NASA TECHNICAL
MEMORANDUM

NASA TM X-58028
June 1969

A DATA MANAGEMENT SYSTEM FOR A SPACE BASE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

NASA TM X-58028

A DATA MANAGEMENT SYSTEM FOR A SPACE BASE

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Houston, Texas
June 1969

ABSTRACT

A 50-man space base will use an onboard computerized data management system to provide the many types of information necessary to increase the efficiency of space base operations personnel and scientific personnel. The required advancements in technological state of the art can be accomplished in time for a subset of the data management system to be used for prelaunch ground checkout if a continuous, coordinated development effort is started immediately.

PREFACE

This paper presents an overview of the relationship of a data management system to a permanent space facility. Detail has been avoided purposely when the detail would not assist in the understanding of the interrelation of the parts of the data management system or in the understanding of the interaction between the data management system and the activity of the space facility. By this means, the authors hope to make more lucid a frame of reference from which the detailed development and design of a data management system can be pursued.

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SUMMARY

NASA is studying a 50-man earth-orbiting space base designed to serve as a flexible scientific laboratory with a life of 10 years. This highly autonomous space base will utilize an onboard computerized data management system to provide the many different categories of information and system control necessary to minimize the man-hours required to operate the space base and to expedite the processing of experiment data. Subsets of the data management system can also be used to aid in ground check-out of the space base and of the logistics vehicle preceding launch. The state-of-the-art advancements required to implement the data management system can be effected for the post-1975 period if a continuous in-house development effort is started immediately.

INTRODUCTION

The concept of a space vehicle as a permanent "base" in space implies self-containment. A self-contained base can provide such things as operations control, system surveillance, process control, and any reference information necessary for usual activities of the base. A system that performs such functions will be called a data management system (DMS). The purpose of this paper is to define such a system for a self-contained space facility that will be referred to as a space base (SB). In addition, subsets of the DMS will be indicated that could be utilized on a space station (SS) and a logistics vehicle, where an SS is the interim buildup to an SB. Further, the relationship of the DMS to ground checkout will be shown and also the relationship to buildup and expansion of the SS and the SB.

The definition of the DMS in this paper will be approached by means of "information categories." The information categories are a result of the SS/SB activity and will be discussed in the section entitled "Space Base Environment." A system for the implementation of each information category will be defined separately and then these systems will be consolidated into one system that satisfies the requirements of all the information categories simultaneously. The systems definition and integration will take place in the sections entitled "Information Categories and Methods of Implementation" and "An Integrated Data Management System," respectively.

Ground checkout and in-orbit buildup are two important phases in the development of an SS/SB. In the section entitled "Ground Test and Space Station/Space Base Buildup," the function of the DMS during these two phases will be discussed.

Unlike most other systems in the SS/SB, the DMS must interface with every other system and will be involved in most activities of the SS/SB. Any change in the systems or the activity of the SS/SB is likely to effect a change in the DMS. Therefore, certain unique constraints must be imposed on the approach for developing a DMS. This subject will be discussed in the section entitled "An Approach to Developing the Data Management System."

The technology is inadequate at present to satisfy certain operational requirements of a DMS in particular and an SB in general. These inadequacies will be discussed in the section entitled "Items Requiring Advancement in the State of the Art."

SPACE BASE ENVIRONMENT

In this paper, the SB will be viewed as a facility in space. The facility will be manned by 50 or more people whose work specialties appear under the classifications of operations, maintenance, or science. The structure will be modular to permit launch in pieces and assembly in orbit. The initial operations will be in a zero-g condition, but eventually the facility will be spun to provide artificial g. The interim buildup to a more autonomous SB will be referred to as an SS.

For the DMS definition, SB information has been organized into the following nine categories.

1. Operations and status
2. Base log
3. Logistic
4. Process control
5. Ground
6. Scientific
7. Maintenance
8. Biomedical
9. Library

The categories overlap somewhat, and several categories could be considered under one heading. However, the authors believe that the system definition is clearer when these categories are used. Each information category will be discussed separately and in more detail in the section entitled "Information Categories and Methods of Implementation."

The SB will be a continually evolving facility, a theme that seems to pervade references 1 and 2. Initial efforts will involve determining to what use the SB can be put. Since the reason for existence of the DMS is derived from the activities in which the SB is involved, the DMS must be able to accommodate itself to a constantly changing environment; in particular, a change in the types and an increase in the number of tasks that must be performed. It follows that the DMS is also evolving and is in no way static. Therefore, the DMS must be designed with the idea not that it might change, but that it will change.

INFORMATION CATEGORIES AND METHODS OF IMPLEMENTATION

One method of defining a DMS consists of identifying and explaining the functional categories of information to be accommodated by the system. In this section, all categories of information will be identified that seem to be desirable in an SB of the class described previously. The power of the required DMS will be further communicated by describing the hypothetical, independent systems that would be required to accommodate each information category separately. These hypothetical systems then will be integrated into an overall DMS in the section entitled "An Integrated Data Management System."

The integrated DMS to be proposed in the section entitled "An Integrated Data Management System" will consist of the following functional units and systems.

1. Multiprocessor computer system
2. Distributed-data-acquisition and control system
3. Central control display
4. Medical control and display
5. Diagnostic control and display
6. Memory buffer unit
7. Fixed- and portable-equipment adapter units
8. Remote control-and-display units
9. Biomedical-preprocessing and fluids-analysis units
10. Mass memory
11. Bulk data storage
12. Reference library storage unit

The function of each of the preceding units will be explained in the section entitled "Information Categories and Methods of Implementation" with the exception of the multiprocessor computer system which will be discussed in the section entitled "An Integrated Data Management System."

Space base information seems to convey maximum meaning when organized in the following categories.

1. Operations and status
2. Base log
3. Logistic
4. Process control
5. Ground interface
6. Scientific
7. Station maintenance and verification
8. Biomedical
9. Library reference

Operations and Status Information (Category 1)

The functions performed by the DMS in which operations and status information are used are intended to minimize the number of personnel needed to operate the base and to maximize the base and personnel safety. As an aid to the crew in daily operations, the DMS automatically will monitor SB status and, in addition, will provide computer control of operations that require complex sequencing of events. The DMS will enhance the safety of the base and the personnel by warning operations personnel of hazardous operating conditions and by automatically initiating safing operations during conditions of extreme emergency.

