and the product: the doucmentation described features that have not yet been implemented in the software.

There was a general consensus during the session on management issues that a centralized high-level management function with responsibility over the information resource was necessary. Such a functionary, entitled Data Administrator or Information Resource Manager, would operate at the highest level of management. His responsibility would be the coordination of all planned and existing data base related activities across all NASA centers. In addition, it was agreed that a coherent short- and long-range data systems plan was essential; this plan would end the present unfocused approach of NASA to DBMS technology among the various program offices.

Participants in this session's panel were:

Identification of Major Known Technical Handicaps of Commercial DBMS	Ed Records Elizabeth Martin
Identification of Major Management Concerns for Use of DBMS Technology	Pete Bracken Ted Albert

Ed Records, manager of the Data Records System (DRS) team, explained some of the problems and observations that his group has been accumulating during the implementation of the DRS prototype. They learned the value of the prototype as the means

to prove DBMS technology and as a testbed for experiments with this new technology. Other findings of this effort included the importance of data base control through a data base administator-type function. The group is trying to create such a role at JPL. Mr. Records also explained some of the problems of UNIVAC's QLP (the query language of UNIVAC's DMS 1100 package), the problems with documentation, and the importance of "tuning" the system to stabilize its performance in terms of processing speed.

Based on the PCDBMS/IDBMS team's use of two commercially available DBMS packages (SEED and ORACLE) on a DEC/VAX minicomputer, Elizabeth Martin, from the Goddard Space Flight Center, explained the major limitations of commercially available DBMSs for minicomputers. The two packages tested suffer from lack of maturity. This is due, in part, to the fact that they are new, state-of-the-art systems that have not been fully tested.

It was found that, in a minicomputer environment, the performance of commercial DBMSs suffers from slow access and retrieval times. The higher the degree of indexing used, the slower the loading times of data in the data base are. But increasing the load rates decreases the query rates. It was commented that for large data bases, big businesses generally use big mainframes, and this raised a question on the adequacy of minicomputers for the types of data base applications that are of interest to NASA. Software technology seems to have approached a limit in efficiency, and new hardware developments may be needed to keep up with the new and more demanding data base requirements.

Most information in NASA's data bases has a spatial and time orientation, but most commercial systems do not have any ability to represent spatial relationships or geographic information. Commercial DBMSs also suffer, in general, from a lack of flexibility in that changing the data base usually involves a reoganization and reloading of the data base.

Benchmark testing for SEED and ORACLE will be finished by March, 1981. Preliminary results indicate that, although there are questions about the robustness of both packages, SEED seems to be more reliable, despite its several limitations.

During the discussion period, Dr. Cardenas suggested that NASA improve its visibility in the data-base community and in such activities as conferences and user groups' meetings. If NASA were to make its special needs better known, vendors could then be more responsive to those needs. A related problem is the lack of travel funds available to most NASA centers to attend these kinds of activities.

The second part of this session was dedicated to the major management concerns for the use of DBMS technology. Peter Bracken, Chief of OSTA's Data Systems Branch, expressed the urgent need for a coherent long-range approach to solving the data systems needs within OSTA. A main problem has been the unfocused approach to DBMS technology by NASA's program offices and a lack of overall centralized planning. At present, NASA is in the process of formulating a sensible 5 to 10 year plan in the data systems area, including DBMS research and development. It is important that groups such as the panel of this workshop provide their input during the planning process. We will also need to cooperate in this effort with other government agencies to arrive at compatible or common approaches to data cataloguing and data accessing, and the use of the three ADS pilot systems to test these data sharing concepts. It must also be noted, however, that this type of interagency cooperation has been difficult to attain in the past.

Ted Albert, Data Administrator of the U.S. Geological Survey, described the organization of the data administration function at the USGS. The data administrator of the USGS chairs a permanent coodination committee with members from the USGS divisions. Mr. Albert stressed once more the need for a Data Administrator or Information Resource Manager at the highest level of management, whose responsibility is to administer and manage the data as a resource.

The emphasis upon how the information resource is logically or mathematically described and structured, as opposed to its hardware and software aspects, requires a new perspective and requires additional training in data base concepts. It is also important to write down a final goal for the information system so that all the planning and intermediate design and implementation steps lead without conflicts to that ultimate goal.

Mr. Albert concurred with Dr. Cardenas in the opinion that OSTA should seek more user involvement. He also stressed the importance of basic research in topics such as data structures, and of standards as a management issue.

