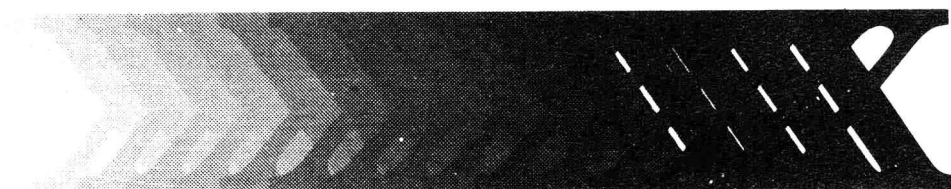


1990 IEEE

Tenth Symposium on Mass Storage Systems

DIGEST OF PAPERS

Tenth IEEE Symposium on Mass Storage Systems



Crisis in Mass Storage

May 7 - 10, 1990 • Monterey Sheraton Hotel • Monterey, California

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Bernard T. O'Lear, Technical Editor

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THE CHAIRMAN'S MESSAGE

The IEEE Computer Society Technical Committee on Mass Storage Systems and Technology is pleased to present this *Digest* of its Tenth IEEE Symposium on Mass Storage Systems. Over the sixteen-year history of the Committee, these Symposia have been held approximately every eighteen months and have served as a forum for both users and developers of storage technologies and systems to focus on the current and evolving critical issues and opportunities in the world of storage systems and technologies.

The theme of this Symposium, "The Crisis in Mass Storage," is focused upon the widening gap between the development of raw hardware and technologies and the need for the development of integrated storage systems. Rapid access to large volumes of information is the foundation of modern systems environments. Without a greater emphasis on the development of integrated storage systems, users with data-intensive applications are left without satisfactory solutions upon which to build their domain-specific environments. In the view of the Committee, the capacity of the next generation of storage technologies will not provide the cost-effective solutions needed to meet user requirements for storage without closing this gap.

The Symposium begins with a Tutorial, "Magnetic and Optical Data Storage," which will review the scientific and technical foundations upon which magnetic and optical data storage are based. Trends in storage products and subsystems will be forecast over the next decade and the potential impact of innovative concepts currently being pursued in electronic memories will be addressed.

Proceeding from this strong foundation, the Symposium includes presentations describing the current directions in existing storage, emerging technologies, innovative approaches, and development opportunities, with an emphasis on overall systems solutions.

Juan Rodriguez has ably served as Chairman of the Program Committee and Technical Chairman of the Symposium, and I wish to extend my grateful appreciation to him for his technical expertise and his many efforts to develop an exciting agenda for this Tenth Symposium. Al Hoagland and Geoff Bate have done an excellent job of preparing concise presentations of detailed technical material for the Tutorial. I am grateful to them for their diligent efforts to develop a unique resource for Symposium attendees, drawing upon their extensive careers in the field of storage. I am especially pleased that Ryal Poppa, the keynote speaker, has graciously agreed to provide the important perspective of the storage industry on the future of storage in the nineties.

Recognizing that the crisis in storage can only be solved through cooperative efforts between users and vendors to develop systematic definitions for interconnecting a spectrum of storage technologies to create total storage systems solutions, the Committee is launching a pioneering effort in conjunction with this Symposium to develop an IEEE standard for storage. It is hoped that this standard will perform a function similar to that performed by the International Standards Organization Open Systems Interconnection layered model for protocols that enabled the interconnectivity of diverse computers and operating systems. A kickoff meeting chaired by Patric Savage will be held on May 10 to launch the efforts of a subcommittee chaired by Sam Coleman to develop the standard. The Committee goal is to have a draft standard for presentation to the IEEE Standards Committee within two years. If successful, this standard will enable the specification of uniform interconnections of diverse storage technologies and devices and thereby facilitate their integration into total storage systems solutions.