The type of functions in operations that would be controlled by the DMS could include the following.

1. Docking and rendezvous operations
2. Fuel transfer
3. Manually initiated safing operations
4. Vectoring or control of external vehicle and satellite maneuvers, or both

Activities performed by the DMS that are involved with base status information could include the following tasks.

1. System surveillance (caution and warning)

2. Automatic emergency safing operations

3. Scheduling and planning of utilization of base personnel and facility resources

The clarity and the speed of the communication between the crew and the DMS is of extreme importance in this category of information; therefore, the operations personnel should be highly trained in the overall functions of the facility in general and the DMS in particular. The control and display units that are used to transfer information in this category must be designed to handle information unique to specific subsystems and experiments while retaining the flexibility required to adapt to changing control and display requirements.

The majority of the control and display of operations and status information will be performed in a centralized area referred to in this paper as central control (CC). Selected scientific or subsystem information could be routed to remote terminals if future studies indicate a requirement for this feature. Care must be taken to ensure that much planning and evaluation is performed preceding any solidification of the CC functions.

A hypothetical system designed to accommodate the operations and status information will be described in the following paragraphs.

Data acquisition. - The DMS will acquire the data that are used for operation and status information in a preconditioned digital form as multiplexed digital data and pulse-code-modulation (PCM) data by utilizing a centralized data acquisition system. This type of system is known as a "distributed system" and makes use of miniature scanning and digitizing units that are built into each subsystem or experiment. These units transmit all data in digital form on a single two-wire cable communication bus to the memory buffer unit that is part of the centralized multiprocessor computer system. All data except data that are entered manually through the control-and-display units (CADU) can then be acquired as required by each computer processor unit (CPU) from the memory buffer unit. This method eliminates the heavy, inflexible, and electrically noisy cable bundles that are associated with previous data acquisition techniques. Reliability and weight problems that are associated with large cable connectors are also eliminated.

Stimulus and control. - Implementation of information in category 1 will utilize miniature signal generators and control switches built in the SB subsystem on a basis of one for each stimuli point. The on/off control of these control units by the multiprocessor will be implemented by using the memory buffer unit and the same type of distributed-system techniques that are used for data acquisition. This implementation will again prevent the problems that are associated with large cable bundles.

Memory buffer unit. - All continuously scanned parameters are stored in the memory buffer unit, and all stimulus parameters are controlled by this unit. Any CPU or computer peripheral must acquire data from the unit and must initiate stimuli actions through the unit. Every CPU may check the status of stimuli actions by communication with the memory buffer unit.

The memory buffer unit can perform out-of-limit checks on selected critical parameters and can notify the multiprocessor when out-of-limit conditions occur. The memory buffer unit also applies data compression processing when desired on any or all measurement data and stores significantly changed parameter values in the bulk data storage unit with an identification code.

Control and display units. - Several CADU will be required in the CC. Full alphanumeric keyboards and reusable hard-copy capacity should be provided in selected units.

Bulk data storage units. - Large amounts of data and information will be produced on the SB during normal operations. This material must be stored onboard for later retrieval by the computer system. Early mission requirements can be met by high-density magnetic tape units if necessary. Later mission requirements will require an implementation method that offers much higher density, read-out rates, and reliability. These methods could utilize concepts such as laser storage on plastic tape or photographic storage (ref. 3). If required, backlogs of data could be shipped to the ground on the logistic vehicle for backup filing and storage operations.

Mass memory. - The SB DMS will require some form of mass memory for computer reloading and test storage. Two types of mass memory that are required are a read-only, highly nondestructive program-storage mass memory, and a read/write, online, fast-access mass memory.

The read-only, nondestructive mass memory will be used for permanent storage of all supervisory and alternate-load computer programs. The data recorded in this memory must be recorded in a highly nondestructive medium. Certain characteristics that are associated with this type of mass memory have been defined. The following characteristics are required.

1. A capacity of one billion data bits

2. A dual read-out access system with the data comparison capability to achieve a highly reliable read-out of data

3. A capability of high read-out rate

4. A pluggable and replaceable memory

No memory systems available at this time meet the preceding requirements. With a concentrated development and design effort, such a memory system could be available by 1973 (ref. 3).

The read/write, rapid-access mass memory will be used as a working temporary storage of data called from mass memory and for storage of programs and test data generated on board the SB. Major characteristics of this type of mass memory are read/write capacity, rapid online access, and long life with high-usage rate. The mass memory could use small data storage drums or thin-film random access memories.

In addition to the units identified previously, the following functional units will be required.

1. CPU

2. Memory module

3. Input/output (I/O) units

A high-level block diagram of the hypothetical system designed to handle operations and status information is shown in figure 1.

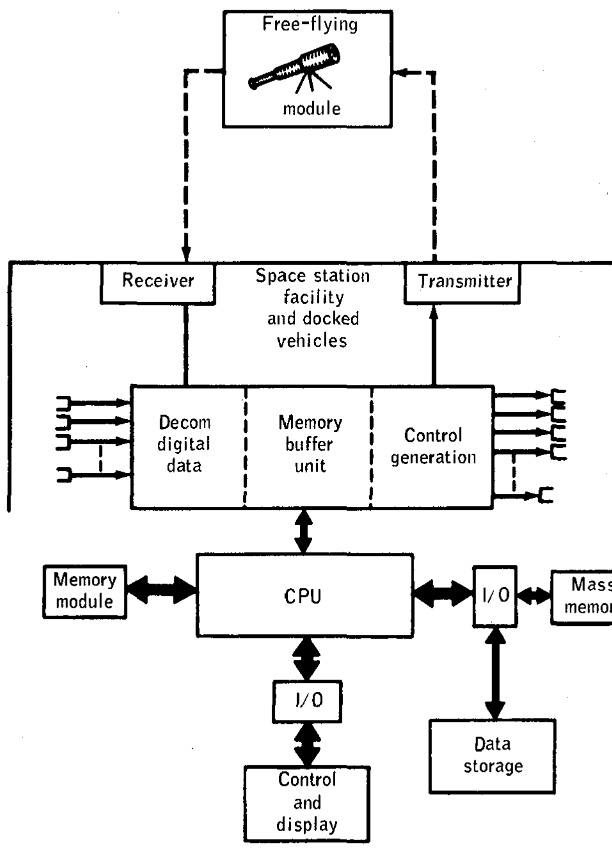

Figure 1. - Operations and status function.

