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National Aeronautics and Space Administration

Lyndon B Johnson Space Center

Aeronutronic Ford
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Space Information Systems Operation

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Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FOREWORD

This document was prepared by the Space Information Systems Operation of Aeronutronic Ford under Engineering Order Number 001P in compliance with DRL Line Item 2.18.

This Engineering Order was authorized under Part II, of Exhibit A, Statement of Work, Modification Number 155 to Contract NAS 9-1261, Schedule 5.

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SECTION 1

INTRODUCTION

1.1 PURPOSE

This document provides the functional system definition for an on-line high density magnetic tape data storage system that can be implemented in a multi-purpose, multi-host environment, and satisfy the requirements of economical data storage in the range of 2 to 50 billion bytes.

Design assumptions shall be made to provide guidelines where specific requirements do not exist. This document shall be a working document and updated as required.

1.2 CONCEPTS/OBJECTIVES

Market and product surveys have shown that, currently, there are no systems available that meet the requirements identified in the originating statement of work. This document will define a storage device that can be modified or altered to comply with these requirements and shall be implemented as a major component within the on-line mass data storage system.

The device capabilities shall be demonstrated as soon as possible within the development phase of this activity. The mass storage system is to be implemented (minimal configuration) in the Building 12 Central Computational Facility, which shall also serve as the test bed for the storage system.

An analytical model of the mass storage system is to be developed to assist in performance evaluation during the feasibility studies and trade-off analysis.

This activity shall also develop a system capable of accepting a sustained 10 megabit per second data thruput rate from the computer channel interface to the storage system. To accomplish this, a new technology, state-of-the-art device will be investigated for implementation into the data staging and buffering functions. An additional objective is to develop and implement a very low error rate data transfer between the mass storage system and the host computer channel. Methods to provide system error rates in order of 1×10^{-11} bits are to be investigated. System analysis shall include trade-offs concerning redundant recording, error correction codes and component reliability.

1.3 APPLICABLE DOCUMENTS

The following documents provide information related to this document.

A. *On-Line Mass Data Storage Requirements Document*, Space Information Systems Operation, SISO-TN790, June 1975

B. On-Line Mass Data Storage Engineering Order (EO) Number 001P, Amendment Number 1, dated 11 September 1975

C. *Univac 1108 and 1110 Exec.-8 Mass Storage File System Performance Evaluation*, MTR-4586, June 1975

D. *Univac 1108 and 1110 Exec.-8 Mass Storage File Activity Analysis*, MTR-4577, December 1974.

E. JSC-10038, *Mass Storage System Simulation Planning*

F. JSC-10167, *Quadruplex Record/Reproduce Cartridge Storage Equipment Performance Specification*

G. JSC-10039, *Reliability Evaluation of the General Electric BEAMOS Memory*

H. JSC-10040, *Mass Storage System Error Rate Analysis*

SECTION 2

SYSTEM GENERIC REQUIREMENTS

2.1 INTRODUCTION

System definition and design effort shall be directed toward a system capable of satisfying the following generalized requirements.

2.2 STORAGE

A. Storage capacity should be expandable in increments up to 50 billion bytes. As identified in the Section 5 of *On-Line Mass Data Storage Requirements Document*, SISO TN 790, data base users with requirements ranging from 2 to 50 billion bytes are currently unable to avail themselves of an economical on-line mass storage system. The economics of implementing a currently available, minimal capacity trillion bit system precludes utilization for storage requirements in the range of 50 billion bytes and under. The cost of disk systems becomes significant in systems of 2 billion bytes and becomes a serious system determinant as the capacity approaches 3 billion bytes.

A minimal system configuration may be implemented for test purposes but must be expandable at least to the 50 billion byte capability.

B. Storage media should provide for data erasure or modification. The file activity, in an on-line data storage system, exhibits properties similar to direct access storage devices (DASD), such as; read old file, modify, create new file, save new file, and purge old files. These functions demand a storage media capable of supporting continuous record, read, and erase activities.

It is not a mandatory requirement that the system be capable of "update in place"; however, the media should be reusable as old files are deleted, edited, and rewritten in another area or on another device.

Storage media such as films, thermo plastics, metalized film strips, etc., that have read only or read mostly characteristics do not satisfy these requirements.

C. Storage media should be modular with 10^8 bytes per module (comparable capacities of large disk packs) in order to provide a faster access time (to a randomly selected file) than is normally exhibited by standard CCT's and existing video tape devices. It was deemed a necessary requirement that the recording media be partitional into small modules that can be positioned over the read/write heads faster than the normal search time of the lengthy serial devices.

The module storage capacity must be comparable to that of presently available large disk pack capacities, (IBM 3330 types) in the order of 100 megabytes. This is necessary to enable disk dump and load routines to place all data on one module rather than interrupting the routines to reposition one or more modules of smaller capacity.

D. Storage media should be self-contained and show no evidence of performance degradation when stored for long periods of time in a computer room environment. The storage media should be enclosed within its own modular container such as exists for the cartridge and disk pack systems.

Degradation of performance is interpreted as loss of signal strength and excessive error rates when the data is retrieved after being stored (without sustaining power or refresh requirements) in a normal computer room environment for a period comparable to existing CCT storage requirements.

The module should allow normal operator handling, i.e, loading, unloading and storing of the module without damage to the recorded information or impairment of the operation of the device itself.

E. Storage modules should be replaceable from a library and interchangeable among like systems. As the size of the data base increases beyond that of the capacity of the on-line system, it is a necessary requirement that the storage modules be placed in an operational library and that indexing, cataloging, and statusing functions be performed to provide a minimum response time to retrieval requests.

One objection to some of the present high density recorders is incompatibility between systems such that data cannot be reliably reproduced when read on a different device. A requirement for this system is that data recorded within a storage module be transportable to another "like device" to be reproduced with the same fidelity as observed on the originating device.

The "like device" may be a redundant component of the original system or it may be located within a totally different computer center.

2.3 RECORDING/REPRODUCING

A. The recorder/reproducer should be capable, under computer direction, of selecting a specific module from a group of modules and of self-loading or self-threading the selected module.

To eliminate the necessity of operator interventions, it is required that the device be capable of automatic operations to record and retrieve data files located on any of the "on-line" storage modules.

As identified in the *On-Line Mass Storage Requirements Document*, three of the four presently available trillion bit storage systems are implemented with mechanical means to automatically select and load their data storage modules. Compared to human intervention, the increased access speed, efficiency, and cost saving constitute the major justification for these requirements.

B. The recorder/reproducer should be mechanically reliable and proven by field usage. Time and budget constraints of the project do not allow a normal research and development period for a mechanical device to be developed and tested for implementation within this system. Past experience dictates that untested and unproven devices will cause serious impacts to development costs and schedules. Therefore, it is a requirement that only field proven mechanical subsystems be implemented for this task.

It is not a requirement that the unit be originally developed as a computer peripheral device. Some devices presently being used in the video and broadcast industry may be implemented for this purpose. However, a prospective vendor must provide a demonstration of a digital adaptation of the video device prior to final device selection.

2.4 USER ACCESS

The system should accommodate multiple user access to the stored data and also prevent unauthorized or accidental access to, and modification of, secure files. The basic concept of the system configuration is that one or two of the host computers will supply most of the data stored within the data base and the other users will access the data for computations and analysis.

Host computers must have the ability to do dump and roll out routines as well as load and roll backs, therefore, all hosts must have full store/recall capabilities.

The multi-host configuration establishes the requirements for a Master File Directory function and full control over file activity and current status.

In addition to the current methods of maintaining data security and integrity, it is desirable that some means of mechanical or physical security be devised. An example would be the present write lockout ring used on CCT's. This would prevent inadvertent or accidental loss of master data files.

2.5 DATA RECORDS/FILES

A. The data should be stored in an organized manner using a record size compatible with the system buffering and data transfer capabilities. The data system organization, file size, and record size shall be determined as a result of the system trade studies concerning data flow, interface data rates, capabilities of the staging subsystem, and characteristics of the selected recording device.

The physical data files should be sized such that one file, or an integer multiple of files, may be stored in a module. The logical record sizes will be a function of the host computer input/output buffer and the channel data transfer rates.

B. It is anticipated that future systems shall be implemented with the capability to retrieve data records or portions of files such that: total data volumes, or files need not be transferred into the requesting host system.

This requirement does not stipulate that the record be updated in place (rewritten without damage to adjacent records). The requirement intent is to lessen the peak load demands on the input/output channels between the host computers and the storage system by minimizing the amount of data to be transferred.

2.6 DATA DUPLICATION

The system should provide a data module or file copy/duplicate and verify capability. For those applications where secure data files demand a backup copy be generated prior to, or simultaneous with a file access, the storage system must be capable of copying the file onto another module and verifying that the data copied is correct.

This requirement specifies a system to be implemented with dual read/write capabilities. It is also a requirement that the storage system be capable of performing the copy/verify functions without the direct control of the host computer programs.

The storage system must provide sufficient data buffering, transfer rate timing, error detection and correction, and control/support software to effectively perform the copy/duplicate requirements.

2.7 DEMAND/RESPONSE

The system should accommodate demand/response transfer rates up to 10 megabits per second. The anticipated increase in the amount of imagery and telemetry data, and the increased capabilities of satellite recorders and network communications make it a necessary requirement that this system be capable of handling data through-put rates up to 10 megabits per second.

The system should be capable of supporting these rates for file sizes which may vary from a few thousand bytes up to several billion bytes and encompass multiple recording cartridges. However, during the peak data rate transfer, only one host system must be supported. Responses to other host computer requests shall be minimal until these high speed, near real-time demands have been met.

Satisfaction of these requirements may necessitate the implementation of multiple speed read/write units with speed changes operable under program control. The requirements will also levy demands upon the size and transfer rates of the data staging/ buffering subsystem.

2.8 ERROR RATE

It is a design goal that the system error rate should be in the order of 10^{-11}, corrected. It is desired that data quality and integrity be improved such that the overall system error rate does not exceed one error in 10^{11} bits transferred.

Several methods of error rate improvement may be implemented to meet this requirement. Redundant recording, polynomial encoding, and retransmission of data block are acceptable methods of error rate improvement. Methods for both random and burst error control should be considered, where necessary, for overall system improvement.

System analysis and trade-off studies will determine the achievable error rates when considering data through-put rates, buffering, and system overhead requirements.

2.9 DATA STAGING

A new technology, state-of-the-art device could be considered to implement the system data staging function, such as, one of the new high speed semiconductor memory devices in the place of the present disk or drum system as the data staging function. The data staging device will be capable of meeting the access and transfer rates demanded by the 10 megabit per second system through-put requirements.

The more likely candidates for this function at present are the beam addressed metal-oxide semiconductor (BEAMOS) memories under development at General Electric Research Center and at Microbit Corporation in Lexington, Connecticut. Bubble memories may also be considered for implementation in this application, however, the available memory capacity and system costs may make the selection prohibitive.

It is not a requirement that this device be available in the system test bed configuration, but design considerations should allow for later implementation.

2.10 SELF TEST

The system should provide a self test feature to verify functional operation. This requirement does not necessitate an automatic or in-line testing capability, however, these may be considered highly desirable features. Self testing implies that the tests be conducted in an off-line mode with respect to the host computer system.

Where possible a test method should be implemented to determine the proper operation of each of the basic functions. All controls and displays necessary for performance validation should be included in the system maintenance features.

Some feature should be included to continuously monitor and indicate the system error rate. Both the read/write errors on tape and the transmission errors between subsystems are candidate functions to monitor for an indication of system performance.