This standards effort is ambitious but it builds upon the substantial work that was initiated by the Committee in its development of the Reference Model for Storage. The Model was developed under the guidance of Stephen Miller and has been reported on in previous Symposia, in a special issue of *Computer* magazine, and in *Advances in Computing* 1989. The Model was developed in a series of Specialists Workshops, co-hosted by Bill Collins, Bernie O'Lear, and Dick Watson, over the preceding five years. Work has continued on the refinement of the Model and the latest version will be presented at the May 10 meeting as a basis for the IEEE standard. The Committee gratefully acknowledges the contributions of Stephen, Bill, Bernie, Dick, Patric, and Sam and the many others who have worked on the development of the Model and who will continue to work on the specification of the draft standard – an arduous and lengthy commitment of time and energy. The IEEE Computer Society has acknowledged Stephen Miller's efforts by awarding him the "Outstanding Contribution Award."

Finally, I would like to express my appreciation on behalf of the Committee to a number of individuals who have given their time and energy over the last ten years and without whom the Committee could not function. Bernie O'Lear has served as General Arrangements Chairman for most of the Symposia and without his contributions, the Committee would not be able to hold these technical meetings. His efforts as Vice-Chair of the Committee are numerous and sustain its operation. Vladimir Nejezchleb and Kathy Sills serve as treasurers and without their efforts, the Symposia would not have the sound financial basis that sustains the work of the whole Committee.

Somewhat unique among technical meetings, a *Digest of Papers* is published and distributed in advance of the meeting. A tremendous amount of skill, negotiation, and finally friendly harassment is necessary to extract papers from authors in time for advance publication and substantial effort is required to prepare a first-class publication. Karen Friedman, Publications Editor, is a unique force in the Committee efforts and, assisted by Belinda Housewright, has continued to surpass her own high standards of publication quality. I would like to commend them for their usual outstanding job of publication and for the smooth operation of the Symposium registration and other functions.

The Committee looks forward to an exciting Symposium and to the beginning of a decade of new and challenging concepts and developments in Mass Storage and Systems Technologies.

Ann U. Kerr, Chair
IEEE Mass Storage Systems and Technology Technical
Committee

Tenth IEEE Symposium on Mass Storage Systems

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MASS STORAGE SYSTEMS TECHNICAL COMMITTEE HISTORY

Bernard T. O'Lear

National Center for Atmospheric Research
Boulder, Colorado

BACKGROUND

The IEEE Computer Society Technical Committee (TC) on Mass Storage Systems (MSS) technology was formulated sometime before the first workshop on MSS was held in 1974 in Washington, D.C. The purpose of the workshop was to open up discussions on data storage technologies and their integration into systems that would provide extensive data storage. A few government agencies, national laboratories, and oil exploration companies had data collections approaching the "terabit" capacity range at the time. The methodologies for handling such archives were starting to be examined and the workshop gathered vendors and users to discuss various related issues.

The user-vendor relationship that is so important for this committee can be traced from the first workshop to the current Symposium. In fact, several attendees of the first workshop have been active members of the TC for over sixteen years. The activities of the TC have centered around the MSS Symposia. In the last six years, the Mass Storage Specialist Workshops have produced the Mass Storage Reference Model. This model has been through two official versions and is now headed for work as a first draft standard.

The Mass Storage Systems and Technology TC has been involved over the years with the organization, storage and retrieval, and hardware requirements of large data collections. Unconventional data collections and processing systems are considered in addition to the conventional types, including special-purpose CPUs, mass storage devices, operating systems, and languages. The MSSTC objectives have generally been defined as follows:

- Conduct symposia where topics and research relating to mass storage systems can be discussed.
- Foster the education of professionals by sponsoring tutorials.
- Promote the inclusion of MSS topics in university curricula at the graduate and undergraduate levels.
- Serve as a forum for manufacturers of mass storage systems.
- Act as a bridge for communication between MSS

vendors and clients.

- Enhance the understanding of Mass Storage System construction evolution and operation.

Some history of the MSSTC has been lost from the early years. Therefore, this reconstruction may be incomplete in some areas. Readers of the account may have additional information the author did not have and are assured missing excerpts or details are not intentional.