Base Log Information (Category 2)

Base log information will provide a permanent historical record of operational events and operational conditions aboard the SB for use by the operations personnel and ground personnel. The data required for this information would be supplied by the DMS and by the SB personnel. Data supplied by the DMS could result in a record of significant operational events and selected SB conditions such as the following types.

1. Results of preventive maintenance test performed

2. Base condition (9 o'clock and all is well)

Remarks and data provided by SB personnel will be used to provide a log of docking operations and of performance and status of manual experiments. Editing and permanent filing operations upon all types of log records will be performed by the DMS at set intervals; for example, at the end of each workshift. The hardware functions necessary to implement base log information are inherent in the implementation of category 1 (fig. 1).

Logistic Information (Category 3)

The logistic information is intended as an aid to SB personnel in monitoring and refurbishing consumables, limited life components, and spares. The data required for this information would be supplied by the DMS and by the SB personnel. Data provided by the DMS could result in information of the following types.

1. The operations and status system would provide the data necessary to maintain a record of the utilization rate of oxygen or other expendables. The logistic function would use these data to project refurbishment requirements.

2. The DMS would maintain a record of the number and the duration of each reaction control jet firing. The logistic information provided to crew personnel would indicate a need for replacement of a jet before a degradation in performance occurs.

Data provided by SB personnel would consist of general logistic-oriented remarks and facts concerning manually utilized consumables. Examples of this type of consumables are food, clothing, and spares.

Editing and permanent filing operations upon all types of logistics information will be performed by the DMS at set intervals. Display of logistic information will occur as requested by the station operations personnel. The hardware functions necessary to implement logistic information are inherent in the implementation of category 1 (fig. 1).

Process Control Information (Category 4)

In some complicated systems that require optimization of many feedback paths, rapid response, and a high degree of flexibility, a programable digital computer is used for control operations in place of analog-type controls. This type of operation performs online, real-time control of the basic operations of a process or a system and is commonly called process control.

The information required to support this type of operation has a minimum amount of interface with station personnel. This personnel interface is limited primarily to communication of the operational modes and the data output of the system. Some examples of SB subsystems that could possibly utilize computerized process control are nuclear-power modules, environmental control systems, manufacturing and experiment systems, and stabilization and control.

The control and display functions may be remote or located in the CC. These functions may be subfunctions of the operation and status display system or may be uniquely tailored to a particular subsystem or experiment. The hardware functions necessary to implement process control information are inherent in the implementation of category 4.

Ground Information (Category 5)

A ground rule for the design of the SB is to minimize reliance on the ground for real-time in-orbit support for command operations and data analysis. However, ground support such as the following will be needed.

1. Relatively low-rate transmission of selectable status information could be made to any accessible ground station.

2. A high-rate bulk-data dump of permanently filed onboard data could be made to selected ground stations for backup storage. Logistics flights also could be used to advantage in this area.

3. An up-data link should also be provided.

The hardware functions necessary to implement ground information are inherent in the implementation of category 1 (fig. 1).

Scientific Information (Category 6)

Scientific information will be derived from two different onboard sources. One type of information will result as the output of onboard and free-flying experiments. This information should contain only a minimum amount of experiment status and operational data. The second type of information will be the results of scientific calculations performed by onboard scientific personnel using the computing power provided by the DMS.

Scientific experiments data that are in electrical form can be processed online, and the results can be displayed or stored. Special interest should be given to all scientific information to ensure that preprocessor/preconditioners derive the maximum amount of information from each parameter before digitizing. This can greatly reduce the computing functions required of the DMS computer system. Data that do not require constant observation by scientific personnel can be acquired, tagged, and stored for later use. Plotting or display of the stored data can be performed when requested, or the data can be subjected to further data reduction.

Experiments often result in pictorial data in nonvideo form such as hard-copy photographs. Except for cataloging operations, this type of data cannot be processed by the DMS when in the hard-copy photographic form. The photographs will be developed and printed on board for analysis by onboard personnel. Copies of the photographs then could be shipped to the ground for microfilming and could be returned by logistic vehicle to the base for storage.

As experience gained through manual analysis indicates what comprises meaningful information in the different types of photographs, it should be possible to convert on board any additional photographs to a form such as video data that are suitable for analysis by the DMS computers or some other pattern recognition device. This type of analysis could include image enhancement operations or pattern identification. However, the hardware required to convert photographs to video or electrical form is not identified as part of the DMS now.

The second type of information in this category is the result of off-line or real-time performing of scientific mathematical calculations by use of scientific programing languages such as FORTRAN. Methods must be provided to enable the scientific personnel to input analysis requirements efficiently and to acquire results in a form suited to postanalysis review and evaluation. The computation power required for the implementation of scientific information is inherent in the implementation of category 1. Special displays with reusable hard-copy output may be required.

Maintenance Information (Category 7)

Maintenance functions to be performed in an SB will be preventive maintenance, fault isolation, repair operations, and verification and reverification operations. Preventive maintenance operations will consist of various levels of subsystem tests performed by the DMS under the control of highly trained subsystem specialists. The overall purpose of the tests will be to reduce system downtime and to provide an in-depth confidence in the ability of the base systems to operate as required.

Fault isolation tests will be initiated when a malfunction is detected by the DMS or the base personnel. These tests could be performed as high-level, end-to-end tests or as detail subsystem unit tests. Fault isolation tests will be performed with the malfunctioning system or unit in an offline configuration when possible. The DMS will control and evaluate the fault isolation tests to the highest degree feasible.

Repair operations will be accomplished by replacing malfunctioning units on the pluggable-module level and repairing faulty modules on board or on the ground. Onboard repair of faulty modules will be performed in a special repair facility by using a computer-controlled equipment adapter unit (EAU). System verification operations will be designed to establish the operational status of base systems after modifications, additions, or repairs have been made.

