The Optical Memory Technology Review (OMTR) was held at the National Bureau of Standards, in Gaithersburg, Maryland, on June 11, from 9:00 am to 6:00 pm and at the Gaithersburg Marriott, in Gaithersburg, Maryland, on June 12, from 8:30 am to 3:00 pm. Enclosed are the OMTR agenda and the presentation materials from one-half of the June 11 afternoon OMTR session.

Materials from the "US Department of Defense Sponsored Optical Disk Studies" as they were presented in the morning session on June 11 are not included, since that session was for employees of the Federal sector, only. Overviews of the "US Department of Defense Sponsored Optical Disk Studies", as they were presented to members of both the Federal and private sectors, in the June 11 afternoon session are included in this "Section 1" and also in "Section 2", which has been mailed to you under separate cover.

"Section 2" contains the presentation materials from speakers in the second-half of the June 11 afternoon session. Also mailed under separate cover, is "Section 3", which contains the presentation materials from the June 12 session, in addition to the list of OMTR participants.

Review Organizer
Roman Fedorak
Code 5023
Naval Air Development Center
Warminster, PA 18974-5000
(215) 441-1278
AV 441-1278

Local Coordinator
Jean Freedman
Room A61, Bldg. 225
National Bureau of Standards
Gaithersburg, MD 20899
(301) 921-3165
October 1, 1986

Dear Optical Memory Technology Review Participant:

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Publication of these materials does not constitute approval by the Naval Air Development Center or the National Bureau of Standards of the findings or conclusions contained herein. These materials are published by the Naval Air Development Center for the exchange and stimulation of ideas.

The objective of the OMTTR was to provide a forum for discussion on optical storage technology and its applications in the US Department of Defense and Federal government. Thank you for your participation.

Review Organizer
Roman Fedorak
Code 5023
Naval Air Development Center
Warminster, PA 18974-5000
(215) 441-1278
AV 441-1278

Local Coordinator
Jean Freedman
Room A61, Bldg. 225
National Bureau of Standards
Gaithersburg, MD 20899
(301) 921-3165
OPTICAL MEMORY TECHNOLOGY REVIEW
June 11 - 12, 1986

Organized by the Naval Air Development Center
Hosted by the National Bureau of Standards

Session 1 (FEDERAL GOVERNMENT EMPLOYEES ONLY)
June 11, 1986
9:00 a.m. - 12:30 p.m.
Green Auditorium
Administration Building
National Bureau of Standards
Gaithersburg, Maryland

Session 2 (FEDERAL GOVERNMENT AND INDUSTRY EMPLOYEES)
June 11, 1986
1:30 p.m. - 6:00 p.m.
Green Auditorium
Administration Building
National Bureau of Standards
Gaithersburg, Maryland

Sessions 3 & 4 (FEDERAL GOVERNMENT AND INDUSTRY EMPLOYEES)
June 12, 1986
8:30 a.m. - 3:00 p.m.
Gaithersburg Marriott
620 Lakeforest Avenue
SALONS A, B, C and D
Gaithersburg, Maryland

Review Organizer
Roman Fedorak
Code 5023
Naval Air Development Center
Warminster, PA 18974-5000
(215) 441-1278
AV 441-1278

Local Coordinator
Ms. Jean Freedman
Room A61, Bldg. 225
National Bureau of Standards
Gaithersburg, MD 20899
(301) 921-3165
SESSION 1

SESSION 1 IS FOR FEDERAL GOVERNMENT EMPLOYEES ONLY

REGISTRATION FOR SESSION 1 BEGINS AT 8:15 AM

SESSION 1: Wednesday, June 11, 1986 9:00 am - 12:30 pm

MODERATOR: Roman Fedorak, Naval Air Development Center

9:00 am Department of Defense Sponsored Optical Disk Study (Fairchild)
10:15 am BREAK
10:45 am Department of Defense Sponsored Optical Disk Study (Sperry)
12:30 pm END OF SESSION 1
LUNCH
AGENDA
OPTICAL MEMORY TECHNOLOGY REVIEW
NATIONAL BUREAU OF STANDARDS
GREEN AUDITORIUM, ADMINISTRATION BUILDING
GAITHERSBURG, MARYLAND

SESSION 2

SESSION 2 IS FOR FEDERAL GOVERNMENT AND INDUSTRY EMPLOYEES

REGISTRATION FOR SESSION 2 BEGINS AT 12:00 PM

SESSION 2 : Wednesday, June 11, 1986 1:30 pm - 6:00 pm

MODERATOR: Roman Fedorak, Naval Air Development Center

1:30 pm  Welcoming Remarks: Raymond Kammer
          Deputy Director
          National Bureau of Standards

          Organizer's Comments: Roman Fedorak
          Naval Air Development Center

1:50 pm  Keynote Speaker: John Riganati
          Director, System Research
          Supercomputing Research Center
          Institute for Defense Analyses

          "US High Technology Industry, Its Principles
          and Challenges...With an Emphasis on the Optical Digital
          Data Disk (OD3) Challenge"

2:10 pm  "Storage Requirements and Applications"
          Bernie Zempolich
          Naval Air Systems Command

2:40 pm  "Status of 5.25-inch Optical Digital Data Disk Technology"
          Di Chen
          Optotech

3:00 pm  BREAK
SESSION 2, OPTICAL MEMORY TECHNOLOGY REVIEW (AGENDA)

3:30 pm  "Interpretation of US Department of Defense Specifications for Device Designers"
Marc Saltzman
Fairchild Communications and Electronics Company

3:50 pm  Overview of Two DOD Sponsored 5.25-inch Optical Disk Studies:
"Optical Memory System Study Presentation"
Tim Rogers
Fairchild Communications and Electronics Company
"Optical Disk Study Overview"
Dave Zempke
Sperry Corporation

5:00 pm  "Portable Optical Memory Systems for Tactical Applications"
Robert Miller
US Army Electronics Laboratory

5:20 pm  "Overview of DOD/NASA Large Optical Disk Systems Development"
Jack D. Petruzelli
US Air Force

5:40 pm  "Digital Map Generation"
Lt. Col. Milton Cone
US Defense Mapping Agency

6:00 pm  END OF SESSION 2
SESSION 3

SESSION 3 IS FOR FEDERAL GOVERNMENT AND INDUSTRY EMPLOYEES

REGISTRATION FOR SESSIONS 3 AND 4 BEGINS AT 8:00 AM

SESSION 3 : Thursday, June 12, 1986 8:30 am - 12:45 pm

MODERATOR : Jean Freedman, National Bureau of Standards

8:30 am "Overview of Magnetic Disk Technology,"
Ron Lares
Control Data Corporation

"Overview of Magnetic Disk Technology"
Bryan Birch
Miltope Corporation

9:10 am "Federal Interest, Requirements, and Plans
For Optical Disk Technology...As Told To
The Federal Council on Computer Storage
Standards and Technology"
Jean Freedman
National Bureau of Standards

9:20 am "Optical Memory Recording Concepts
and Current Commercialization Trends"
Leonard Laub
Vision Three

10:15 am BREAK
SESSION 3, OPTICAL MEMORY TECHNOLOGY REVIEW (AGENDA)

10:45 am Presentations and Panel Discussion:
"Overview of Optical Digital Data Disk Research and Development"

PANEL DISCUSSION MODERATOR: Leonard Laub

"Overview of Optical Digital Data Disk Research and Development"
John Morgan
Philips and DuPont Optical Company

"Overview of Optical Digital Data Disk Research and Development"
Gerald Poshkus
Eastman Kodak Company

"Overview of Optical Digital Data Disk Research and Development"
Roger Hilde
3M Company

"Overview of Optical Digital Data Disk Research and Development"
Bryan Birch
Hitote Corporation

12:45 p.m. END OF SESSION 3
LUNCH
SESSION 4

SESSION 4 IS FOR FEDERAL GOVERNMENT AND INDUSTRY EMPLOYEES

SESSION 4: June 12, 1986 1:45 pm - 3:00 pm

MODERATOR: Jean Freedman, National Bureau of Standards

1:45 pm "Optical Digital Data Disk System Components...The Status of Research and Development"
Oliver Bessette
RCA Corp.

2:10 pm "Overview of the National Space Science Data Center; Optical Disk System Integration"
Brian Lopez-Swafford
National Aeronautics and Space Administration

2:30 pm "Issues in Optical Disk Longevity and Approaches to Optical Disk Life Testing"
William Nugent
Library of Congress

2:50 pm "Summary of the Presentations and Discussions from the June 11 and 12, 1986, OPTICAL MEMORY TECHNOLOGY REVIEW"
Leonard Laub
Vision Three

3:00 pm END OF SESSION 4
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   Institute for Defense Analysis  
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PRINCIPLE 0

THE PRIMARY PURPOSE OF A CORPORATION BASED ON HIGH TECHNOLOGY IS TO MOVE TECHNOLOGY INTO THE MARKETPLACE.
A NORMAL MARKETPLACE

Figure 2. "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (ODD) Challenge", John Riganati, Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20760.
Figure 3. "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (OD²) Challenge", John Rivanati Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20760.
THERE ARE TWO KINDS OF INVENTION

1. GIVEN A GOAL, FIND A MEANS TO REACH IT,

2. DISCOVER A FACT, IMAGINE WHAT IT COULD BE USED FOR.

Figure 4, "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (OD^3) Challenge", John Riganati Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20760.
Figure 5. "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (OD3) Challenge", John Riganati Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20760.
Figure 6. "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (OD^3) Challenge", John Raganati Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20760.
A JAPANESE PROJECTION

THE "ADVANCED NATION'S DISEASE"

Figure 7. "US High Technology Industry, Its Principles and Challenges... with
An Emphasis on the Optical Digital Data Disk (ODD) Challenge", John
Riganati Supercomputing Research Center. 4380 Forbes Blvd, Lanham,
MD 20706.
Figure 8. "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (OD3) Challenge", John Riganati Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20760.
RELATIONSHIP OF QUALITY TO HIGH TECHNOLOGY IN JAPAN

● W. EDWARDS DEMING'S 1950 MESSAGE FOR JAPAN:

IMPROVED QUALITY — IMPROVED PRODUCTIVITY & DECREASED COST

● QUALITY IS HIGH TECHNOLOGY

Figure 9: "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (OD³) Challenge", John Riganati Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20760.
DEMING'S SEVEN DEADLY DISEASES

1. LACK OF CONSTANCY OF PURPOSE

2. SHORT TERM THINKING

3. MANAGEMENT BY OBJECTIVES
   - NOURISHES SHORT TERM THINKING
   - ANNIHILATES LONG TERM PLANNING
   - DEMOLISHES TEAM WORK
   - BUILDS FEAR
   - CREATES BITTERNESS
   - ENCOURAGES MOBILITY

4. BARRIERS TO PRIDE OF WORKMANSHIP

5. FAILURE TO ADOPT A POLICY OF NEVER-ENDING IMPROVEMENT

6. HOPE FOR QUICK RESULTS (INSTANT PUDDING)

7. "BOTTOM LINE" FINANCIAL MANAGEMENT WITHOUT REGARD TO FIGURES THAT ARE UNKNOWN OR UNKNOWABLE

Figure 10. "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (OD3) Challenge", John Rigantti Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20760.
Serendipity vs the Lowest Bidder

LATENT BENEFITS OF CONSENSUS PROCESSES

- The history of technology is the history of the birth, weaning, and (mostly) death of ideas.

- There are two types of ideas:
  - Radical new ideas; and
  - Ideas whose time has come.

Figure 12: "US High Technology Industry, Its Principles and Challenges" by John R. Gatti, Supercomputing Research Center, 4300 Forbes Blvd., Lanham, MD 20706.
LATENT BENEFITS OF CONSENSUS PROCESSES (CONTINUED)

- For ideas whose time has come, properly executed consensus processes can substantially improve their probability of survival.

- In the United States, consensus processes are most commonly carried out by standardization groups.

---

LATENT BENEFITS OF CONSENSUS PROCESSES
(CONTINUED)

• Unfortunately, there are two types of standardization:

  - Bureaucratic standardization
    (which stultifies growth); and

  - Consensus-based standardization
    (which enables growth).

• Any action based on consensus requires all participants to understand not only the opposing views but the technical, business, or sociological reasons for those views.

SUMMARY OF PRINCIPLES

0. The primary purpose of corporate activity in high technology is to move technology into the marketplace.

I. Despite principle 0, pragmatic management decisions at this time in these United States can only be based on the path of least resistance.

II. Nations rise and fall. As a historically young nation, the U.S. can be still on the rise if we really believe this to be true and act accordingly.

SUMMARY OF PRINCIPLES (CONTINUED)

III. Technological progress is real.

IV. Consensus processes contain latent benefits well beyond standardization of specifications.

SUMMARY OF CHALLENGES TO OD³

0. Don't let the accountants wear you down.

I. Use the low end to advance the high end!

II. Don't believe there is anything "Japanese" about good management practices.

Figure 17. "US High Technology Industry, Its Principles and Challenges... With An Emphasis on the Optical Digital Data Disk (OD³) Challenge", John Riganati Supercomputing Research Center. 4380 Forbes Blvd, Lanham, MD 20706.
SUMMARY OF CHALLENGES TO OD³
(CONTINUED)

III. Constantly evaluate: is progress real?

IV. Use the consensus process to purify ideas as well as specifications.

OPTICAL MEMORY

STORAGE REQUIREMENTS AND APPLICATIONS

FOR USE IN MILITARY ENVIRONMENTS

BERNARD A. ZEMPOLICH

NAVAL AIR SYSTEMS COMMAND

Figure 1. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPI, Washington, DC 20361-3500.
NOTICE: THIS IS AN EDITED VERSION OF THE AUTHOR'S PRESENTATION

GIVEN AT THE NATIONAL BUREAU OF STANDARDS - NAVAL AIR DEVELOPMENT

CENTER OPTICAL DISK SYMPOSIUM. THE VIEWS AND OPINIONS EXPRESSED ARE

THOSE OF THE AUTHOR'S AND NOT OFFICIAL POSITIONS OF THE NAVAL AIR SYSTEMS


MATERIAL DOES NOT CONTAIN THE PHOTOGRAPHS SHOWN DUE TO THE LACK OF TECHNICAL

CAPABILITY TO REPRODUCE THE PICTURES IN HARD COPY FORM. THE PROSE THAT

HAS BEEN ADDED IS FROM PREVIOUSLY PREPARED PRESENTATIONS THAT WERE CLEARED

FOR PUBLIC RELEASE.

Figure 2. "Optical Memory Storage Requirements and Applications for Use in Military
Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems
Command, AIR 935C, Room 440, JPL, Washington, DC 20361-3500.
MEMORY REQUIREMENT FOR TECHNICAL MANUALS ASSOCIATED WITH A CARGO-TYPE AIRCRAFT.

CURRENTLY THERE ARE 155 TECHNICAL MANUALS PUBLISHED FOR AND REQUIRED TO OPERATE AND MAINTAIN ONE PARTICULAR CARGO AIRCRAFT. THE MANUALS CONSIST OF APPROXIMATELY 70,000 (SEVENTY THOUSAND) PAGES AND TOTAL WEIGHT IS 500 LBS. 12½ CUBIC FEET OF SHELF SPACE IS REQUIRED FOR STORAGE OF THE MANUALS.

THE FLIGHT MANUAL IS FLOWN ON BOARD EVERYDAY AND IS STORED ON THE FLIGHT DECK.

- THERE ARE 53 MANUALS ON THE FLIGHT DECK.
- TOTAL WEIGHT 200 LBS.
- CONTAINS 23,000 PAGES
- REQUIRES AT LEAST 50 CUBIC FEET OF SHELF SPACE FOR STORAGE ON FLIGHT DECK.

REVISIONS OVER A 10 YEAR PERIOD ARE APPROXIMATELY 140,000 PAGES APPROXIMATELY 14K/YEAR
450 WORDS/PAGE AVERAGE, 1170 SEPARATE, FORMAL CHANGES.

BY EXAMPLE, ONE HIGH PERFORMANCE FIGHTER AIRCRAFT HAS APPROXIMATELY 7,000,000 PAGES OF DOCUMENTATION ASSOCIATED WITH IT IN THE OPERATIONAL ENVIRONMENT.

"TRANSLATION FACTOR"

COMMERCIAL - 250 WORDS/PAGE
MILITARY - 450 WORDS/PAGE

Figure 3. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 950, Room 440, JPI, Washington, DC 20361-3500.
PROGRESS IN ELECTRONICS TECHNOLOGY

Figure 5. " Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPI, Washington, DC 20361-3500.
Figure 6 graphically shows the "hour glass constriction" facing the naval avionics community today. That is, how to transition from a current inventory of analog "black boxes" to one in which, by the 1990s, the inventory will be approximately 90% digital in nature. At the same time that we are going through this transition, we must maintain hardware interchangeability and not upset, nor negate, established hardware and software standards.

### NAVAL AVIATION USE OF MEMORY TECHNOLOGY

<table>
<thead>
<tr>
<th>YEAR OF INTRODUCTION</th>
<th>TECHNOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MID-TO LATE 1960's</td>
<td>CORE/MAG, TAPE</td>
</tr>
<tr>
<td>1972</td>
<td>CORE/DRUM/TAPES</td>
</tr>
<tr>
<td>1974</td>
<td>MAG, FILM/DRUM/TAPE/BIPOLAR</td>
</tr>
<tr>
<td>1974</td>
<td>CORE</td>
</tr>
<tr>
<td>1985</td>
<td>2X CORE</td>
</tr>
<tr>
<td>1987</td>
<td>CMOS SOLID-STATE DRUM</td>
</tr>
<tr>
<td>1987</td>
<td>BIPOLAR E²PROM</td>
</tr>
<tr>
<td>1990</td>
<td>BIPOLAR/ RAM E²PROM</td>
</tr>
</tbody>
</table>

---


1971 1/2 FT³
1979 1/20 FT³
1986 1/3 SIZE OF A U.S. DMF.
TECHNOLOGY TRANSITION & INSERTION FLOW CHART

By the early 1960s, naval aviation operational needs in combination with the need for on-board equipment flexibility led to the introduction of general purpose, programmable digital computers into naval aircraft/avionic systems. The programmability of the machines permitted rapid changes to be made through software modifications rather than through hardware changes. The advent of the integrated circuit also hastened the introduction of general-purpose digital computers throughout naval aviation because of the weight and volume savings that these devices have over other computing technologies. These "first generation airborne computers" were termed "centralized"; that is, all Operational Flight Programs (OFPs) are contained in a single machine. Unfortunately, while computer hardware made great strides forward in the state-of-the-art during this period in time, attendant software tools did not. Thus, while the use of digital computers in naval aircraft allowed the introduction of many new operational capabilities, navy management also had to live with costly, highly complex, and in many instances, inefficient use of the computer as an operational resource due to the (then) lack of quality software development tools.

As the solid-state technology matured and its products applied to militarized computers, the physical characteristics of the on-board computers decreased, which, in turn, led to the appearance of a number of light-weight, lower cost computers which, in turn themselves, led to their incorporation (physically) into the various subsystems themselves. Thus the term "embedded computers" came about. And eventually, these machines were connected together in what could be termed a "federation" of computer resources.