MEETING SUPPORT

Starting with the Fourth Symposium, logistical and financial support, and support for the *Digest of Papers*, was transferred to TC members in Boulder, Colorado. Vladimir Nejezchleb and Kathy Sills assumed support for treasurer and bookkeeping responsibilities. Bernard O'Lear and Karen Friedman took over meeting planning and *Digest of Papers* production. These people have continued in their support roles through the current Tenth Symposium meeting. Other people providing meeting support included Julie Olano, Mary Mulle, and Belinda Housewright.

COMPUTER MAGAZINE

Two special issues of *Computer* magazine, July 1982 and July 1985, were dedicated to MSS. They were both compiled and edited by Stephen Miller.

TUTORIALS

Tutorials were initiated in conjunction with the Sixth Symposium. The Tutorials have since been a part of every Symposium. The purpose of the Tutorials is to bring the meeting attendees up to date on particular issues relating to MSS before the Symposium begins. To date, all *Tutorial Notes* have been compiled or printed by Patric Savage of Shell Development Company. The Tutorial titles and Tutorial chairs follow:

MEETING CO-SPONSORSHIP

The Committee has co-sponsored or provided specific sessions or talks on MSS theory or applications for the following meetings:

Date	Number	Title	Chair(s)
June 3, 1984	Sixth	Mass Storage System Tutorial	George Michael, Patric Savage
November 4, 1985	Seventh	Mass Storage Systems: Site Architecture and A Comparative Analysis	Stephen Miller
May 11, 1987	Eighth	Integrating Distributed System and MSS Architectures	Dick Watson
October 31, 1988	Ninth	Building Blocks for Storage Systems	Ann U. Kerr
May 7, 1990	Tenth	Magnetic and Optical Data Storage	Al Hoagland, Geoffrey Bate

- Winter OSA Topical Meeting on Optical Data Storage, January 17-20, 1983
- SPIE meeting on Optical Storage Media and Optical Disk Systems and Applications, June 8-9, 1983
- SPIE meeting on Applications of Optical Digital Data Disk Storage Systems, June 25-28, 1984
- Rothchild Meeting, 1986-88
- GCF Meeting, 1987-88
- Arctic Environmental Data System Workshop, March 1988
- Supercomputing '88, November 1988
- NSF CMU Meeting, 1988

SPECIALIST WORKSHOPS

The '80s witnessed an effort by some TC members to try and define Mass Storage Systems and how they were composed, built, and managed. A series of MSS Specialist Workshops began at NCAR in September 1983. The original objective was to find some commonality in the systems that had been constructed and examine if any systematic approach to their structure could be defined. The series of meetings led to the generation of the IEEE MSS Reference Model that was published in *Advances in Computers* (Vol. 27, 1988). It was updated by a set of papers that appeared in the *Digest of Papers* from the Ninth Symposium. It is now the chartering document of a Storage Systems Standards effort that the MSSTC will spawn at the Tenth Symposium. The Storage Systems Standards Working Group will be chaired by Samuel S. Coleman, LLNL. This Working Group will be closely supported by the MSSTC Standards Subcommittee,

chaired by Patric Savage of Shell Development Company. Stephen Miller was the driving force for this effort through all of these Workshops. The Workshops took place at NCAR in the following time frames:

- September 26-28, 1983
- October 17-19, 1984
- September 9-11, 1986
- September 14-16, 1987
- April 5-7, 1988

Examination of attendance records for these workshops show the following people contributed to one or more of the workshops:

Stephen Adams (1)	Arthur Keller (1)
David Arneson (3)	Dave Kitts (2)
Thomas Bagg (1)	Ed Kubaitis (1)
Garret Boer (1)	Dennis Luck (1)
John Burgess (1)	Prakash Mankekar(1)
Bill Burr (1)	Tyce McLarty (2)
Clarence Carr (1)	John Merrill (1)
Joseph Choy (1)	Stephen Miller (5)
Sam Coleman (4)	Marc Nelson (3)
Bill Collins (5)	Bernard O'Lear (5)
Prem Dewan (1)	J. M. Randal (2)
William F. Dorfmann (1)	Bill Rawsky (1)
Charles Edwards (1)	Rick Reid (1)
Joseph Falcone (2)	Patric Savage (4)
Joseph Ferrero (1)	Howard Turtle (1)
Gary Forbus (1)	David Tweten (2)
Bruce Griffing (1)	Donald Waddell (1)
Kent Harness (3)	Richard Watson (4)
Clay Johnson (3)	Karen Webb(1)
William Jones (2)	Greg Williams(3)
Ralph Keirstead (1)	