The DMS will be used to implement the preceding base maintenance functions in order to reduce the number of maintenance personnel on board. The implementation will be effected by automating as many of the maintenance and record-keeping functions as possible.

The DMS will also use, to the greatest extent possible, the intuitive knowledge of each subsystem that is possessed by the men responsible for the original design and the development of each SB subsystem and subsystem module. The use of this knowledge will be effected by providing the DMS with preprogramed diagnostic tests written by the subsystem designer with the use of a specially designed test language. New tests can be written on board as required.

A hypothetical system designed to accommodate the operations and status information will be described in the following paragraphs.

Data acquisition and control. - The data acquisition and the control functions of the memory buffer unit, as defined in the implementation of category 1, will be used by the maintenance system primarily for online preventive maintenance tests and high-level fault isolation tests. In addition, fixed and portable EAU that provide, under computer control, stimulus generation and signal conditioning when connected to a faulty module or subsystem will be used for detail fault isolation and reverification tests. The portable EAU will be controlled by the DMS computer system through a single 2-wire serial communication bus. This bus leads to connection plugs throughout the SB and to EAU built into selected nonaccessible subsystems such as the nuclear-power modules. The computer also has parallel communication with an EAU that is permanently built into the repair facility and that will be used to diagnose faulty electronic modules that may be transported to this area.

Display. - One or more specialized CADU will be required for maintenance information. In addition to the units identified previously, the following units will be required.

1. CPU
2. Memory module
3. I/O units
4. Mass memory units
5. Bulk data storage unit

A high-level block diagram of the hypothetical system designed to handle maintenance information is shown in figure 2.

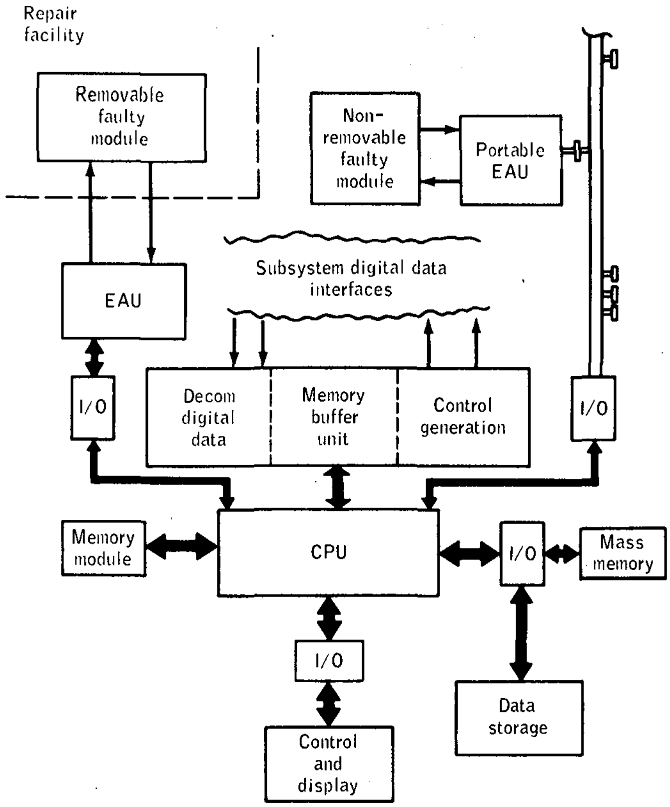

Figure 2. - Maintenance function.

Biomedical Information (Category 8)

The information in category 8 will be generated in the process of providing medical checkup services for base personnel, providing clinical services, and performing extensive, continuing biomedical experiments. This category of information also involves providing the editing and filing operations necessary to provide complete medical records for base personnel, all medical experiment control and data filing, and, to the greatest extent possible, correlation of data acquired through medical diagnostic examination of personnel.

A hypothetical system designed to accommodate the operations and status information will be described in the following paragraphs. Special modules designed for acquiring and conditioning the data required to formulate biomedical information could include biomedical preprocessor units and a fluids-analysis unit.

Biomed preprocessor. - All data acquired through patient instrumentation will be preprocessed and preconditioned as required to derive maximum information from each parameter. As an example, parameters such as heart rate and breath rate will be preprocessed in this unit and will be made available to the memory buffer unit in digital format. Other data will be entered manually through the control keyboard.

However, the computer will perform diagnostic correlations between various parameters, and will analyze complex waveforms as required in a real-time or online basis.

Fluids-analysis unit. - The fluids-analysis unit would perform chemical analysis of body fluids under manual control or computer control or both, and would provide outputs of the results in a digital form.

Control and display. - A special biomedical CADU will be required. In addition to the units identified previously, the following units will be required.

1. CPU
2. Memory module
3. I/O units
4. Mass memory units
5. Bulk data storage units

A high-level block diagram of the hypothetical system designed to handle biomedical information is shown in figure 3.

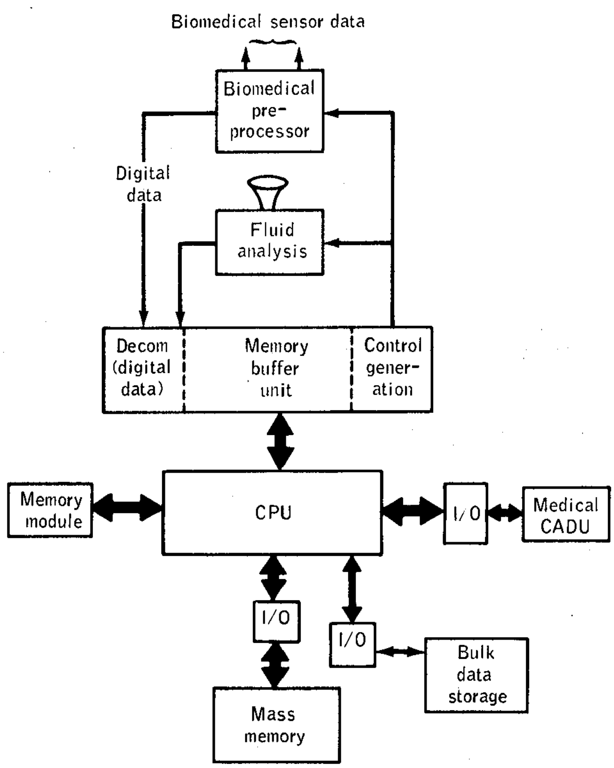

Figure 3. - Biomedical functions.