2.11 AVAILABILITY

The mass storage system shall meet the availability requirements of a multi-host data processing environment. This environment is normally characterized by 24-hour per day operation and could result in almost continuous useage of the mass storage system.

To meet these design goals, only proven products shall be selected as elements of the mass storage system. Where possible, off-the-shelf products with verifiable records of reliability in manufacture and operation shall be selected as system elements. Reconfiguration capability shall also be used to meet the availability goals. Units of storage medium shall be removable and can be redundant. Multiple storage devices may be configurable for fail-over or backup operations.

Systems trade-off studies and configuration analysis shall determine the extent of component redundancy, bypass procedures, and allowable system degradation, necessary to meet the availability requirements to support a particular user application.

2.12 MODES OF OPERATION

The mass storage system shall be capable of supporting basically two different modes of operation. The first mode, and the easiest to support, is that of multi-host access to the mass storage system in a batch processing environment. The second mode is that of a single host system performing high speed continuous (uninterruptable) data processing. System simulations and configuration analysis shall determine the extent of support to be provided for each of these modes of operations.

In the batch mode, the processing generally can be stopped at any point in the process and continued with little or no loss of data, or processing time. This ability to stop in mid process or to recover from a system failure during operation exhibits less demands upon component redundancy and system availability requirements. Also in batch mode, data processing operations can be tailored to meet thru-put and data rate requirements that prevent data losses due to over-runs, retransmission, or physical equipment limitations.

The high speed continuous mode demands 100 percent system availability during the support periods. This availability levies heavier requirements on the levels of component redundancy, fail-over procedures, and allowable system degradation. In addition, these support requirements directly affect equipment sizing and capabilities. Data transfer buffers, staging subsystem partitions, and storage device read/write speeds must be tailored to meet the thru-put and data rate requirements.

SECTION 3

SYSTEM LEVEL FUNCTIONAL DESCRIPTION

The On-line Mass Storage System shall provide a high density storage media for various user applications operating in a multi-host environment. As such, it shall provide all functions necessary for communications and data transfer between the media and the host system. Also included are supplemental functions that enhance the storage systems operations. Modularity of the mass data system shall be a prime consideration for implementation and design, in order to ensure minimum impact due to adding or deleting components and to permit a variety of available configurations.

The following discussion lists those functions that should be inherent in a mass storage system. There is no distinction of functions in terms of what may be implemented for a prototype configuration or limited set of equipment. In addition, there is no attempt to classify functions in terms of mandatory, desirable, or optional.

3.1 ON-LINE MASS STORAGE SYSTEM FUNCTIONS

The following paragraphs indicate the candidate applications contemplated for the On-line Mass Storage Systems. Each application reflects an existing or planned need for fast access or archive storage. Each configuration reflects a multi-host environment, processing subsystem (hardware and software), and the application (generally software only). Each function requires certain operational capabilities and characteristics of a mass data storage system, exclusive of the requirements levied on the design of the on-line mass storage system.

System functions are outlined for the following candidate applications:

- IDSD Central Computing Facility
- Shuttle Data Reduction Center
- Earth Resources Pattern Recognition Processing (LACIE).

Also included is a description of a typical application of the MSS to an Earth Resources Multispectral Scanner Image Processing System.

It is not intended that a mass storage system be capable of simultaneously supporting the identified functions, but that each configuration may have a storage system unique to that application.

3.1.1 IDSD Central Computing Facility. A multi-file, fast-access storage capability supports the processing environment of the UNIVAC 1108/1110 series processor subsystem. File maintenance utilities of the EXEC 8 software (SECURE) are used to provide backup file copies, delete files, and monitor the allocation and use of disk storage to support this environment. For example, when allocated space for a data file exceeds 90 percent use, a potential overflow condition exists. This utility selects the smallest, least used file currently stored on disk for transfer to an auxiliary storage medium (tape).

In this process the mass storage medium replaces the auxiliary medium in both storage extent and device allocation. The mass storage medium provides volume storage to permit transfer of multi-tape files. The mass storage system must respond similar to the device allocated by the current operation or respond to a logical request for file transfer (mass storage interface handler).

A second process to be supported is the transfer of files from mass storage to configure the host disk subsystem for the intended processing environment. In this case, as in the prior case, data is transferred from the mass storage system to the host then to the disk subsystem .

A third process to be supported is the creation of backup files. Newly created files or modified files shall require the creation of a new backup (or copy) file. This process could be supported by the mass storage system or obviated by its reliability.

Utilities within the SECURE to be supported by the mass storage system are as follows:

- SAVE. All SECURE files are copied to backup tapes on a weekly or daily basis. Weekly SAVE copies are maintained for 3 weeks before, daily SAVE copies are maintained for a week before release or deletion. Up to 60 tapes are SAVE'd weekly. From 15 to 20 percent of the SECURE files are SAVE'd daily.

- VERIFY. Any SAVE operation is verified and a checksum is performed on the block number.

- ROLOUT. When additional disk storage space is needed, space from one of the catalogued files on disk is released. If the tape is a newly created tape or modified tape without a backup, a copy is made to tape.

- ROLBAK. If a catalogue file is requested that is available on the system, a request is issued for the latest backup copy and the file is loaded.

- LOAD ALL. All catalogued files on disk have been cleared and the files must be reloaded to disk.

Characteristics of the functional capabilities shall include the following:

A. The logical transaction to be performed is the transfer of a labeled or named file of information to/from mass storage.

B. The modification to the EXEC 8 software must be minimal, i.e., the mass storage device should be defined to the system as a sequential device such as a mag tape handler. However, mass storage system will probably require an additional interface handler.

C. Transfer of a file of information shall be disk to host then to mass storage. File size can be a million bytes or greater. The mass storage system shall match the physical block sizes required to message process a file of data to the host system. Communications mode of operation, via the host channel, shall be a high speed, burst mode of operation rather than a multiplex mode of operation.

D. Channel characteristics and channel operations of the host shall be emulated by the On-Line Mass Storage System interface. Operations internal for file management shall be transparent to the host.

E. Multiple host systems shall be capable of creating a file, retrieving a file, or replacing a file. Mass storage shall be addressable to the file level, as opposed to a continuous sequential search. Mass storage shall be manipulatable to the addressable units of storage within the mass storage system. Addressable units of storage shall be mapped/allocated directly by the mass storage system or in multiples of the storage unit to maximize the effective usage of mass storage for all applications and minimize the file management required to map the storage throughout the mass storage system.

F. Data transfer rates to the host shall be host dependent, up to the current design goal of 10 million bits per second.

3.1.2 Shuttle Data Reduction Center. Shuttle Data Reduction Center functions are based on three phases of operations:

A. Transfer of FM/PCM data from a multi-track tape source to an FM processor for information processing and transfer to a volume storage device. Once initiated, the process is continuous until the data is exhausted from the instrumentation tape recorder. The volume processed could be as great as 200×10^6 bytes.

B. Information is retrieved from volume storage by the Shuttle Information Extraction System (SIES), processed, and returned to volume storage. This process is to be block-oriented to eliminate transfer of the total file to the system prior to initiation of processing activities.

C. Information processed to volume storage by SIES is subjected to an interactive analysis by a user in the graphics terminal subsystem. This process may require concurrent multi-file access.

Functional capabilities required by each operation phase are defined in the following paragraphs.

3.1.2.1 Shuttle Data Reduction Facility.

- FM Telemetry Processor may require the mass storage system to interface to a MODCOMP IV, PDP11/45, or INTERDATA computer subsystem.

- The application is telemetry data reduction. Processing could be continuous until the multi-track instrumentation tape is read completely. The resulting information could establish a file extending over more than one tape cartridge. File length is variable and may be composed of multiple block transfers of 2000-3000 byte blocks (this is an order of size, not of variability in size).

- File extent is not known when the process is initiated, therefore, an overflow capability is required for staging functions as well as mass storage allocation and use (overflow to more than one cartridge).

3.1.2.2 SIES

- Demand/response data transfer to a large general purpose processor shall be supported for block transfer sizes from 2000- to 10,000-bytes.

- Channel interfaces to CYBER, PDP10, or IBM equipments may be required. Simultaneous support to more than one interface may be required.

- Processing activities will be initiated on the data retrieved from mass storage and returned to mass storage when completed, i.e., 5000 bytes in, 5000 processed bytes out. These applications resemble standard data center processing activities.

- Files may be updated/modified in this respect: Information within a file can be accessed on boundaries established by the addressable units of storage with the storage area allocated to the file. The capability to update in place within the file of data at each addressable unit of the storage system shall not be required.

3.1.2.3 Graphics Terminal Subsystem.

- In this configuration, a processor subsystem with minimal information management software shall retrieve data from mass storage for user analysis.

- Concurrent multi-file access is a distinct possibility.

- Block sizes are of the order 1000-5000 bytes.

- Data transfer rates to the terminal subsystem are not defined.

3.1.3 Earth Resources Pattern Recognition Processing (LACIE). This function performs several activities that may be supportable by the MSS. Imagery information derived by LANDSAT shall be archived, manipulated, and processed. (See Figure 3-1.) The characteristics of the functional capabilities required to support these operations are as follows:

A. Storage of several megabytes of data for periods of 3 months or more. Significant formatting and reformatting requirements exist for the application.

B. Storage of up to 42 ITEL 7330 disk-equivalents of data.

C. Retrieval of 10,000 byte files by the Goodyear STARAN computer and the return of a 20,000-byte message after processing.

D. Capability to acquire data from five separate files (5 biophases of LANDSAT data), or an alternate capability to consolidate the files into a single file.