Dennis Fife, from the National Bureau of Standards (NBS), presented the management concerns of the Application Systems Division of NBS. This group works on standards for the government in the data base/DBMS areas. It cooperates with the American National Standards Institute (ANSI) and has no operational goals of its own. For this reason, it is often difficult at the NBS to maintain user contact and keep up with technological advancements.

Mr. Fife mentioned that the European Economic Community has released a study (Ref. 18) consisting of three different reports

entitled "Database Administration", "DB Maintenance", and "Selection and Evaluation of DBMS".

During the discussion period, Dr. Cardenas indicated that NASA suffers from a man-power shortage in the DBMS area due to an image problem. Its salaries and research activities are not attractive enough to a large number of graduates who can find better working conditions in industry. NASA should take steps to improve its recruiting procedures to attract good computer science and MBA graduates.

There was some discussion about the role of the user in the specification of requirements for a system. At times, it could be argued that the input of the user can only be partially valid because of his possible ignorance of the available technology. Another question related to this is that of the extent and timing of user participation: should the user get involved throughout the specification process, or should he get involved only after the analyst has specified a framework? These and other questions of user involvement in requirements analysis remain open.

At the end of the session, the question of the unavailability of funds for travel was raised. It poses a serious problem that affects all NASA centers, and there is no solution foreseen in the near future. It makes user contact more difficult and reduces the exposure of NASA to external organizations such as user group meetings and conferences. A suggestion was made to consider other alternatives to travel such as teleconferencing and computer conferencing.

SECTION VI

SESSION 4: "WHAT, SPECIFICALLY, IS THE ADBMS TASK ACCOMPLISHING?"

The fourth session dealt exclusively with the Applications Data Base Management System (ADBMS) task. This task is managed by JPL, and, as it was explained in the introduction, it also provided the coordination for this workshop.

The ADBMS task is subdivided into four subtasks that have produced to date three draft documents: Refs. 2, 15, and 16. The fourth subtask will produce a fourth document (Ref. 19) within the first quarter of 1981. All the members of the DBMS Panel received, in advance, these documents, and were asked to review them.

The objective of this session was to review the outputs and the direction of this task.

The session consisted of the following five presentations, followed by a discussion period:

Overview and Methodology	Guy Lohman
Generic Data Management Requirements From Ocean Users	Kofi Apenyo
Assessment of Representative Existing Data Systems	Kofi Apenyo
Existing Standards Relevant to DBMS	Jose Urena
Functional Requirements	Guy Lohman

Guy Lohman, manager of the ADBMS task, explained that the ADBMS's objective is to develop a multimission general-purpose data management system for applications data bases. The approach taken is a systems top-down approach, and it is intended to be an evolved effort, basing the future on the experience gained from the ADS pilots and the other prototypes. The intention is to minimize redundant development of data management software, facilitate data exchange and use, and reduce the impact of changes to hardware and software.

Kofi Apenyo presented the results of Brad Fujimoto's subtask on user requirements for DBMS technology for the oceanic community. At this phase of work, the oceanic community was surveyed and a number of interviews were made, concentrating on scientists at JPL and the Goddard Space Flight Center. In subsequent phases, other disciplines will be surveyed.

Based on these surveys, a series of requirements have been identified in the following areas: data, data documentation and information about data, access and output, data manipulation and services. A user requirements document with the results of these surveys (Ref. 19) will be released in the first quarter of 1981.

The Survey of Representative Scientific Data Systems concentrated upon the study of oceanographic data systems, leaving for a later date the study of other disciplines. The characteristics of the systems surveyed have been summarized in the form of a table according to seven different areas of characterization. The study includes the common characteristics that have been identified in all the systems that were surveyed. The results of this study (Ref. 15) is in draft form.

One of the subtasks of the ADBMS task consists of identifying those applicable standards that should be adopted in the final design of the ADBMS. Jose Urena, from the ADBMS task, explained that in a first phase of the study, a survey of all government, industry, and NASA standards and candidates for a standard was undertaken. In the second phase of the study, these standards will be evaluated for their applicability to the ADBMS. The results of the survey (Ref. 16) are in draft form.

All of the above outputs from the ADBMS subtasks provide an input to the Functional Requirements subtask. Guy Lohman, responsible for this subtask, presented an overview of the first draft of the document (Ref. 2), and explained the methodology used for the completion of the project. The document includes a top-down functional analysis of the functions to be performed by the ADBMS.