EXECUTIVE COMMITTEE

The MSSTC has *always* had some number of people guiding its activities over the years. As near as can be determined, the following list is the succession of TC chairs to the present:

- David N. Freeman
- Erik Salbu
- Irv Tjomsland
- Bernard T. O'Lear
- Patric Savage
- Ann Kerr (current MSSTC chair)

The current Executive Committee is listed next, followed by the names of those who are known to have served in some executive capacity in previous years.

Current Executive Committee:

Bill Collins	Stephen Miller
John Davis	Vladimir Nejezchleb
Joe Falcone	Bernard T. O'Lear
Karen Friedman	Jack Petruzelli
Bruce Griffing	Juan Rodriguez
Al Hoagland	Patric Savage
Clay Johnson	Kathy Sills
Ann Kerr	Tracy Wood
George Michael	

Past Executive Committee members and/or early workshop planners:

Saburo Adachi	John R. Morrison
Alfred Brooks	David A. Nelson
David N. Freeman	Erik Ringkjøb
Richard Kenville	Erik Salbu
Robert R. C. Lamay	D. Lynn Shirley
William C. Lynch	Irv Susskind
Jim MacMillan	Irving Tjomsland
Thomas Marrill	Albert B. Tonik
Lynn Moore	Clinton Woodworth

MASS STORAGE SYMPOSIA

The combination of workshops (leading to Symposia), their order, and subject titles follow.

IEEE Mass Storage Workshop

May 22-23, 1974

Washington, DC

Presentations:

- Mass Storage Technology
- Magnetic Recording for Mass Memories

- Magnetic Bubble and Disk file Mass Storage
- Semi-Conductor Memories
- Optical Memories
- Mass Storage Usage
- Social Security Needs in Mass Storage
- Improving Patent Examination by Computer Search of Mass Storage
- Legal Storage and Retrieval
- System Design
- The Design and Evaluation of Large Electronic Memories
- The Data-Computer System: A Network Data Utility
- Mass Storage at Aetna Life and Casualty: Today and Tomorrow
- Storage Hierarchies: A Reasonable Compromise
- Mass Storage Products
- Masstape
- The TBM Memory System
- Application of Queing to Continuous Media Devices
- System 190, Laser Mass Memory System
- Automated Tape Library (XTL)
- Holographic Information Storage and Retrieval

Second Workshop on Mass Storage Systems

January 27-28, 1976

Valley Forge, PA

Plenary Session: User Requirements

Presentations:

- Current Media Inventories and Management Procedures at a Typical Large Commercial Installation
- Current Media Inventories and Management Procedures at a Typical Large Federal Installation
- Large User Profile in the United Kingdom
- Forecast for Media and Procedures of the 1980s

Small Group Discussions:

- Programming Host Computers for MSS
- Backup and Recovery Procedures
- Review of MSS Architecture
- Internal Software/Firmware
- Media Conversion
- Querying MSS
- MSS Housekeeping
- Media Evolution
- Data Base Storage Hierarchies
- MSS Requirements of Two Major Federal Agencies

Third IEEE-CS Workshop on Mass Storage Systems

April 5-7, 1977

Palo Alto, California

Plenary Session: MSS User Field Operating Experiences

Panel Discussion: Planning for MSS

Presentations:

- Justification of MSS
- Selecting the MSS Applications
- MSS Implementation and Conversion Problems
- Does (Can) MSS Satisfy Performance Requirements?
- Does (Can) MSS Improve Data Administration and Security?
- The Future of MSS Media Technology
- Can MSS Support Distributed Processing?
- MSS Architecture Improvement Needs
- User Acceptance of MSS - Use and Abuse
- Status and Future of MSS