As time progressed, the introduction of general-purpose, programmable digital computers continued to bring about quantum improvements in operational capabilities to fleet aircraft. Unfortunately, due to the (then) lack of computer hardware standards, these machines were individually unique from both the hardware and software support standpoint. This situation was further exacerbated by the fact that the solid-state technology industry continued to introduce microelectronic circuits with greater densities, higher speed performance, and myriad circuit types which made obsolete almost over-nite technology advancements which had not yet been fully operationally utilized in the fleet environment.

The continuation of proliferation of hardware, the absence of suitable standards, and the ever-increasing speed at which new solid-state devices were being invented and/or created and then manufactured, led to the establishment by the late 1970s of standards for computer hardware and the related higher order languages. As a generalization, it can be stated that this is the technical management situation which exists today throughout all of the three services.

As we enter the decade of the 1980s, there are many questions yet to be answered relative to computer architectural and language standards. Specifically, it is postulated that the decade of the 1980s and 1990s will see the introduction of Real-Time Computer-Controlled, Aircraft Distributed Systems containing several hundred microprocessors interconnected by various digital bus schemes. These microprocessors will be embedded throughout the aircraft as computer resources which control the operation of a highly fault-tolerant, reconfigurable, hierarchically structured aircraft/avionics system.
TECHNICAL APPROACH

TECHNICAL APPROACH

(see Figure 13)

The technical approach to the development of aircraft/avionic digital computers over the past fifteen years or so is graphically shown in Figure 13. As stated previously, the introduction of solid-state digital (integrated circuits) devices permitted the rapid introduction of general-purpose computers into naval aircraft. As a function of time, the cost of these integrated circuits decreased dramatically, thus in turn, decreasing the total cost of the computer hardware. As illustrated, the attendant software costs rose almost as fast as were hardware costs decreasing. This economic reversal of costs gave rise to a whole new field of endeavor which was then covered by the broad generic title of "software engineering".

Encompassed under the aegis of the emerging software engineering discipline, one could find such tasks, activities, and efforts such as: analysis and design, test and evaluation, documentation, verification and validation, higher order languages and compilers. More recently, the term software engineering appears to have lost favor, and is being replaced by terms such as software environment, software tools, and software work (factory?).

Regardless of the names given to these various software-related efforts and their individual merit and/or quality, their impact upon reducing the cost of operational software costs was indeterminate at best because of the lack of standard hardware during that particular period of time. Specifically, with each new computer introduced into the fleet inventory, the software support was unique unto itself and thus added to the already heavy logistic burden. However, it was not until the technical managers came to the full realization that in order to reduce software costs, a standard computer architecture had to be identified. Specifically, an Instruction Set Architecture (ISA) had to be identified and selected as a standard if we were to gain any control over the skyrocketing costs for generating and supporting naval aircraft Operational Flight Programs.

REASONS FOR PROLIFERATION OF HARDWARE

EQUIPMENT PROCURED AT DIFFERENT PERIODS IN TIME
DIFFERENT PROCUREMENT METHODS
PROCUREMENT BY DIFFERENT ACTIVITIES
USE IN DIFFERENT VEHICLES
URGENCY TO MEET DEPLOYMENT REQUIREMENTS
LACK OF STANDARD EQUIPMENT

REASONS FOR PROLIFERATION OF HARDWARE

(see Figure 15)

Figure 15 lists the major reasons for proliferation of naval aircraft/avionics programmable digital computers over the past decade or so. The reasons given are considered to be self-explanatory. Perhaps in the future, one or more of these reasons may again be used to introduce yet another new computer. On the other hand, the last reason listed in the figure - "Lack of Standard Equipment" - is no longer valid nor acceptable for introducing a new machine without compelling major management or operational considerations. For as is well known to those individuals associated with R&D efforts sponsored by the Naval Air Systems Command, there is currently an established aircraft/avionic standard modular digital computer - the AN/AYK-14.

REPRESENTATIVE SOFTWARE SYSTEMS

(see Figure 17)

Figure 17 provides a rather dramatic graphical overview of the myriad types of software systems which must currently be supported by NAVAIR management. Additionally, only when one considers the fact that the majority of these software "packages" are either updated, modified, or changed over a period of time for a multitude of reasons can the true dimension of the enormity of software management, control, and maintenance be fully appreciated.

the Software Monster
Along with the explosion of applications of programmable computers came an unwanted "Software Monster" whose ferocious appetite for consuming great mouthfuls of dollars (color him green) seemed unlimited. Proliferation of hardware, coupled with the fact that software development, test and evaluation, and support depends very heavily upon a highly manpower-intensive market has helped to feed the Software Monster on a continuous basis ever since the initial introduction of programmable machines into naval aircraft systems.

<table>
<thead>
<tr>
<th>1940 - 60</th>
<th>1960 - 80</th>
<th>1980 - 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANALOG</strong></td>
<td><strong>CENTRAL DIGITAL</strong></td>
<td><strong>DISTRIBUTED DIGITAL</strong></td>
</tr>
<tr>
<td>• WIRED PROGRAMS</td>
<td>• STORED PROGRAM</td>
<td>• DISTRIBUTED HIERARCHIAL STORED PROGRAM</td>
</tr>
<tr>
<td>• DEDICATED ANALOG PROCESSORS</td>
<td>• CENTRAL PROCESSOR(S)</td>
<td>• REDUNDANT CENTRAL PROCESSOR(S)</td>
</tr>
<tr>
<td>• INTEGRATION THROUGH</td>
<td>• COMMUNICATION THRU I/O INTEGRATION THROUGH CENTRAL PROCESSOR/STORED PROGRAM</td>
<td>• DISTRIBUTED DEDICATED FUNCTIONAL PROCESSORS</td>
</tr>
<tr>
<td>• NO REDUNDANCY</td>
<td>• SOME REDUNDANCY</td>
<td>• COMMUNICATION THRU BUS NETWORK</td>
</tr>
<tr>
<td>• LITTLE FAULT TOLERANCE</td>
<td>• SOME FAULT TOLERANCE</td>
<td>• LARGE SCALE USE OF REDUNDANCY</td>
</tr>
<tr>
<td>• NO DYNAMIC RECONFIGURATION CAPABILITY</td>
<td>• NO DYNAMIC RECONFIGURATION CAPABILITY</td>
<td>• FAULT TOLERANCE AND DYNAMIC RECONFIGURATION</td>
</tr>
<tr>
<td>• DISCRETE &amp; SSI HARDWARE</td>
<td>• MSI &amp; LSI HARDWARE</td>
<td>• HARDWARE</td>
</tr>
</tbody>
</table>

Figure 22 lists, by decades, the technical characteristics of aircraft/avionic equipment. It is self-evident, of course, that for the time period 1980 - 2000, the items listed have yet to be fully implemented.

---

AVIONICS SYSTEM ARCHITECTURES


Figure 23 depicts in topography form, the classical Analog, Centralized Digital, and postulated Distributed Digital Systems implementations for the designated time frames.
AVAILABILITY

- BITE
- REDUNDANCY
- RECONFIGURABILITY
- MAINTAINABILITY

AVAILABILITY
(see Figure 24)

In order for any future naval aircraft to be fully operationally "available" from the standpoint of the on-board avionics, it must have incorporated into the basic system architecture the characteristics itemized in Figure 24. In order to achieve a high level of system availability, Built-In Test Equipment (BITE), must be complemented by redundancy schemes and reconfigurability of subsystem functions and capabilities. Maintainability of avionics systems in an austere environment has also become a mandatory operational requirement.

SYSTEM

PSEUDO-HIERARCHICAL
ARCHITECTURAL STRUCTURING

- TOTAL AIRCRAFT/AVIONICS SYSTEM
- PARTIONING OF AIRCRAFT/AVIONICS SUB-SYSTEMS
- INTER-CONNECT BUS STRUCTURE
- SYSTEM-WIDE PROCESSING ARCHITECTURE
- SUB-SYSTEMS DEFINITION
- COMPUTER SYSTEMS

---

SYSTEM PSEUDO-HIERARCHICAL ARCHITECTURAL STRUCTURES

(see Figure 26)

As we enter the decades of the 1980s, there is an absence of a generally accepted system architectural approach to the design and development of on-board aircraft/avionics equipments and systems. In the absence of any systems architectural definition, I have proposed, as shown in Figure 26, a "Pseudo-Hierarchical Architectural structuring". I have chosen to designate this concept as "pseudo" solely because of the current lack of a "reduction to practice" of such an approach. It should be noted, however, that the top-down decomposition of the system architectural structure is real from an engineering design viewpoint and does indeed lend itself to a logical, natural methodology for decomposition into its constituent parts.

SYSTEM MISSION
(see Figures 26, 28, and 30)

Assuming that the System Architectural Structuring concept is valid, one could state then that the "System Mission" of Figure 28 is the equivalent of the "Total Aircraft/Avionic System" listed previously in Figure 26. More specifically, each term represents the TOP of the system architectural structure shown in the viewgraphs.

Figure 28 illustrates how an aircraft designed for a given System Mission can be partitioned into a number of "clumps" of aircraft/avionic sub-systems. For example, the Vehicle clump of sub-systems would contain such equipments as the flight controls, pilots' displays, and the electrical generators. The Core clump would contain the communications, navigation, and the computational resources. The Mission/Sensors clump would contain the specific radars, acoustic sensors, or the electronic warfare equipments. The Weapons clump is of course self explanatory as to its contents.

It should be noted that these four major portions or clumps of sub-systems are "glued" together by the System Architecture, Integration, and Common Hardware as shown in the center circle in Figure 30.

PROCESSING SYSTEM ARCHITECTURE
(see Figure 30)

Figure 30 depicts what I have chosen to call "Processing System Architecture" (PSA). The PSA consists of the software, hardware, and computer architecture, interconnected as shown so as to indicate the inseparability of the three prime facets of the on-board embedded computer resources.

ARCHITECTURE DEFINED

ARCHITECTURE is used here to describe those attributes of a computer visible to the programmer and does not include implementation details.

TACTICAL DATA/EMBEDDED COMPUTER SYSTEM
APPLICATIONS PROGRAMS

COMPUTER ARCHITECTURE
INSTRUCTION SET REGISTERS ETC.

INTERNAL ORGANIZATION
IMPLEMENTING HARDWARE

- VISIBLE TO OPERATIONAL USER
- VISIBLE TO DESIGNER
- VISIBLE TO MANUFACTURER AND FIELD MAINTENANCE

ARCHITECTURE DEFINED
(see Figure 32)

The prose provided with the graphical representation of the various aspects of the on-board embedded computer resources as seen by the various users more than adequately defines the term "Architecture". For information purposes, Figure 32 was used as part of the material which was given to a number of audiences to which the concept of the Military Computer Family (MCF) Program was presented.

Figure 34. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPI, Washington, DC 20361-3500.
SYSTEM ARCHITECTURE ALTERNATIVES
(see Figure 34)

Figure 34 is a "road map" of the various System Architecture Alternatives available to designers and developers of future aircraft. It would seem reasonable to assume that more and more we will see the Distributed or Federated Control approaches used in future aircraft, while the Central Control approaches would be more likely to continue to appear in aircraft updates.

So far we have addressed many different concepts and approaches relative to the design of future aircraft/avionic systems. However, if we indiscriminately exercise these various concepts, alternatives, and approaches, we could be creating a "Hardware Monster" not unlike the previously mentioned Software Monster.

For like the creator of the Frankenstein monster, the designer has to be certain of his control of the overall system architecture before putting the various parts together. Certainly it is not too far fetched to visualize a Hardware Monster "pasted" together from Government Furnished Equipment (GFE) and/or Contractor Furnished Equipment (CFE), and standard and/or non-standard parts, devices, and components, all of which are controlled by an electronic "heart" consisting of up to 200 microprocessors. This electronic heart would send out its digital "heart beats" over a "nervous system" made up of either a standard twisted-pair bus structure or a high-speed fiber optic bus structure. Needless to say, early in the system conceptual and definition phase of the program, the various options must be cut down at the earliest possible time.

AN INTEGRATED AVIONICS ARCHITECTURE EXAMPLE

## SYSTEM DESIGN FEATURES - HARDWARE UTILIZATION

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>IMPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDARDIZED INTERFACES</td>
<td>MULTISOURCE SUPPLY, TECHNOLOGY UPDATING SIMPLE</td>
</tr>
<tr>
<td>MULTIFUNCTION SENSOR ROLES</td>
<td>MAXIMUM FAULT/DAMAGE TOLERANCE</td>
</tr>
<tr>
<td>RECONFIGURABLE PROCESSING ELEMENTS</td>
<td>GREATER FAULT/DAMAGE TOLERANCE EASES LOGISTICS/MAINTENANCE</td>
</tr>
<tr>
<td>SERIAL DATA TRANSMISSION</td>
<td>LIGHTER, FEWER COMPONENTS</td>
</tr>
<tr>
<td>INTEGRATED, COORDINATED SYSTEM DESIGN</td>
<td>MAXIMUM FAULT/DAMAGE TOLERANCE PERFORMANCE/ADVANTAGE</td>
</tr>
</tbody>
</table>

PRIOR DIGITAL SYSTEMS

- INDEPENDENT SUBSYSTEM ORGANIZATION
- LIMITED CROSS UTILIZATION OF INFORMATION
- CENTRALIZATION OF COMPUTATION

FUTURE DIGITAL SYSTEMS

- RESOURCE SHARING ACROSS SUBSYSTEMS
- INFORMATION CORRELATION
- DECENTRALIZED COMPUTATION

— BUT CONTROL IS CENTRALIZED —

RECONFIGURABLE SYSTEMS

HARDWARE IS EASIER

SOFTWARE IS TOUGHER

BUT...

ONCE SOLVED, SOFTWARE

• DOESN'T AGE

• IS TRANSFERABLE

• IS INDEPENDENT OF PRODUCTION VOLUME

BUT...

Figure 42. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPI, Washington, DC 20361-3500.
Figure 44. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPL, Washington, DC 20361-3500.
It is a sufficient enough problem for engineering managers to have to address the consequences of either the aforementioned Software Monster or the Hardware Monster independently. Unfortunately, future Real-Time, Computer-Controlled Distributed Systems require that both of these two "bugaboos" be addressed simultaneously, and with the same degree of management and technical attention.

Figure 44 is an attempt on my part to visually demonstrate the inter-relationships between computer software and hardware resources and the system architecture, integration, and common hardware requirements. It is hoped that the need for simultaneous consideration of all of these factors can be seen from the structure of the matrix.

In Figure 44, the foundation for the entire system is shown at the bottom of the viewgraph entitled "System Architecture". Being that it is a FOUNDATION, it cuts across each of the vertical bars which are meant to convey the idea that the "Missions" are independent, separable, and unique to each operational mission need. Contained within this concept of the System Architecture as the foundation upon which all the operational systems are built is the premise that any item identified within the block has general applicability to all naval aircraft systems (when required).

The horizontal bars listed under "Common Functions" are used to indicate equipments or software which cut across various Missions, but are uniquely tailored to the particular operational application. For example, signal processors and their associated software programs are used in many naval aircraft; however, it is only for the Anti-Submarine Warfare (ASW) Mission that the processor and its associated software are tailored for the acoustic processing role. In like fashion, the aircraft displays may have some identical hardware and software used across all aircraft, but again, any one particular combination of controls and displays is unique to each Mission application.
The ideal answer to concerns over the proliferation of both hardware and software is shown in Figure 46. Here we have a single production line manned by anthropomorphic microelectronic circuit boards producing a single standard microcomputer.

**Figure 46.** "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JP1, Washington, DC 20361-3500.
If one accepts as valid the projected number of microcomputers/microprocessors projected for future naval aircraft/avionic applications, than one can also expect that the activities of the anthropomorphic figures shown will also take place. Specifically, the various "scenes" taking place in Figure 47 are meant to portray such common digital system situations such as: contention, idle resources, queuing, and simultaneous multiple accessing of common data bases.

Fig. 49. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPI, Washington, DC 20361-3500.
THE SUM OF THE TWO SOFTWARE TRENDS INDICATES A POINT OF DISTRIBUTION WHICH MAY BE OPTIMUM. FURTHER, AT EITHER END OF THE DISTRIBUTION SPECTRUM THE WORST OF BOTH WORLDS MAY EXIST!

DISTRIBUTED SYSTEM TRADEOFFS

DISTRIBUTED SYSTEM TRADEOFFS

(see Figure 50)

Figure 50 graphically displays how the cost/complexity of software goes down with an increasing percentage of distribution of the on-board embedded computer resources. This reduction in software cost/complexity is due to benefits that are inherent in a fully distributed system; for example: matching localized processing needs to performance requirements; independent and incremental growth; improved reliability due to modularity enforced by hierarchal hardware decomposition; and computer power sharing that is readily available with the use of a high-speed bus structure.

Unfortunately, as the percentage of distribution increases, the problems associated with the software "overhead" has an overriding negative impact upon the attributes gained by going to a distributed network of embedded computer resources.

As can be seen graphically, the cost/complexity factor will reverse itself at some point, and again rise and cause to occur all of the traditional problems that have been experienced to date with software generation and its subsequent support.

The point at which the cost/complexity factor is fully minimized is, at this point in time, an unknown because there is very little experience with Real-Time, Computer-Controlled, Distributed Systems. Additionally, the ambiguity associated with the determination of the minimization of the cost/complexity factor is further complicated because advanced design concepts such as redundancy, reconfigurability, and fault-tolerance have not been taken into consideration in computing the cost/complexity factor.
Figure 52. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPL, Washington, DC 20361-3500.
If the aforementioned consideration of cost/complexity versus the
degree of computer resources distribution gives technical managers
headaches, and causes them many sleepless nights; their burden will
increase if the introduction of new products from the world-wide
solid-state (microelectronics) industry is allowed to continue un-
abated.

For example, while we have yet to determine how we will control the
introduction and subsequent logistic support of Large Scale Integrated
(LSI) circuits, the industry is on the verge of manufacturing Very
High Speed Integrated Circuits (VHSICs). As is public knowledge, the
VHSIC effort is being sponsored by the Department of Defense for
sound management reasons; however, regardless of their inherent
technical worth to the operational environment, the VHSIC chips
will, as with all of its technology predecessors, add to the bur-
den of logistic support in both the hardware and software arenas.

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Figure 53. "Optical Memory Storage Requirements and Applications for Use in Military
Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems
The purpose of this view graph (Figure 54) is to illustrate that prior to the introduction of higher density integrated circuits, such as "Medium Scale Integration" (MSI) and "Large Scale Integration" (LSI), the maintenance technician could remove a particular component of an aircraft/avionic sub-system purely by visual recognition of the unit itself. That is, the degree of physical identity as to what role (factor) a particular "black box" played in the system was clearly identifiable in most cases by its physical characteristics. For example, the classical radar antenna in an aircraft has been mechanical in structure, and is rotated by mechanical motion. With future systems, one will find a fully solid-state technology antenna, which would be electronically scanned to provide the required coverage in both the azimuth and height directions. There will be little, if any, mechanical motion.