A discussion period followed the presentations in which the two different approaches to DBMS design taken by the ADBMS task, and the ADS pilot program were confronted. The ADBMS task takes a top-down approach, soliciting input from the users from the beginning of the design process, and it is an evolutionary effort using the experience learned from the DBMS pilots and prototypes. For this reason it would be premature, at the present time, to proceed with the design and development of the system before enough time has been allowed to evaluate and experiment with the pilot systems. The ADS pilot program's approach is to build a framework system to learn about the technology used and the user's response and reaction, and subsequently and progressively build a system that asymptotically approaches the "ideal system." Inthis approach, the "ideal system" is progressively defined as experiments on the system proceed. During the discussions, it became clear that both approaches are equally valid, and that both efforts should use each other's experience to come up, finally, with an overall better solution to the problem.

Traditionally, NASA has implemented mission-unique data systems. For reasons of economy, the present trend is to develop multimission systems that provide a set of functions common to most missions, and yet provide the necessary flexibility to accommodate mission-unique requirements. This is the idea followed by generalized DBMS such as the ADBMS. The ADBMS task is not oriented, at the present time, to the more general data management problem. It is a worthwhile effort, however, that should be included in the overall End-to-End Information System activities within NASA. This task does not consider real-time, or near-real-time (data-driven) systems. The performance parameters are unknown as yet, but they will be determined later with benchmarks.

The possibility of partitioning the data base, so that only those subsets of data that are called for by the user become part of the DBMS, was suggested. In this way, the DBMS could be greatly unloaded. Partitioning of data bases is helped by the format specification languages and the properties of data independence that DBMS technology provides.

The approach to DBMS software standards taken by the Computer Corporation of America in their work defining a standards architecture for NBS was explained by Dennis Fife of NBS. The approach has two aspects: (1) It will provide a family of DBMS software standards to satisfy a significant portion of the community, and (2) it is a modular approach. The DBMS has been divided into 38 components that cover all the perceived functions of DBMSs. The interfaces between these components will be standardized, and, in this way, vendors could provide add-on components to competing products.

There is a concern with the seemingly unlimited growth rates in which OSTA data are received. However, Dr. Tom Renfrow of JPL pointed out that data quantity is secondary to the information contents of those data and the way in which that information is utilized. In any case, it has been observed that the increased budget for development of data generation systems (such as sensors) is not usually followed by an increase in the budget for the handling of the newly generated data, creating a growing gap from which NASA is presently suffering.

SECTION VII

SESSION 5: "WHAT ARE FUTURE PROBLEMS AND POSSIBILITIES?"

The objectives of this session, on the third day of the workshop, were: (1) to discuss the possibilities and problems of DBMS technology, (2) to explore new technologies that can be foreseen in the future, and (3) to determine what areas of research can be promising and may require further investigation. The results of this session are among the final recommendations of the workshop.

The subjects and participants of this session were:

The Integrated Programs for Aerospace-Vehicle Design (IPAD)	David Lowendorf
Discussion of Technology Trends/Problems	Alfonso Cardenas
The NASA End-to-End Data System (NEEDS) Project	Lee Holcomb
Image Processing in the Total System and DBMS Milieu	Fred Billingsley
High-Level User Languages and Knowledge-Based Systems	Walt Truszkowski

David Lowendorf, representing the IPAD project, explained how NASA started 10 years ago to combine in one effort all of the programs performing engineering analysis and design of aerospace and aircraft vehicles. Mr. Lowendorf described the achitectural approach for a DBMS for this program, and a multischema concept that supports the relational and network data base models under a single family of languages. As an illustration, an example using a portion of the wing of the Space Shuttle was presented. The functional requirements for the system have been completed, and the design phase is presently under way.

Dr. Cardenas presented in this session his views on what are the present trends in data base technology. About the relational organization of DBMSs, Dr. Cardenas pointed out that although it offers a very promising and interesting set of features, and has been received with enthusiasm by a portion of the data base community, today's relational systems have some performance problems that have made the use of the relational model less than widespread. The development of alternative hardware architectures with specialized data base machines and intelligent controllers could solve to a large degree this and other performance problems. The trend at the present time for data base designers is to adopt the CODASYL model, which is in more

widespread use and is being standardized by the American National Standards Institute (ANSI) as the first of a family of DBMS standards.