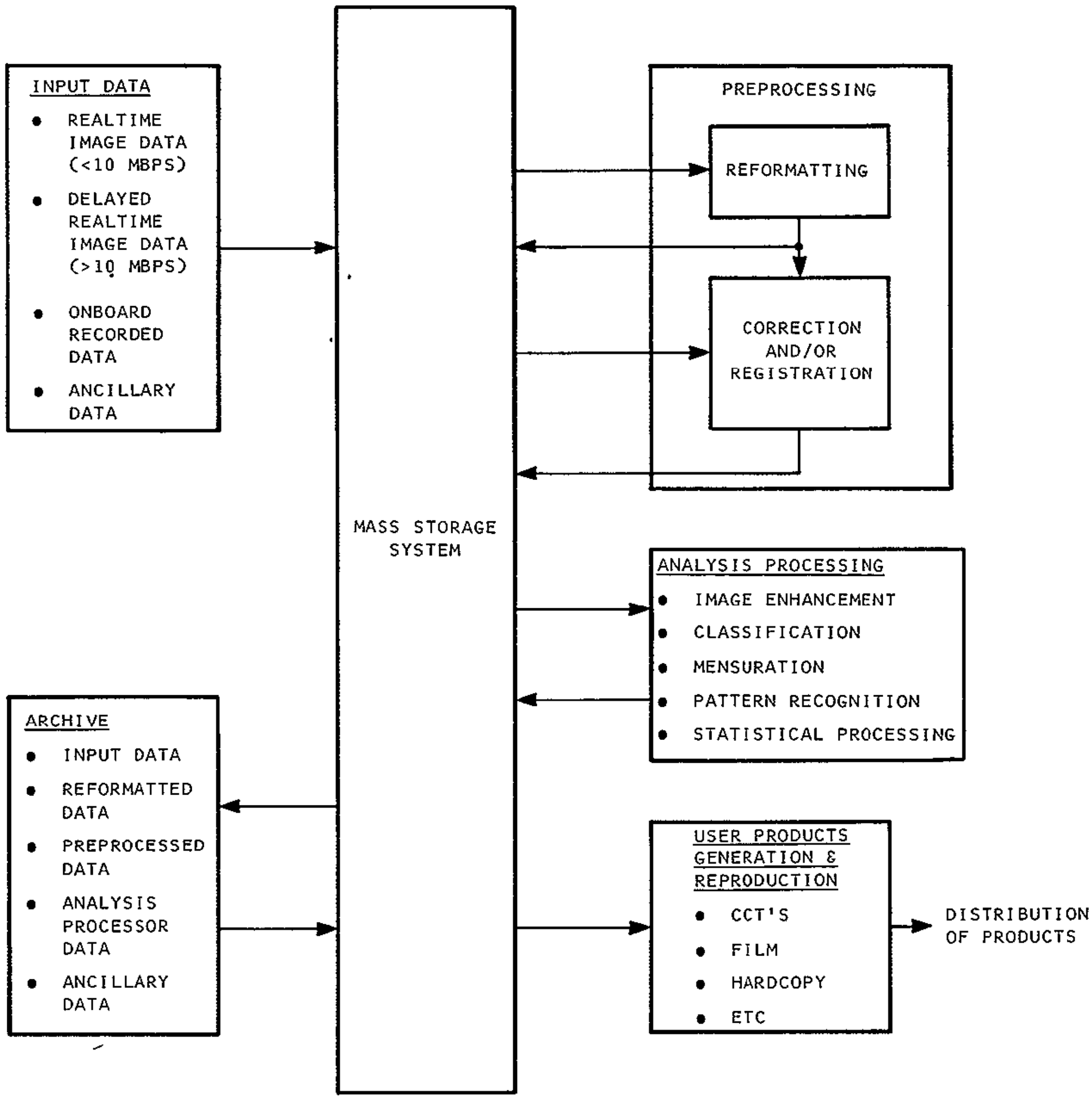

Figure 3-1 Proposed Mass Storage for Earth Resources Processing, Functional Block Diagram

E. File transfer to the array processor on a demand/response basis. Block sizes for this transfer are not defined.

F. Principal data to be stored includes: satellite data frames characterized by the frame, pixel, and scan line designations. User analysis requirements may reflect the need to select data by frame number, scan line, and pixel.

3.1.4 Earth Resources Multispectral Scanner Image Processing (Typical). The processing functions that are performed on multispectral scanner data can typically be categorized as Preprocessing or Analysis Processing. Examples of preprocessing functions are reformatting, data correction such as radiometric and geometric, and temporal registration. Analysis processing includes such functions as image enhancement, classification, mensuration, pattern recognition, and statistical processing.

An On-Line Mass Storage System can be utilized to record data at various points throughout the preprocessing and analysis processing cycles. Example usages are input data storage, reformatted data storage, preprocessor output storage, analysis processor output storage, and ancillary data storage. Characteristics of these usages are:

A. Input Data Storage

- Data recorded directly from downlink if experiment data rate is less than 10 Mb/s.
- For experiment data rates greater than 10 Mb/s, the data is first recorded at the downlink rate on a high rate recorder then replayed into the mass storage system.
- Onboard recorded data is replayed into the mass storage system.
- Data input to the mass storage system (MSS) will serve as the source data for the preprocessor.
- Data input shall be stored in the downlink format, which is blocked in major and minor frames.

- Major frame size could vary from $5x10^4$ to $2x10^8$ bytes.
- Minor frame size could vary from 20 to $1.5x10^4$ Bytes.
- Input data volume could vary from $2x10^9$ to $2x10^{11}$ bytes/day for LANDSAT data or approximately $2x10^{10}$ Bytes/mission for SHUTTLE data.
- Data must be retrieved from the MSS in addressable major frame blocks for reformatting purposes.
- Input data contained in the MSS will be archived as a permanent record of the input experiment data.
- Copies of input data will be provided to users upon request.

B. Reformatted Data Storage

- As a maximum, all input data will be retrieved, reformatted, and returned to the MSS.
- Input data will be reformatted from the downlink format to a band interleaved by line (BIL) or a band sequential (BSQ) format.
- In a BIL format, the data is blocked according to the major frame size (paragraph 3.1.4A); however, the sequence of the data has been changed.
- The BIL data can be sub-blocked by scan line, where each sub-block contains the data from all bands for one scan line.
- The data volume for a BIL sub-block could vary from $1.5x10^4$ to $2.5x10^5$ bytes.
- In a BSQ format, the data is blocked by scene, where a scene of data represents an area equal to the swath width squared.
- The data volume for a BSQ block could vary from $4.5x10^7$ to $4.5x10^9$ Bytes.

- The BSQ data can be sub-blocked by band, where each sub-block contains the data from all scan lines in a scene for one band.
- The data volume for a BSQ sub-block could vary from $1x10^7$ to $4x10^8$ bytes.
- Data retrieved from the MSS for data correction or registration processing will be addressable by block or sub-block.
- Reformatted data in the MSS could be archived for permanent storage.
- Copies of reformatted data could be provided to users upon request.

C. Preprocessor Output Storage

- Preprocessor output data consists of data that has been reformatted and corrected and/or registered.
- All reformatted data could be retrieved, preprocessed, and returned to the MSS.
- The format and block sizes of the preprocessed data shall be the same as for the reformatted data (paragraph 3.1.4B).
- The preprocessed data in the MSS will serve as the source data for the analysis processor and will be addressable by block or sub-block.
- Preprocessed data in the MSS will be archived for permanent storage.
- Copies of preprocessed data will be provided to users upon request.

D. Analysis Processor Output Storage

- All preprocessed data could be processed by the analysis processor and returned to the MSS.

- The format and block sizes of the analysis processor data shall be the same as for the reformatted data (paragraph 3.1.4B).

- The analysis processor data in the MSS will be used as the source data for generating user products such as film and CCT's, and will be addressable by block or sub-block.

- Analysis processor data in the MSS will be archived for permanent storage.

E. Ancillary Data Storage

- Ancillary data to be contained in the MSS will consist of all supporting data, exclusive of imagery data, that is required for annotation and image processing.

- Ancillary data is obtained from spacecraft telemetry, interactive input terminals, and other support processing systems.

- The volume of ancillary data is approximately 10 percent of the volume of imagery data.

- Reports, tabs, catalogs, etc., generated by the preprocessor and analysis processor are included under the term of ancillary data and are stored in the MSS.

- Ancillary data contained in the MSS may be archived for permanent storage.

- Copies of ancillary data will be provided to users upon request.

3.2 FILE MANAGEMENT FUNCTIONS.

The file management functions relate to the manipulation of data on a data file basis. The management file is generally organized into a set of physical records based on the media in which it resides. In addition, the user may organize the management data in a manner that is easy and convenient for him to utilize. This generally results in a unit of organization termed the logical record. The logical record may be smaller than, equal to, or greater than the physical record on a tape or a sector on a disk. The smallest unit of organization within the logical record shall be defined as the data item. Based on the above concepts and definitions, the following functions have been categorized as file management type.

3.2.1 Data Transfer Command Interpretation. The data transfer function involves the receipt of a Logical Request from the Host and the interpreting of this request. The request shall include the following:

- File Name or Identifier
- Source of File
- Destination of File
- User Code or Identifier
- New or Old File
- Other Housekeeping Information.

3.2.2 Master File Directory. The MSS shall be responsible for the maintenance of a Master File Directory. The directory shall contain: the list of all data sets currently resident in the system, their location in the system, an indication of their status (active or archived), date of creation or most recent update, and any other necessary identifying parameters.

3.2.3 Data Transfer Function. The initiation and monitoring of all data transfers between devices of the mass storage facility shall be the responsibility of the System Control Unit (SCU). The data transfers shall be accomplished on a complete file basis. Any necessary blocking and unblocking (formatting) of physical data records between device types shall be performed. Advisories of transfer completion and status shall be referred to the host system. The status shall indicate any error or abnormal condition encountered. Retry attempts, where warranted, shall be initiated to complete an unsuccessful data transfer. If a requested file is not on line (designated as archived in the Master File Directory), an operator advisory shall be issued. The host system shall also be advised of the status.

3.2.4 Security Function. The validation of user codes against access authorization codes shall be performed in order to ensure proper dissemination and modification of data.

3.2.5 Host Communication. The On-Line Mass Storage System shall perform all the necessary basic communication functions with the multi-host system.

3.2.6 Peripheral Devices Handlers. All special and standard peripheral devices connected to the MSS control bus shall be initialized, controlled, and statused by the respective I/O handlers. The I/O handlers include: the high density recorder controllers, staging controller, and host channel interfaces.

3.2.7 Transaction Logging. All transactions related to a Host request shall be logged for subsequent analysis and recovery efforts. Logged data shall include: user ID, file name, transfer types, transfer status, and other pertinent activity and performance data.

3.2.8 Volume Directory. The system shall record a directory for each storage module that identifies its contents. The directory shall contain a module ID and a file directory. The file directory shall identify each file name or identifier contained in the module, its starting location, access codes, and date of creation or last update.

3.2.9 Module Handling. The MSS shall provide the capability to remove and mount storage modules within its system. This shall include the proper update of the Master Data Directory to indicate files removed due to the unloading of a cartridge. It shall also indicate new data sets available for access when a new cartridge is mounted.

3.2.10 Archival. The intent is to provide a tool by which data modules may be identified removed and labeled for transfer to archive status. An Archival Directory shall be maintained listing all archived data. The archive directory shall include the same type information as the master directory.

3.3 RESOURCE MANAGEMENT FUNCTIONS

In order to ensure effective utilization of components and resources available, and to monitor activity, the system shall perform functions designated as Resource Management. These functions are identified in the following paragraphs.

3.3.1 Component Activation. Since the MSS is composed of individual devices and modules, the control of data paths and/or items that are active shall be provided by the SCU. Priority of transfers shall be established to resolve contention for paths or components.

3.3.2 Device Utilization. The system utilization of the Storage and Staging Subsystems shall be performed by the SCU. A current mapping of the individual units utilized shall be monitored to assist in identifying the amount of reserve available, and full or saturated units. Proper advisory to the cognizant personnel shall be provided.

3.3.3 Analysis Reports. The generation of statistics or reports on the system transactions shall be accomplished for use in optimizing performance, identifying usage, monitoring system reliability and capacity, and recognizing changes required in the system. The reports and information may be provided on demand or periodically in hardcopy form.

3.3.4 File Management Backup. In order to ensure availability to critical Host environments, the system shall provide a backup capability where requirements so dictate.

3.3.5 Acknowledge Completion of Job Tasks. The system shall provide responses to the host computer indicating the successful or unsuccessful completion of operations requested. For unsuccessful operations, status information shall be sent to the host computer indicating the cause of the failure of operation.

3.3.6 Redundant Recording. If required, to meet the objective system error rates, the system shall allocate data recording in such a manner that the data will be recorded redundantly on the media to ensure that data will not be lost due to storage irregularities. Bad areas, on the media, if previously marked, shall be detected and avoided during normal read/write operations.

3.3.7 Automatic Switchover. Ths system shall provide automatic switchover to a redundant subsystem, if a failure occurs during operation. The extent of redundency shall be determined as a result of the trade-off studies and configuration analysis.

3.3.8 Quality Control. The system shall perform a quality control function on data sets through system validation routines to ensure data integrity and maintain statistics of good/bad data records. The system shall also implement an error detection and correction encoding scheme capable of maintaining required system error rates.