Figure 55. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AFR 9350, Room 440, JPI, Washington, DC 20361-3500.
(see Figure 56)

Figure 56 contrasts with the previous view graph in that it is a depiction of the future where the combination of high density solid-state electronic technology and modern electronic mechanical packaging concepts such as Standard Avionics Modules (SAMs) and Modular Avionics Packaging (MAP) will provide such a highly dense physical package with uniform overall dimensions that the capability to physically and electronically separate the parts of the system based on visual recognition will be negated and "become a thing of the past".

---

The Real-Time, Computer-Controlled, Distributed System of the future will require that the system conceptual and definition phase of each future aircraft program consider the inter-relationships of the factors identified in Figure 58. While the technical partnership between the software and hardware has been recognized for sometime now, the growing scope of software implications beyond the operational applications programs and the associated software development tools has only recently been addressed with the same degree of rigor as was the recent effort associated with the definition of the Department of Defense's ADA High Order Language.

I have recently reached the conclusion that the inter-
relationship of computer hardware, software, and firmware
is no longer inseparable, and therefore I propose that the
sum of these computer resource factors be addressed by a
term which clearly denotes the amalgamation of the three
distinct parts. For better or worse, I have picked the
term "TECHWARE" to identify this summation of the three
parts. In my definition, "TECHWARE is the combination
of solid-state technology and software and firmware which
results in a physically permanent product that performs an
operational, mathematical, and/or an engineering function."

Figure 61. "Optical Memory Storage Requirements and Applications for Use in Military
Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems
CHALLENGES TO BE FACED

- AMOUNT OF EMBEDDING INTO THE SYSTEM ARCHITECTURE.
- SYSTEMS ENGINEERS NOT COMPUTER SPECIALIST/ENGINEERS PERFORMING THE DESIGN FUNCTION.
- PRIMARY FAILURES WILL BE AT THE SYSTEM LEVEL NOT AT THE COMPONENT LEVEL.
- LACK OF ECONOMIC LEVERAGE.
- RAPIDITY OF CHANGE IN THE MICROPROCESSOR STATE-OF-THE-ART.
- FIXED FUNCTION VS. PROGRAMMABLE MICROPROCESSORS.
- LACK OF PRECISE DEFINITIONS THROUGHOUT THE FIELD.

CHALLENGES TO BE FACED
(see Figure 62)

The items listed in Figure 62 represent my best judgment as to the challenges to be faced by the management and engineering staffs both in government and in industry involved in the system conception, definition, design, development, test and evaluation, and subsequent logistic support of future Real-Time, Computer-Controlled Distributed Systems for aircraft/avionic applications in the navy fleet arm of the future.

ITS' ONLY A RANDOM FAILURE SIR! IT WILL NEVER HAPPEN AGAIN

Figure 64. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPL, Washington, DC 20361-3500.
DIGITAL TECHNOLOGY
STRATEGY

IF MANAGEMENT DOES NOT MANAGE
CHANGE, THEN CHANGE WILL
CHANGE MANAGEMENT

ANÔN.

Figure 6B. "Optical Memory Storage Requirements and Applications for Use in Military Environments." Bernard A. Zempolich, US Dept of the Navy, Naval Air Systems Command, AIR 9350, Room 440, JP1, Washington, DC 20361-3500.
1. A tape recorder salesman enters the office of a prospective client. He is extolling the virtues of his low cost tape recorder. Unfortunately, all of his maintenance people accompanied him on this visit.

2. Naturally, he is inquisitive about the need for two platoons of maintenance people. The periodic maintenance people perform the day-to-day routine preventive maintenance, cleaning tape heads, adjusting tape tension, replacing worn tapes, replacing gaskets, etc. This work would typically be done on the flight line. When the tape recorder has a component or subassembly failure either depot or factory personnel would repair these unscheduled failures. Hence two platforms of maintenance personnel are required.

3. Periodic maintenance can be deferred or eliminated but then the failure rate skyrockets. This happened with the P3 flight incident recorder.

4. Clearly, one can juggle the ratio of scheduled to unscheduled maintenance costs but it is a no win proposition.

5. A solid state recorder would cost a little more than a tape recorder, but it would require no scheduled maintenance. Eliminating moving parts would drastically reduce the unscheduled maintenance costs. Thus, a solid state recorder will minimize the total ownership cost to the user. However, initial cost is the major criteria in selecting recorders aboard aircraft regardless of life cycle costs. Thus, tape recorder companies could sell the tape recorder for one dollar and make money in the maintenance of the recorders. Of course a $1 tape recorder would delight the procurement personnel. Since solid state recorders are virtually maintenance free, the initial cost cannot be transferred to maintenance costs. Hence a life cycle cost approach to procurement must be taken if reliable cost effective hardware is desired.
Figure 70. "Optical Memory Storage Requirements and Applications for Use in Military Environments," Bernard A. Zempolitch, US Dept of the Navy, Naval Air Systems Command, AIR 935C, Room 440, JPI, Washington, DC 20361-3500.

Periodic people clean and fiddle with it to keep it working.

Why do you have 2 platoons of Maintenance People?

The unscheduled people fix it when it breaks.
I want a recorder built like a hockey puck and just as Reliable!

Hmm... that means it's going to have to be SOLID STATE
### 5.25" Optical Disk Drive Manufacturers

<table>
<thead>
<tr>
<th>US:</th>
<th>Media Source</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTOTECH</td>
<td>DAICEL CHEMICAL</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>OSI</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PLASMON</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3M</td>
<td></td>
</tr>
<tr>
<td>ISI</td>
<td>SUMITOMO CHEM</td>
<td>1</td>
</tr>
<tr>
<td>OSI</td>
<td>OSI</td>
<td>4</td>
</tr>
<tr>
<td>OPTIMEM</td>
<td>ATG</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3M</td>
<td></td>
</tr>
<tr>
<td>CHEROKEE</td>
<td>PLASMON</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3M</td>
<td></td>
</tr>
<tr>
<td>LASER DRIVE</td>
<td>-</td>
<td>4</td>
</tr>
</tbody>
</table>

| JAPAN:      |                    |        |
| TOSHIBA     | -                  | 2      |
| HITACHI     | -                  | 3      |
| RICOH       | -                  | 4      |
| SONY        | -                  | 3      |
| SANYO       | -                  | 3      |
| CANON       | -                  | 3      |
| SHARP       | -                  | 3      |
| MITSUBISHI  | -                  | 4      |
| MATSUSHITA  | -                  | 4      |
| FUJITSU     | ASAHI CHEM         | 4      |
| NEC         | -                  | 4      |
| JVC         | -                  | 4      |
| PIONEER     | -                  | 4      |

| EUROPE:     |                    |        |
| PHILIPS     | OSI                | 4      |

1 - IN PRODUCTION, 2 - DELIVERED BETA UNITS, 3 - DEMONSTRATED EXPERIMENTAL UNIT, 4 - UNDER DEVELOPMENT

---

**Figure 1.** "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotech, 140 Wooten Road, Colorado Springs, CO 80910-3378.
### 5.25" Worm Media Sources

<table>
<thead>
<tr>
<th>Structure</th>
<th>Writing Process</th>
<th>Sensitive Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asahi Chemical</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>ATG</td>
<td>Trilayer</td>
<td>Bubble forming</td>
</tr>
<tr>
<td>Canon</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>Daicel</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>Dainippon Ink</td>
<td>Monolayer</td>
<td>Maxwell</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Garrett</td>
</tr>
<tr>
<td>Fuji Photo Film</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>Fujitsu</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>Hitachi</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>Matsushita</td>
<td>Monolayer</td>
<td>Phase Change</td>
</tr>
<tr>
<td>Mitsui Toatsu</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>OSI</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>Plasmon</td>
<td>Moth Pattern</td>
<td>Ablation</td>
</tr>
<tr>
<td>Ricoh</td>
<td>Monolayer</td>
<td>Deformation</td>
</tr>
<tr>
<td>Sanyo</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>Sony</td>
<td>Multilayer</td>
<td>Alloying</td>
</tr>
<tr>
<td>Sumitomo Chemical</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>TDK</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
<tr>
<td>Toshiba</td>
<td>Monolayer</td>
<td>Ablation</td>
</tr>
</tbody>
</table>

Figure 2. "Status of 5.25-inch Optical Digital Data Disk Technology," W. Chen, Uptotech, 740 Wooten Road, Colorado Springs, CO 80915-3514.
APPLICATIONS:

ARCHIVAL UPDATABLE DATA STORE:

ON-LINE: - Small business database
- Personal computer database

OFF-LINE: - Medical records and images
- Financial records
- Legal records
- Maps and navigation records
- Security sensitive data

DISK BACK-UP:

- Winchester disk back-up with random access capability

ELECTRONIC PUBLISHING:

- Updatable publication
- Updatable software distribution

IN FIELD MASS DATA ACQUISITION:

- Seismic data acquisition
- Earth resources data acquisition
- Reconnaissance data acquisition

HARSH ENVIRONMENT APPLICATIONS:

- Radiation hardening
- Extreme temperature
- Extreme EMI

Figure 3. "Status of 5.25-inch Optical Digital Data Disk Technology." Di Chen, Optotech, 740 Wooten Road, Colorado Springs, CO 80915-3519.
FOCUSED LASER BEAM DIAMETER $S$ AT FULL-WIDTH-HALF-MAXIMUM (FWHM)

$$S = 0.5 \frac{\lambda}{n.a.}$$

where $n.a.$ is the numerical aperture of the lens

$$n.a. = \sin \theta$$

For uniform illumination, the Airy disk diameter is

$$d = 1.22 \frac{\lambda}{2 \ n.a.}$$

For Gaussian beam profile, the $1/e^2$ point diameter is

$$d = (4/\pi) \frac{\lambda}{2 \ n.a.}$$

TYPICAL VALUES:  
$
\lambda = 800 \text{ nm}$  
$n.a. = 0.5$  
$S = 0.8 \text{ um}$

Figure 4. "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotechn, 740 Wooten Road, Colorado Springs, CO 80915-3518.
<table>
<thead>
<tr>
<th>Laser structure</th>
<th>Wave length (nm)</th>
<th>Power output P_{cw}(mW)</th>
<th>P_{pulsed} (50ns)</th>
<th>Threshold current I_{th}(mA)</th>
<th>Efficiency (mW)</th>
<th>Beam divergence $\theta_B, \theta_T$</th>
<th>Astigmatism Z(\mu m)</th>
<th>Polarization ratio numerical aperture $\eta = 0.50$</th>
<th>Spatial mode (profile)</th>
<th>Axial mode (spectral)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSP</td>
<td>820 to 850</td>
<td>20</td>
<td>25</td>
<td>55</td>
<td>0.25 to 0.4</td>
<td>12° 30°</td>
<td>5</td>
<td>20:1</td>
<td>Near Gaussian</td>
<td>Single</td>
</tr>
<tr>
<td>TJS</td>
<td>800 to 830</td>
<td>7</td>
<td>10</td>
<td>30</td>
<td>0.3</td>
<td>11° 40°</td>
<td>-</td>
<td>-</td>
<td>Near Gaussian</td>
<td>Single</td>
</tr>
<tr>
<td>TIS</td>
<td>800 to 830</td>
<td>15</td>
<td>15</td>
<td>28</td>
<td>0.4 to 0.5</td>
<td>14° 40°</td>
<td>5</td>
<td>-</td>
<td>Near Gaussian (extra peak)</td>
<td>Single</td>
</tr>
<tr>
<td>TS</td>
<td>800 to 830</td>
<td>15</td>
<td>15</td>
<td>28</td>
<td>0.4 to 0.5</td>
<td>14° 40°</td>
<td>5</td>
<td>-</td>
<td>Near Gaussian</td>
<td>Single</td>
</tr>
<tr>
<td>DH (Single M)</td>
<td>820 to 850</td>
<td>5</td>
<td>5</td>
<td>65</td>
<td>0.3</td>
<td>12° 40°</td>
<td>-</td>
<td>30:1</td>
<td>Near Gaussian</td>
<td>Single</td>
</tr>
<tr>
<td>SML</td>
<td>770</td>
<td>5</td>
<td>5</td>
<td>70</td>
<td>0.3</td>
<td>10° 36°</td>
<td>-</td>
<td>-</td>
<td>Near Gaussian</td>
<td>Single</td>
</tr>
<tr>
<td>LOC CDH</td>
<td>800 to 830</td>
<td>20</td>
<td>40</td>
<td>100</td>
<td>0.4</td>
<td>10° 30°</td>
<td>8</td>
<td>60:1</td>
<td>Near Gaussian</td>
<td>Single</td>
</tr>
<tr>
<td>DH (Multi M)</td>
<td>800 to 850</td>
<td>5</td>
<td>50</td>
<td>100</td>
<td>0.17 (cw)</td>
<td>34° 60°</td>
<td>12 to 35</td>
<td>5/1</td>
<td>&quot;Rabbit ears&quot;</td>
<td>Multiple</td>
</tr>
<tr>
<td>V groove</td>
<td>780 to 800</td>
<td>20</td>
<td>20</td>
<td>100</td>
<td>0.20</td>
<td>30° 60°</td>
<td>-</td>
<td>-</td>
<td>&quot;Rabbit ears&quot;</td>
<td>Multiple</td>
</tr>
</tbody>
</table>

Figure 5. "Status of 5.25-Inch Optical Digital Data Disk Technology," Di Chen, Optotech, 740 Wooten Road, Colorado Springs, CO 80915-3518.
Figure 6. "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotech, 740 Wooten Road, Colorado Springs, CO 80915-3518.
Figure 7. "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotech, 740 Wooten Road, Colorado Springs, CO 80915-3518.
RECORDING CAPACITY:

(1) BIT SIZE 
LIMITED BY:  
* OPTICS  
* LASER DIODE WAVELENGTH  
* BIT BOUNDARY STABILITY  
* MINIMUM DOMAIN SIZE FOR M-O  
PRESENT STATUS: 0.8 TO 1.0 UM BIT DIAMETER FOR WORM AND 1.0 TO 1.5 UM FOR M-O  

(2) BIT SPACING 
LIMITED BY:  
* ADJACENT BIT INTERFERENCE  
* PEAK SHIFT  
* BIT BOUNDARY STABILITY  
PRESENT STATUS: 1.5 TIMES THE BIT SIZE  

RESULTING AREAL DENSITY: 44 TO 69 MBITS/SQ. CM.  
FOR WORM  
20 TO 44 MBITS/SQ. CM.  
FOR M-O  

FOR AN ANSI STANDARD 5.25" OPTICAL DISK, AT CONSTANT LINEAR DENSITY, THE RAW BIT CAPACITY IS 466 TO 730 MEGABYTES PER DISK SIDE FOR WORM, 212 TO 466 MEGABYTES PER DISK SIDE FOR M-O. 

---

Figure 8. "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotech, 740 Wooten Road, Colorado Springs, CO 80915-351d.
LASER DIODE POWER OUTPUT VS DATA RATE

(1) HEATING OF THE SENSITIVE LAYER FOR HOLE FORMING:
   \[ P(1) = A \frac{T}{t} \]

(2) HEATING OF THE SUBSTRATE
   \[ P(2) = B \frac{T}{\sqrt{t}} \]

WRITING POWER ON THE RECORDING MEDIA
   \[ P = P(1) + P(2) = \left( \frac{A}{t} + \frac{B}{\sqrt{t}} \right) T \]

FOR Te ALLOY FILM ON PC SUBSTRATE, THE REQUIRED POWER IS EMPIRICALLY GIVEN AS
   \[ P \text{ (mW)} = 0.26/t + 2/\sqrt{t} \quad \text{t in usec.} \]

At 2 MHz data rate, using a 100 nsec pulse, the required laser power on the recording media is 9 mW. The required power is 46 mW at 20 MHz.

Figure 9. "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotecn, 740 Wooten Road, Colorado Springs, CO 80915-3518.
DA: ARAJI

(1) WRITE POWER

LIMITED BY

AVAILABE LASER POWER

BEAM INTENSITY TRANSMISSION EFFICIENCY IN OPTICAL HEAD

PRESENT STATUS

MAXIMUM PEAK LASER DIODE POWER OUTPUT = 30 MW

TYPICAL BEAM INTENSITY TRANSMISSION EFFICIENCY = 50% for WORM and 35% for M-O

MINIMUM WRITE PULSE LENGTH IS 40 NSEC.

(2) BIT ELONGATION:

Linear on track velocity of current optical disks falls in the range of 15 to 3.7 m/sec.

Bit elongation = Linear velocity x Write pulse length

<table>
<thead>
<tr>
<th>Bit Spacing (um)</th>
<th>Linear Velocity (m/sec)</th>
<th>Pulse Length (usec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.20</td>
<td>15.0</td>
<td>0.08</td>
</tr>
<tr>
<td>0.60</td>
<td>7.5</td>
<td>0.08</td>
</tr>
<tr>
<td>0.30</td>
<td>3.7</td>
<td>0.08</td>
</tr>
<tr>
<td>0.30</td>
<td>7.5</td>
<td>0.04</td>
</tr>
</tbody>
</table>

*Bit elongation causes reduction in areal density.
*Reduction in pulse length means higher laser power.
*Current laser power of 30 mw output or 15 mw on the disk means that the pulse width is limited to no less than 0.04 usec using common WORM or M-O media.
*Allowing 0.3 um bit elongation means that 7.5 m/sec is the upper limit of the linear velocity.
*At a bit spacing of 1.5 um bit spacing, this yields the upper limit of the raw data rate of 5 magabit/sec. This represents the lower range for WORM and upper range for M-O.

Figure 11. "Status of 5.25-inch Optical Digital Data Disk Technology." Di Chen, Optotech, 940 Wooten Road, Colorado Springs, CO 80915-3514.

OMTR/103
ACCESS TIME:

(1) SEEK TIME:
LIMITED BY: *WEIGHT OF THE OPTICAL HEAD
*FOCUSING AND TRACKING ACTUATOR STABILITY
*POWER REQUIREMENT OF SEEK ACTUATOR
PRESENT STATUS: 150 msec FOR STEPPER MOTOR
50 msec FOR LINEAR MOTOR IN 5.25" OPTICAL DISK DRIVES

(2) ROTATIONAL LATENCY TIME:
LIMITED BY: *ALLOWABLE LINEAR VELOCITY FOR WRITING
*DISK SUBSTRATE MATERIAL TOLERANCE
PRESENT STATUS: 16.7 TO 50 msec average

(3) MOTOR SPEED SETTLING TIME (FOR CONSTANT LINEAR VELOCITY CASE ONLY)
PRESENT STATUS: 1 TO 3 sec.