Reference Information (Category 9)

The SB personnel will include highly skilled scientific specialists performing advanced experimentation and research. The level of effort will require extensive support in the form of a library of highly diversified reference information and efficient methods of performing search, location, and display operations on this information. A desirable goal would be the storage of a complete library of technical, educational, and entertainment materials. Microfilm storage and filing techniques are being developed by various worldwide governmental and industry agencies that will be perfected in the decade of the 1970's. The primary efforts required by NASA would consist of coordination and acquisition efforts between the appropriate organizations and the development of a suitable bulk storage device. These efforts could also provide technological and educational spin-offs of vast importance to mankind well before the SB is operational.

A hypothetical system designed to accommodate the operations and status information will be described in the following paragraphs.

Library storage unit. - A storage device with the ability to contain and to read out all types of pictorial information is required. The storage method utilized by this device need not have the extremely high reliability required for computer loads but should have an extremely long life and, because of the large volume of data, fast scan and read-out methods. Several approaches show promise for implementation of this function in the mid 1970's. Two examples are recording of information on plastic tape with a high-power laser and storing information in salt crystals by use of holographic techniques.

Remote control-and-display units. - Control-and-display units will be provided for simultaneous viewing of library information by base personnel. The CADU may be located permanently or may be acquired from a supply area and plugged into remote outlets in areas such as personnel living quarters.

Alternate storage and viewing techniques. - An alternate approach for interim stations with limited simultaneous viewing requirements could consist of a centralized microfilmed information file with portable viewers. Card catalog searches would still be performed by the computer system.

In addition to the units identified previously, the following units will be required.

1. CPU

2. Memory module

3. I/O unit

4. Mass memory

A high-level block diagram of the hypothetical system designed to handle reference information is shown in figure 4.

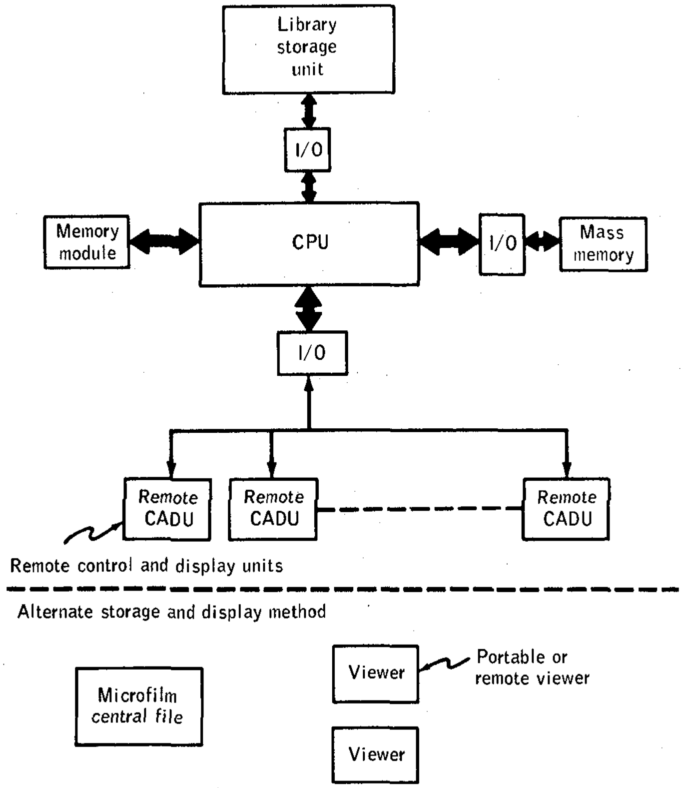

Figure 4. - Library function.

AN INTEGRATED DATA MANAGEMENT SYSTEM

Hypothetical independent system configurations with the functional capacity to handle the various SB information categories were presented in the section entitled "Information Categories and Methods of Implementation." These system configurations will be integrated now into a total DMS that utilizes a centralized multiprocessor computer system. The background and the origins of this type of computer system are described briefly.

Computer systems that utilize different system configurations have been developed for centralized multicomputer complexes. These systems seek to achieve online system backup, reconfiguration flexibility, and system expansion capability by use of independent computers interconnected by different types of switching and communication systems. This type of multicomputer system is generally known as a "centralized" system and has several identifiable characteristics.

1. All computers in the system have access to the same measurement and control parameters through a shared data acquisition system.

2. Any computer is capable of functioning in place of another in the event of malfunction or computer overload.

3. All computers may use a common set of peripherals and control consoles.

The actual physical location of the computer and the computer peripheral units depends solely upon the capability of the electronic technology to provide reliable, efficient, interunit communication and switching that is fast enough to meet overall system operating requirements.

Multicomputer complexes are now in the process of evolving into multiprocessor computing systems that use various forms of crossbar switching and common-bus interconnection techniques to allow a significantly higher degree of online communication among the individual CPU, memory modules, and I/O units. The multiprocessor concept also allows a significant reduction in the number of basic computer submodules (CPU, I/O, and mass memory) because I/O units, memory modules, and CPU are now available for common use to be reconfigured as required to implement each computing function.

Other problems associated with previous computer systems, such as fault isolation, repair, and providing spares, are alleviated as a result of having the pluggable module size reduced from the level of a complete computer to the CPU, memory-unit, and I/O-unit level. Utilizing this lower level of pluggable modularity also satisfies the basic requirement that the DMS be designed for easy expansion and technological updating.

A system representation of the DMS multiprocessor computer system is shown in figure 5. The specific form of interunit communication has not been defined yet.