3.4 UTILITY FUNCTIONS

The following utility functions are necessary to supplement the main functions. In general these functions are operator, not host, initiated.

3.4.1 Media Initialization. If the subsystems are required to be initialized prior to placement on-line, this function shall be performed by the SCU. The initialization function may involve writing track addresses, statusing and marking bad tape or memory areas, writing starting data positions of tracks or sectors, loading file directories, allocating staging boundaries, etc.

3.4.2 Copy Function. The MSS shall provide the capability to copy a current file from one cartridge to another cartridge.

3.4.3 Dump Capability. The system shall provide a formatted Dump of the Master File Directory or Volume Directory in hardcopy form. Also a formatted binary dump of a file by Track, Block, etc., shall be available. As an option, a display may be utilized if a CRT device is available.

3.4.4 Purge/Delete Capability. A utility function shall provide the ability to purge an entire volume or to delete a specified file including its directory information. Special files, designated as temporary by the user, shall be deleted based on a predetermined usage algorithm.

3.4.5 Tape Organization. The purpose of this utility function is to reorganize a tape to enhance its usage. Deleted and purged files shall be removed and all remaining active files packed together to better utilize tape space.

3.4.6 System Recovery. The system shall have the capability of performing system recovery of any outstanding transactions due to a system failure.

3.5 DIAGNOSTIC FUNCTIONS

The diagnostic functions shall assist in the troubleshooting and diagnosis of the data storage unit controller or the staging unit. System functions are assumed to be available for the mini-computer and its peripherals as standard deliverables from the manufacturer and are not discussed here.

3.5.1 Subsystem Diagnostics. This function shall provide the operator with the capability to select and initiate those functions necessary to verify operation of designated controllers or peripheral devices. The monitoring of the specified action and its status shall be returned to the maintenance personnel as required.

3.5.2 Media Diagnostic. Media diagnostic functions relate to the storage media itself (the tape cartridge). This set of diagnostics shall include the capability to identify bad tracks, blocks, etc., and to provide the proper marking on the media.

SECTION 4

FUNCTIONAL CONFIGURATION

4.1 INTRODUCTION

The On-Line Mass Storage System is separable into four subsystems; (1) Host Interface Units, (2) System Control Unit, (3) Mass Data Storage Equipment, and (4) Staging Subsystem. Interaction between these subsystems and the communications paths necessary to perform these functions are illustrated in Figure 4-1.

A. Host Interface Units. Host computer systems shall access the mass storage system through the individual Host Interface Unit (HIU). These units shall provide the handshaking, command interpretation, interrupt acknowledgement and response, data reformatting, timing, and buffering necessary to interface the host systems to the System Control Unit (SCU) and the Staging Subsystem controller.

B. System Control Unit. The SCU shall monitor and control all activities concerned with the storage and retrieval of data files within the On-Line Mass Storage System. The SCU shall configure and control the activities of the HIU, the Mass Data Storage Equipment (MDSE), and the Staging Subsystem. Logical requests from a host system shall be validated and processed by the SCU. All file management functions shall be performed by the SCU including: management of the Master File Directory, storage allocation, and command processing. The SCU shall issue a physical request to the MDSE to access a specific area of the medium for retrieval or storage of data. The SCU shall configure and control the elements of the On-Line Mass Storage System for the transfer of data to/from the host system. Quality assurance functions shall be performed by the SCU to ensure the complete transfer of a file of information.

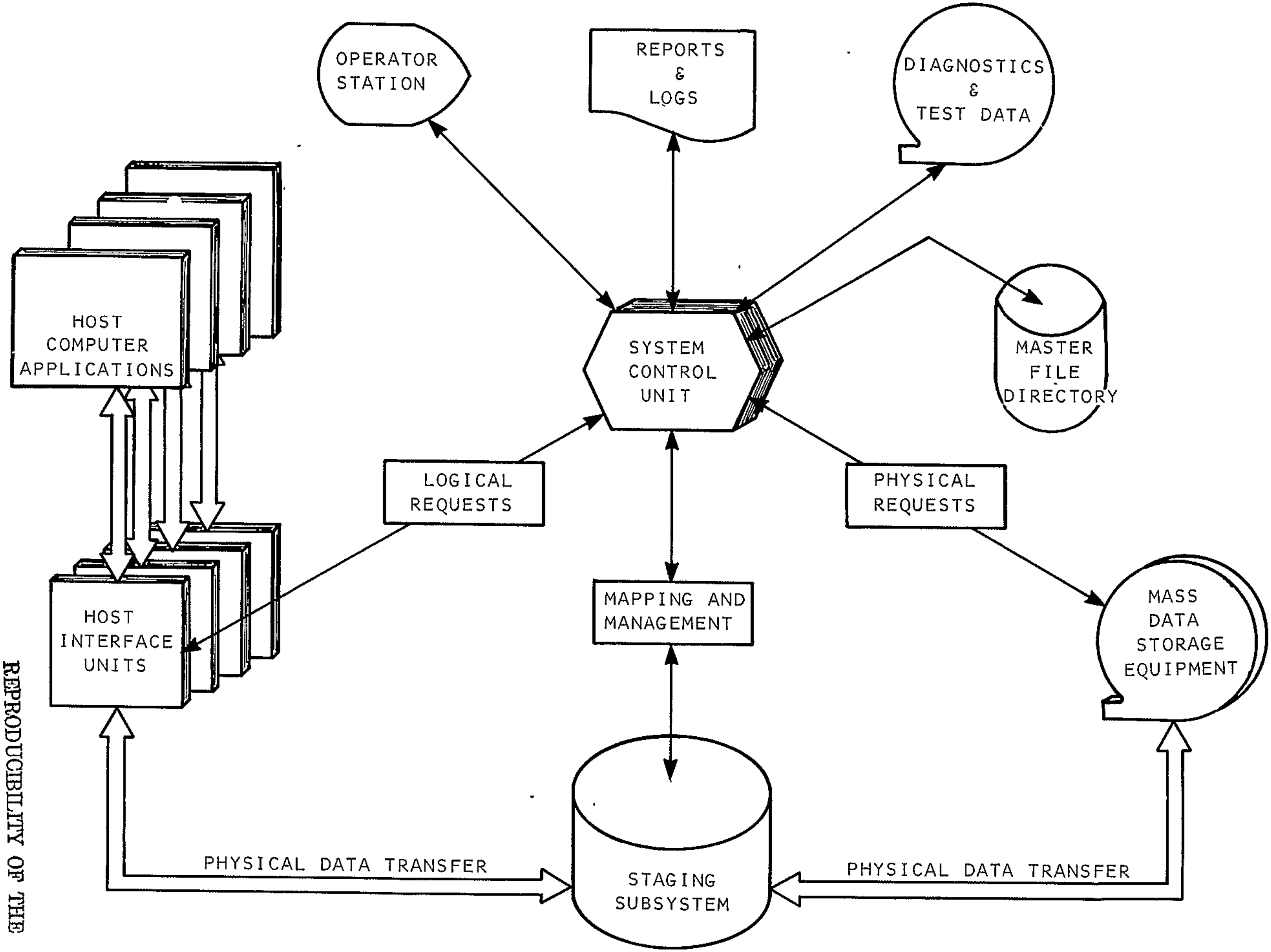

Figure 4-1. Mass Data Storage System, Functional Diagram

C. Mass Data Storage Equipment. MDSE shall provide the volume storage capability for the Mass Storage System (MSS). Each storage unit shall consist of: a volume tape storage medium; two separate and independent read/write stations; and all associated electronics for addressed search, writing, and recovery of recorded data. Each storage unit shall provide multiple removable cartridges as the storage medium. Each of the cartridges shall be selectable by computer control, retrieved, mounted, and threaded automatically at the selected read/write station. Each read/write station shall interface the SCU to receive the access request for file management functions. Each read/write station must also interface the Staging Subsystem to transfer data.

An error detection and correction capability shall be provided by each read/write station to the data transferred to/from a cartridge. Error correcting techniques applied to the retrieved data shall be independent of the read/write station used to record the data.

D. Staging Subsystem. The Staging Subsystem is a multi-ported volume storage equipment operating as a passive device to provide the storage for concurrent read/write operations by the MDSE and HIU. The staging equipment shall support the read/write rates established by the source/destination devices of the host systems and the MDSE.

Support of a multi-host environment may require partitioning the volume storage of the Staging Subsystem. Partitions in the passive device may either be predefined based on assignment of physical interfaces (HIU's and Read/Write Stations), or created dynamically by the SCU. In the latter case, the partitions would be created by the SCU in its management of the volume storage of the Staging Subsystem. Partitions of the Staging Subsystem would also be assigned by the SCU in its configuration and control of file transfers through the subsystem.

4.2 HOST INTERFACE UNITS

The HIU functions are illustrated in Figure 4-2. Each HIU connects the communications channel of the host system with subsystems of the MSS. Logical requests, i.e., host requests for file retrieval or creations, are transferred from the host to the SCU via the HIU. Physical data transfers to/from the host system are routed from/to the Staging Subsystem via the HIU. In addition to its communications responsibility, the HIU shall isolate each system from the other. A HIU shall also isolate a failure of the MSS from the host system and vice versa. In effect, all activities performed by the MSS shall be transparent with respect to the requested operation.

A HIU must match the original equipment manufacturer interface specifications. These specifications describe the sequence of channel commands, diagnostics, and error condition to be emulated by the Mass Storage System Interface Unit. For each host system supported, one or more HIU's may be required. Types of systems to be supported include: the UNIVAC 1100 series computer subsystems (1108/1110), CDC CYBER series computer systems, IBM 360/370 selector channels, and minicomputer interfaces such as the INTERDATA 8/32. HIU design shall be compatible with support of any of the above interfaces. However, a single host interface type shall be selected for development as the prototype unit for the test bed configuration of the MSS.

Isolation of the systems shall be accomplished through control of the logical (formats, types of commands, conventions) and physical (hardware interface, timing) components of the HIU. To support interface control, the interface unit may be required to reformat or align the data transferred from one system to the other. In addition, the interface unit shall have the capability to support on-line and off-line modes of operation, with respect to the host system, without inhibiting host activities to other equipment sharing the same host channel.