Figure 12. "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotech, 740 Mooten Road, Colorado Springs, CO 80915-3519.
### Magneto-Optic Recording Status

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>MATERIAL</th>
<th>S/N</th>
<th>R/W RATE-MB/s</th>
<th>SUBSTRATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDD</td>
<td>Tb Fe Co</td>
<td>52</td>
<td>0.5-9</td>
<td>PMMA</td>
</tr>
<tr>
<td>SONY</td>
<td>Tb Fe Co</td>
<td>52</td>
<td>0.5-9</td>
<td>PMMA</td>
</tr>
<tr>
<td>OLYMPUS</td>
<td>Gd Tb Fe</td>
<td>49</td>
<td>0.5-9</td>
<td>PMMA</td>
</tr>
<tr>
<td>SHARP</td>
<td>Gd Tb Fe</td>
<td>43</td>
<td>2</td>
<td>ETCHED-GLASS</td>
</tr>
<tr>
<td>MITSUBISHI</td>
<td>Gd Tb Fe Ge</td>
<td>49</td>
<td>0.5-9</td>
<td>GLASS -2P</td>
</tr>
<tr>
<td>NHK</td>
<td>Gd Tb Co</td>
<td>40</td>
<td>3-6</td>
<td>GLASS</td>
</tr>
<tr>
<td>RICOH</td>
<td>Tb Fe Co</td>
<td>45</td>
<td>1</td>
<td>GLASS</td>
</tr>
<tr>
<td>PHILIPS</td>
<td>Gd Tb Fe</td>
<td>30</td>
<td>0.125</td>
<td>GLASS</td>
</tr>
<tr>
<td>XEROX</td>
<td>Tb Fe</td>
<td>37</td>
<td>1-10</td>
<td>GLASS</td>
</tr>
<tr>
<td>3M</td>
<td>RE - Ti</td>
<td>&gt;50</td>
<td>1-10</td>
<td>GLASS</td>
</tr>
<tr>
<td>NIKON</td>
<td>TbFe-GdFeCo</td>
<td>55</td>
<td>1</td>
<td>GLASS</td>
</tr>
</tbody>
</table>

SIGNAL-TO-NOISE RATIO

(1) WORM MEDIA
LIMITED BY:  * SENSITIVE LAYER GRAIN NOISE
* SUBSTRATE SURFACE NOISE
* STAMPER AND REPLICATION INTRODUCED FIXED PATTERN NOISE
* OTHER DEFECTS
PRESENT STATUS: S/N = 60 DB AND BER = 10 \( \exp(-5) \)
IS TYPICAL AT BEGINING OF LIFE,
S/N IS LIMITED BY NOISE

(2) M-O MEDIA
LIMITED BY  * LOW M-O EFFECT
* SENSITIVE LAYER NOISE
* STAMPER AND REPLICATION INTRODUCED NOISE
* SUBSTRATE SURFACE NOISE
* OTHER DEFECTS
PRESENT STATUS: S/N = 50 DB AND BER = 10\( \exp(-5) \)
IS TYPICAL AT BEGINING OF LIFE
S/N IS LIMITED BY LOW SIGNAL LEVEL

---

ENVIRONMENTAL TEST DATA FOR 5.25" OPTICAL DISKS WITH POLYCARBONATE SUBSTRATE AND Te ALLOY SENSITIVE LAYER

Figure 15. "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotech, 740 Wooten Road, Colorado Springs, CO 80915-3518.
STABILITY

(1) BIT BOUNDARY STABILITY:
FOR M-O MEDIA: *DOMAIN WALL STABILITY MUST BE ASSURED UNDER
(A) WRITE/ERASE FIELD,
(B) OPERATING TEMPERATURE EXTREMES*,
(C) ADJACENT BIT HEATING.
FOR WORM MEDIA: *NO KNOWN BIT BOUNDARY INSTABILITY FOR Te ALLOY

(2) MEDIA DEGRADATION:
FOR M-O MEDIA: *M-O LAYER MUST BE PROTECTED
*DEGRADATION CAN BE RETARDED
BY ALLOYING WITH ADDITIVES OR
COATING WITH A PROTECTIVE
LAYER. DEGRADATION APPEARS TO GROW FROM EXISTING DEFECTS.
FOR WORM: *Te IS NOT STABLE BUT TeSe
COMPOUND IS REASONABLY STABLE. DEGRADATION INTRODUCES MOSTLY SINGLE BIT DEFECTS

PRESENT STATUS: *FIVE YEARS WRITE AND TEN YEARS READ LIFE FOR WORM,
TWO TO FIVE YEARS LIFE FOR M-O.

* OPERATING TEMPERATURE RANGE ACCORDING TO THE ANSI STANDARD IS FROM 10 TO 50 DEGREES CENTIGRADE.

Figure 16. "Status of 5.25-inch Optical Digital Data Disk Technology," Qi Chen, Optotech, 740 Wooten Road, Colorado Springs, CO 80915-3514.
<table>
<thead>
<tr>
<th></th>
<th>WORM</th>
<th>MO CompPt.</th>
<th>CuriePt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DENSITY</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>WRITEPOWER</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>DRDW</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>S/N</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>STABILITY</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>TEMPERATURE RANGE</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>ERASIBILITY</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

- good
- fair
- poor

Figure 12. "Status of 5.25-inch Optical Digital Data Disk Technology," Di Chen, Optotech, 74u Wooten Road, Colorado Springs, CO 8515-351d.
CONCLUSION:

(1) WRITE-ONCE-READ-MOSTLY OPTICAL RECORDING TECHNOLOGY IS MATURING. 5.25" OPTICAL DISK DRIVES WITH THE FOLLOWING PERFORMANCE IS NOW READILY AVAILABLE:

- Capacity (MByte/Side) 200
- Data Rate (MBits/Sec) 2.2
- Access Time (mSec) 200
- Media Life (Years) 5 (Write), 10 (Read)

(2) PERFORMANCE LIMITATIONS BASED ON CURRENT TECHNOLOGY FOR THE 5.25" DRIVES ARE AS FOLLOWS:

- Capacity (MBytes/Side) 600
- Ave. Access Time (mSec) 50
- Data Rate (MBits/Sec) 5
- Media Life (Years) 20

(3) WRITE-ONCE-READ-MOSTLY OPTICAL STORAGE DEVICES AND WINCHESTER DRIVES COMPLIMENT EACH OTHER. THEY CAN BE TEAMED TO MAKE A POWERFUL MEMORY SYSTEM WHICH OFFERS HIGH ACCESS TIME, REMOVABLE CARTRIDGE, ERASABLE DATA AND PERMANENT DATA STORAGE.

(4) 5.25" DRIVE FORM FACTOR IS SUITED FOR NOT ONLY THE PC AND MINI COMPUTER MARKET, BUT ALSO JUKE BOX APPLICATIONS AS WELL BECAUSE THE EASE OF DISK TRANSPORT AND HIGHER VOLUME PACKING DENSITY AS COMPARED TO SYSTEMS USING 12" DISKS.


Figure 18. "Status of 5.25-inch Optical Digital Data Disk Technology," D. Chen, Outotech, 740 Wooten Road, Colorado Springs, CO 80915-3518.
OUTLINE:

- PRINCIPLE DOD SPECIFICATIONS
- COMPARISON OF ENVIRONMENTAL REQUIREMENTS FOR EQUIPMENT
  LAND, SEA, AND AIR
- DISK DRIVE PACKAGING METHODS TO ACHIEVE ENVIRONMENTAL
  REQUIREMENTS
  - OVERALL PACKAGING CONSTRAINTS
  - THERMAL CONSIDERATIONS
  - VIBRATION AND SHOCK CONSIDERATIONS
- RESULTING ENVIRONMENTAL AND DESIGN REQUIREMENTS OF
  OPTICAL DISK DRIVES

Figure 1. "Interpretation of DOD Specifications for Device Designers", Marc
Saltzman, Fairchild Communications and Electronics Company. Century
Blvd., Germantown, MD 20874-1182.
SPECIFICATIONS AND STANDARDS OUTLINE
FOR MILITARY ELECTRONICS EQUIPMENT

- PRINCIPLE SPECIFICATIONS
  - MIL-E-5400 AIRBORNE
  - MIL-E-16400 NAVAL SHIP OR SHORE
  - MIL-E-4158 LAND USE

- COMMON OUTLINE
  1.0 SCOPE (5400 ALSO DEFINES TEMPERATURE CLASSES)
  2.0 APPLICABLE DOCUMENTS
    LIST OF ALL SPECS AND STANDARDS REFERENCED
    FREQUENT REFERENCES TO MIL-STD-454
  3.0 REQUIREMENTS
    DETAILED DESIGN DIRECTION: SPRINGS, SOLDERING, MOUNTING, PRESSURIZATION ...
    SERVICE CONDITIONS: VIBRATION, SHOCK, TEMPERATURE ...
  4.0 QUALITY ASSURANCE
    TESTING - REFERENCES TO TEST DOCUMENTS: MIL-STD-810 (ENVIRONMENTAL)
    MIL-STD-462 (EMI)
    OTHERS

---

Figure 2. "Interpretation of DOO Specifications for Device Designers," Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.
OFTEN USED SPECIFICATIONS AND STANDARDS

- **EQUIPMENT DESIGN STANDARDS**
  
  MIL-STD-454: THE KEY DOCUMENT FOR APPROVED PARTS/PROCESS DESCRIPTION  
  74 REQUIREMENTS: BEARINGS, FASTENERS, ADHESIVES, SEALING...  
  FURTHER REFERENCES, EXAMPLE - REQ 17 PRINTED WIRING BOARDS  
  REFERENCES TO MIL-STD-275  
  MIL-P-55110  
  
  MIL-STD-461: ELECTROMAGNETIC EMISSION AND SUSCEPTIBILITY REQUIREMENTS  
  FOR CONTROL OF EMI  
  
  DOD-STD-1788: NEW STANDARD FOR LRUs. INCLUDES THERMAL, STRUCTURAL,  
  DESIGN METHODS, QUALIFICATION, AND TESTING. PARALLELS  
  MIL-E-5400 IN MANY AREAS  

- **EQUIPMENT TEST SPECIFICATIONS AND STANDARDS**
  
  MIL-STD-810: A KEY DOCUMENT THAT DESCRIBES TESTING IN 20 ENVIRONMENTAL AREAS  
  
  MIL-STD-5422: FOR USE WITH MIL-E-5400. 14 TEST AREAS SIMILAR TO MIL-STD-810  
  
  MIL-STD-462: FOR USE WITH MIL-STD-461. EMI TEST PROCEDURES

---

*Figure 3.* "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 21114-1182.
### COMPARISON OF ENVIRONMENTAL REQUIREMENTS

<table>
<thead>
<tr>
<th>Continuous Operating</th>
<th>USAF MIL-E-45000F</th>
<th>UEC MIL-E-34800</th>
<th>ARMY USAGE MIL-E-4150F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>Class 1: -54 to 56 and unsheltered</td>
<td>Range 1: -54 to 65</td>
<td>Cold Area -51 to 69</td>
</tr>
<tr>
<td></td>
<td>Class 1b: -56 to 55</td>
<td>Range 2: -20 to 65</td>
<td>Desert &amp; Tropics 0 to 53</td>
</tr>
<tr>
<td></td>
<td>Class 2: -54 to 71</td>
<td>Range 3: -30 to 65</td>
<td>All Indoor Areas 0 to 53</td>
</tr>
<tr>
<td></td>
<td>Class 3: -54 to 99</td>
<td>and unsheltered</td>
<td>Reduce high temperature extreme by 1.54°C per 1000 feet above sea level.</td>
</tr>
<tr>
<td></td>
<td>Class 4: -54 to 115</td>
<td>and unsheltered</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 5: -54 to 99</td>
<td>(ship)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ship or shore)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intermittent Operating</th>
<th>USAF MIL-E-45000F</th>
<th>UEC MIL-E-34800</th>
<th>ARMY USAGE MIL-E-4150F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>Class 1: 71 all for 36 minutes</td>
<td>Not Specified.</td>
<td>Not Specified.</td>
</tr>
<tr>
<td></td>
<td>Class 1b: 71</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 2: 93</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 3: 125</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 4: 150</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 5: 125</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Operating/Storage</th>
<th>USAF MIL-E-45000F</th>
<th>UEC MIL-E-34800</th>
<th>ARMY USAGE MIL-E-4150F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Class 1: -57 to 65</td>
<td>Range 1: -62 to 71</td>
<td>All Areas -51 to 69</td>
</tr>
<tr>
<td></td>
<td>Class 1b: -57 to 65</td>
<td>Range 2: -62 to 71</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 2: -57 to 65</td>
<td>Range 3: -62 to 71</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 3: -57 to 115</td>
<td>Range 4: -62 to 71</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 4: -57 to 115</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 5: -57 to 115</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum Temperature</th>
<th>USAF MIL-E-45000F</th>
<th>UEC MIL-E-34800</th>
<th>ARMY USAGE MIL-E-4150F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of Change</td>
<td>Class 1: -57 to 65 at 1°C</td>
<td>Four (4) hours from maximum to minimum temperature in each range</td>
<td>Not Specified.</td>
</tr>
<tr>
<td></td>
<td>Class 1b: -57 to 65</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 2: -57 to 65</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 3: -57 to 65</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 4: -57 to 115</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 5: -57 to 115</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Figure 4.** "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.
## COMPARISON OF ENVIRONMENTAL REQUIREMENTS (CONT'D.)

<table>
<thead>
<tr>
<th></th>
<th>USAP MIL-E-5005</th>
<th>USN MIL-E-16404</th>
<th>ARM E US AGE MIL-E-41587</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Altitude</strong></td>
<td>Class 1: 0 to 50,000 ft (30 to 15,240 m)</td>
<td>Not Specified.</td>
<td>Operating: 0 to 50,000 ft (30 to 15,240 m)</td>
</tr>
<tr>
<td></td>
<td>Class 2: 0 to 100,000 ft (30 to 24,384 m)</td>
<td></td>
<td>Non-Operating: 0 to 50,000 ft (30 to 15,240 m)</td>
</tr>
<tr>
<td><strong>Altitude Rate of Change</strong></td>
<td>0.5 in Hg per second.</td>
<td>Not Specified.</td>
<td>Not Specified.</td>
</tr>
<tr>
<td><strong>Temperature Altitude Combination</strong></td>
<td>See Figures 1 through 4.</td>
<td>Not Specified.</td>
<td>Not Specified.</td>
</tr>
<tr>
<td><strong>Relative Humidity</strong></td>
<td>Up to 100% condensation on equipment.</td>
<td>Up to 95% including condensation on equipment.</td>
<td>Minimum: 30% from minimum operating temperature to 16°C. Above 16°C relative humidity based on a dew point at -7°C (see Figure 5). Maximum: 100% including condensation from the minimum operating temperature to 27°C. Above 27°C the relative humidity based on a dew point at 27°C (see Figure 5).</td>
</tr>
</tbody>
</table>

*Figure 5. "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.*
### COMPARISON OF ENVIRONMENTAL REQUIREMENTS (CONT'D.)

<table>
<thead>
<tr>
<th>ENVIRONMENTAL REQUIREMENT</th>
<th>MIL-E-5500T</th>
<th>MIL-E-16469Q</th>
<th>MIL-E-81597</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sinusoidal Vibration</strong></td>
<td>Propeller Aircraft: 5 to 500 Hz at the amplitudes shown in Figure 6. Jet Aircraft: 5 to 2000 Hz at the amplitudes shown in Figure 6. Helicopters: 5 to 200 Hz at the amplitudes shown in Figure 7, Curve IIIb.</td>
<td>Type I vibration test per MIL-STD-167-1 for each of the three (3) cases: 6-15 Hz, 0.064 in. double amp; 16-25 Hz, 0.064 in. double amp; 26-50 Hz, 0.064 in. double amp. Five (5) minutes at each integral frequency; e.g., 5 min. at 6 Hz, 5 min. at 5 Hz, etc. Endurance test to dwell at resonance for two (2) hours.</td>
<td>Not Specified - Refer to detailed equipment specification.</td>
</tr>
<tr>
<td><strong>Combined Sinusoidal and Random Vibration</strong></td>
<td>Per the detailed equipment specification.</td>
<td>Not Specified.</td>
<td>Not Specified.</td>
</tr>
<tr>
<td><strong>Shock (equipment required to operate afterwards)</strong></td>
<td>15 G's, 1 milisecond duration; 2 shocks in ± direction and 3 shocks in - direction. Repeat for the remaining axes (total number of shocks = 18).</td>
<td>Grade A, Type A, Class I, shock test per MIL-S-901. NOTE: Class I is for equipment that will perform without resilient mountings. Test: For equipment &lt; 250 lbs. a total of 9 hammer blows: 3 blows to each of the principal axes of the equipment using hammer drop heights of 1, 3, and 5 feet respectively. Test equipment specified in MIL-S-901.</td>
<td>Not Specified - Refer to detailed equipment specification.</td>
</tr>
<tr>
<td><strong>Shock, Equipment Mounting to Determine Crush Safety (no failure of attachment structure permitted)</strong></td>
<td>30 G's, 1 milisecond duration; 2 shocks in ± direction and 2 shocks in - direction. Repeat for the remaining axes (total number of shocks = 12).</td>
<td>Not Specified.</td>
<td>Not Specified.</td>
</tr>
</tbody>
</table>

*Figure 6. "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.*
OPTICAL DISK DRIVE PACKAGING METHODS

PACKAGING TYPICAL OF EQUIPMENT BAY MOUNTED BOXES
- DESIGN PER DOD-STD-1788 (SIMILAR TO AIR TRANSPORT RACK (ATR) BOXES)

- TOP AIR INLET
- REAR INTERFACE CONNECTOR
- BOTTOM AIR INLET

DISK DRIVE COMPARTMENT
POWER SUPPLY
\~4.5"  2 PWBs
\~1.5"
SUPPORT ELECTRONICS
\~1.5"

BOX INCREMENTS ARE 1.30 INCHES

PACKAGING TYPICAL OF PANEL MOUNTED BOXES SUCH AS USED IN THE COCKPIT AREA
- ADAPT DRIVE TO FIT IN ENVELOPE DEFINED BY MS2512 -

HOLE FOR FRONT PANEL FASTENER
QUICK RELEASE FASTENERS

MEDIA ACCESS PANEL (SEALED)
ELECTRONICS ACCESS

COOLING AIR LOUVERS
DAGGER PIN INTERFACE

TOP VIEW
MAY BE REQUIRED

Figure 7. "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.
TEMPERATURE/ALTITUDE REQUIREMENTS
FOR AIRBORNE ELECTRONICS EQUIPMENT

- SEVEN TEMPERATURE ALTITUDE CURVES IN MIL-E-5400
- THE CLASS 2 CURVES TO THE RIGHT COVER MOST APPLICATIONS AND ENVELOPE THE REQUIREMENTS FROM MIL-E-4158 AND MIL-E-16400
- CURVES USED TO DETERMINE DRIVE TEMPERATURE IN A FREE CONVECTION ENVIRONMENT

Figure 6. "Interpretation of EMD Specifications for Device Designers", Marc Saltman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.
FREE CONVECTION PARAMETRIC ANALYSIS

• THERMAL ANALYSIS INPUTS
  - DRIVE DIMENSIONS
  - FIN STRUCTURE
  - AMBIENT CONDITIONS

• RESULTS
  - SURFACE AREA ENHANCEMENT OR OTHER MEANS TO DECREASE DRIVE TEMPERATURE ESSENTIAL
  - DESIGNERS MUST CONSIDER EFFECT OF ALTITUDE
  - DRIVES OPERATED IN FREE CONvection ENVIRONMENTS MUST DISSIPATE MINIMAL ENERGY
  - 10 WATT DRIVE → ΔTs OVER AMBIENT OF 20°C OR LESS
  - 20 WATT DRIVE → ΔTs OVER AMBIENT OF 40°C OR LESS
  - DRIVE INTERNAL TEMPERATURES WOULD BE 5 TO 10°C HIGHER AND WELL OVER PRESENT DAY MEDIA CAPABILITIES

Figure 9. "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company, Century Blvd., Germantown, MD 20874-1182.
USE IN RELATION BELOW TO DETERMINE EXIT AIR TEMPERATURE

\[ T_{\text{out}} = T_{\text{in}} + \frac{Q}{\dot{m}c_p} \]

\( \text{POWER DISSIPATION} \)

FROM GRAPH

\( T_{\text{out}} \) REPRESENTS A THERMODYNAMIC LOWER LIMIT FOR THE DRIVE CASE TEMPERATURE

---

FORCED AIR COOLING PARAMETRIC ANALYSIS

- THERMAL ANALYSIS INPUTS
  - DRIVE SURFACE AREA
  - AIR MASS FLOW RATE
  - AIR INLET AIR TEMPERATURE
  - HYDRAULIC DIAMETER (BASED ON FIN SPACING AND CLEARANCE AROUND THE DRIVE)

- RESULTS
  - FLOW RATE OF 0.5 LB/ MINUTE RESULTS IN CASE TEMPERATURES/INTERNAL TEMPERATURES IN THE RANGE OF 54 TO 66°C
  - STATIC PRESSURE CHANGE THROUGH A TYPICAL PACKAGE IS < 2 INCHES H2O

Figure 11. "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.
SINUSOIDAL VIBRATION REQUIREMENTS FOR EQUIPMENT DESIGNED FOR INSTALLATION IN PROPELLER AIRCRAFT (5-500 Hz) AND JET AIRCRAFT (5-2000 Hz)

- CURVE IIIA FROM MIL-E-5400. FOR USE WITH EQUIPMENT MOUNTED IN THE FORWARD HALF OF THE FUSELAGE OR IN THE WING AREA WITH THE ENGINES AT THE REAR OF THE FUSELAGE.

