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SURVEY OF MASS STORAGE SYSTEMS

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Mass storage systems

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is a survey of current and past mass storage systems including manufacturer, cost, and descriptions of hardware and software. A brief overview of future systems is included.

PREFACE

This survey was conducted by Barbara H. Brooke and was authorized under Project R32020110. Dale E. Howell, Chief, Applications Division and Lawrence A. Gambino, Director, Computer Sciences Laboratory supervised the work. Carl S. Huzzen gave helpful comments and direction.

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SURVEY OF MASS STORAGE SYSTEMS

INTRODUCTION. Much interest has developed in recent years regarding mass storage systems to handle the large volume of data that government and private industry have compiled. There is a special interest in mass storage systems within the Defense Mapping Agency (DMA) and the Engineer Topographic Laboratories (ETL) because of potential use with Goodyear's Associative Array Processor - STARAN. The STARAN is capable of processing large amounts of data in parallel, but it does not have a large storage system from which to access data to make the most efficient use of the processor. As part of the project to look at the feasibility of using the STARAN for information storage and retrieval/data base management, the Applications Division of the Computer Sciences Laboratory (CSL), ETL, undertook this survey of mass storage systems.

Mass storage systems are usually considered to be systems capable of storing at least 10^{12} bits of information. These systems are usually on-line, i.e., no human handling of the data is necessary. Maximum access time should be less than 15 seconds. Systems that do not meet the 10^{12} bits criteria are not included in this survey.

CURRENT SYSTEMS. The following are some of the systems that are currently (or soon will be) available:

System Name: UNICON

Manufacturer and Location: Precision Instrument Company
Santa Clara, CA

Cost: This modular system is available in 1.28×10^{11} bit increments.

Minimal System	$395,000
Read/Write Unit	$200,000
Read Only Unit	$163,000
Trillion Bit System	$3,500,000

Availability: Currently available. Delivery - 12 months from date of final contract.

Installations: ILLIAC IV Installation
ARPA (Advanced Research Project Agency) network
Mountain View, CA

ERDA (Energy Research and Development Agency)
(formerly AEC)
Oak Ridge, TN

System Description: Hardware: The UNICON (Unidensity Coherent Light Data Processing System) is a laser mass memory system that stores digital data on a permanent medium. The original UNICON (model 690) was one unit of a trillion bits. This model is the system used on the ARPA network with the ILLIAC IV. The UNICON now being delivered is the System 190. This system is modular in increments of 1.28×10^{11} bits. The three basic units used to configure a mass storage system are (1) the Model 191 control unit, (2) the Model 192 read/write unit, and (3) the Model 193 read-only unit. The 190 can be interfaced to a host computer to provide online auxiliary storage, or it can operate independently as a stand-alone storage unit.

Data strips of polyester sheets coated with a thin layer of rhodium metal are the recording media. A laser vaporizes a small hole 3 microns in diameter in the rhodium of the data strips to record a digital "1" and is turned off to record a "0". Each data strip contains 10,125 tracks, and each track can contain 20,400 eight-bit bytes recorded longitudinally on the strip. There are 1.6×10^9 bits available to users on each strip. On each strip, there are other 'its used for the preamble, error recovery, record markers, check code, and clock bits.

The data strips are stored in packs (10 strips in each pack). Each 192 or 193 can hold eight packs, and the 191 can control up to eight 192's or 193's in any combination. Thus, the System 190 can provide an online storage capacity of 1.024×10^{12} bits.

The 191 control unit is a programmable controller that provides logical control and monitoring functions required to operate the 192 and 193 units. The 191 is also the physical interface between a host computer if the System 190 is to provide online auxiliary storage. The 191 can control searches, or load and unload operations on all eight units simultaneously, and it has one data path that can be connected through a multiplexor to any one of the eight memory units.

The 192 read/write unit is the recording unit for the 190. The 192 contains a rotating drum (on which data strips are mounted), a laser, servo and optical equipment (to allow direct track accessing), and a microprocessor. The microprocessor is used to interpret control signals and addresses sent by the control unit. After the microprocessor interprets these, it executes the hardware subroutines to carry out the control functions. The 192 also has a small "clean room" that contains the data strip pack, strip loading area, optical path, and drum.

The 193 read unit is identical to the 192 except that the 193 only reads data. A lower powered laser is used in this unit and there is no intensity control system or laser modulation system.