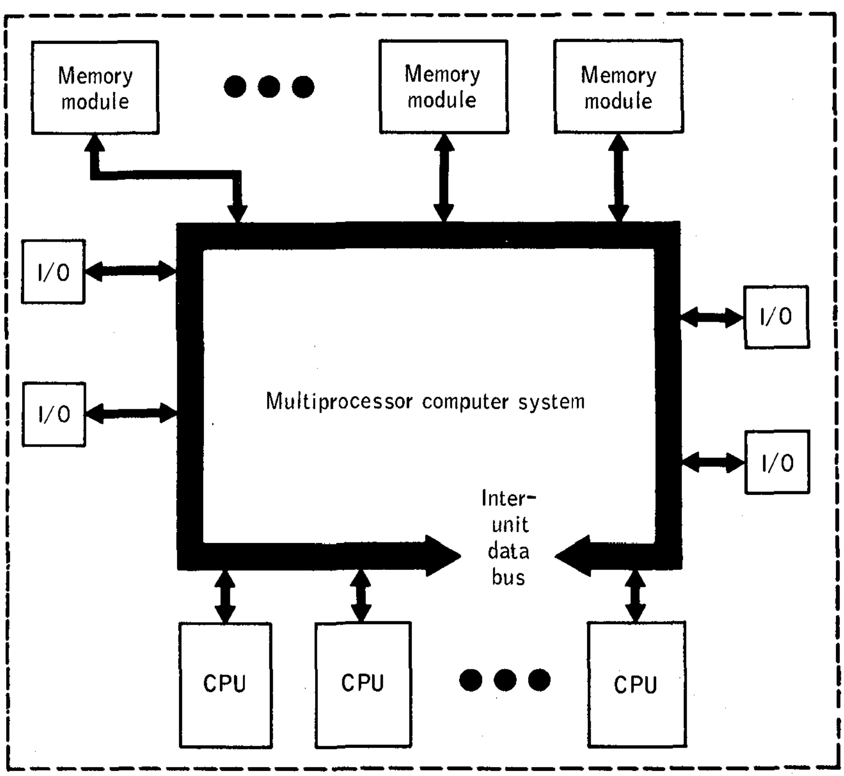

Figure 5. - Multiprocessor computer system.

Figures 6 to 9 present the DMS configurations required to implement the information categories identified in the section entitled "Information Categories and Methods of Implementation." Each figure will indicate the additional hardware required to integrate each new category identified and the hardware identified in previous figures. As a result, the last figure in the series (fig. 9) will also represent the total integrated DMS as proposed for the SB.

Figure 6 contains the hardware modules necessary to provide the following information categories.

1. Operation and status

2. Base log

3. Logistic

4. Process control

5. Ground

6. Scientific

Figure 7 identifies the hardware modules necessary to provide the information category of maintenance. Figure 8 identifies the hardware modules necessary to provide the biomedical category. Figure 9 identifies the hardware modules necessary to provide the library category.

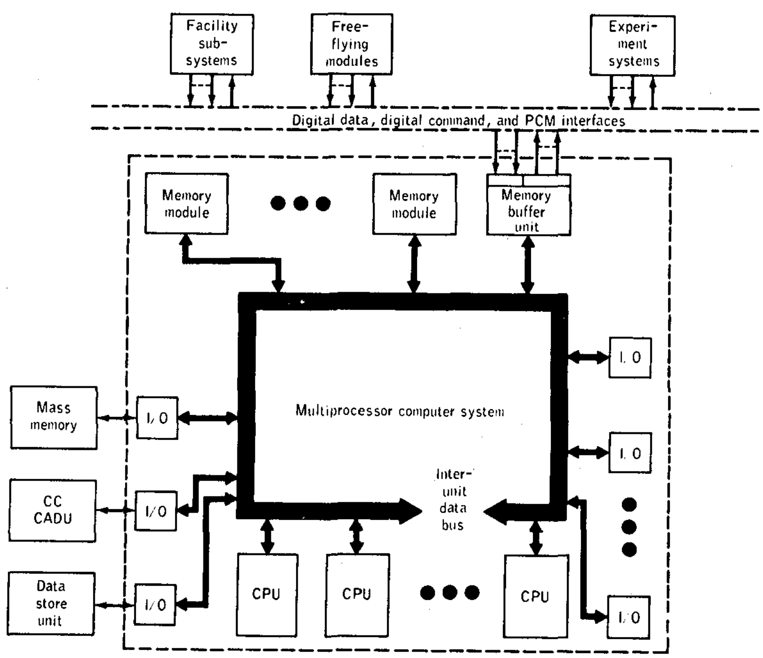

Figure 6. - Operations and status information.

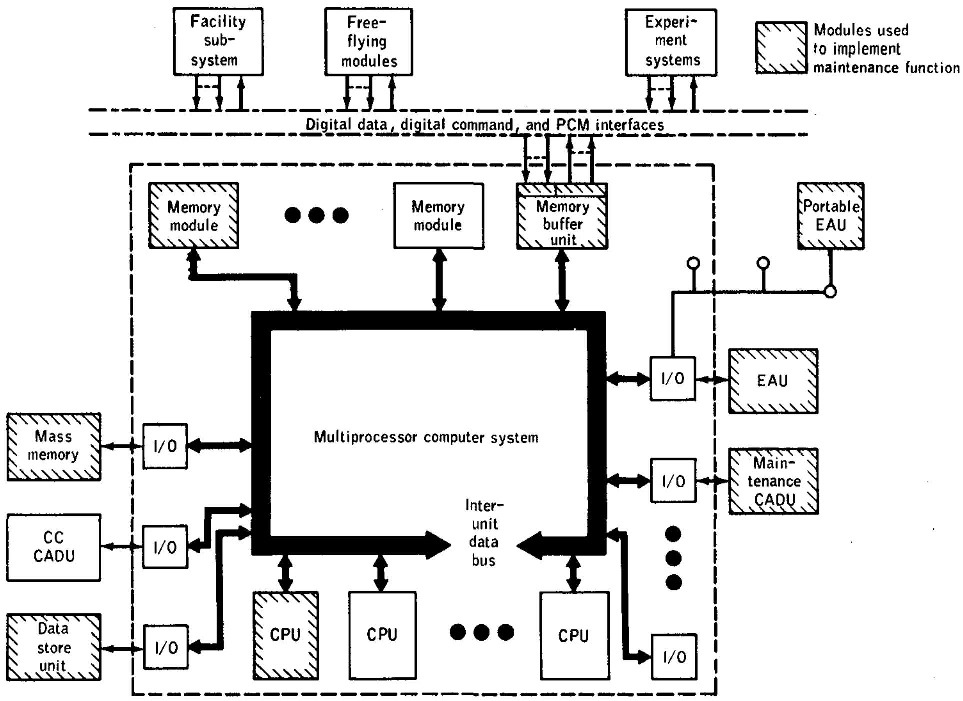

Figure 7. - Maintenance information.