- CURVE IIIA COVERS MOST SITUATIONS FOR OPTICAL DISK DRIVE USAGE.

- USE THE CURVE WITH THE ISOLATION CHARACTERISTICS TO DETERMINE THE SINUSOIDAL VIBRATION PROFILE SEEN BY THE DRIVE.

---

**Figure 12.** "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company, Century Blvd., Germantown, MD 20874-1182.
Figure 13. "Interpretation of MIL Specifications for Device Designers," Microelectronic Components and Electronics Company, Fort Lee, New Jersey.

Assumes commercially available isolators "filtering" curve corresponding to MIL-A-1182 MIL-STD.

- Can be converted to G loading by relation indicated on graph.

- Assumes D.A. of 0.20 at 0 Hz.
- Maximum G's of 2.72 at 100 Hz.
- Maximum G's of 2.50 at 1,800 Hz.
- Maximum G's of 2.00 at 3,000 Hz.
- Maximum G's of 2.00 at 5,000 Hz.
- Maximum G's of 1.148 at 15,000 Hz.

OMTR/123
Figure 14. “Interpretation of DOU Specifications for Device Designers”, Marc Saltzman, Fairchild Communications and Electronics Company, Century Blvd., Germantown, MD 20874-1182.
Figure 15. "Interpretation of NAND Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.

**RANDOM VIBRATION LEVELS**

**SEEN BY THE DRIVE**

- DOTTED PORTION OF CURVE REPRESENTS TRANSPORTATION TYPE LEVELS AFTER FILTERING BY ISOLATION SYSTEM.
- SOLID PORTION OF CURVE REPRESENTS JET AIRCRAFT LEVELS AFTER FILTERING.
- JET AIRCRAFT LEVELS BECOME DOMINATE AT 300 Hz.

**RESULTS:**

FROM THE VIBRATION STANDPOINT, TRANSPORTATION LEVELS AT LOW FREQUENCY MAY REPRESENT A GREATER PROBLEM THAN IN A HIGH PERFORMANCE AIRCRAFT.
SUMMARY OF OPTICAL DISK DRIVE
ENVIRONMENTAL REQUIREMENTS

DRIVE REQUIREMENTS

- CONTINUOUS OPERATING TEMPERATURE (AMBIENT AIR)
  CONVECTIVELY COOLED DRIVE -54 to 76°C
  FORCED AIR COOLED DRIVE -54 to 43°C
- MINIMUM AND MAXIMUM STORAGE TEMPERATURE -62 to 95°C
- ALTITUDE AND ALTITUDE RATE OF CHANGE
  S.L. to 70,000 FEET ± 0.49 PSI/SEC
- MAXIMUM RELATIVE HUMIDITY
  100% WITH CONDENSATION AND FROSTING

- SINUSOIDAL VIBRATION INPUT TO DRIVE PER GRAPH
- RANDOM VIBRATION INPUT TO DRIVE PER GRAPH
- SHOCK: CONTINUOUS OPERATION
  3.0 G PEAK, 11 MSEC
  1/2 SINE PULSE
  12 G PEAK
  40 G PEAK
- STEADY STATE ACCELERATION:
  CONTINUOUS OPERATION 7.5 G's
  OPERATE AFTER 11.3 G's
  STRUCTURAL INTEGRITY 17.0 G's

NOTES
1. REQUIRES ADDITIONAL AIRFLOW
2. REQUIRES PACKAGING PROTECTION VIA FULL OR PARTIAL SEALING AND AIR DRYING/FILTRATION

Figure 16. "Interpretation of DOD Specifications for Device Designers", Marc Saltzman, Fairchild Communications and Electronics Company. Century Blvd., Germantown, MD 20874-1182.
OPTICAL MEMORY SYSTEM
STUDY PRESENTATION

PREPARED FOR:
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA

BY:
FAIRCHILD COMMUNICATIONS & ELECTRONICS COMPANY
GERMANTOWN, MD

CONTRACT # G229-86C-0424

5 DECEMBER 85

UNDER DIRECTION OF ROMAN FEDORAK

---

Figure 1. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
FAIRCHILD - P. JAMES, M. SALTZMAN, T. ROGERS

3M COMPANY - C. HARRISON, F. WHITEHEAD, R. MILLER

CHEROKEE DATA SYSTEMS - W. HALL, M. DEESE

Figure 3. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
OPTICAL MEMORY SYSTEM PROJECT STATEMENTS

- PROBLEM
  - EXTREMELY LARGE CAPACITY OF DATA STORAGE REQUIRED TO
    ACHIEVE NEAR TERM MILITARY SYSTEM PERFORMANCE OBJECTIVES

- OBJECTIVE
  - EXPLOIT CURRENT AND NEAR FUTURE OPTICAL DISK TECHNOLOGY
    FOR RELEVANCY TO A SOLUTION FOR A MILITARY MASS MEMORY
    (OMS) THAT SATISFIES MILITARY APPLICATIONS

- PRODUCT
  - HIGH LEVEL DESIGN OF MILITARY PERFORMANCE OMS
  - DEVELOPMENT PLAN

Figure 4. "Optical Memory System Study Presentation," Tim Rogers, Fairchild
  Communications and Electronics, 20301 Century Boulevard, Germantown,
  MD 20874-1182.
APPLIED OBJECTIVES

- INVESTIGATE 5 1/4" OPTICAL DISK TECHNOLOGY

- CONSIDER MILITARY SPECIFICATIONS, APPLICATIONS, AND PERFORMANCE REQUIREMENTS

- PERFORMANCE - CAPACITY - 250 MBYTES
  ACCESS - 100 MSEC
  TRANSFER - 5 Mb/SEC

- CONCENTRATE ON KEY ELEMENTS

Figure 5. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
STUDY OUTLINE

I EXPLORE STATE OF OPTICAL MEMORY SYSTEM TECHNOLOGY
II DEVELOP SYSTEM REQUIREMENTS
III INVESTIGATE FEASIBILITY OF A COMMON WORM, EROM DRIVE
IVA MEDIA EVALUATION
IVB OPTICAL HEAD EVALUATION
IVC DRIVE EVALUATION
IVD SYSTEM SUPPORT ELEMENTS EVALUATION
V TOP LEVEL SYSTEM DESIGN/SPECIFICATION
VI DEVELOPMENT PLAN
VII NUCLEAR RADIATION ANALYSIS/TESTING
VIII ARCHITECTURE INVESTIGATION

Figure 6. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ENVIRONMENTAL MILITARY REQUIREMENTS

USAF  USN  USA
MIL-E-5400T  MIL-E-16400  MIL-E-4158

TRANSLATE EXTERNAL ENVIRONMENT SPECIFICATIONS TO LOCAL DISK DRIVE ENVIRONMENT DEVELOP

"DESIGN TO" REQUIREMENTS

Figure 8. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
<table>
<thead>
<tr>
<th>Continuous Operating Temperature (°C)</th>
<th>USAF MIL-E-5100T</th>
<th>USN MIL-E-14400G</th>
<th>ABBE MIL-E-4158F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1:</td>
<td>54 to 55</td>
<td>Range 2: Exposed -20 to 65 and unsheltered (ship or shore)</td>
<td>Cold Area -51 to 49</td>
</tr>
<tr>
<td>Class 2:</td>
<td>54 to 71</td>
<td>Range 3: Exposed -20 to 65 and unsheltered (sheltered)</td>
<td>Temperature Area 60 to 90</td>
</tr>
<tr>
<td>Class 3:</td>
<td>54 to 71</td>
<td>Range 4: Sheltered -40 to 50 non-controlled environment (ship or shore)</td>
<td>Desert &amp; Tropics 0 to 75</td>
</tr>
<tr>
<td>Class 4:</td>
<td>54 to 125</td>
<td>Range 5: Sheltered 0 to 50 controlled environment (ship or shore)</td>
<td>All Indoor Areas 0 to 50</td>
</tr>
<tr>
<td>Class 5:</td>
<td>54 to 95</td>
<td>Test to MIL-STD-810, Method 501, Proc. 1.</td>
<td>Reduce high temperature extreme by 1 °C per 1000 feet above sea level.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intermittent Operating Temperature (°C)</th>
<th>Class 1: 31 all for 30 minutes</th>
<th>Not Specified.</th>
<th>Not Specified.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Non-Operating/Storage Temperature</th>
<th>Class 1: -57 to 65</th>
<th>Class 2: -57 to 65</th>
<th>Class 3: -57 to 125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1A:</td>
<td>-45 to 65</td>
<td>-45 to 65</td>
<td>-45 to 125</td>
</tr>
<tr>
<td>Class 2A:</td>
<td>-45 to 65</td>
<td>-45 to 65</td>
<td>-45 to 125</td>
</tr>
<tr>
<td>Class 3A:</td>
<td>-45 to 65</td>
<td>-45 to 65</td>
<td>-45 to 125</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum Temperature Rate of Change</th>
<th>Class 1: -47 to 65 at 1°C</th>
<th>Four (4) hours from maximum to minimum temperature in each range.</th>
<th>Not Specified.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1A:</td>
<td>-47 to 65 5°C per second</td>
<td>-47 to 65 5°C per second</td>
<td>-47 to 65 5°C per second</td>
</tr>
<tr>
<td>Class 2A:</td>
<td>-47 to 65 1°C per second</td>
<td>-47 to 65 1°C per second</td>
<td>-47 to 65 1°C per second</td>
</tr>
<tr>
<td>Class 3A:</td>
<td>-47 to 65 1°C per second</td>
<td>-47 to 65 1°C per second</td>
<td>-47 to 65 1°C per second</td>
</tr>
</tbody>
</table>

Figure 11. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1102.
### SUSTAINED ACCELERATION LEVELS FOR JET AIRCRAFT

<table>
<thead>
<tr>
<th></th>
<th>FORE</th>
<th>AFT</th>
<th>UP</th>
<th>DOWN</th>
<th>LATERAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-STD-810 OPERATIONS</td>
<td>2.0</td>
<td>6.0</td>
<td>9.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td>NON-STD-1788 OPERATIONS</td>
<td>7.5</td>
<td>7.5</td>
<td>11.3</td>
<td>6.0</td>
<td>6.1</td>
</tr>
<tr>
<td>MIL-STD-810 STRUCTURAL INTEGRITY</td>
<td>3.0</td>
<td>9.0</td>
<td>13.5</td>
<td>4.5</td>
<td>6.0</td>
</tr>
<tr>
<td>DOD-STD-1788 STRUCTURAL INTEGRITY</td>
<td>11.25</td>
<td>11.25</td>
<td>17.0</td>
<td>9.0</td>
<td>9.15</td>
</tr>
</tbody>
</table>

**NOTES:**

1. MIL-STD-810 levels are for fuselage locations near the aircraft center of gravity. Refer to the standard for additional yaw, pitch, and roll accelerations away from he CG.

2. Multiply the MIL-STD-810 levels by 2 for catapult launched aircraft.

**Figure 12.** "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
Figure 14. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
## Sustained Acceleration Levels for Jet Aircraft

<table>
<thead>
<tr>
<th></th>
<th>Fore</th>
<th>Aft</th>
<th>Up</th>
<th>Down</th>
<th>Lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MIL-STD-810</strong> Operations</td>
<td>2.0</td>
<td>6.0</td>
<td>5.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>NON-STD-1788 Operations</strong></td>
<td>7.5</td>
<td>7.5</td>
<td>11.3</td>
<td>6.0</td>
<td>6.1</td>
</tr>
<tr>
<td><strong>MIL-STD-810</strong> Structural Integrity</td>
<td>3.0</td>
<td>9.0</td>
<td>13.5</td>
<td>4.5</td>
<td>6.0</td>
</tr>
<tr>
<td><strong>NON-STD-1788 Structural Integrity</strong></td>
<td>11.25</td>
<td>11.25</td>
<td>17.0</td>
<td>9.0</td>
<td>9.15</td>
</tr>
</tbody>
</table>

### NOTES:

1. MIL-STD-810 levels are for fuselage locations near the aircraft center of gravity. Refer to the standard for additional yaw, pitch, and roll accelerations away from the CG.

2. Multiply the MIL-STD-810 levels by 2 for catapult launched aircraft.

---

**Figure 15.** "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SUMMARY OF OPTICAL DISK DRIVE ENVIRONMENTAL REQUIREMENTS

DRIVE REQUIREMENTS

- CONTINUOUS OPERATING TEMPERATURE (AMBIENT AIR)
  - CONVECTIVELY COOLED DRIVE
    -54 TO 76°C
  - FORCED AIR COOLED DRIVE
    -54 TO 43°C
- MINIMUM AND MAXIMUM STORAGE TEMPERATURE
  -62 TO 95°C
- ALTITUDE AND ALTITUDE RATE OF CHANGE
  S.L. TO 70,000 FEET
  ±0.49 PSI/SEC
- MAXIMUM RELATIVE HUMIDITY
  100% WITH CONDENSATION AND FROSTING
- SINUSOIDAL VIBRATION INPUT TO DRIVE
- RANDOM VIBRATION INPUT TO DRIVE
- SHOCK: CONTINUOUS OPERATION

  OPERATE AFTER
  STRUCTURAL INTEGRITY
  126 PEAK
  40G PEAK
  3.0G PEAK, 11 MSEC
  1/2 SINE PULSE

- STEADY STATE ACCELERATION:
  - CONTINUOUS OPERATION
    7.5G
  - OPERATE AFTER
    11.3G
  - STRUCTURAL INTEGRITY
    17.0G

NOTES:
1/ Requires additional airflow.
2/ Requires packaging protection via full or partial sealing and air drying/filtration.

Figure 16. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ADM OPTICAL DISK PERFORMANCE PARAMETERS

GOALS OF STUDY

TECHNOLOGY - 5 1/4" WRITE ONCE MEDIA AND DRIVE
- SINGLE HEAD SYSTEM
CAPACITY - 300 MEGABYTES OF USER DATA (APPLICATION DOES NOT REQUIRE DUAL SIDED MEDIA)
PEAK TRANSFER RATE - 10 MEGABITS/SECOND
DISK CONFIGURATION - CAV SYSTEM
RPM - 2900 REVS PER MINUTE
LATENCY - 20 MILLISECONDS
AVERAGE ACCESS TIME - 80 MILLISECONDS
TRACK TO TRACK ACCESS - 1 MILLISECOND IN FINE SEEK ACCESS
SIZE - 9" LONG X 6" WIDE X 3.75" HIGH
WEIGHT - 5 POUNDS
POWER - 40 WATTS

NADC OBJECTIVES

CAPACITY - 250 MEGABYTES OF USER DATA
PEAK TRANSFER RATE - 5 MEGABITS/SECOND
ACCESS TIME - 100 MILLISECONDS MAXIMUM

Figure 17. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
THEORETICAL LIMITS
Figure 22. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
THEORETICAL PERFORMANCE - CAV RECORDING

\( \lambda = 830 \text{ NM} \)

CAPACITY = 400 MB.

\( d = 0.6 \text{ UM} \)

RATE = 13.6 MBPS.