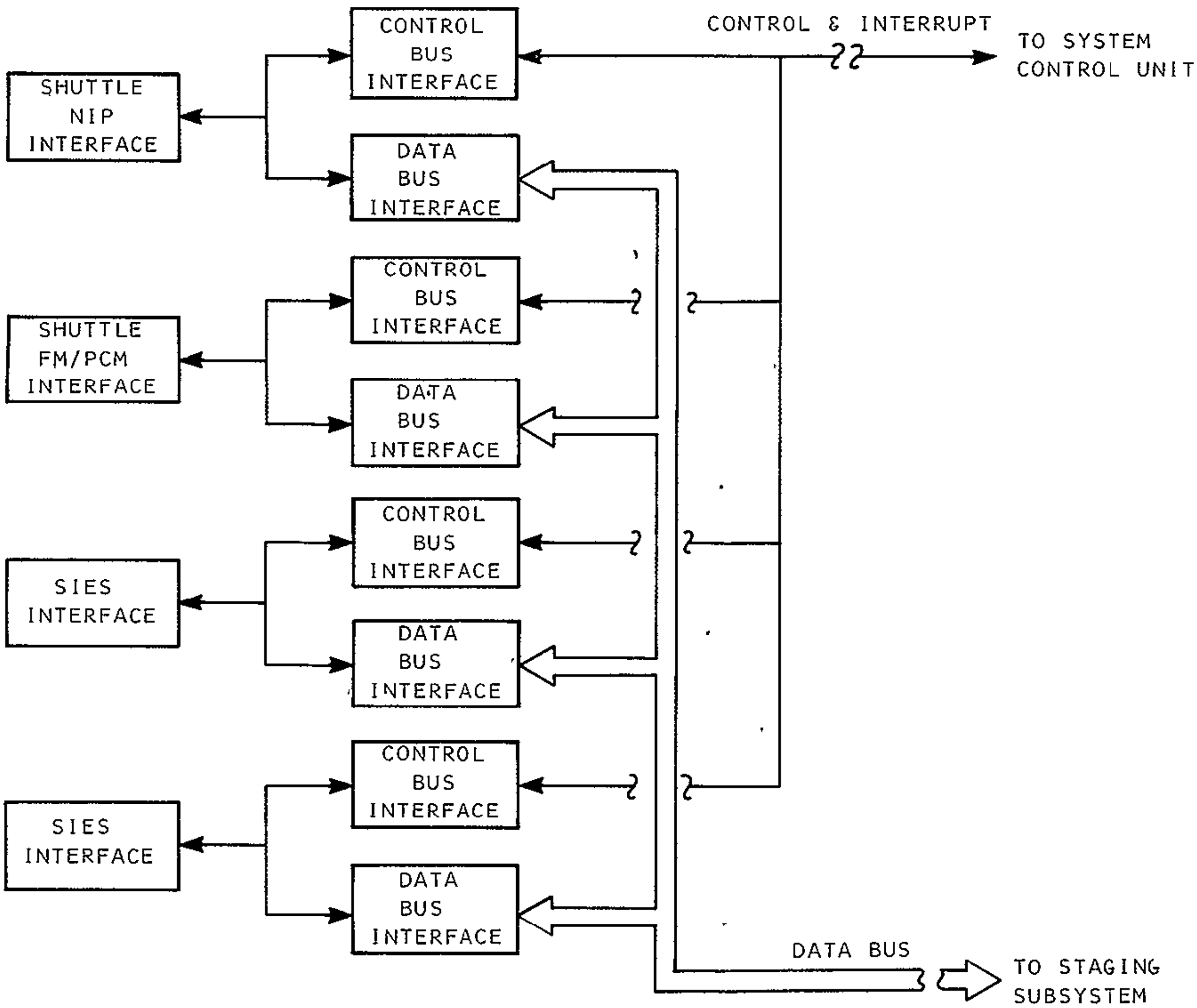

Figure 4-2. Proposed SDRC Configuration Host Interface Unit, Functional Diagram

4.3 SYSTEM CONTROL UNIT

Control of the configuration and communications within the Mass Storage System shall be accomplished by the SCU. The SCU shall also perform all file management functions for the system. The SCU functions are illustrated in Figure 4-3. Cost and design goals of the Mass Storage System, support the application of a minicomputer architecture to the SCU functions.

4.3.1 SCU Control Function. The SCU shall configure and control the MSS equipment via interfaces to each HIU, MDSE recorder unit, and Staging Subsystem. In addition, the SCU shall support the peripheral complement of the minicomputer system; disk, tape, operator station, card reader/punch, and printer. At least 16 I/O interfaces shall be supported by the SCU. The SCU shall establish the on-line, off-line, test, and maintenance modes of operation for the MSS equipment via these interfaces.

4.3.2 SCU Communication Function. Communications control by the SCU includes the management of host requests and MSS responses in a multi-host environment. At least four host interfaces shall be capable of concurrent operations in the MSS. At least two MDSE units, each complemented by two read/write stations, shall be capable of providing the on-line mass storage. The Staging Subsystem shall consist of single or multiple storage elements to be allocated by the SCU to a HIU or to a specific file transfer.

The SCU shall queue the logical requests from host systems. Each host request shall represent a "transaction" to the system. Transactions shall then be assigned a priority by the SCU, however the transactions may be processed partly in parallel due to the wait-times for access to the MDSE. The SCU shall then assign a communications data path for the transfer, to include: the selection of a read/write station, partitioning or configuring the staging subsystem, designation of the HIU, and coordination of the read/write operations on the staging subsystem in order to support continuous stream processing. The SCU shall also provide the capability to trace a transaction through the processing steps in order to ensure valid and complete file transfer.

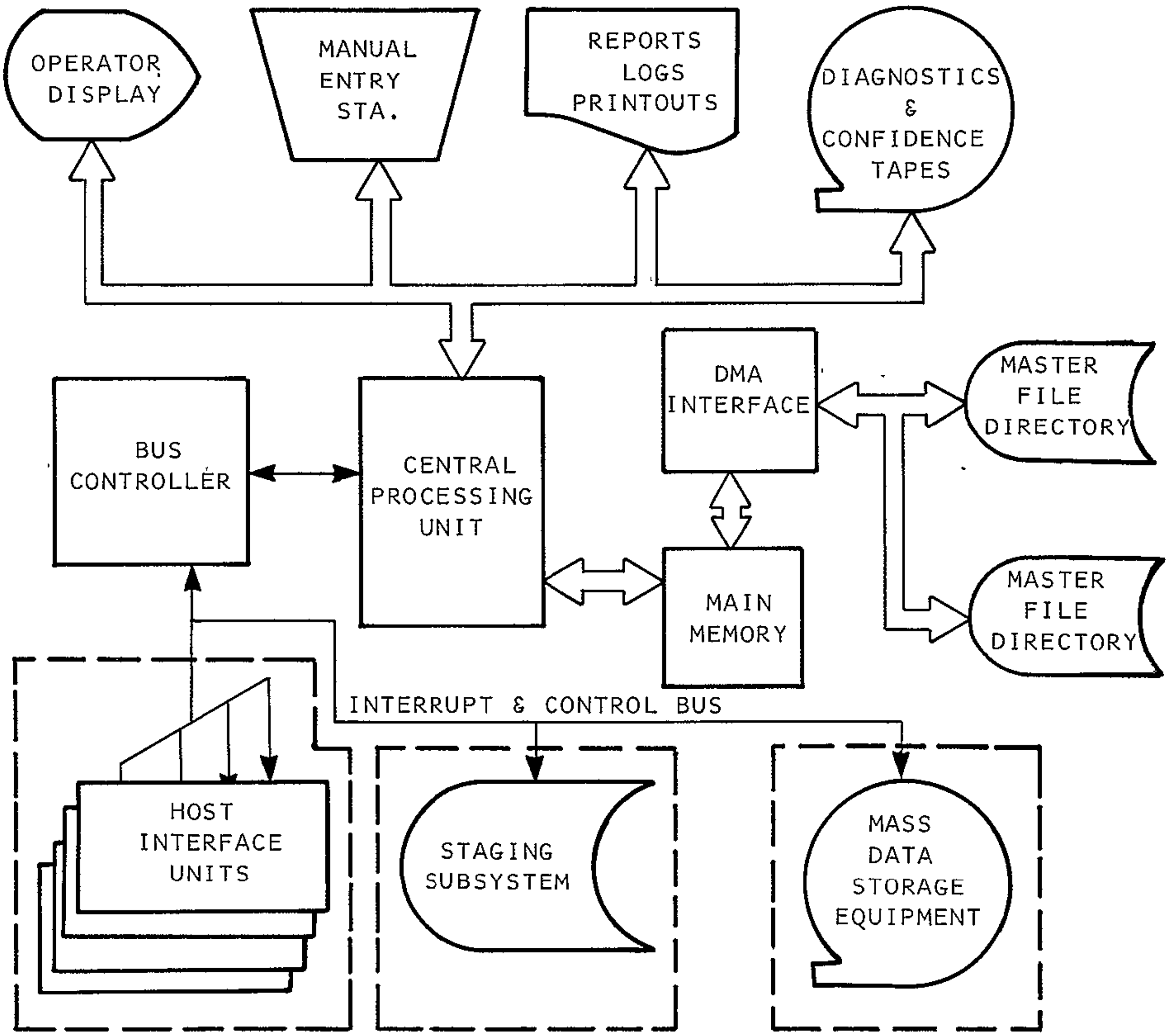

Figure 4-3. System Control Unit Functional Diagram

4.3.3 SCU File Managment Function. All file management functions are performed by the SCU. The SCU shall validate and process all host requests, such as;

- Retrieve filename
- Insert or catalog filename
- Purge filename.

The SCU shall manage the directory of all files of information defined to the system and maintain a current catalog of all files on-line in the Master File Directory.

The SCU shall manage mass storage resources including allocation and deallocation of MDSE storage capability. The unit of storage allocated shall be selectable as an installation parameter and shall be defined in the detailed design phase. The directory of file names shall include the FILENAME, physical address of the stored information, and file length in terms of the number of storage blocks allocated.

4.4 MASS DATA STORAGE EQUIPMENT

The MDSE functions are shown in Figure 4-4. The MDSE shall be comprised of magnetic tape drives and controllers to interface with the SCU and Staging Subsystem. Controller interfaces shall be designed to minimize the software required for the recording, searching, and playback of non-sequential data files from tape. This equipment shall be cumulative to provide a volume storage capability of 50 x 10^9 bytes (8 bits/byte) with access times for a file of information in a storage unit less than 30 seconds.

Provision shall be made to enable selective addressing of specific data records, on tape, for the purposes of writing, reading, or modifying operations. Data record addresses shall be capable of being read during high speed search operation in either forward or reverse direction. The controller shall automatically perform all required tape search operations and place the data into buffer storage (read operation), or retrieve the data from buffer storage (write operation) without SCU intervention. When completing the requested task, the controller shall interrupt the SCU with notification that the requested command has been either completed or unsuccessfully attempted.

The MDSE shall provide the capability to detect and correct the characteristic errors of the recording medium to provide an error rate of a single bit in 10^{11} bits of data transferred. Techniques used to accomplish the error rate shall be independent of the read/write station and device/cartridge combination used to record the data.

Dual read/write capability is a minimum requirement for a recording unit of the MDSE in order to support the multi-host environment of the MSS. Dual read/write capability shall also support the copy and verify functions of the system to create and verify a copy of an existing file. This capability shall also be used to support the "wrap-around" condition encountered in "continuous in input processing", i.e., as a cartridge is filled another cartridge is readied to begin recording.

A recorder unit shall have a selectable or servo-driven variable rate capability. Variable record rates shall provide the capability to support a wide class of host applications and minimize the volume storage requirements on the Staging Subsystem.