The Precision Instrument Company claims the following operating characteristics for the System 190:

•Data Buffer Rate	8 Megabits/second
•Data Strip Load Time	Manual from offline file (similar to disk or tape load time) - less than 60 seconds
•Access Time to Unload, Select & Load Strip on Drum	10 seconds maximum to access online strips
•Access Times (milliseconds) when Strip is on Drum	
Maximum	250
Average access time to any record	220
•Sequential Track Access	Essentially zero for sequential read or write
•Drum Transfer Rate (bits/second)	3.2×10^7
•Number of Tracks/Strip	10,125
•Number of Bits/Track	1.6×10^5 plus
•Data Strip Capacity	1.6×10^9 plus

Software: The UNICON System 190 is delivered with a standard set of routines and utilities that perform the following system functions: strip initialization, maintenance and diagnostics, System 190 driver, track finding on data strip, general I/O, overlapped seek, loading/unloading of data strip, and data buffer I/O control. If the System 190 is to be configured as a peripheral to a host computer, two other packages are provided - the basic addressing package and the tape command interpreter. Stand-alone systems probably will be unique and will require special software that Precision Instruments can provide.

System Name: IBM 3850 Mass Storage System

Manufacturer and Location: International Business Machines Corporation, White Plains, NY

Cost: The system is modular with a minimum configuration of 2.8×10^{11} bits.

Minimum capacity model $477,000

Two trillion bit system $2,300,000

Availability: Currently

Installations: Intelligence Community
NASA (National Aeronautics and Space Administration), Greenbelt, MD

System Description: Hardware: The IBM 3850 Mass Storage System is a magnetic tape cartridge storage facility for use with the IBM 370 OS/VS. The 3850 is made up of the 3851 Mass Storage Facility (MSF), the 3330-series Disk Storage, and the 3830 Storage Control Model 3 or the Integrated Storage Controls (ISC). Data stored on cartridges in the 3851 are staged under control of the 3830 or the ISC to the 3330 disks for access by the CPU. After processing, either the new data sets or the old data sets are destaged back to the data cartridges in the 3851. All disk space is then released for other use.

Each data cartridge contains 4 x 10^8 bits stored on a magnetic tape 3 inches (7.6 centimeters) wide and 770 inches (19.6 meters) long. The data is stored on tape in the same manner as on a disk (each disk cylinder is stored in a fixed location on the tape). Two cartridges are called a mass storage volume with a volume holding as much data as a 3336 disk.

There are four basic models that have capacities of 2.8 x 10^{11} bits, 8.2 x 10^{11} bits, 1.4 x 10^{12} bits, and 1.9 x 10^{12} bits of data with 706, 2044, 3382, and 4720 cartridges respectively.

The 3851 MSF contains the data cartridges, cartridge accessors, accessor controls, and data recording devices for storing and retrieving information. The cartridges are stored in vertical honeycomb cells. Under microprogramming control, the 3851 performs several functions, such as maintaining an inventory of data cartridges and mass storage volumes, allocating disk devices and disk space, accepting CPU requests for data, allocating data recording devices, issuing commands to the cartridge accessor, initiating and monitoring the staging/destaging of the 3830 model 3 or the ISC, and performing error recovery procedures.

The 3330-series Disk Storage is the same as the 3330 used for any System/370. It consists of the 3333 Disk Storage and Control, models 1 and 11, and 3330 Disk Storage, models 1, 2, and 11. All standard and optional features are supported. A disk drive dedicated to staging operations is designated as a staging drive. The remainder of the drives attached to the 3830 model 3 or ISC are available to the operating system and are used the same way as direct access storage devices in any System/370.

The disk storage control is either the 3830 model 3 or the Integrated Storage Controls feature with staging adaptor, for models 158 and 168. Either control carrys out the following functions: translating virtual disk unit and cylinder addresses to their real counterparts, staging and destaging data between the MSF and the disk storage, and controlling the transfer of data between the CPU and the disk.

IBM's Mass Storage System, as mentioned above, includes the 3851 Mass Storage Facility and the 3330-series Disk Storage. IBM claims that the transfer rate of the Mass Storage System is the same as that of the 3330-series disks, 4.8×10^6 bits per second with an average access time of 30 milliseconds.