Figure 23. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1782.
FOCAL SPOT QUALITY

STREHL INTENSITY - ACTUAL PEAK INTENSITY
THEORETICAL PEAK INTENSITY

FOR SI > .8 SYSTEM IS DIFFRACTION LIMITED

FIGURE IS REDUCED BY ANY PRACTICAL PHENOMENA
- OPTICAL WAVEFRONT DISTORTION
- FOCUS ERROR
- SUBSTRATE THICKNESS
- OPTICAL ALIGNMENT

OPTICAL TOLERANCES/ERROR CONTRIBUTORS
- TILT BIREFRINGENCE
- MEDIA FLATNESS, THICKNESS

MAX ERROR OF FOCUS FROM OLD SOURCES AT NA = 0.6, λ = 830 MM
BECOMES 2 = 1.15 μM

VERTICAL CONTROL MUST WORK OVER 100-200 μM RANGE

Figure 24. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
PRACTICAL LIMITATIONS

- POWER, WAVE LENGTH
- TRACKING, FOCUS
- DEFECTS, NOISE, CONTRAST; SNR
- ENCODING, EDAC
- ENVIRONMENT

Figure 25. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
RPM = 3000 - 2000
f of laser pwr, servom, mechanical balance

Data transfer rate - 10 MB/s - 5 MB/s
f of above + 1.5 µm pit spacing, NA = 0.6
Code off = 1.5 (Space modulation)

B.E.R. = 1 x 10^-5 Initial, 1 x 10^-4 End of life

N.A. = 0.55 - 0.6, 0.6 increased requirement on media
and servom system

Tracking signal variations - <10%
NA > 0.55

Data density - f of NA, signal amplitude (MTF) detection
track pitch (50% response curve occurs at mark to mark
spacing of ~1.5 µm)

Figure 26. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
CAPACITY

250 M BYTES

WRITE THRESHOLD - AT 8 M/SEC
THRESHOLD = 4-6 MW/UM$^2$
NOMINAL - 10-20 MW/UM$^2$

ROTATIONAL SPEED
DIODE LASER POWER

MIN. SPACE MARK

450 NS AT 1000 RPM
130 NS AT 3000 RPM

---

Figure 27. "Optical Memory System Study Presentation." Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>IMPACT AND LIMITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRACK PITCH</td>
<td>VARIATIONS PRODUCE CHANGES IN TRACKING SIGNAL AMPLITUDE. FOR NA &gt; .55, TRACKING SIGNAL VARIATION IS LESS THAN ± 10%.</td>
</tr>
<tr>
<td>OBJECTIVE NUMERICAL APERTURE</td>
<td>VALUES &gt; .55 REDUCE SENSITIVITY OF TRACKING SIGNAL TO TRACK. HIGH NA VALUES REQUIRE HIGH PERFORMANCE FOCUS SERVO.</td>
</tr>
<tr>
<td>DATA DENSITY</td>
<td>SUGGESTED MAX. 9 MM DATA DENSITY = 1.6 UM TRACK PITCH = 1.6 UM PIT PERIOD = 1.5 UM READ SIGNAL AMPLITUDE DEPENDS ON THE MF OF THE OBJECTIVE NA = .6 OBJECTIVE = 50% AT THIS DATA DENSITY (667 BIT/MM LINEAR DENSITY).</td>
</tr>
</tbody>
</table>
| STORAGE CAPACITY                   | 120 MM O.D. 4″盤
   OMT = 50.8 MM
   LINEAR DENSITY = 667 BIT/ MM
   TOTAL = 300 M BYTES CAV

**Figure 28.** "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20841-182.
<table>
<thead>
<tr>
<th>Rotation Speed</th>
<th>1800 RPM</th>
<th>Higher rotation speed possible if focus and tracking servos are able to compensate for disk mechanical tolerances.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write Threshold</td>
<td>Current A.I. media requires 4.4 mW/μm² at the rotation speed above.</td>
<td>Current A.I. media writes well formed features at 10-12 mW through NA = 0.6 lens using data density and rotation speed suggested above. Threshold of feature formation corresponds to 2.7 mW through a 0.6 NA lens.</td>
</tr>
<tr>
<td>Data Transfer Rate</td>
<td>For a linear data density of 667 bit/mm DTR = 3.65 M bits/sec @ 30 Hz</td>
<td>Higher data transfer rates will require higher rotation speed and increased servo performance.</td>
</tr>
<tr>
<td>Life</td>
<td>Under normal office environment estimated at ≥ 10 yrs.</td>
<td>EOL is defined as a bit error rate of ≥ 1 x 10⁻⁶.</td>
</tr>
</tbody>
</table>

Figure 29. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
Figure 30. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
Figure 31. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SYSTEM PERFORMANCE

MEASUREMENT PARAMETER - ERROR RATE

INTEREST - SIGNAL TO NOISE OVER ENTIRE ENVIRONMENTAL OPERATING RANGE

---

Figure 32. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
### Long Term Limitations

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Impact and Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Performance Parameters</td>
<td>Drive/media system interaction limiting factor, media limits are more a function of substrate material selection rather than active layer limit.</td>
</tr>
<tr>
<td>Rotation Speed</td>
<td>Limited by substrate and servo system of the drive.</td>
</tr>
<tr>
<td>Life</td>
<td>Life expectancies at the extreme environmental conditions has not been tested for to date.</td>
</tr>
</tbody>
</table>

---

*Figure 33. “Optical Memory System Study Presentation,” Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.*
DEFINITIONS

SIGNAL - Amplitude and phase difference between marks and unaltered media.

WORM - Heating sensitive media layer - removes material and expose higher or lower reflectivity layer. Readout via amplitude and phase modulation of light.

ERASABLE - Magnetic optic - heating plus bias magnetic field overcomes coercivity of sensitive layer. Readout via rotation polarized light.

Figure 35. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
• GREATER STRESS DUE TO ENVIRONMENT

• ACCELERATE AND AUGMENT FAILURE MECHANISMS

• POLYMERS WILL NOT MEET TEMPERATURE, HUMIDITY, VIBRATION, SHOCK, ACCELERATIONS

Figure 36. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ELEVATED ENVIRONMENTS PREDICTED MEDIA FAILURE MODES

- REDUCTION IN RE-READ STABILITY
- POSSIBLE RECIPROcity FAILURE FOR WRITE THRESHOLD
- SUBSTRATE PHYSICAL AND CHEMICAL DEGRADATION
- SUBSTRATE MECHANICAL INSTABILITY UNDER VIB & ACCELERATED G-FORCES

Figure 37. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
### General Media Problem Analysis

<table>
<thead>
<tr>
<th>Environment</th>
<th>Performance Parameter</th>
<th>Limiter</th>
<th>Potential Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensing Condensation, Humidity, and Frost</td>
<td>Optical Transmittance</td>
<td>None allowed</td>
<td>Controlled environmental box or hermetically sealed box</td>
</tr>
<tr>
<td>Altitude</td>
<td>Air gap</td>
<td>Dependent on optics of drive</td>
<td>&quot;Substrate Incident&quot; would eliminate</td>
</tr>
<tr>
<td>Temperature</td>
<td>Disk stability (-10°C to 55°C (PMMA substrate))</td>
<td>Change of the substrate material</td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td>Drive/Disk Interaction</td>
<td>Unknown-No data</td>
<td>Depends on level of problem</td>
</tr>
<tr>
<td>Acceleration</td>
<td>Vertical Plane Deflection</td>
<td>Unknown-No data</td>
<td>Change of the substrate material and construction</td>
</tr>
<tr>
<td>Radiation Exposure</td>
<td>Optical Transmittance, materials change, performance change, written data change</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Figure 38.** "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
POLYMERIC - RUN OUT, TEMPERATURE, HYGROSCOPIC
GLASS - FRAGILITY, DIFFICULT TO GROOVE, WEIGHT AND COST
ALUMINUM - DIFFICULT TO USE, SURFACE ROUGHNESS, DIFFICULT TO GROOVE, COST
CAST EPOXY - PRODUCTION SCALE UP, COST, LIMITED TESTING

Figure 39. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
MILITARY SPECIFICATION MEDIA DEVELOPMENT PLAN

Figure 41. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
MEDIA DEVELOPMENT OBJECTIVES

- THIN FILM MATERIALS EVALUATION/CHARACTERIZATION
- DESIGN OF THIN FILM MEDIA STRUCTURES
- SUBSTRATE SELECTION/EVALUATION
- DEVELOPMENT OF MOISTURE, CHEMICAL, AND THERMAL BARRIER LAYERS
- DEVELOP AND OPTIMIZE DEPOSITION PROCESS
- DEVELOP APPROPRIATE BONDING TECHNOLOGY
- MEASURE DYNAMIC PERFORMANCE OF MEDIA
- PERFORM ACCELERATED LIFE TESTS, RADIATION TESTING, ETC., ON COATINGS AND COMPLETE DISCS
- CONDUCT COMPLETE RESEARCH ANALYSIS OF FAILURE MODES
- ITERATIONS FOR FINE TUNING THE ABOVE TASKS

Figure 42. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
WRITE READ STABILITY AT EXTREME ENVIRONMENTS
MECHANICAL AND CHEMICAL STABILITY AT EXTREME ENVIRONMENT
INTERFACE TO SUBSTRATE COMPATIBILITY
PROCESS COMPATIBILITY FOR SUBSTRATE
RADIATION RESISTANCE
EMP RESISTANCE
MANUFACTURABLE
RECIPROCITY LIMITS
- TEMPERATURE AND HUMIDITY SHOCK RESISTANCE

Figure 43. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ACTIVE LAYER - TARGET SPECIFICATIONS

- WRITING ENERGY 5-6MW
- LIFETIME > 10 YEARS IN NON CONTROLLED ATMOSPHERE
- HIGH OPTICAL ABSORPTION AT 800-855 nm
- REFLECTIVITY IN UNWRITTEN AREAS 20-30%
- REFLECTANCE AND THRESHOLD TUNABILITY
- SATURATION AT 7-10 mw WITH SHARP TRANSITIONS
- C/N 50db, (55-60db GOAL)
- BER AND DEFECT DENSITY ~ 10^-6
- 40 MBYTE CAPACITY (5 1/4", CAV)
- LOW FABRICATION COST

Figure 44. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
FEASIBILITY OF COMMON "ORM/ERASABLE DRIVE"
SYSTEM ANALYSIS

- WRITE ONCE

- ERASABLE
  (MEDIA DECISION)

- MULTI FUNCTION
  (MEDIA DECISION)

---

Figure 48. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ERASABLE OPTICAL MEDIA COMPARISON

<table>
<thead>
<tr>
<th>Media Defect Error Rate</th>
<th>MagneticOptic</th>
<th>Phase Change</th>
<th>Dye/Polymer</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBER</td>
<td>10^-5</td>
<td>10^-5</td>
<td>10^-5</td>
</tr>
<tr>
<td>Read Cycle Degradation</td>
<td>none</td>
<td>some</td>
<td>some</td>
</tr>
<tr>
<td>Media Life (20C, 50%)</td>
<td>&gt; 8 yrs</td>
<td>&gt; 3 yrs</td>
<td>&gt; 25 yrs</td>
</tr>
</tbody>
</table>

Environmental Integrity
- o Temp & RH: > 60C, 80%, > 60C, 80%, > 60C, 80%
- o Chemical: good, good, good
- o EMI & Rad.: ?
- o Shock/Vib.: ?

Failure Mechanism
- Oxidation
- Pinholes
- Fatigue
- Photobleaching

Figure 50. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
<table>
<thead>
<tr>
<th></th>
<th>MO</th>
<th>POLYMER</th>
<th>PHASE CHANGE</th>
<th>REVERSIBLE DEFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>STORAGE CAPACITY</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ERROR RATE</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ENVIRONMENT</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LIFE</td>
<td>0</td>
<td>+</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>ERASE CYCLES</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>STATUS</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>COST</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>

+ HIGHER PERFORMANCE
0 NEUTRAL
- LOWER PERFORMANCE

Figure 51. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
<table>
<thead>
<tr>
<th>ITEM</th>
<th>WRITE ONCE</th>
<th>ERASABLE</th>
<th>MULTI-FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTICAL MEDIA</td>
<td>IN PRODUCTION DOES NOT MEET MIL SPEC REQUIREMENTS</td>
<td>PILOT SAMPLES AVAILABLE DOES NOT MEET MIL SPEC REQUIREMENT</td>
<td>NSD FROM ERASABLE REQUIRES TWO MEDIA DEV. PROGRAMS</td>
</tr>
<tr>
<td>OPTICAL HEAD</td>
<td>IN PRODUCTION RUGGED SAMPLES AVAILABLE DOES NOT MEET MIL SPEC REQUIREMENTS</td>
<td>NOT AVAILABLE MORE COMPLEX THAN W/O HEAD</td>
<td>NSD FROM ERASABLE</td>
</tr>
<tr>
<td>MECHANICAL</td>
<td>SHOCK AND VIBRATION ISOLATION TECHNIQUES ADAPTABLE FROM RUGGED OPTICAL W/O</td>
<td>HIGHER HEAD MASS REQUIRES DESIGN IMPROVEMENTS OVER W/O</td>
<td>NSD FROM ERASABLE</td>
</tr>
<tr>
<td>SERVOS</td>
<td>REQUIRES DEV. PROGRAM TO MEET HIGH INITIAL LOAD REQUIREMENT</td>
<td>MORE DIFFICULT DESIGN THAN W/O</td>
<td>NSD FROM ERASABLE</td>
</tr>
<tr>
<td>WRITE READ</td>
<td>CHANNEL WELL DEFINED</td>
<td>POSSIBLY LOWER SNR MAY REQUIRE BETTER DESIGN</td>
<td>NSD FROM ERASABLE</td>
</tr>
</tbody>
</table>

NSD - NO SIGNIFICANT DIFFERENCE

Figure 52. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
<table>
<thead>
<tr>
<th>ITEM</th>
<th>WRITE ONCE</th>
<th>ERASABLE</th>
<th>MULTI-FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORMAT AND CODES</td>
<td>INSENSITIVITY TO RANDOM HIGH INTENSITY ENVIRONMENT EFFECTS DESIRED</td>
<td>NSD</td>
<td>NSD</td>
</tr>
<tr>
<td>ENVIRONMENTAL</td>
<td>DOES NOT MEET MIL SPEC REQUIREMENTS PROGRAM REQUIRED</td>
<td>MEDIA MAY BE MORE SUSCEPTIBLE TO ENVIRONMENTAL STRESS</td>
<td>NSD FROM ERASABLE TWO MEDIA DEV. PROGRAMS</td>
</tr>
</tbody>
</table>

NSD - NO SIGNIFICANT DIFFERENCE

Figure 53. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
Figure 56. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
OPTICAL HEAD ELEMENTS

LASER ASSEMBLY - LASER, COLLIMATING/CORRECTING OPTICS, PHOTODETECTORS, COOLER

OPTICAL ELEMENTS - OBJECTIVE, BEAM SPLITTER, MIRRORS, PHASE PLATES, POLARIZERS

ACTUATORS - FOCUS, TRACKING

OPTOMECHANICAL PACKAGE - CONTAINS ALL OF THE ABOVE

OPTIONS - PARTITION/SEPARATE OPTICAL HEAD ELEMENTS FIXED AND MOVEABLE ASSEMBLIES

---

Figure 57. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
PROBLEMS

- NOISE SUPPRESSION
- SIGNAL AMPLITUDE
- SEPARATION OF SERVO AND DATA SIGNALS
- STABILITY TO ENVIRONMENT
- SIGNAL BANDWIDTHS
- LIGHT LOSS

SOLUTIONS

- SEPARATE DATA AND SERVO LASER BEAMS
- ENVIRONMENTAL CONTROL

Figure 58. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
OBJECTIVE LENS

PROBLEM

- MULTIELEMENT DESIGN
- HIGH MASS
- HIGH POWER CONSUMPTION REQUIRED TO CONTROL

SOLUTION

- MOLDED, SINGLE ELEMENT, ASPHERIC OBJECTIVE
- SPLIT OPTICAL HEAD CONFIGURATION AIDS SOLUTION WITH LOWER MASS OBJECTIVE ASSEMBLY

Figure 59. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ANALYSIS OF AVAILABLE OPTICAL HEADS

- ENVIRONMENTAL LIMITATIONS
- SIZE, WEIGHT, POWER PROBLEM
- DYNAMIC PERFORMANCE
- RESONANT MECHANICAL STRUCTURES
- UNSEALED ENCLOSURES
- ACTUATION DEFICIENCIES
- G LOAD TOLERANCE TOO LOW
- UNRELIABLE POSITION TRANSDUCER
- LASER POWER TOO LOW TO SUPPORT DATA RATES (5-10 MB/SEC)
- LASER TEMPERATURE CONTROL
- ALIGNMENT/DISTORTION PROBLEMS
- FASTENING/MOUNTING OF HEAD ELEMENTS INADEQUATE

Figure 60. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
LASER ASSEMBLY

ELEMENTS - LASER, COLLIMATING/CORRECTION OPTICS, MONITORING/PHOTODETECTION

PROBLEMS - ASTIGMATISM, ASYMMETRICAL EMISSIONS, BEAM POINTING, INSTABILITIES,
NOISE, TEMPERATURE RANGE, POWER OUTPUT
- AVAILABLE IN 20 MW - 40 MW POWER RANGE
  10K - 100K HOURS LIFE

SOLUTIONS - MATCHING LASER TO OPTICS
- MAINTAIN HIGH ALIGNMENT TOLERANCE
- AVAILABILITY OF IMPROVED DEVICES IN NEAR TERM
- CONTROLLED TEMPERATURE TO MAINTAIN PERFORMANCE
- PROJECTIONS FOR 100MW, 1M HR, MULTIPLE BEAM DEVICES
  (NOT IN SAME DEVICE)

Figure 61. "Optical Memory System Study Presentation," Tim Rogers, Fairchild
Communications and Electronics, 20301 Century Boulevard, Germantown,
MD 20874-1182.
## Focus and Fine Tracking Servo Considerations

- **Performance Requirements**: Focus: ± 0.25 μm for up to 250 μm vertical acceleration. Fine tracking: ±0.1 μm for up to 100 μm radial runout.

- **Closed-Loop Coarse Seek**: Eliminates major part of radial runout. Fine tracking can be optimized for extended environment. Possible problems include coupling of coarse and fine servo feedback and form factor maintenance.

- **Resolution/Accuracy**: Maintaining 1.6 μm ± 0.1 μm tracks and 2mm ± 0.25 μm focus is easy in benevolent environment. High G loads, shock, vibration make this tough in high-performance aircraft.

- **Bandwidth**: Dictated by disk characteristics and extended military environment. 3kHz for focus servo and 5kHz for fine tracking servo.

- **Power**: Will increase due to environmental forces.

- **Stability**: In addition to recovering from high G force loads, servos must compensate for misalignment of optics and detectors, laser pointing errors, and non-uniform voice coil heating.

---

*Figure 62. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.*
REACTION TO HIGH G FORCES - SHOCK, VIBRATION, AND INERTIAL FORCES WILL HAVE FREQUENCY COMPONENTS UPPER BOUNDED BY THE SERVO-BANDWIDTHS. ANTICIPATION SENSORS PROBABLY NOT REQUIRED. BUT, NEED BEEFY VOICE COILS/ACTUATORS, WHICH REQUIRE MORE SPACE AND POWER AND DISSIPATE MORE HEAT. THERE IS ALSO A CONCERN THAT HIGH VIBRATION LEVELS MAY CAUSE COUPLING BETWEEN FOCUS AND TRACKING SERVOS.