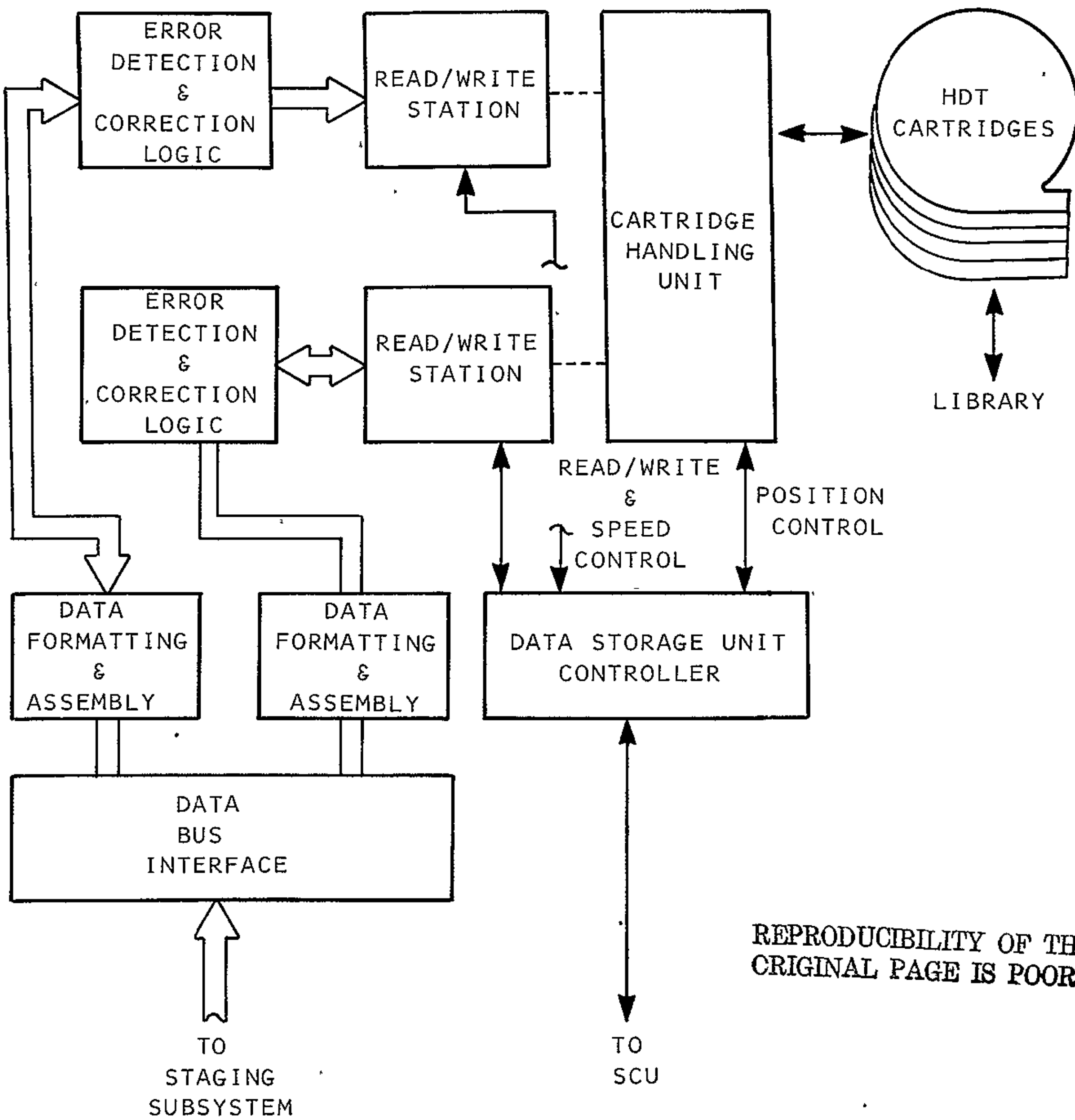

Figure 4-4. Mass Data Storage Equipment, Functional Diagram

Cartridges used in the MDSE shall be removable and interchangeable between units. The magnetic tape shall be contained in a dust-tight protective cartridge and self-threaded by the tape drive, thereby eliminating the possibility of operator induced tape contamination, edge damage, or other problems normally occurring with human handling and shelf storage of tape. The storage modules shall be self-contained and evidence no degradation of performance when stored for a period of 3 to 5 years in a normal computer room environment. Degradation of performance is interpreted as excessive error rates when the data is retrieved after being stored in a normal computer room environment. The capability shall exist to interchange tape recordings for update or playback on MDSE of the same type, i.e., recordings made on any MDSE can be used on any similar MDSE. This playback requirement shall meet the specified operating performance on any of the MDSE units.

The commands for the MDSE shall be interlocked so that tape or equipment damage is impossible, as the result of any combination or sequence of commands. An illegal combination of motion commands shall result in the tape recorder entering the STOP mode. Status information with regard to the operating mode, tape position, and command in process shall be accessible by the SCU at all times.

In addition, the MDSE shall contain a maintenance panel for computer control simulations, and off-line testing and maintenance functions. All Motion and Function commands to the MDSE shall be SCU controllable and switch selectable to local control for maintenance purposes.

Each circuit or groups of circuits shall be designed such that a catastrophic component failure shall not cause damage to associated components or circuitry. The design shall also eliminate the need to sequentially turn ON or OFF power supplies, etc. Random loss or submarginal performance of any power supply(s) shall not cause damage to the circuits or components.

4.5 STAGING SUBSYSTEM

The staging subsystem functions are illustrated in Figure 4-5. The staging subsystem is an extension of mass storage capability to enable the transfer of information from the high density volume storage device to the demand/response interface of a host processing system. The staging device shall support the interface rate(s) of the mass storage recording device for data transfer to/from mass storage. The staging device shall also support the demand/response characteristics through the HIU supporting rates up to 10 million bits per second. The staging device for the MSS shall be configured by the SCU to support data transfers from a host to mass storage and from mass storage to a host.

Host applications (Refer to Section 3) to be supported could require the staging subsystem equipment configuration to take the form of a number of storage elements (partitions or volume storage elements) each with a read or write capability. The Staging Subsystem could also be constructed as a single volume storage element with multiple ports to permit concurrent read and write operations. Volume storage capability of the Staging Subsystem shall be of the order of several megabytes of data. Size of the volume storage depends directly on the methods used to partition the storage capability for use in a multi-host support environment. The relationship between volume requirements and the partitioned support of a multi-host environment shall be derived in the detailed design phase of the system.

Size of the staging subsystem storage or the "apparent" size of its storage is also important to operations of the recording device. Inability to support a continuous transfer of data to/from the recorder will require the device to stop, reposition, and restart at the resumption of data transfer. Several alternatives exist to minimize the stop/start activities of the device including the design of a device to match or synchronize the rate of the recorder with the "apparent" or available storage of the staging device.

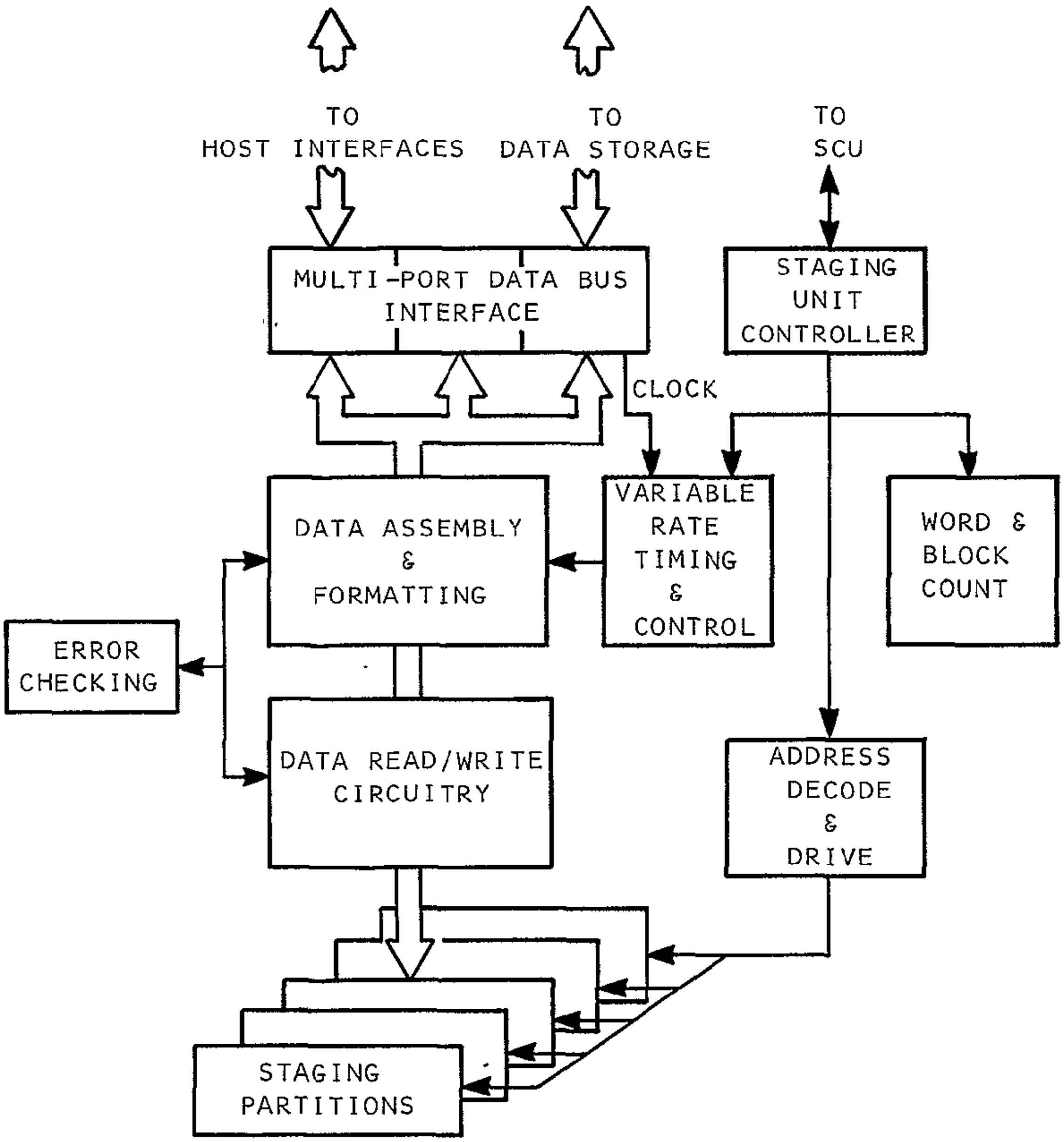

Figure 4-5. Staging Subsystem, Functional Diagram

Conceptual design of the Staging System proposes a "passive" volume storage element as the device. This device shall support DMA type operations by the MDSE or HIU in the following manner. A logical request to the SCU would result in pre-determination of the partitions required in the staging system to support the request. Up to 100 percent of the Staging Subsystem could be assigned. Partition characteristics would be then provided to the HIU and MDSE, and their interfaces monitored to initiate the sequence of read/write operations performed. The rate-matching function noted above may be required to eliminate any potential overlap of concurrent read/write operations. The Staging Subsystem shall complement the error protection incorporated by the HIU or MDSE to protect data transfers, e.g., parity checks on a word boundary could be supported by the Staging Subsystem.

SECTION 5

MASS DATA STORAGE SYSTEM OPERATIONS

5.1 INTRODUCTION

This section provides, in sequential descriptive format, the possible or probable operations necessary within the mass storage system to perform the basic tasks identified in Section 3. The task descriptions are intended to be general in nature such that a system design can be accomplished without limiting the applications or usefullness of the system to performing only these identified operations.

It is assumed that most or all of the system applications can be supported by the proper utilization of one or more of the following operations:

- Recall/Retrieve Data Files
- Store Data Files
- Retrieve/Modify/Replace Data Files
- Load Files (Cartridges)
- Remove/Archive/Exchange (Cartridges)
- Copy Files (Off-line)

5.2 RECALL/RETRIEVE DATA FILES

The following operation description is based on the assumptions that: both the host system (or multi-hosts) and the MSS are functioning properly, the Master File Directory (MFD) and all support programs have been loaded, the subsystems and interfaces have been checked, and the host application has initiated a logical request to retrieve a data file.

A. Host channel program or I/O control program initiates a service request to the Host Interface Unit (HIU) according to the vendor channel interface specifications.

B. If the HIU is not busy, i.e., control of the interface has been released from the last transaction, the HIU must respond to the request for service.