Software: Software support for the 3850 comes from OS/VS1 and OS/VS2. This support includes

1. Mass Storage Control Tabel Create Programs to define the 3850 Mass Storage System environment.

2. Mass Storage System Communicator to provide communication between the CPU and the mass storage control.

3. Job Control Language (JCL) parameters to indicate the data sets to be processed as mass storage data sets.

4. VSAM options to allow the user to choose between three different staging procedures.

5. BSAM, QSAM, BPAM, BDAM, EXCP, and XDAP to process data sets on mass storage volume.

6. Access Method Service utilities extensions to provide commands to allow a user to handle the mass storage volumes properly.

7. Password protection facility to control access to date sets.

System Name: CDC 38500 Mass Storage System

Manufacturer and Location: Control Data Corporation
Minneapolis, MN

Cost: The system is modular with the smallest system containing 1.28×10^{11} bits.

Minimal System $326,335

Availability: Third quarter 1976

Installations: None

System Description: Hardware: The CDC 38500 Mass Storage System is a magnetic tape cartridge storage facility for use with the IBM System/370. A similar system for use with the CDC Cyber 170 is expected in the next year. The CDC 38500 is similar to IBM's 3850 in that it is a tape cartridge storage facility for the System/370. However, unlike IBM's system, the 38500 will operate with any operating system on the 370. The 38500 is made up of the Mass Storage Facility (MSF) and the Disk Storage Subsystem. Data stored on a cartridge is stored in data set form, with up to eight data sets per cartridge. The data can be staged to either the CDC 33301/02 disks or the IBM 3330-series disks, or the data may be read directly into central memory.

Each data cartridge contains 6.4×10^7 bits stored at an effective recording density of 6,250 bits per inch (2,437.5 bits per centimeter). The tapes on the spools are 2.7 inches (6.9 centimeters) wide and 100 inches (254 centimeters) long. Each cartridge magazine has a capacity of 2,052 cartridges. Average access time for a cartridge is 2.5 seconds. The data rate of the read/write station is 6.4×10^6 bits per second.

The CDC mass storage facility can be configured for almost any size beginning with 1.28×10^{11} bits. The number of data paths, the number of read/write transports, the amount of redundancy, and the access performance required may also be selected for a given system. A minimum configuration requires the following: a Mass Storage Adaptor connected to the Storage Control unit, one Mass Storage File with two R/W Stations connected to the Mass Storage Adaptor, adequate central memory to load and execute the VDAM system task (approximately 50K), user Type 2 SVC routine, basic SMF accounting, S/370 block multiplexor channel, CDC 38302 Storage Control Unit or equivalent, and adequate disk work space for staging the data sets and for the VDAM files.

The Mass Storage Facility contains the storage control, mass storage adaptors, and mass storage files. The mass storage adaptor provides control and attachment facilities between the mass storage file and the system 370. The cartridges in a file are moved by the cartridge selector, and the read/write transports make the data accessable to the System/370 for either staging or direct use. The mass storage file has drawers that allow access for manual entry and removal of cartridges under system control.

The disk storage subsystem is either the users current direct access subsystem or CDC's 33301/2 disk system, which may serve as the staging device. Once the data has been staged to the disk storage subsystem, it is available to the System/370 in standard disk format.

Software: The software package CDC supplied with the 38500 is the Virtual Data Set Access Method (VDAM) which interacts with the 370 operating system through normal user calls. No internal changes are necessary in the IBM system to use VDAM. The CPU communicate via a standard Type 2 User Supervisor Call and VDAM. Three program components compose VDAM - System Task, Operating System Interface, and Utilities. These Components perform all functions necessary to control the MSF hardware, to stage the data sets to disk, and to archive any new or updated data sets.

System Name: TBM (Terrabit Memory)

Manufacturer and Location: Ampex Corporation
Sunnyvale, CA

Cost: Expandable in 8.8×10^{10} bit increments

Minimal system 5.36×10^{9} bits $500,000

5.36×10^{9} bits with redundancy $620,000
and write without host

Availability: Currently. Delivery - 9 months from date of contract.