Figure 63. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
INTEGRATED VS. SEPARATE OPTICAL HEAD CONSIDERATIONS

INTEGRATED

+ ALL COMPONENTS IN A SINGLE PACKAGE
+ EASIER TO BUILD
+ OPTICAL PATHS SHORTER
+ CAN HERMETICALLY SEAL AS A UNIT

- LARGE MASS (ACTUATOR DESIGN ISSUE; INCREASES REACTIONS TO INERTIAL FORCES)
- ALL COMPONENTS SUBJECTED TO ACTUATOR FORCES
- LARGER SIZE (PHYSICAL DIMENSIONS)

SEPARATE

+ REDUCE MASS
+ FASTER SEESKS
+ FEW COMPONENTS SUBJECTED TO ACTUATOR FORCES
+ SMALLER SIZE OF MOVING PART

- OPTICAL DESIGN MORE DIFFICULT
- BEAM POINTING STABILITY PROBLEMS
- MAINTAINING ALIGNMENT TOUGHER
- INCREASES OTHER DRIVE TOLERANCES

Figure 64. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SEPARATE WRITE AND READ BEAMS OF DIFFERENT WAVELENGTH

ADVANTAGES:

- PERMITS DRAW
- AVOIDS SATURATION OF SERVO TRANSDUCERS DURING WRITING
- PERMITS CONTINUOUS, UNINTERRUPTED READING
- EASIER IMPLEMENTATION OF CONTINUOUS SERVO

- HIGHER CAPACITY
- HIGHER DATA RATE
- LOWER ERROR RATE
- HIGHER THROUGHPUT BY ELIMINATING MULTIPLE REVOLUTIONS

DISADVANTAGES:

- PROBLEMS OF KEEPING BEAMS MUTUALLY ALIGNED
- INCREASED ALIGNMENT DIFFICULTY WITH TEMPERATURE EXCURSIONS
- INCREASED COMPLEXITY
- INCREASED COST

RECOMMENDATION:

- IMPLEMENT AND TEST BOTH APPROACHES OVER ENVIRONMENTAL AND INERTIAL INPUT RANGES

Figure 65. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
LASER COOLER PERFORMANCE

EXAMPLES

MAINTAIN
25°C LASER TEMP.  30 MW DIODE LASER

CASE I - 50°C AMBIENT
- 142 MW ELECTRICAL INPUT TO LASER
- 30 MW LIGHT OUTPUT
- 112 MW HEAT FROM LASER
- 280 MW ELECTRICAL INPUT TO COOLER (39% EFFICIENT)
- 392 MW HEAT INTO ENVIRONMENT

CASE II - 120°C AMBIENT
- 112 MW HEAT FROM LASER
- 1800 MW ELECTRICAL INPUT TO COOLER (6% EFFICIENT)
- 1912 MW HEAT INTO ENVIRONMENT

Figure 66. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
LASER POWER REQUIRED AT MEDIA SURFACE
AS A FUNCTION OF DISK LINEAR VELOCITY

ASSUMPTIONS:
- 1.0 μm WIDE MARKS
- STEADY-STATE WRITING
- MARK WIDTH ≈ FWHM SPOT WIDTH
- WRITING IN LINEAR RANGE OF MEDIA
## Critical Head Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration</td>
<td>Integrated</td>
<td>All components in a single package</td>
</tr>
<tr>
<td>Mass</td>
<td>80gm</td>
<td>Meet access times and maintain required radial position throughout inertial range</td>
</tr>
<tr>
<td>Spot Size</td>
<td>0.9 to 1.0 ( \mu \text{m} )</td>
<td>Achieve capacity and data rate</td>
</tr>
<tr>
<td>Write Laser Power AT Media</td>
<td>10-15 ( \text{mW} )</td>
<td>Achieve data rate</td>
</tr>
<tr>
<td>Maximum Size</td>
<td>Approx. 30 x 60 x 90 ( \text{mm} )</td>
<td>Maintain 5 1/4&quot; form factor</td>
</tr>
<tr>
<td>Focus Servo Bandwidth</td>
<td>3KHz</td>
<td>Maintain focus to within ( \pm 0.5 \mu \text{m} )</td>
</tr>
<tr>
<td>Tracking Servo Bandwidth</td>
<td>5KHz</td>
<td>Maintain track centering to within ( \pm 0.1 \mu \text{m} )</td>
</tr>
<tr>
<td>Maximum Temperature</td>
<td>+15°C over temperature outside drive</td>
<td>Minimize power dissipation</td>
</tr>
<tr>
<td>Tracking Servo Range</td>
<td>500( \mu \text{m} )</td>
<td>Worst-case radial dynamic positioning error or coarse actuator over inertial range plus total radial tolerance</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>-40°C to +86°C</td>
<td>Consistent with military environment</td>
</tr>
</tbody>
</table>

Figure 68. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
CRITICAL HEAD PARAMETERS (CONT'D.)

VIBRATION INPUT  TBD
SUSTAINED ACCELERATION 7.5G
HEAD DESIGN SUPPORTS

MAINTAIN FOCUS/TRACKING AND
ERROR RATE
CONSISTENT WITH MILITARY ENVIRONMENT

CAPACITY - 400 MB CAV
RATE - 10 MB/s
FINE SEEK - 1ms
MAX SEEK - 80ms
ENVIRONMENT

Figure 69. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
DISK DRIVE

Figure 70. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
DRIVE ELEMENTS

- BASEPLATE

- HEAD/DISK CHASSIS

- SPINDLE MOTOR

- HEAD DISK ASSEMBLY (HDA)

- DRIVE CONTROL ELECTRONICS

- SHOCK/VIBRATION ISOLATORS

- CARTRIDGE LOAD/UNLOAD MECHANISM

Figure 71. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182,
DRIVE PROBLEMS

- SHOCK AND VIBRATION ISOLATION METHODS NOT ADEQUATE FOR MILITARY ENVIRONMENT
- CONSTRUCTION OF SUPPORT STRUCTURES NOT RUGGEDIZED
- CONTAMINATION CONTROL METHODS NOT APPLICABLE
- COMPONENTS NOT MILITARY QUALITY LEVEL
- RADIATION SENSITIVITY IN OPTICAL COMPONENTS

---

Figure 72. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
- LASER POWER CONTROL
- OPTICAL BEAM FOCUS
- TRACK FOLLOWING
- SPIN MOTOR CONTROL

COMPLEX DRIVES EMPLOY BEAM ALIGNMENT, MATCHING UNIT POWER TO MEDIA

Figure 73. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
- CONTROL VELOCITY TO < 1%

- BRUSHLESS D.C. MOTOR, ENCODER FEEDBACK

- EFFICIENCY AND LOW INERTIA REQUIRED TO REACT TO DISTURBANCES

- RESPONSE CURVE IMPLEMENTED WITH SAMPLED CONTROL SYSTEM

- RADIAL RUN OUT < 10μM, TILT < 5 M RADIANS

ABOVE REQUIRED TO MEET EXPECTED LOADS

---

Figure 74. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
FOCUS SERVO

- COMPONENTS DISK RUN OUT, ACCELERATION, SUBSTRATE THICKNESS AND TILT
- FOCAL POINT HELD ± 2.0 µm OVER ± 200µm
- ENCASE OBJECTIVE LENS IN LINEAR MOTOR ASSEMBLY
- CAN MOVE ALTERNATE ELEMENTS - MIRRORS, PRISMS, LENSES
- TRANSDUCERS TECHNIQUES - ASTIGMATIC, CRITICAL ANGLE, KNIFE EDGE
- EACH TECHNIQUE HAS ERROR, NON LINEARITY AND LIMITED RANGE

FUTURE
- FLYING ELEMENTS - REDUCED COST AND MASS
  HIGH PERFORMANCE
- FLYING HEADS
- SELF FOCUSING SUBSTRATES

Figure 75. "Optical Memory System Study Presentation," Tim "Ogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182."
TRACKING SERVO

- Translates or tilts on optical element
- Tracking signal comes from preformatted tracks or grooves

FUTURE DIRECTIONS
- Discontinues tracking error signal limits access time
- Bipolar version of signal will boast rates
- Lower mass moving element
- High efficiency motors
- Fixed optics

Figure 76. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
LASER POWER CONTROL

- MAINTAIN CONSTANT LASER POWER (READ AND WRITE)
- INSURE SERVO TRANSUCER SIGNAL PRODUCES CONSISTENT AND ACCURATE INDICATION OF FOCUS AND TRACK ERROR WHILE PRESERVING READ SIGNAL FIDELITY
- INSURE WRITING PROPERLY DURING VELOCITY, MEDIA SENSITIVITY AND TEMPERATURE CHANGES
- PHOTO DIODE SAMPLES PortION OF LASER POWER

RECOMMEND A WRITE CONTROL SYSTEM OPERATING IN SAMPLE DATA MODE
READ CONTROL SYSTEM CONTINUES

Figure 77. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
RADIAL ACTUATION TRACKING

COARSE AND FINE ACTUATORS
COARSE - LARGE RANGE LIMITED BW
FINE - SMALL RANGE HIGH BW
100 µM OF RADIAL RUN OUT IS CONTROLLED TO 0.1 µM

COARSE POSITION SERVO
STEPPE Motors
D.C. SERVO MOTORS WITH BAND, RACK AND PINION ACTUATORS
FEEDBACK SIGNAL - FROM TRACKING ACTUATOR
HIGH PERFORMANCE CLOSED LOOP SERVO COARSE ACTUATOR

FINE ACTUATOR
VOICE COIL
RANGE ±10 TO ±200 TRACKS

---

Figure 78. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>WEIGHTING FACTOR</th>
<th>SPLIT BAND</th>
<th>RACK &amp; PINION</th>
<th>LEAD SCREW</th>
<th>WIRE DRIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOLDING FORCE</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>SEEK TIME</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>REQUIRED SPACE</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>RESOLUTION</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>WEAR</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>HYSTERESIS</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>LOW FRICTION</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>COST</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>LUBRICATION</td>
<td>5</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>DEBRIS GENERATION</td>
<td>5</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>POSSIBLY</td>
</tr>
<tr>
<td>OVERALL</td>
<td></td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

RECOMMENDATION: RACK AND PINION

Figure 79. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
CONCERNS
- ACCURACY OF ALIGNMENT
- REPEATABILITY
- STRUCTURAL INTEGRITY

QUESTION AS TO VIABILITY OF COMMERCIAL TYPE CARTRIDGE APPLICATION

Figure 80. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
DESIGN RECOMMENDATIONS

- DUAL RADIAL ACTUATORS
- RACK AND PINION COARSE ACTUATOR
- D.C. SERVO MOTOR
- MICROPROCESSOR BASED CONTROL
- FOCUS SERVO BW 3 KHZ
- TRACKING SERVO BW 5 KHZ
- CONTINUOUS SERVO FORMAT
- ACTUATORS TO MEET INERTIAL FORCES AND ACCESS TIME

Figure 81. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
- HEAT EXCHANGE SYSTEM DESIGN
- THERMAL COMPENSATION
- REMOVABLE MEDIA SYSTEM
- COMMON DRIVE
- CONTAMINATION CONTROL SYSTEM
- VIBRATION STABILIZATION/ISOLATION SYSTEM
- SERVO MOTORS, ACTUATORS AND CONTROL THAT MEET THERMAL AND INERTIAL REQUIREMENTS
- OPTIMIZE RADIAL SERVO ARCHITECTURE
- ABOVE CONSISTENT WITH DRIVE FORM FACTOR

Figure 82. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SYSTEM PACKAGING

Figure 83. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
OVERALL PACKAGING DESIGN CONSIDERATIONS

AVIONICS EQUIPMENT BAY APPLICATIONS

- Design drive, PWBS, and power supply to fit in #6 LINE REPLACEMENT UNIT (LRU) 7.5 WIDE X 7.64 HIGH X 12.76 LONG

- Design to comply with DOD-STD-1788

- Cooling air available

- Not essential to have rapid access to media

Figure B4. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
MECHANICAL PACKAGING

• OVERALL PACKAGING CONSTRAINTS (WEIGHT, DIMENSIONS, ETC.)
  - AVIONICS EQUIPMENT BAY
  - PANEL MOUNTED EQUIPMENT

• THERMAL DESIGN METHODOLOGY
  - FREE CONVECTION DESIGN
  - FORCED AIR COOLED DESIGN

• VIBRATION/SHOCK DESIGN METHODOLOGY

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Figure 85. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
Figure 86. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
VIBRATION ISOLATION

- Sinusoidal and random vibration isolation considered in Task 2 discussion
- Conclusion: The low frequency end of the spectrum requires special attention
- Strategy for minimizing low frequency structural disturbances
  - Attenuation of external forcing functions
    - Use two-stage isolation system
    - Low band pass periodic force isolators
    - High band pass aperiodic force isolators
    - Avoid anisothermal isolator material
    - Provide large sway space inside drive
  - Attenuation of internal forcing functions
    - Avoid use of sheet metals
    - Use high temperature polymers
    - Use structural decoupling elements
  - Attenuation of sympathetic resonances
    - Frequency detune eigenvalues of linked components
    - Phase detune eigenvalues of unlinked components

Figure 87. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SINUSOIDAL VIBRATION LEVELS
SEEN BY THE DRIVE

- ASSUMES COMMERCIALLY AVAILABLE ISOLATORS "FILTERING" CURVE IIIA MILITARY INPUT.
- CAN BE CONVERTED TO G LOADING BY RELATION INDICATED ON GRAPH.
- RESULTS:
  - MAXIMUM D.A. OF 0.2G AT 13 Hz
  - MAXIMUM G'S OF 2.72 AT 23 Hz
  - AT 1800 RPM = 30 Hz
    D.A. = .055 INCH
    G's = 2.52 G's
  - AT 3000 RPM = 50 Hz
    D.A. = .009 INCH
    G's = 1.148 G's

Figure 88. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
FREE CONVECTION PARAMETRIC ANALYSIS

- THERMAL ANALYSIS INPUTS
  - DRIVE DIMENSIONS
  - FIN STRUCTURE
  - AMBIENT CONDITIONS

- RESULTS
  - SURFACE AREA ENHANCEMENT OR OTHER MEANS TO DECREASE DRIVE TEMPERATURE ESSENTIAL
  - DESIGNERS MUST CONSIDER EFFECT OF ALTITUDE
  - DRIVES OPERATED IN FREE CONVECTION ENVIRONMENTS MUST DISSIPATE MINIMAL ENERGY
  - 10 WATT DRIVE $\Delta T_s$ OVER AMBIENT OF 20°C OR LESS
  - 20 WATT DRIVE $\Delta T_s$ OVER AMBIENT OF 40°C OR LESS
  - DRIVE INTERNAL TEMPERATURES WOULD BE 5 TO 10°C HIGHER AND WELL OVER PRESENT DAY MEDIA CAPABILITIES

Figure 89. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
FORCED AIR COOLING PARAMETRIC ANALYSIS

- THERMAL ANALYSIS INPUTS
  - DRIVE SURFACE AREA
  - AIR MASS FLOW RATE
  - AIR INLET AIR TEMPERATURE
  - HYDRAULIC DIAMETER (BASED ON FIN SPACING AND CLEARANCE AROUND THE DRIVE)

- RESULTS
  - FLOW RATE OF 0.5 LB/MINUTE RESULTS IN CASE TEMPERATURES/INTERNAL TEMPERATURES IN THE RANGE OF 54 TO 66°C
  - STATIC PRESSURE CHANGE THROUGH A TYPICAL PACKAGE IS < 2 INCHES H₂O

Figure 90. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ERROR MANAGEMENT

Figure 91. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ERROR DETECTION AND CORRECTION (EDAC)

PURPOSE:

- IMPROVE OPTICAL DISK CHANNEL PERFORMANCE BY DETECTING AND CORRECTING ERRORS
- THE HIGH RAW DATA ERROR RATE OF THE OPTICAL DISK REQUIRE THE USE OF EDAC

Figure 92. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1188.
ERROR CONTROL

- DEFINITION - TECHNIQUES TO REDUCE THE OCCURRENCE OF ERRORS IN THE SYSTEM AND THE METHODOLOGIES USED TO DETECT AND CORRECT ERRORS DURING TRANSMISSION

- METHODS TO REDUCE NUMBER OF ERRORS
  - RUGGEDIZE OPTICAL DRIVE COMPONENTS
  - PROTECT SYSTEM FROM EXTREME ENVIRONMENTS AND CHANGES
  - REDUCE THE MEDIA DEFECT RATE AND BURST LENGTH CHARACTERISTICS
  - USE ERROR TOLERANT CODING AND DECODING SCHEMES

- METHODS USED TO DETECT ERRORS
  - PARITY CHECKING
  - CONSTANT RATIO CODES (4 OF 8, 2 OF 7, ETC.)
  - CYCLIC REDUNDANCY CHECKS (CRC CODES)
  - FIRE CODES
  - COMPUTER GENERATED POLYNOMIAL CODES
  - REED-SOLOMON CODES

- METHODS USED FOR ERROR CORRECTION
  - FIRE CODES
  - HAMMING CODES
  - REDUNDANT SECTOR CODES
  - REED-SOLOMON CODES
  - INTERLEAVED REED-SOLOMON CODES

Figure 93. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
**FDAC: CODE REQUIREMENTS**

- **DEFECT LENGTH PROBABILITY DISTRIBUTION IS**

  \[ P = (1 + x/(L(M - 1)))^M \]

  **WHERE,**
  
  \[ M = 4 \]
  
  \[ L = 2 \]
  
  \[ x, \text{ DEFECT LENGTH IN NUMBER OF BITS} \]
  
  \[ P, \text{ PROBABILITY THAT ERROR BURST IS} \times \text{BITS} \]
  
  OR GREATER IN LENGTH

- **BEGINNING-OF-LIFE DEFECT EVENT RATE = 1.0E-5 DEFECT EVENTS PER BIT**

- **END-OF-LIFE DEFECT EVENT RATE = 1.0E-4 DEFECT EVENTS PER BIT**

- **SECTORS WITH MORE THAN 2 BYTES IN ERROR ARE RETIRED AT BEGINNING-OF-LIFE (EXCEPT READ-ONLY DISKS) OR AT WRITE TIME**

- **ASSUME THAT END-OF-LIFE DISTRIBUTION IS THE SAME AS THAT FOR BEGINNING-OF-LIFE EXCEPT THAT MAXIMUM DEFECT LENGTH IS 100 BITS**

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**Figure 94.** "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: CODE PERFORMANCE CRITERIA

- Achieve an uncorrectable sector event rate of less than $1.0 \times 10^{-13}$ uncorrectable sectors per bit.

- Low miscorrection probability. EDAC "corrects" valid data when it tries to correct a burst of errors that exceeds in length the capability of the code.

- Circuit complexity and cost. LSI ICs enable complex codes to be implemented.

- Processing time. Faster ICs and microprocessors are reducing processing time.