Fourth IEEE MSS Symposium: The Gap Between MSS Products and User Requirements

April 15-17, 1980

Denver, Colorado

Presentations:

- An Observation on the Incorporation of Mass Storage Devices
- Mass Storage Technologies for Large-Scale Data Storage Requirements
- Mass Storage in Multiple Host Systems
- System Perspective of Organization of Mass Storage Systems
- Interfacing Subsystems with Local Wideband Networks
- System Evolution of MSS Hierarchies
- System Design of the SLIDESTORE
- MASSTOR Shared VSS: A New Approach to Global File Management and Control
- Storage Attachment Architecture
- Optical Disk Approaches as Mass Storage
- Optical Mass Storage Technology
- High Performance Digital Film Memory Systems
- Archiving of Operational Landsat Data
- Operational Characteristics of the NCAR Mass Storage Device
- Experience with the LASL Common File System
- Mass Storage Systems and Large Research Libraries

Fifth MSS Symposium: Hardware and Software Issues for Mass Storage Systems

October 26-28, 1982

Boulder, Colorado

Presentations:

- An Historical Perspective of Mass Storage

- Measuring the Potential for New Storage Technologies
- Design Philosophy - Evolution of the Application
- Software Considerations in Mass Storage Systems
- Simulation of Automatic File Migration Policies
- Cooperating File Systems for a Local Network
- Software Implications of Mass Storage
- The Optical Magnetic Question
- Optical Materials Issues: Archivable and Reuseable
- Evolution of Disk Drive Technology during the '80s
- Tape in the MSS Environment
- Flexible Disk as an MSS Tool
- Mass Store Requirements Survey

Sixth MSS Symposium: The Mass Storage Spectrum - A Study of Extremes

June 4-7, 1984

Vail, Colorado

Presentations:

- MSS Generic Model: A Beginning
- Los Alamos Central File System
- Two MSS-Host Interfaces
- File Storage Management at U of Illinois
- Storage in the LLNL Octopus Network
- The MASSTOR Systems "Shared VSS" Correspondence to the MSS Generic Model
- Definition of a File Management System Model
- IBM 3850 MSS
- 7600 Optical Storage Subsystem Architecture
- Storage Technology Optical Storage, 7640
- A 10^{13} Bit Optical Disk Jukebox System
- Trends in High-Density, Digital, Magnetic Tape Recording
- SHBR-12 as a Mass Storage Device
- High-Density Magnetic Tape Recording for Mass Storage
- Advanced Technology for High Recording Density Disk Storage

Seventh MSS Symposium: Toward Automated Mass Storage Systems

November 4-7, 1985

Tucson, Arizona

Tutorial: Site Architecture and Mass Storage Systems

Presentations:

- Toward a Reference Model of Mass Storage Systems
- A High Data Rate, High Capacity Optical Disk Buffer
- Supercomputers and Mass Storage
- 3480 Technology
- Automated Cartridge Repository

- Hitachi Optical Disk Systems
- OSAR (Optical Storage and Retrieval)
- Rotary Digital Cassette Recorder for Mass Archival Storage

Eighth MSS Symposium: Emerging Solutions for Data Intensive Applications

May 11-14, 1987

Tucson, Arizona

Tutorial: Integrating Distributed System and Mass Storage System Architectures

Presentations:

- Development of a Modular 10^{14} - 10^{16} Bit Mass Storage Library
- Interfacing a Mainframe Database Retrieval System with Optical Disk
- The NCAR MSS
- An MSS for Realtime Image Data Caching
- NASA Space Data Storage Solutions
- Evolution of 19mm Magnetic Tape Standards for Video, Instrumentation
- Mass Storage Mechanization for Cray Computer Systems
- The Need for a Low-Cost, Reliable, Open-Ended IBM 3850 MSS Replacement
- FMS-File Management System at Boeing
- Virtual Library System
- NFS
- Mass Storage at San Diego Supercomputer Center
- Magneto-Optical Mass Store System with 130mm Write-Once Disk Compatibility
- Storage Tek 4400 Automated Cartridge System
- 8.8 GByte Capacity Magnetic Disk Storage System
- D-1 Magnetic Tape
- The PolyMorphic System
- Mass Storage Reference Model Version 2.0, May 1987