Some relational systems with an especially interesting set of features are System R, INGRES, and Query-by-Example.

Dr. Cardenas predicted an increasing number of applications for DBMS technology. The trend towards a high-benefit/cost payoff will help generalize the use of DBMSs. In the near future, DBMSs will be accepted as a standard by the data processing community.

More functional capabilities are expected in generalized DBMSs and the trend towards higher level languages will continue.

The field of data communications is closely tied to DBMSs. It is common that the adoption of DBMS technology provokes the advent of data communication (DC) technology. Data Base/Data Communication (DB/DC) systems will become increasingly popular, and this trend will have the effect of increasing the organizational visibility of data base systems.

An important area of research in distributed data base systems is logically integrated but physically distributed data bases. The technology necessary to develop a system with these characteristics is not available today. Another area of research presently under active investigation is the problem of integrating heterogeneous data bases.

Lee Holcomb, from the Office of Aeronautics and Space Technology (OAST), gave a presentation on the NASA End-to-End Data System (NEEDS) Program. NEEDS has been supporting for the past 6 months an internal study of the goals and objectives of the program from an Agency-wide perspective.

Some of the drivers of the NEEDS program are the requirements to facilitate multidisciplinary studies and to improve the quality and understanding of the data.

The NEEDS program intends to respond to the anticipated characteristics of missions during the next decade or two. These characteristics include a growth in the number of orbiters launched and in the data rates (1/2 to 1 gigabit/second from 50 megabits/second in individual instruments) and volumes (growing to 10^{13} bits). Other requirements are a growing interest in real-time control of the instruments, and a requirement for reduced delivery times.

The focus of NEEDS Phase II was the front-end of the End-to-End Information System. NEEDS Phase III intends to address the back-end (archival and distribution) problem. Phase III of the

NEEDS program will start in 1981.

Mr. Holcomb explained the requirements for the program, and identified eight top-priority tasks that are the key areas for NEEDS Phase III:

(1) Standard interfaces and protocols.

(2) Data storage.

(3) Future system concepts.

(4) Data base access and data exchange.

(5) Operations cost reduction (command and control).

(6) On-board fault tolerance/reliability.

(7) High-rate data handling.

(8) High computational speed computer and high-rate data processing.

At the present time, a detailed plan is being prepared for each one of these areas. Mr. Holcomb also requested input from the Panel from a technical basis on the preparation of the plan, and indicated need for the cooperation of his office with the OSTA office in the planning process.

Fred Billingsley, from the Jet Propulsion Laboratory, explained the image processing problem and the way it relates to the total system and DBMS milieu. Some image processing areas in which DBMS technology can be useful are:

(1) Cataloging of images and software.

(2) Annotation of the data.

(3) Retrieval of the images.

(4) Processing using modular systems.

Mr. Billingsley explained that, in the future, the lack of commonality in some image processing areas will prove to be costly and time consuming. These areas include image data formats and conventions, hardware-dependent executive languages, and planning relative to the ultimate user by the agencies involved in producing imagery.

The image processing requirements lead to a set of development needs that Mr. Billingsley identified as:

(1) Increased emphasis on very-large-scale integration research and development for computationally expensive image processing functions.

(2) Fundamental research to understand how partially integrated data sets may be utilized effectively.

(3) Research into digital image data communication, program plan development, new technology developments, algorithm development for data compression, and storage and access technology.

(4) Cost/benefit studies of a multidisciplinary large "Earth resources DBMS" approach versus the individual discipline approach.

Dr. Cardenas pointed out that present data handling systems use the operating system for file organization. This aproach provides a very expensive sequential search and low data independence. There is some research underway at UCLA on alternative ways to speed up this sequential search.

Dr. Guy Lohman gave a short presentation on the status of video disc technology, and explained some of the present performance characteristics and specifications that suggest a very promising future for this new type of storage technology.

NASA, in cooperation with an Artifical Intelligence Group at the University of Maryland, is conducting research on knowledge-based systems. Walt Truszkowski, from the Goddard Space Flight Center, explained that the objective of this research activity is to design, implement, and demonstrate a proof-of-concept system for real-time information representation, storage, retrieval, and manipulation based on the "frames" concept. An experimental system is being implemented, and a limited proof-of-concept system is scheduled for demonstration for the last quarter of 1981.