C. The HIU then transfers the logical request, "RECALL FILENAME" or "RETRIEVE FILENAME", to the System Control Unit (SCU) to retrieve and transfer an information file to the host system.

D. The logical request is examined by the SCU for validity, i.e., format and filename are examined for uniqueness within the facility.

E. When the SCU verifies that the request is valid (file is accessable by the requesting host), the MFD is examined for physical address of its location. This physical address specifies the device number, cartridge number, cartridge location, and file address that must be identified to the system in order to complete the request.

F. If the required cartridge is not currently assigned to the system, an appropriate response to the system operator must be made. If the file is "on the system", an access request will be formatted and queued to the MDSE.

G. The MDSE controller then responds to the access request and commands the selected cartridge to be positioned on an un-busy read/write station. If both stations are busy, the command is placed in queue until a station is available.

H. With the cartridge in place and the files being searched, and as the read/write head is approaching the requested address, communications are enabled to the staging device for the requested tape-to-host file transfer.

I. This communication is established by an MDSE request to the SCU for a data path to staging.

J. The SCU interrupts the Staging Subsystem controller, requesting a file transfer giving source device/station and destination (HIU address) along with the starting and ending addresses of staging to be allocated.

K. As each physical block or track of information is transferred, the data quality is checked and an error correction routine is initiated, when necessary, to obtain the predetermined error rates.

L. As the physical blocks or tracks of information are transferred, the staging device accumulates the volume specified. Double buffering of the staging volume is anticipated to allow simultaneous filling and emptying of the staging area.

M. A buffer full flag from staging initiates an SCU request to the host interface for transfer of the file to the host system (Input Data Request).

N. When the SCU receives an input acknowledge from the host channel, the data path is established between the staging subsystem and the host channel interface unit.

O. The volume of data in staging is transferred to the host under the control of the input channel. The host interface shall check the data quality as the data is transferred.

NOTE

The size of the data blocks transferred from the staging device depends upon the application and addressable storage units of the staging subsystem. The data path from host to staging operates in a demand/respond mode and may be double buffered to provide adequate timing and interface with the receiving device.

P. When the transfer is complete, SCU is notified and the path is initialized for transfer of the next volume.

Q. Once transfer of the file is complete, a summary message must be derived by the SCU from MDSE and Staging. This summary message shall also be provided to the operator station and the host system. The SCU then releases the staging area for other usage and records the transaction in the activity log.

5.3 STORE DATA FILES

As in the procedure for retrieving a data file, it is assumed that the host system(s) and the mass storage system are functioning properly, that the Master File Directory and support programs have been loaded, the subsystems and interfaces have been checked, and that the host application program has initiated a logical request to store a data file.

A. Host channel program or I/O control program initiates a service request to the HIU according to the channel interface specifications.

B. If the HIU is not busy, i.e., control of the interface has been released from the last transaction, the HIU must respond to the request for service.

C. The HIU transfers the logical request "STORE FILENAME" to the SCU to allocate an area on the storage device and receive the information file which is awaiting transfer. The request states the source code, file size (number of words or blocks), and the type of data (new file, old file or update).

D. The logical request is examined by the SCU for validity, i.e., format and filename are examined for uniqueness within the file directory.

E. The SCU then searches the MFD for the physical location of the requesting hosts OLD files. It is determined whether the cartridge containing the old files is presently "on the system" and if there is sufficient area remaining on the cartridge to contain the information file.

F. If the required cartridge is not on-line or a new tape is necessary to contain the file, the SCU makes the appropriate response to the operator.

G. The SCU formats and queues a storage request to the MDSE. The MDSE controller responds and commands the selected cartridge to be loaded on an un-busy read/write station.

H. Responding to a "search and halt" command, the tape is positioned at a predetermined track address and the read/write station is ready to accept data. A ready message is sent to SCU which notifies the HIU to initiate transfer of the file.

I. SCU then commands the staging controller to accept data from HIU and provide the required buffer area. The SCU also provides the staging area mapping functions along with the starting address and word count.

J. When the data bus and staging area are available, the file is transferred on a demand/response basis under the control of the HIU.

NOTE

The staging area is considered to be double buffered for timing and data throughput rate matching. It is highly desirable that the tape drives provide variable speeds such that the throughput rates from host to tape can be compatible and the necessary staging area can be minimized.

K. As the first staging buffer is filled, the buffer full flag to SCU initiates the staging to MDSE data transfer.

L. The tape is brought up to speed and the file header is written as the data is assembled into the track assembly registers.

M. Data is continuously transferred from alternate staging buffers to the MDSE until the file transfer is complete.

N. When the block count is reached or end-of-file is detected, the HIU notifies the SCU.

O. As the last of the file is transferred to tape, the SCU will status the MDSE for errors, overruns, lost data blocks, etc. If the transfer is successful, the path is cleared and the staging buffer area is released (no retry is necessary). The SCU also sends a message to MDSE to rewind and store the cartridge, and set the read/write station to a not-busy state.

P. SCU also updates the MFD and records the transaction in the activity logs.

5.4 RETRIEVE/MODIFY/REPLACE DATA FILES

This section describes the procedures necessary to simultaneously: retrieve an extensive file of data from tape, allow the host application to modify the information in small portions, and store the modified data in a new file located on a different cartridge. The systems are assumed to be functioning properly and that the host has requested an access to "RETRIEVE FILENAME". Also, the systems shall have performed validation, MFD search, and data retrieval functions as described in paragraphs 5.2 A through P.

A. If the logical request to "RETRIEVE FILENAME" has been processed properly and a correct response received by the host, the host shall initiate a second logical request to MSS through a separate I/O channel and Host Interface Unit prior to any data transfer.

B. This second request, to "CREATE FILENAME", requests initialization of a file in the file directory and allocation of storage for the new file.

C. The logical request is examined by the SCU for validity, format, and uniqueness of the file name. The file name may represent a new file or a current copy of an old file, however, the file indication must be unique.

D. If the file name is unique, storage area must be allocated for the pending transfer.

NOTE

Prior to the job initialization, the operators instructions shall have described procedures for providing clean certified cartridges for new file allocation. Also if the input file is contained on more than one cartridge, all cartridges shall have been loaded on the MDSE in locations to minimize the delay necessary to put away one cartridge and replace it with another.

E. The SCU formats and queues a physical request to the MDSE controller to position a new cartridge on the second read/write station, validate the cartridge number, record the file header, and standby for the new file data to be stored.

F. With the storage device ready to accept data, a message is sent to SCU which notifies the HIU and the host system that both the input files and the output files have been set up.

NOTE

> Since it is the purpose of the task to input an extensive file, modify it in small pieces and output it "on the fly", the system configuration requires a dedicated data path for both the input and output files. The task utilizes both read/write stations of the MSDE and two separate HIU's. No other tasks shall be supported until the completion of this task and the units can be released for other assignments.

G. The data input process shall proceed as described in paragraph 5.2 "RETRIEVE FILENAME" and the output process as described in "STORE FILENAME" in paragraphs 5.3 I through P.

NOTE

> This operation levies the requirement upon the staging system and the SCU that the staging area is partitionable, capable of full duplex input and output and that some means of 'memory protect' be implemented to prohibit accidental overrun or other destruction of file data.

H. To complete the RETRIEVE/MODIFY/REPLACE procedures, the SCU must accumulate the status messages and compare the number of data blocks transferred, staged and stored. If all transfers are verified and no blocks are lost, a successful transfer is reported to the host.

5.5 LOAD FILES (CARTRIDGES)

Provisions should be made for manually loading the cartridge handling equipment (carrousel) and the creation of a listing of the "working files" within the file directory, as opposed to the archived or off-line files.

Operational procedures shall specify (from task descriptions or job orders) which files are to be brought from the library and loaded on the MDSE for those tasks.

A. The operator shall manually load the carrousel with the requested tape cartridges, then enter a request from the console that an initial loading form be displayed (on a CRT) to enable the input of data to the "working file" directory stating cartridge locations.

B. When the form is completed and entered, the SCU builds the ON-LINE file directory by searching the MFD until the files associated with the cartridge number have been located.

C. These FILENAMES are then listed or tabulated in an area designated as the working file index. The list identifies all labled files as being "on-line". The listing is completed for each of the cartridge numbers entered.

NOTE

> To eliminate the possibility of a mistake or an input error when loading, each cartridge number will be verified when the cartridge is selected and positioned on the read/write station. This can be accomplished by placing the cartridge number in the search track at the beginning of tape such that the first information received is that number and it can be compared immediately with the request from the SCU before the first addresses have been reached.

D. During the normal data base activities when a file is requested and is not listed in the working file as being on-line, SCU searches the MFD to determine the corresponding cartridge number.

E. The SCU then notifies the operator to retrieve the cartridge from library. The operator must decide which position can be unloaded and the new cartridge inserted. The operators of the host computer systems may be polled to aid in the selection of files to be removed. Operational guidelines will be established for this purpose.

5.6 REMOVE/ARCHIEVE/EXCHANGE FILES (CARTRIDGES)

Provisions must be made for methods to determine whether a cartridge position is filled or unloaded. The method should be mechanical and provide a position status indication to the MDSE controller.

5.6.1 Initial Cartridge Requests

A. As a cartridge is removed from a location, the status changes from loaded to unloaded. The change should cause an interrupt to the SCU requesting an update to the working file directory, giving the corresponding position.

B. The SCU then scans the position/cartridge number table and sends the cartridge number to the working file identifying those files that are being deleted.

C. The "on-line" file catalog is purged of the corresponding FILENAMES. No further action is necessary to identify the files as being returned to archive status. The fact that they are no longer listed in the on-line index is sufficient indication.

5.6.2 Subsequent Cartridge Requests. Subsequent requests for those files or a request for other files from the library will be handled in the following manner:

A. As the new cartridge is placed in the empty position, the status indicator changes to "filled".

B. The status change causes an interrupt to the SCU for a request that the loading form be displayed on the CRT.

C. The loading form is then updated with the new cartridge number for that position.

D. As the update is entered, SCU searches the MFD for the associated FILENAMES corresponding to the cartridge number.

E. The working file directory is updated with a listing of those new FILENAMES.

F. The cartridge number will be verified, as previously stated, upon the first access for information from that particular cartridge.

5.7 COPY FILES (OFF-LINE)

The following procedures are required to copy or duplicate a file, i.e., read the information on an existing cartridge and copy it onto another cartridge. It is also required that the COPY function be performed "off-line" from the requesting host system, primarily within the MSS.

In addition to the host system providing the initiation of a copy request, other sources which can initiate a copy/duplicate request are; operator initiated requests from the SCU console and from software initiated requests resulting from a subsystem monitor within the SCU. File monitors state that when a particular file has been read (or accessed) a fixed number of times or the read error rate has reached a minimum threshold level, a new file shall be created from the "OLD" file data.

The assumptions for copy files are the same as in the previous paragraphs concerning the proper functioning of the subsystems and the loading of the file directory and support programs.

It is also assumed that the MDSE Controller will have sufficient data buffering to allow data to be transferred from one R/W station to the other without requiring the utilization of the Staging Subsystem.

5.7.1 Host "COPY FILENAME" Requests.

A. The host channel program or I/O program initiates a service request to the HIU. If the interface is not busy, it must respond to the request for service.

B. The host transfers the logical request "COPY FILENAME", to the SCU to duplicate the contents of one file to another area on a different cartridge.

C. The logical request is examined by the SCU for validity and the MFD is examined for the physical address of its location. If the file is "on the system", an advisory is sent to the MSS operator that a copy request has been made.