Ninth IEEE MSS Symposium: Storage Systems: Perspectives

October 31-November 3, 1988

Monterey, California

Tutorial: Building Blocks for Storage Systems

Presentations:

- Mass Storage Reference Model Special Topics
 - The Bitfile Server in the Reference Model
 - Storage Server as Physical Box
 - Physical Volume Repository
 - Bitfile Mover
 - Mass Store Model System Management
- Networking Storage Systems: A Problem Statement
- Regional and Backbone Networks

- Dept. of Energy Nuclear Weapons Complex Network
- Mass Store Archiving in Network Environments
- Security Aspects of MSS: A Problem Statement
- An MSS Security Primer
- Implementations:
 - NCAR/Los Alamos
 - Optical Storage at Data/Ware Development
 - Non-Erasable Media Computer Structures/Ricoh
 - Import/Export/NCAR
 - MSS/Fujitsu
 - 2 Terabyte Optical Archival Store at U. of Wisconsin-Madison
 - Cimarron
 - FileTek
 - 30 Terabyte MS Architecture/PRC
 - UNIX-MVS-based MSS for Supercomputers/NASA Ames and Sterling Software
 - File Migration/NCAR
- CD-ROM as a MSS
- D-1 through DAT
- Tape Recorder
- Terabyte Optical Tape Recorder
- High-Capacity Optical Disk

Tenth IEEE MSS Symposium: Crisis in Mass Storage

May 7-10, 1990

Monterey, California

Tutorial: Magnetic and Optical Data Storage

Presentations:

- Review of IEEE MSSTC Activities
- Review of IEEE-CS MSS Reference Model
- The Livermore Distributed Storage System: Requirements and Overview
- The Livermore Distributed Storage System: Implementation and Experiences
- A Standard Method for Creating Self-Defining Data Structures for Information Archive and Transfer
- Developments in R-DAT Data Recorders
- Magnetic Tape Technology in the 1990s
- A Mass Storage Subsystem using ANSI X3B6 ID-1 Recorders
- A Survey of DCRSi and D-2 Technology
- Multi-Terabyte Automated Mass Storage
- Magnetic Tape Recording: Archival Considerations
- Applying Semantic Data Modeling Techniques to Large Mass Storage System Designs
- Mass Storage System Advances at Los Alamos
- User and Administrator Interfaces for a Mass Storage System
- Automating the Data Center Operation: "Do We Have a Choice?" "Can We Manage it Effectively?"

- Development of Omniserve
- Integration of the Optical Storage Processor and the DBC/1012 Data Base Computer
- Data Catalogs for Archive Systems
- Automated Cartridge System Library Server
- The Importance of Meta-Data in Mass Storage Systems
- Early Experience with Mass Storage on a UNIX-Based Supercomputer
- Re-engineering the Los Alamos Common File System
- DataTree™ and UniTree™ Software for File and Storage Management
- Searching for a UNIX Mass Storage System for a Supercomputer Environment
- Overcoming UNIX Kernel Deficiencies in a Portable, Distributed Storage System
- Hiding Mass Storage Under UNIX: NASA's MSS-II Architecture
- Network File for ISDN
- A High Capacity, High Performance, Small Form Factor Magnetic Tape Storage System
- An Architecture for a Transparent Networked Mass Storage System
- Product Requirements by the Reference Model: A Case Study
- A Distributed File and Tape Management System for the LEP Experiments at CERN
- Storage Management Issues for Cray Research
- A 1990s Solution to the Crisis in Mass Storage
- Impact of HPPI and Fibre Channel Standards on Data Delivery

CONTRIBUTIONS

The following section lists organizations whose representatives gave presentations or chaired panels for the Workshops or Symposia:

Universities

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MIT
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Optical Sciences Center – University of Arizona
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University of California at San Diego
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