Installations: Department of Defense
Ft. Meade, MD

System Description: Hardware: The Ampex Terabit Memory (TBM) system is a video tape storage facility which stores large volumes of digital data on standard 2-inch-wide tape (5.1 centimeters) of the type used with commercial color television recorders. The Terabit Memory was developed jointly by the Department of Defense and the Ampex Corporation. The first TBM was part of the TABLON network and was interfaced with an IBM 360. The system offered now is a self-contained system that can be used in a stand-alone configuration or that can be interfaced to a commercially available CPU. The TBM has two functional units: the Memory Section and the Control Section. The Memory Section includes the tape transports, transport driver, and data channel units. The tape transports have only the mechanical elements needed to move the tape (1,000 inches per second, 25.4 meters per second); all control electronics are contained in the transport driver. The basic building block or module of the TBM is the tape transport. Each module consists of two transports, each with one TBM tape. Each module's capacity is 8.8×10^{10} bits. Because each module is based on the transports only, expansion cost of online data is minimized. The transport driver is a NOVA minicomputer, which controls or directs all transport and internal data activities. The third element of the memory section is the data channel unit, which contains all of the data electronics. Read and write channels are independent so that data may be read or written onto separate transports. The second functional unit, the Control Section, consists of one or two DEC PDP11/45 computers called the System Control Processor (SCP), of interface core buffers, and of channel control hardware. The SCP complex performs the following functions:

1. Manages all communication to and from host CPU's.

2. Manages the storage and retrieval of data sets when requested from the CPU.

3. Maintains the Master File Directory.

4. Manages allocating and scheduling of all TBM System resources.

5. Provides centralized data security.

6. Automatically generates data set backup copies.

7. Provides archiving facilities.

8. Maintains usage statistics.

9. Provides report generation.

The number of interface core buffers used is determined by the throughput requirements of each installation. Standard I/O devices may be attached to the SCP.

The storage medium used in the TBM system is magnetic video recording tape. The tape is on standard 10.5-inch (26.67 centimeters) reels. Each reel holds 48,000 inches (1,219.2 meters) of tape. The data is recorded in transverse recording mode. All data is recorded twice, i.e., 100 percent redundancy recording. Including this redundancy, effective density is 700,000 bits per square inch (108,500 bits per square centimeter). Error rates are less than two in 10^{10} data bits. Selected data blocks can be individually erased and re-recorded (erasing is prerequisite to re-recording). And, each TBM tape can contain data equivalent to 1,800 fully recorded, 800-bits-per-inch (312 bits per centimeter) standard computer tape.

The TBM can be configured to meet storage needs and throughput desired. Up to 31 modules (two transports per module) can be added to give a total of 2.8×10^{12} bits of data online. Transport drivers can be added. If this is done, six simulataneous read/write commands could be executed to increase data throughput to 396 megabits per second.

The average random access time for the TBM system is 3 seconds with 8×10^9 bits per TBM tape and 15 seconds with 4×10^{10} bits per TBM tape. The average random throughput with 8×10^9 bits per data set is 750 data sets per hour per controller for tapes with 4×10^{10} bits. The TBM data rate is 6 megabits per second per channel.

Software: The TBM is delivered with standard software to drive all components of the system. Software to interface to a host has been developed for the IBM 360. There is interest in developing interfaces for CDC and UNIVAC equipment, but as of this report none have been started.

System Name: HRMR

Manufacturer and Location: Radiation Systems Division
Harris Intertype Corporation
Melbourne, FL

Cost: Under contract to RADC (Rome Air Development Center)

Availability: 2nd generation Sept. 1976

Installations: RADC (Rome Air Development Center)
Rome, NY
Fred Haritatos 315 330-2455

System Description: Hardware: The HRMR (Human Read Machine Read) Information Processor System is a holographic mass storage system which records ASCII data or hardcopy documentation in both human readable microimages and machine readable digital data form on COSATI standard microfiche. The HRMR uses a holographic technique that synthetically generates holograms of binary data blocks. The system has three major units: the subsystem control module, the recording module, and the readout module. The prototype system delivered to RADC had a manual storage and retrieval system, but the second generation system planned for delivery in September 1976 has an automated storage and retrieval system as well as an automated film processing system. This second generation system will be interfaced to a host computer (not determined at this time) as a part of a data base system.

Standard 4-inch by 6-inch (10.16 by 15.24 centimeter) microfiche cards are the recording media. Data can be recorded in three basic formats on these cards. The first format has 98 images arranged in rows of human readable data and one row of binary bits, which represent the encoded equivalent of the 98 images. The second format contains 36 images of optically scanned hardcopy documents (graphic arts mode) and their equivalent data in digital form. The third format is all machine readable and has 70 files of all digital data recorded in one-dimensional holograms that have a total fiche capacity of 28 million bits. There is random access to any file on a fiche. The access time to any fiche is 15 seconds. Up to 6,750 microfiche can be stored in a stack in a carrousel arrangement. More stacks can be added to increase the amount of online data.