D. Operator mounts a clean, certified tape cartridge, calls up the initial loading form, and keys in the new cartridge number and location to the File Directory. The input should specify that this is a new tape.

E. The SCU formats and queues a storage request to the MDSE. The MDSE controller responds and commands the new cartridge to be positioned on read/write station number two.

F. When the cartridge is in place and the read/write station is ready to accept data, a ready message is sent to MDSE to "COPY" the file from the location being provided, to the newly allocated storage tape.

NOTE

The COPY command is interpreted by the MDSE controller to position the requested cartridge on read/write station number one and to enable a data path between the read/write stations for direct transfer of the data from the output of number 1 to the input of number 2.

In addition, the SCU COPY command sets up and initiates the data verify circuitry necessary to determine the quality of the data being transferred. This circuitry shall decode the block or track numbers and temporarily hold the number in a register until the block has been received at station number 2. If an error is detected during transfer a response is sent to the SCU notifying it of an error and giving the block or track number in which it occurred.

G. The file is transferred on a continuous basis under the control of the MDSE controller, with timing and speed control for station number 2 being provided by station number 1.

H. When the transfer is complete, i.e., end-of-file detected or block count complete, the SCU is notified. If no errors were detected, or the error rate is under the specified number indicating a valid copy, the file directory is updated with the new FILENAME and physical location information.

I. The SCU then sends a "copy complete" message to the host system via the HIU. The host will respond with directions to the operator as to the retention or distribution of the master and copy files.

5.7.2 Operator Initiated "COPY FILENAME" Requests. In this mode of operation, the request for copies may be initiated from the operators console (CRT keyboard). The requests may be the result of a stand-alone job order requesting copies to be made of certain files (imagery, telemetry, etc.) to be shipped to another location and implemented within a remote system.

The requests may also result from job orders that require copies to be generated for security or protection from system catastrophic failures. Requests for copies should be generated during periods of low activity since the process requires the utilization of both read/write stations, and access to the MDSE is prohibited until the copy routines are completed.

A. The logical request "COPY FILENAME" to the SCU is initiated by the operator from the keyboard entry.

B. The remaining steps in the operator initiated copy operation are the same as the host initiated copy request.

C. The SCU shall notify the operator (via CRT) upon the completion of the copy routine. The operator has already received the instructions as to the distribution of the master and copies, with the original job order.

5.7.3 Data Quality Monitor "COPY FILENAME" Requests. It may be desirable, though not necessary, that subsystem monitors be implemented to determine the number of detected errors during a data transfer. This may levy additional requirements upon the error detection/correction circuits to provide the number of detectable errors and not just those that are uncorrectable).

A usage algorithm or activity monitor may also be implemented to determine the number of accesses to a file. As the number of accesses increase, the amount of tape wear and distortion increases to the point of increasing error probabilities. Either of these types of monitors could be implemented to initiate the copy requests.

A. The Data Quality Monitor queues the logical request to "COPY FILENAME". The remaining steps in the monitor initiated copy operation are the same as the host initiated request.

B. During the transfer, the copy/verify routine logs the number of uncorrectable errors and the block addresses of these errors.

C. The SCU notifies the operator that the file transfer is complete and the number of uncorrectable errors, if any, that were indicated.

D. The operator should then decide whether or not the copy is a suitable replacement for the original file. If not, the operator should take steps to read the file into the originating host to rebuild the master file. The blocks containing errors should be scanned and additional error correction techniques employed to reproduce the erroneous portions of the master.

SECTION 6

SYSTEM DEVELOPMENT PLANS

This section identifies those development plans that are considered pertinent to the design of this system, but are not covered by the generic requirements and functional descriptions.

6.1 DEVELOPMENT TIMELINE

A requirement of the Phase II amendment to SISO EO-001P states that the system design shall be completed to the point of publishing the hardware and software design specifications, and conducting the critical design review (CDR) on or about September 1, 1976.

To accomplish this activity, a preliminary design review (PDR) shall be held on or about June 15, 1976 to initiate the detailed design efforts. Conceptual configuration, feasibility studies, and trade-off analysis along with some preliminary simulation modeling shall be completed prior to April 15, 1976.

6.2 PROPOSED SYSTEM COST

To produce a viable alternative to compete with the presently available On-Line Mass Storage Systems, it is a design goal that the system cost remain below $300,000, including a minimal staging/buffering subsystem and a storage device with dual read/write capability. This figure is a production run goal, not the estimated development system cost.

6.3 IMPLEMENTATION

The mass storage system (MSS) is to be implemented (minimal configuration) in the JSC Building 12 Central Computational Facility which shall serve as the test bed for the MSS performance evaluation.

The test bed configurations shall provide the capability to demonstrate the operations specified in paragraph 5.1 These operations shall be demonstrated for the two basic configurations shown in figures 6-1 and 6-2. In the Data Reduction Configuration emphasis will be placed on the Read/Modify/Replace Data Files operation utilizing a single host system with dual I/O channels. The Multi-processor Support Configuration will primarily be used to demonstrate those functions relating to a multi-host processing environment.

The test bed facility shall provide UNIVAC 1100 series host computer systems and utilize the EXEC-8 as the host operating system.

A software model of the mass storage system is to be developed to assist in performance evaluation during the feasibility studies and trade-off analysis. An analysis of the available modeling programs and recommendations for the development of the system models is provided in JSC-10167, Quadruplex Record/Reproduce Cartridge Storage Equipment Performance Specification.

6.4 RELIABILITY/MAINTAINABILITY

Reliability and maintainability support shall be provided during the system development cycle. This effort shall permit trade-offs to be conducted so the system and product reliability and maintainability can be achieved.

Configuration analyses shall be performed on the Mass Storage System during the conceptual design stages. The task shall involve obtaining data for the system components to maximize the availability of the equipment configuration.

6.5 SYSTEM CONCEPTUAL DESIGN REVIEW

It is intended that this document provide the basic information to conduct a "Conceptual" design review as an initial phase of the system development planning.

To assist in this review, some trade-off studies have been conducted and their results are described in the following study reports.

- JSC-10038, Mass Storage System Simulation Planning
- JSC-10167, Quadruplex Record/Reproduce Cartridge Storage Equipment Performance Specification

- JSC-10039, Reliability Evaluation of the General Electric BEAMOS Memory
- JSC-10040, Mass Storage System Error Rate Analysis.

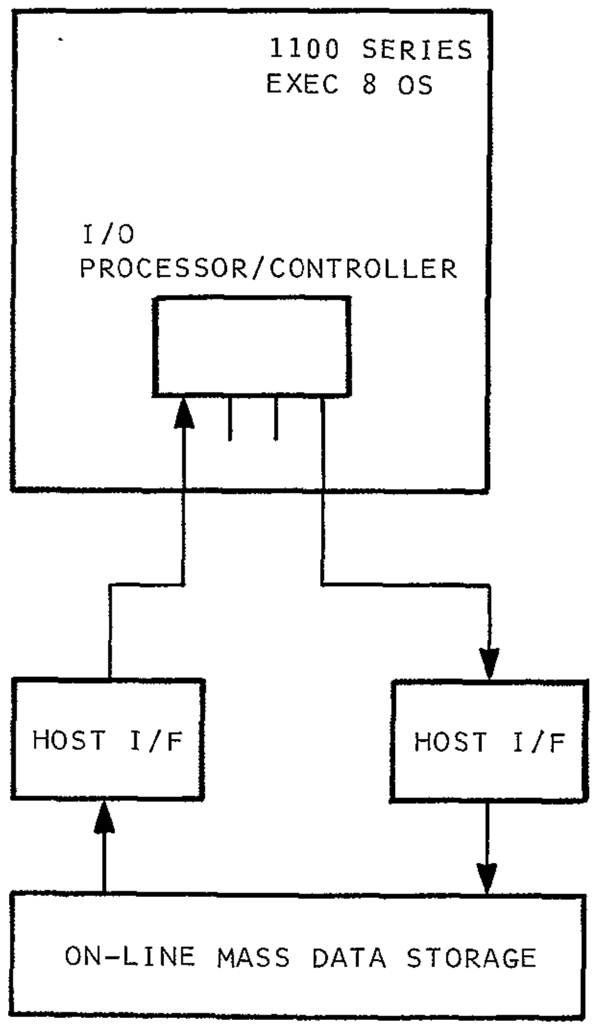

Figure 6-1 Test-Bed Data Reduction Configuration

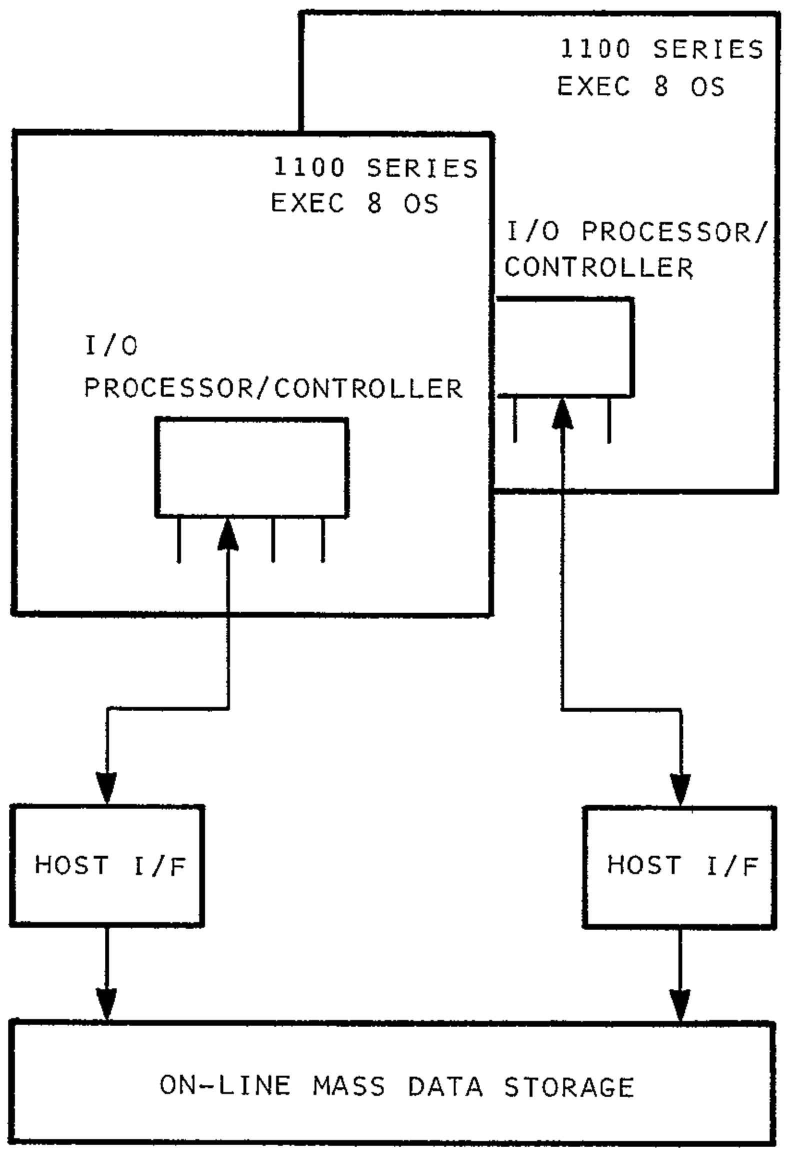

Figure 6-2 Test-Bed Multi-Processor Support

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