SECTION VIII

SESSION 6: "WHAT HAVE WE DECIDED?"

The objective of the last session of the workshop was to summarize the results of the three days of meetings and to agree on a set of recommendations that the panel of the workshop would issue as input to the planning process of the OSTA Data Systems Program.

The session consisted of a discussion by all members of the Panel on a set of proposals for results and recommendations proposed by the chairman of the workshop, Dr. Guy Lohman.

The list of results and recommendations that the Panel agreed upon appears in Sections I and II.

REFERENCES

1. Data Management and Computations Issues and Recommendations. National Academy of Sciences, National Research Council, Washington, D.C., September 1980. Draft 7.

2. Lohman, G. M., Functional Requirements for an Applications Data Base Management System Draft. Jet Propulsion Laboratory, Pasadena, Calif., November 1980.

3. NEEDS System Team, NASA End-to-End Data System (NEEDS) System Concept. Office of Aeronautics and Space Technology, Washington, D.C. Contact: Mr. John Sos, Code 560, NASA/Goddard Space Flight Center, Greenbelt, Maryland, 20771.

4. OAST Program Plan for the NEEDS Program, Phase II. Goddard Space Flight Center, Greenbelt, Maryland, November 1978.

5. Brown, W. J., and Johnson, J. A., Oceanic Pilot System Functional Requirements. Report No. 715-63. Jet Propulsion Laboratory, Pasadena, Calif., February 25, 1981. (JPL internal document.)

6. Kutch, T., and Sakamoto, R., Survey of Federal, National, and International Standards Applicable to the NASA Applications Data Service. Report No. WP-80W00970. The MITRE Corporation, Washington D.C., December 26, 1980.

7. Candidate NASA Data Sets Applicable to the Climate Program. Goddard Space Flight Center, Greenbelt, Maryland, October 1979.

8. User Requirements for a NASA Climate Data Base Management System, prepared by OAO Corp., Beltsville, Maryland. Goddard Space Flight Center, Greenbelt, Maryland, October 1979.

9. NASA Pilot Climate Data Base Catalog, preliminary, prepared by OAO Corp., Beltsville, Maryland. Report No. OAO/TR-81/0010, Goddard Space Flight Center, Greenbelt Maryland, January 1981.

10. ADP Feasibility Study for Host Computer System for the Pilot Climate Data Base Management System (PCDBMS). Goddard Space Flight Center, Greenbelt, Maryland, May 1980.

11. Gary, P., Posey, K., Durachka, R., and Abilock, J., NEEDS Integrated Data Base Management System Functional Requirements. Goddard Space Flight Center, Greenbelt, Maryland, March 1980.

12. Evaluation of Data Base Management Systems for the NERDS IDBMS Demonstration. Goddard Space Flight Center, Greenbelt, Maryland, May 1980.

13. NERDS DBMS Data Paths and Performance Parameters. Goddard Space Flight Center, Greenbelt, Maryland, Sepember 1980.

14. Van Wie, P., Fisdel, D., and Howell, D., "A Transportable Executive System for Use With Remote Sensing Applications Software". Goddard Space Flight Center, Greenbelt, Maryland. Presented at the 1980 Machine Processing of Remotely Sensed Data Symposium, March, 1980.

15. Apenyo, K., Survey of Representative Scientific Data Base Systems. Draft. Jet Propulsion Laboratory, Pasadena, Calif., November 1980.

16. Ureña, J. L., Survey of Standards Applicable to a Data Base Management System. Draft. Jet Propulsion Laboratory, Pasadena, Calif., November 1980.

17. Data Base Management Systems Panel, Second Workshop Summary, Publication 80-50, G. M. Lohman, Editor. Jet Propulsion Laboratory, Pasadena, Calif., November 1, 1980.

18. Experience of DBMS Usage in Europe, European Economic Community. Order from: Publications Department of the National Computing Center Ltd., Oxford Rd., Manchester, MI 7ED, United Kingdom.

19. Fujimoto, B., User Requirements for NASA Data Base Management Systems, Part 1: Oceanographic Discipline. Draft. Jet Propulsion Laboratory, Pasadena, Calif., February 23, 1981.

APPENDIX

NASA/OSTA DBMS WORKSHOP ATTENDEES[1]

Dr. Ted Albert	United States Geological Survey
Dr. Kofi Apenyo	Jet Propulsion Laboratory
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