The subsystem control module contains a PDP/11 central processing unit with disk drive, a magnetic tape drive for data input, an operator input/output unit with a display, a modem for data input/output, and a computer interface unit. The interface unit communicates with the laser recorder and hologram reader and accepts input from a graphic arts scanner. The modem unit allows remote data input/output, and the graphic arts scanner inputs data to implement the graphic arts mode of operation.

The recording module as indicated can operate in three modes. The recording module contains a 4-inch (10.16 centimeter) wide film cassette, an x-y table, and an optical line scanner (OLS). A 6-inch (15.24 centimeter) length of film is pulled from the roll, cut, and transported to an x-y table. The film is then positioned and pulled down onto the table by a vacuum system. Once the film is in position, the table moves under the OLS, which contains lenses, beam forming apertures, and a 15-sided rotating mirror. An argon-ion laser illuminates the OLS. The laser is controlled by an electro-optic modulator, which is itself controlled by electronics via a buffer and a D/A converter. The recording system is automated through exposure and processing. Each fiche requires 10 seconds to process. However, a new fiche can be started every 2 seconds. After each fiche has been processed, it must be manually clipped and put into the stack. The data stream that comes from the controller is recorded sequentially on each fiche.

The readout module in the second generation will be completely automated, unlike the prototype. A fiche is retrieved from the carrousel and automatically transported to the x-y table. Once it is aligned by sense diodes, the fiche is transported to the readout optical system, which has a HE-NE laser, illumination optics, and transform optics. This dual optical system reads two holograms at once into two photodetector arrays. When the reading is finished, the fiche is released and sent back to the carrousel.

Software: Software for the PDP/11 to act as a control module is provided. No other software is available at this time.

HISTORICAL SYSTEMS. There are some systems that have been reported on in the past that are not being marketed now or that are undergoing changes. These systems are listed below:

System Name: MASSTAPE

Manufacturer and Location: Grumman Data Systems
Garden City, NY

Comments: The MASSTAPE system is undergoing "re-engineering." Grumman is responding on an individual basis to RFP's for mass storage systems.

System Name: MMR-1A (formerly IVC-1000)

Manufacturer and Location: International Video Corporation
Sunnyvale, CA

Comments: This was a video recording device, not a system. The product has been discontinued as of 1 August 1975 by IVC. There is a possibility that the product will be picked up by another company and a controller added.

System Name: MMSS-1

Manufacturer's Name and Location: System Development Corporation

Comments: Announcements were made about the system, but no system was ever marketed.

System Name: PDR-5

Manufacturer's Name and Location:

Comments: The company that originally handled PDR-5 is no longer in business

System Name: SCROLL

Manufacturer's Name and Location: Control Data Corporation
Minneapolis, MN

Comments: Announcements were made for this mass storage system, but no product was ever marketed.

FUTURE TECHNOLOGIES. There are several technologies that may make future contributions to mass storage technology, but most are in the early development or research stages at this time. Some of these technologies include erasable and nonerasable holography, magnetic bubbles, magneto-optics, and semiconductors.

IBM, Bell Laboratories, and Hewlett-Packard are trying to develop the magnetic bubble memories. Bubble memories are dynamic and behave like a shift register. Access times depend on the particular organization of a chip. Bubble memories are volatile, but this can be overcome by using a permanent magnet. Bell Laboratories have delivered a prototype memory to Western Electric. The prototype contains 460,544 bits.

Electrical technologies include charge coupled devices (CCD's) and electron beam memories. The CCD's are arranged in shift register format like the bubble memories, with the access times also depending upon the organization of a chip. The CCD's must be "refreshed". Projected cost per bit should be competitive with magnetic disk, but access time will be faster. Another electrical technique for storing data as a charge is beam-addressed, metal oxide semiconductor (BEAMOS) memories. The BEAMOS technology is based on an electron beam that addresses sites and reads and writes data on a simple MOS chip, which stores the information. This type of memory is nonvolatile. Access time is less than 30 microseconds, and the transfer rate is 10 megabits per second. A prototype with controller has been developed by General Electric Company. The present modules have 3×10^7 bits and 1×10^9 bits. There is some chance that the future module capacity can be increased to allow a 10^{12} bit system. General Electric is also in the development stages of an ion-beam storage system. This recording system allows updates and additions, but it is not erasable. It would be a 10^{12} bit archival storage system.