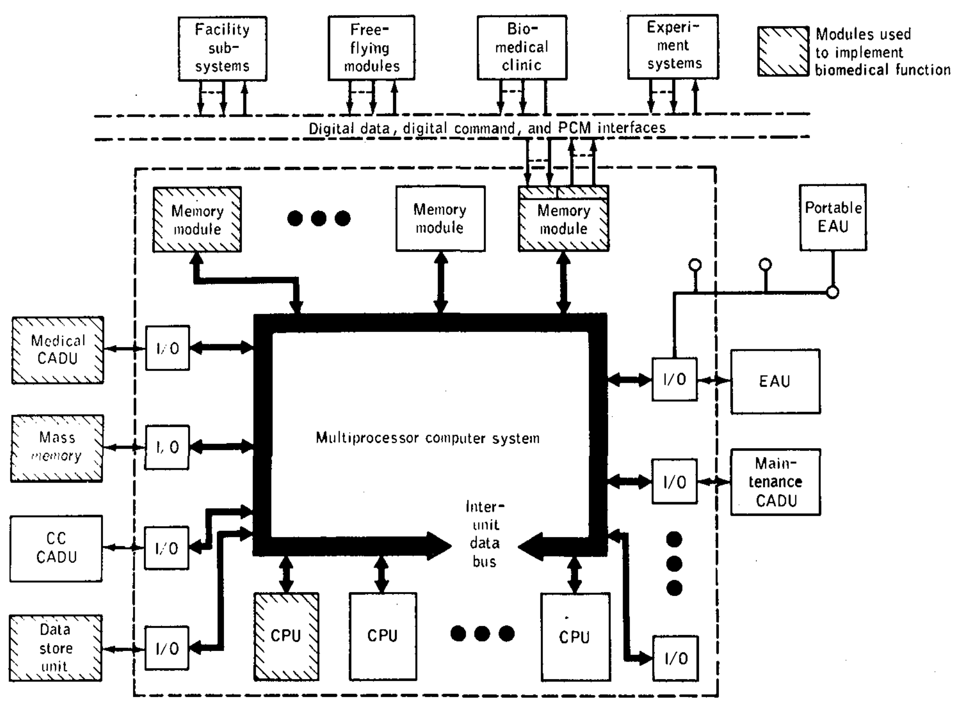

Figure 8. - Biomedical information.

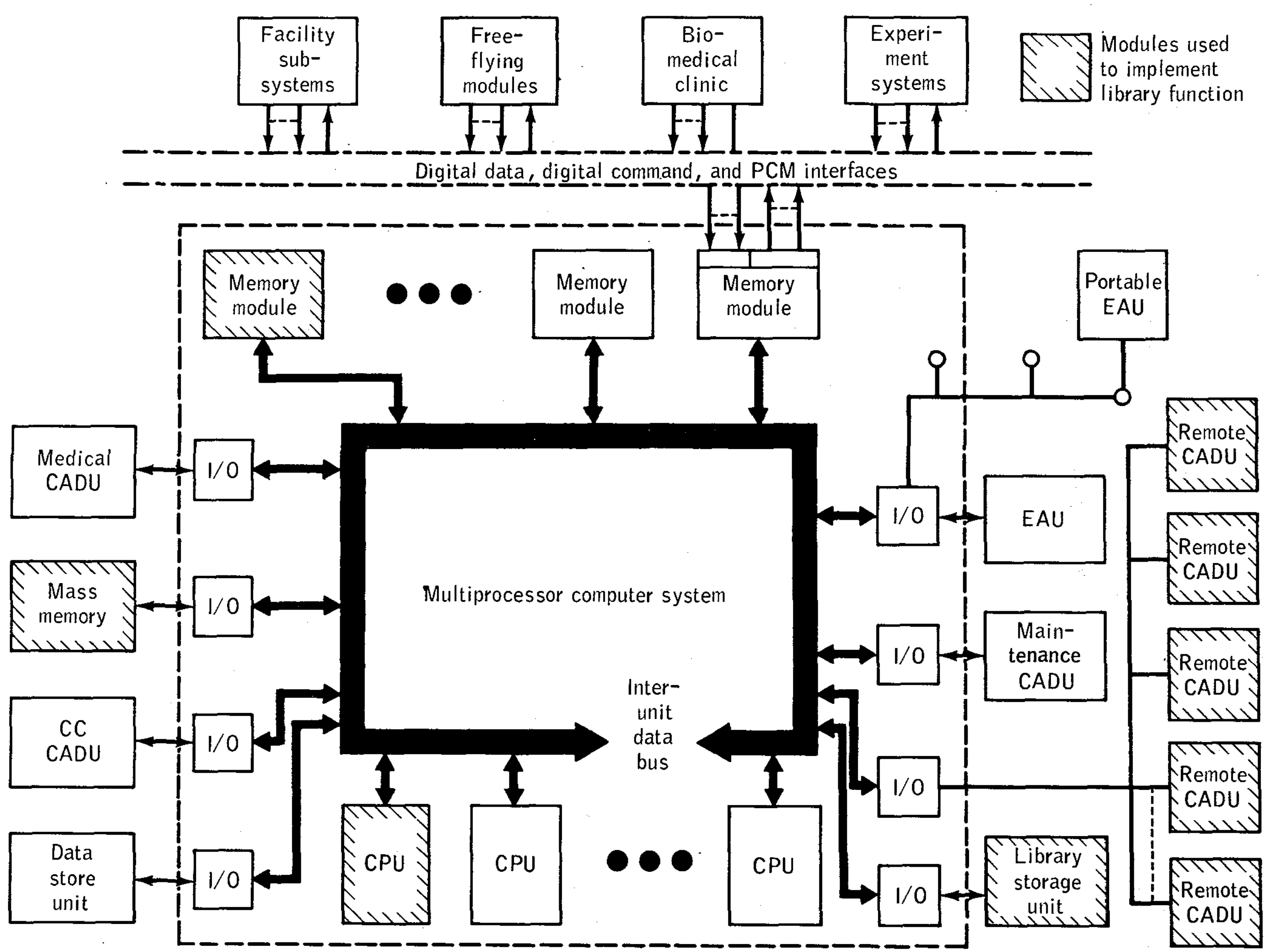

Figure 9. - Library information

GROUND TEST AND SPACE STATION/SPACE BASE BUILDUP

Subsets of the DMS that could be utilized in the SB buildup will be considered, starting with the final configuration of the DMS defined by the section entitled "An Integrated Data Management System." The first launch will constitute the SS. A typical subset of the DMS for the first launch would be sufficient to handle the following categories of information.