Optical storage systems being investigated use two system approaches--bit-by-bit serial and holographic. The UNICON, already described, is an example of a bit-by-bit serial system. Other approaches which use reversible materials to allow read/write operation are in the early stages of development. Development of advanced holographic systems that allow read/write random access memories are in the research stage. One company (RCA), which worked under contract to NASA, is bringing this work to a close. They feel that several technological breakthroughs are needed to continue this work. However, RCA is continuing to work on holographic memories for archival image data. Video read-only systems are appearing, but they do not yet offer a recording station and are unusable for online computer storage. It appears that it will be at least a decade before optical storage of digital data will play an important role in mass storage systems.

CONCLUSIONS. Magnetic tape has been the most common form of mass storage. Because of the state-of-the-art in other technologies, it appears that magnetic tapes will continue to be the medium used in mass storage systems for the next decade.

Bibliography

1. Ampex Corporation, Ampex Terabit Memory System TBM, Sunnyvale, CA, n.d.

2. Barrekette, E. S., "Topical Meeting on Optical Storage of Digital Data," Applied Optics, Vol. 13, No. 4, April 1974.

3. Barrekette, E. S., "Trends in Storage of Digital Data," Applied Optics, Vol. 13, No. 4, April 1974.

4. Control Data Corporation, Introduction to Control Data Mass Storage System for System 370, Minneapolis, MN, n.d.

5. Control Data Corporation, Mass Storage Facility, Minneapolis, MN, n.d.

6. Control Data Corporation, Mass Storage System (For Use with IBM System 370, Minneapolis, MN, n.d.

7. Control Data Corporation, Mass Storage Tape Cartridge, Minneapolis, MN, n.d.

8. Control Data Corporation, The Data-Set Approach to On-Line Mass Storage, Minneapolis, MN, n.d.

9. Damron, S. et al, "A Random Access Terabit Magnetic Memory," American Federation for Information Processing, Fall Joint Computer Conference, Proceedings, 1968.

10. General Electric Company, BEAMOS (Beam-Addressed Metal Oxide Semiconductor), Schenectady, NY, n.d.

11. Gentile, Richard B., and Lucas, Joseph R., Jr., "The TABLON Mass Storage Network," American Federation for Information Processing, Spring Joint Computer Conference, Proceedings, 1971.

12. Harris-Intertype Corporation, Radiation Systems Division, HRMR Human Read/Machine Read Storage and Retrieval System, Melbourne, FL, n.d.

13. Harris-Intertype Corporation, Radiation Systems Division, HRMR Program Executive Summary, Melbourne, FL, n.d.

14. Hughes, W. C., et al, BEAMOS--An Electron Beam Addressed Semiconductor Mass Memory, General Electric Company, Schenectady, NY, n.d.

15. Hoagland, Albert S., "Mass Storage - Past, Present and Future," American Federation for Information Processing, Fall Joint, Computer Conference, Proceedings, 1972.

16. Houston, George B. "Trillion Bit Memories," Datamation, pp. 52-58, October 1973.

17. International Business Machines, IBM 3850 Mass Storage System Facts Folder, White Plains, NY, n.d.

18. International Business Machines, Introduction to the IBM 3850 Mass Storage System (MSS), White Plains, NY, n.d.

19. International Business Machines, 3850 Mass Storage System All Your Working Data On-Line - All the Time, White Plains, NY, n.d.

20. International Business Machines, 3850 Mass Storage System Its Whys and What-is-its, White Plains, NY, n.d.

21. Kozma, Adam, Holograms for Archival Storage, Electro-Optics Operation, Radiation Systems Division, Melbourne, FL, n.d.

22. Precision Instrument, System 190 Functional Description, Santa Clara, CA, n.d.

23. Salbu, Erik, "Current Status and Outlook of MSS: The TBM Memory System," Ampex Corporation, Sunnyvale, CA, 6 March 1974.

24. Shen, J. T. and Christy, D. O., Information Storage and Retrieval (ISAR) System - Technical and Technological Survey Analysis and Preliminary Architecture, Naval Electronics Laboratory Center, San Diego, CA, 6 June 1973.