1. Operations and status
2. Maintenance
3. Logistics records
4. Base log

During the initial period of SS operation, the performance of the DMS will be evaluated, and changes to the system will be phased in as conditions arise that warrant the change. As was concluded in the section entitled "Space Base Environment," the SS/SB environment is changing continually; hence, a change is expected in the DMS as well. The development system on the ground will also be evolving continually and hopefully will stay well ahead of the needs of the system in flight.

The next two launches will include the zero-g hub and two nuclear-power modules. If the systems in the modules of the two launches need the support of a subset of the DMS until the modules are mated with the SS, it is possible to have portable subsets of the DMS that would be installed in each of the modules. Once the modules are mated to the SS, the DMS subsets together with the subset on the SS can be consolidated. If the new subsets are not needed in the SS, the subsets can be carried down by a logistics vehicle and recycled for another launch. It may be that a DMS subset is not needed to support a module before mating with the SS but is needed for ground checkout. Then, the subset can fly with the module and can be recycled or removed before launch or can be connected externally.

The DMS can be used in ground checkout from factory buildup to launch. Among other things, the implementation of such information categories as operations and status, process control, and base maintenance will accomplish this function in space. It follows, then, that all equipment necessary to acquire data, process data, and output information required for a checkout decision will be built into the SS/SB for use in space. There is no reason to assume that this equipment cannot be used in ground checkout.

This reasoning can be carried a little farther to say something about how the DMS might help to conduct the ground checkout. The DMS subset would be the first system activated on a module when the factory buildup of each module is considered. As more systems are placed in the module, the DMS could be used to ensure the integrity of the systems. When a ground station is used during checkout (in the factory or on the pad), the ground station could do the coordination between the module and whatever ground support equipment is needed. In this case, the ground station would act as a remote control and display for the DMS and would initiate sequences in the DMS that would be used later in space.

AN APPROACH TO DEVELOPING THE DATA MANAGEMENT SYSTEM

When the DMS is designed, it must be designed to perform a set of functions that will not be explicitly defined at the time. In addition, the DMS must be designed to be changed and expanded easily. Further, the change and the expansion will not stop at launch but will continue throughout the foreseeable life of the SS/SB. This continuation follows since, as stated in the section entitled "Space Base Environment," the SS/SB is evolving continually, and the DMS functions are reflections of the SS/SB activity. The adverse affect on the operational competence of the DMS that is fostered by lack of explicit functional definition must be minimized.

Two things can be done to minimize the effect of the conditions defined in the previous paragraph. First, the design concept can encompass such ideas as modularity of both hardware and software carried to whatever level is practical at the time and reflecting the idea that the system will change. Second, the development approach must provide a matrix that encourages the DMS to continue to evolve for an indefinite period, even after the DMS is being used in space.

A permanent DMS development system is essential to continuing evolution of the DMS. In addition, the operation of the DMS is affected to a large extent by the systems to which the DMS is interfaced. Therefore, suitable equipment to simulate the responses of these systems is necessary. Together, the DMS development system and the simulation equipment will be adequate to evaluate and demonstrate new ideas that affect the DMS.

A continuing effort of this type can be done best in-house. Since uninterrupted evolution is essential, only an in-house effort can ensure a permanent facility in which to house a permanent DMS development system and the associated simulation equipment. Totally contained and defined pieces of the system can be contracted without affecting the continuity of the development.

ITEMS REQUIRING ADVANCES IN THE STATE OF THE ART

Present technology is inadequate to satisfy certain DMS requirements. A discussion of these inadequacies follows.

The preceding sections of this paper indicate that the DMS will be intimately involved in the everyday life of everyone in the SS/SB. For this reason, each individual in the SS/SB will have occasion to interface often with the DMS. Since a computer is the heart of the DMS, a simple way must be found for a man to communicate with a computer. Similarly, extracting meaningful concise information from vast amounts of data and keeping the operator meaningfully informed during continuous operations will be necessary.

As the SB becomes increasingly more self-sufficient, the need to generate computer programs in space will increase. The programing will consist of minor changes at first but gradually will become more comprehensive. At present, programs are written on coding sheets and then are transferred to bulky card decks. If nothing else, the availability of storage space for coding sheets and punched cards might be questioned. Therefore, techniques must be found for generating computer programs in space.

Closely related to the need for generating computer programs in space is the need to find efficient techniques for verifying computer programs and test sequences on the ground and in space. Some elements of a solution to generating computer programs in space may simplify finding efficient techniques for verifying computer programs and test sequences on the ground and in space.

Since the DMS will undergo a continual change as a result of the demands of the SS/SB, a computer system must be evolved that is easily changeable and easily expandable. Along with the computer system, an easily expandable mass memory device and, in contradistinction to the mass memory device, a bulk storage device must be developed. Also, easily changeable software capable of efficiently using the computer system, the mass memory device, and the bulk storage device must be developed.

Finally, techniques for automated bench testing must be developed. These techniques will be dependent on such things as the amount of self-test that will be built into each box and on the effectiveness and level of module replacement.

The following list is a result of the preceding discussion. The listed items require advances in the state of the art.

1. A simple way for a man to communicate with a computer

2. Techniques for keeping the operator meaningfully informed during continuous operations

3. Extracting meaningful concise information from vast amounts of data

4. Techniques for generating computer programs in space

5. Efficient techniques for verifying computer programs and test sequences on ground and in space

6. A computer system that is easily changeable and easily expandable

7. Adequate mass memory devices that are easily expandable

8. Bulk storage devices of both read-only (library information) and read/write (data storage) capacity

9. A software system that is easily changeable, easily expandable, and capable of efficiently using the results of items 7 and 8

10. Techniques for automated bench testing

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