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Figure 96. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: RECOMMENDED CODE
INTERLEAVED REED-SOLOMON (RS) CODE

- CORRECTS ALL ERRORS WITH LENGTH OF 8 SYMBOLS (8BITS) OR LESS
- MINIMUM DISTANCE = 17 SYMBOLS
- FIVE INTERLEAVES USED IN BLOCK OF 512 SYMBOLS
- 16 REDUNDANCY SYMBOLS PER INTERLEAVE, 16% OVERHEAD
- GENERATOR POLYNOMIAL OF DEGREE 16 WITH COEFFICIENTS FROM GF(256)
- DECODING STEPS:
  - COMPUTE SYNDROMES
  - GENERATE ERROR-LOCATOR POLYNOMIAL
  - FIND ROOTS OF THE ERROR-LOCATOR POLYNOMIAL
  - TAKE LOGS OF THESE ROOTS TO COMPUTE ERROR LOCATIONS
  - COMPUTE ERROR VALUES

Figure 97. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: RECOMMENDED CODE
INTERLEAVED RS CODE

- PROBABILITY OF UNCORRECTABLE ERROR

<table>
<thead>
<tr>
<th>RAW DEFECT EVENT RATE</th>
<th>UNCORRECTABLE SECTOR EVENT RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(DEFECT EVENTS PER BIT)</td>
<td>(UNCORRECTABLE SECTOR EVENTS PER BIT)</td>
</tr>
<tr>
<td>1.0E-5</td>
<td>1.4E-27</td>
</tr>
<tr>
<td>1.0E-4</td>
<td>3.8E-18</td>
</tr>
</tbody>
</table>

- MISCORRECTION PROBABILITY = 4.12E-8

Figure 98. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
Figure 99. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: RECOMMENDED CODE
INTERLEAVED RS CODE

HEADER FIELD

• USE REDUNDANCY CHECK CODE

• GENERATOR POLYNOMIAL OF DEGREE K OVER GF(2)

• DETECTS ALL ERRORS OF LENGTH K BITS OR LESS

Figure 100. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: RECOMMENDED CODE
INTERLEAVED RS CODE

IMPLEMENTATION

- HARDWARE
  - COMMERCIAL AVAILABLE IC WITH MIL VERSION EXPECTED
  - USED IN CODE GENERATION AND INTERLEAVING
  - IN DECODER, HARDWARE USED FOR SYNDROM COMPUTATION
  - BUFFER BETWEEN DEVICE AND HOST HAS CAPACITY OF AS MUCH AS ONE TRACK
  - TRANSFER FROM DEVICE TO BUFFER AND BUFFER TO HOST IS ASYNCHRONOUS
  - ERRORS ARE CORRECTED BEFORE SECTORS ARE SENT TO HOST
  - BUFFER IS MEMORY MAPPED

Figure 101. "Optical Memory: System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: RECOMMENDED CODE
INTERLEAVED RS CODE

IMPLEMENTATION

- SOFTWARE
  - IMPLEMENTS REMAINING STEPS OF DECODING ALGORITHM
  - SOFTWARE AVAILABLE FOR Z8 AND 8088 MICROPROCESSORS
  - PROCESSING TIME

CORRECTION TIMES (MICROSECONDS)

<table>
<thead>
<tr>
<th># OF ERRORS</th>
<th>Z8 a 12 MHZ</th>
<th>8088 a 8 MHZ</th>
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<tr>
<td>0</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>1</td>
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<td>4</td>
<td>3,300</td>
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<tr>
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<td>8,100</td>
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<tr>
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<td>13,500</td>
</tr>
<tr>
<td>8</td>
<td>7,600</td>
<td>16,000</td>
</tr>
</tbody>
</table>

Figure 102. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: TRACK FORMAT CONSIDERATIONS

- NEED ERROR TOLERANCE IN TRACK FORMAT

- SPECIAL FIELDS AND MARKS MUST BE ERROR- TOLERANT:
  - SYNCH FIELDS AND MARKS
  - HEADER FIELDS
  - SECTOR AND INDEX MARKS

Figure 103. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: TRACK FORMAT CONSIDERATIONS
Synchronization

- DEVICE MUST BE TOLERANT OF DEFECTS THAT FALL WITHIN SYNCH FIELDS AND MARKS
- SELECT ERROR-TOLERANT SYNCH MARKS
- REPLICATE SYNCH MARKS WITH SOME NUMBER OF BYTES IN BETWEEN
- DESIGN CONTROLLER SUCH THAT NO SINGLE SYNCH MARK IS REQUIRED TO BE DETECTED
- DESIGN PLL SUCH THAT IT CAN FLYWHEEL THROUGH MAXIMUM DEFECT LENGTH
- USE TIMING WINDOWS IN SYNCH MARK DETECTION TO MINIMIZE PROBABILITY OF FALSE DETECTION
- USE RESYNCH FIELDS THAT ARE TOLERANT TO ERRORS

---

Figure 104. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: TRACK FORMAT CONSIDERATIONS
HEADERS

- USE SEVERAL CONTIGUOUS REPLICA S OF THE HEADER
- USE TRACK ORIENTATION TO GENERATE HEADER INFORMATION WHEN HEADER IS IN ERROR
- ELIMINATE HEADER BY PLACING ADDRESS IN DATA FIELD

Figure 105. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
EDAC: TRACK FORMAT CONSIDERATIONS
DEFECT MANAGEMENT

- RETIRE SECTORS WITH A SPECIFIED AMOUNT OF DEFECTS

- USE DYNAMIC DEFECT MANAGEMENT TO FLAG MARGINAL SECTORS OR SECTORS TO BE RETIRED

Figure 106. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communication and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ERROR MANAGEMENT

- Definition - The orderly handling of static and dynamic errors that occur when transferring information to or from the optical disk.

- Problems most likely to occur in optical disk systems:
  - Physical media defects
  - Read/write errors
  - Loss of synchronization through large defects
  - False sync mark detections
  - Missing sync marks
  - Defective sectors
  - Missing or incorrect formats
  - Defective header fields
  - Command and protocol errors
  - Time-outs

Figure 107. "Optical Memory System Study Presentation." Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ERROR MANAGEMENT - STRATEGIES

- PHYSICAL MEDIA DEFECTS
  - RETIRE SECTORS AT FORMAT TIME
  - RETIRE MEDIA IF EXCESSIVE DEFECTS OCCUR

- WRITE DATA ERRORS
  - IF SMALL NUMBER OF ERRORS THEN USE CORRECTION METHODS
  - IF EXCESSIVE ERRORS THEN REWRITE SECTOR TO ALTERNATE LOCATION

- READ DATA ERRORS
  - REREAD SECTOR
  - USE CORRECTION METHODS

- MAINTAINING SYNC THROUGH LARGE DEFECTS
  - USE SOME CRITERIA (I.E., RUN LENGTH VIOLATION, LOSS OF SIGNAL AMPLITUDE, ETC.) TO SHUT OFF UPDATING OF THE PLL'S FREQUENCY AND PHASE MEMORY

- FALSE SYNC MARK DETECTION
  - INCREASE MARK WIDTHS
  - INCREASE MARK FREQUENCY
  - QUALIFY MARK WITH A TIMING WINDOW

- MISSING SYNC, INDEX, AND SECTOR MARKS
  - USE ERROR TOLERANT MARKS
  - USE REDUNDANT MARKS
  - MAKE LUNAR PULSES INSENSITIVE TO THEIR LOSS

Figure 108. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ERROR MANAGEMENT - STRATEGIES (CONT'D.)

- TIMEOUT ERRORS (WATCHDOG, SEEK TIMEOUT)
  - REPORT ERRORS TO FMS

- COMMAND OR PROTOCOL ERRORS
  - REPORT ERRORS TO FMS

- DEFECTIVE HEADER FIELD
  - USE RELATIVE SECTOR POSITION ON TRACK TO DETERMINE SECTOR ADDRESS
  - RETIRE SECTOR AND REWRITE TO ALTERNATE LOCATION
  - NEVER STORE VITAL INFORMATION IN HEADER FIELD THAT IS SENSITIVE TO LOSS

Figure 109. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
MODULATION CODES

PURPOSE

- METHOD FOR MAPPING DATA OR MODULATING DATA ONTO STORAGE MEDIA

SELECTION CRITERIA

- EFFICIENCY - NUMBER OF STORED BITS PER LASER MARK
- SELF-CLOCKING - ABILITY TO EXTRACT CLOCK FROM DATA TRANSITIONS.
  CODE MUST BE ABLE TO ACQUIRE AND HOLD SYNCH THROUGH DEFECTS
- READ RESOLUTION - MEASURE OF DETECTION ACCURACY GIVEN IN TERMS OF TIMING WINDOW SIZE
- INTERSYMBOL INTERFERENCE - INTERFERENCE BETWEEN ADJACENT SYMBOLS
- BANDWIDTH - OVERALL CHARACTERIZATION OF CODE IN FREQUENCY DOMAIN.
  NO OR SMALL DC COMPONENT AND NARROW BANDWIDTH ARE DESIRED
- CIRCUIT COMPLEXITY AND AVAILABILITY - TYPE, SIZE AND COST OF CIRCUIT REQUIRED TO IMPLEMENT CODE

Figure 110. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
POSSIBLE CODE CHOICE

- **EFM** - EIGHT OF FOURTEEN MODULATION, A (2,10) RLL CODE. USED FOR CD'S AND CD-ROM'S.

- **TOON** - TWO OUT OF NINE. A NON SELF-CLOCKING BLOCK CODE WITH A HIGH LEVEL OF LARGE AMPLITUDE AND OFFSET VARIATION INSENSITIVITY. REQUIRES IMBEDDED CLOCKING. USED BY OSI FOR 1 GB 12" W/O OPTICAL DRIVE.

- **MFM** - MODIFIED FREQUENCY MODULATION. A (1,3) RLL CODE. USED BY ISI FOR 100 MB 5 1/4" W/O OPTICAL DRIVE.

- **3Ø (1,7)** - A (1,7) RLL CODE. USED BY RCA FOR 1.25 GB 14" W/O WIDEBAND OPTICAL DISK DATA ACQUISITION RECORDER.

- **(2,7)** - THE MOST WIDELY USED RLL CODE. KODAK, HITACHI, AND OTHERS ARE USING IT FOR BOTH W/O AND ERASABLE OPTICAL DRIVES IN THE 3.5" TO 14: FORM FACTOR RANGE.

*Figure 111. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.*
FMS DEFINITION

- GIVES USER CAPABILITY TO CREATE NAME SPACES (FILES)

- RESPONSIBLE FOR STORING, RETRIEVING AND MANAGING DATA STORED IN MASS MEMORY
  - MAPS LOGICAL FILES INTO PHYSICAL LOCATIONS
  - ALLOCATES, DEALLOCATES, AND ADMINISTERS MASS STORAGE EFFECTIVELY

Figure 113. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
PROBLEMS OF OPTICAL DISK TECHNOLOGY FOR FILE MANAGEMENT

- LARGE WRITE-ONCE, READ MOSTLY MEMORY
  - OPTIMIZE DIRECTORY, FILE STRUCTURE FOR EASE OF READING AT EXPENSE OF WRITE TIME
  - DIRECTORY SPACE VS. FILE SPACE (MANY SMALL FILES/FEW LARGE FILES, READ-ONLY FILES/READ-WRITE FILES, PRE-ALLOCATED SPACE/DYNAMICALLYAllocated SPACE)
  - STORAGE OF DIRECTORY, FILE UPDATES (PRE-ALLOCATED SPACE/DYNAMICALLY ALLOCATED SPACE, RELATING UPDATE TO PREDECESSOR FOR RETRIEVAL)
  - IDENTIFYING WRITTEN DATA AS CURRENT OR OUT-OF-DATE

- LONG AVERAGE SEEK TIMES COMPARED TO MAGNETIC MEDIA
  - ARRANGE DIRECTORY AND FILES SO AS TO MINIMIZE COARSE SEeks AND ROTATIONAL DELAY
  - LOGICAL VERSUS PHYSICAL FILE ACCESS CONSIDERATIONS (SEQUENTIAL, RANDOM, INDEXED SEQUENTIAL ACCESS)

- SECTOR (512 BYTES) IS SMALLEST ADDRESSABLE UNIT ON DISK
  - ANY CHANGE IN SECTOR CONTENTS REQUIRES REWRITING ENTIRE SECTOR

\[ \Rightarrow \text{RECORD (LOGICAL UNIT) STORED AS SECTOR (PHYSICAL UNIT) FOR EFFICIENCY} \]

Figure 114. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
GOALS

- MINIMIZE OVERHEAD
  - FMS PROCESSING TIME
  - SPACE NEEDED FOR STORING FMS DATA (E.G., DIRECTORY)
  - COMMUNICATION BETWEEN HOST AND FMS

- MAXIMIZE THROUGHPUT FOR HOST
  - MINIMIZE COARSE SEEKS (~80 MS)
  - MAXIMIZE USE OF SEQUENTIAL TRACKS/SECTORS
  - MINIMIZE TRANSMISSION DELAYS

- PERMIT USE WITH REMOVABLE AS WELL AS FIXED MEDIA

  ⇒ MAINTAIN DIRECTORY ON OPTICAL DISK MEDIA

- EFFICIENT USE BY VARIETY OF APPLICATIONS
  - SMALL NUMBER OF LARGE FILES (E.G., TERRAIN MAPS)
  - NUMEROUS FILES OR VERSIONS OF SAME FILES (E.G., DATA EXTRACTION, DATA RECORDING)
  - READ-MOSTLY APPLICATIONS (E.G., MAPS)
  - WRITE-MOSTLY APPLICATIONS (E.G., DATA RECORDING)
  - READ/WRITE APPLICATIONS

Figure 115. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
GOALS (CONTINUED)

- Transition to read/write optical disk technology transparent to host
  - Ideally no change required to host software to interface with/use worm or RW optical disk

- EMS internal to ODM as an ordering option
  - Application dependent
    - If more efficient for host to embed knowledge of file structure and location in application software, customer should not need to purchase ODM EMS (e.g., for certain map data bases where file = ODM track)
    - Host interfaces with ODM on controller level

---

Figure 116. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown MD 20874-1182.
RECOMMENDED FMS APPROACH

- Files consist of one or more tracks
- Two files cannot co-exist on same track
- Files allocated sequential sectors until a directory sector detected
- File operations:
  - Add file/delete file/update file (create/extend)
- Directory created in non-volatile SCM during power up
  (update ODM during power-down)
- Record occupies one sector
  (smallest addressable entity on disk)
- Record operations:
  - Add record/change record/delete record

Figure 117. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SYSTEM ARCHITECTURE

Figure 118. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SYSTEM ARCHITECTURE - FUNCTIONAL DESCRIPTION

○ LAYER 1 - WORM DRIVE
  - READ/WRITE INTERFACE TO OPTICAL MEDIA
  - MEDIA SPIN CONTROL
  - HEAD MOTION AND POSITION CONTROL
  - DATA ENCODING/DECODING (MFM, RLL2-7, ETC.)
  - ESDI INTERFACE TO CONTROLLER

○ LAYER 2 - CONTROLLER
  - ESDI INTERFACE TO DRIVE
  - COMMAND AND DATA INTERFACE
  - ERROR DETECTION AND CORRECTION
  - ERROR MANAGEMENT AT THE SECTOR LEVEL
  - INTERFACE TO FILE MANAGEMENT SYSTEM
  - SECTOR BUFFERING

○ LAYER 3 - I/O INTERFACES
  - PROVIDES DATA PATH FROM OPTICAL DISK UNIT TO HOST
  - SUPERVISES PROTOCOL BETWEEN HOST AND CONTROLLER

○ LAYER 4 - FRONT END PROCESSOR
  - FILE MANAGEMENT SYSTEM
  - ERROR MANAGEMENT AT THE FILE LEVEL
  - OPERATING SYSTEM
  - DATA COMPRESSION/DECOMPRESSION
  - INTERFACE BETWEEN HOST AND CONTROLLER

Figure 120. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
• USES ESDI DISK INTERFACE
• CAN WORK WITH OPTICAL OR MAGNETIC DISK DRIVES
• DATA RATES UP TO 10 MBITS/SECOND
• BUILT IN ERROR MANAGEMENT SYSTEM
• HARD OR SOFT SECTORED DISK FORMATS
• ONE FULL TRACK SECTOR BUFFER
• INTERLEAVED REED-SOLOMON EDAC
• USER SELECTABLE INTERLEAVE FACTOR (1-6)
• CAN SUPPORT UP TO SEVEN DRIVES
• CAN WORK WITH OR WITHOUT THE FRONT END PROCESSOR CARD
• USER PROGRAMMABLE SEQUENCER FOR CHANGING DISK FORMATS
• CAN HANDLE POST DATA FIELDS FOR SECTOR LINKAGE

Figure 121. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
**Choice of Three High Performance 16-Bit CPUs**

- M8088 (PLM/86)
- Z8000 (JOVIAL, ADA)
- F9450 (MIL-STD-1750ISA)

**Contains Local Program and System Memory (ROM, RAM)**

**Has On-Board Non-Volatile Memory for Saving System Parameters, Indexes, Directories, etc., During Power Down**

**Contains Optional File Management System**

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**Figure 122.** "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
I/O MILITARY INTERFACES

Figure 124. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
HOST INTERFACES

- MIL-STD-1553B
  - ACCEPTED AND WIDELY USED BY AIR FORCE, NAVY, AND ARMY
  - HALF DUPLEX OPERATION
  - PARTY LINE, SUPPORTS UP TO 32 TERMINALS
  - SERIAL BUS STRUCTURE
  - COMMAND/RESPONSE PROTOCOL
  - MESSAGE SYNCHRONOUS, BIT ASYNCHRONOUS
  - 32 WORD MESSAGE LENGTH
  - 1 MHz DATA RATE

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIDELY USED</td>
<td>SMALL MESSAGE LENGTH</td>
</tr>
<tr>
<td>GOOD AS CONTROL BUS</td>
<td>LOW DATA RATE</td>
</tr>
</tbody>
</table>

Figure 125. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
HOST INTERFACES (CONT'D.)

- MIL-STD-1773
  - STATUS: NOT YET ACCEPTED, STILL IN COMMITTEE
  - FIBER OPTIC VERSION OF MIL-STD-1553B
  - DUAL DATA RATE: 1 MHZ FOR EXISITING SYSTEMS
    10 MHZ FOR NEW SYSTEMS

ADVANTAGES
- HIGH DATA RATE

DISADVANTAGES
- NOT YET ESTABLISHED

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Figure 126. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
HOST INTERFACES (Cont'd.)

- MIL-STD-1379 (NTDS)
  - STATUS: USED BY NAVY ABOARD SHIPS AND AIRCRAFT
  - THREE POINT-TO-POINT MODES
    A. PARALLEL (SLOW) - 41.6 KWORDS/SEC
    B. PARALLEL (FAST) - 250 KWORDS/SEC
    C. SERIAL - 10 MBIT/SEC
  - SYNCHRONOUS PARALLEL OPERATION
  - MESSAGE SYNCHRONOUS, BIT ASYNCHRONOUS
  - VARIABLE MESSAGE SIZE, SYSTEM DEPENDENT
  - VARIABLE WORD SIZE, SYSTEM DEPENDENT

ADVANTAGES

- HIGH DATA RATE
  - VARIABLE PROTOCOL

DISADVANTAGES

- POINT-TO-POINT ARCHITECTURE

Figure 127. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
• HIGH SPEED DATA BUS (HSDB)
  - STATUS: IN DEVELOPMENT BY AIR FORCE/SAE
  - HALF DUPLEX
  - PARTY LINE, 128 TERMINALS
  - TOKEN PASSING BUS STRUCTURE
  - UP TO 4 KWORD MESSAGE SIZE
  - 20 TO 100 MHZ DATA RATE (30 MHZ TYP)
  - FIBER OPTIC OR WIRE OPERATION

ADVANTAGES
- HIGH DATA RATE
- MULTI USER BUS
- LARGE MESSAGE SIZE

DISADVANTAGES
- NOT YET DEVELOPED

Figure 128. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
NUCLEAR RADIATION

Figure 129. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
NUCLEAR RADIATION HARDENING ANALYSIS
NADC STUDY

ACTIVITY

- DETERMINATION OF RADIATION LEVELS
- TARGETING OF OMS HARDWARE FOR ANALYSIS
- SCOPE AND METHODS OF TESTING AND ANALYSIS
- SYSTEM GENERATED EMP

TARGETING OF OMS HARDWARE

- OMS HARDWARE
  - ELECTRONICS
  - SERVO/MECHANICAL
  - OPTICAL (DISKS, HEADS)
- RADIATION HARDENING TECHNOLOGY DEVELOPED
  - ELECTRONICS
  - SERVO/MECHANICAL
- CONCLUSION: RADIATION ANALYSIS FOR OPTICAL HARDWARE ONLY

Figure 130. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
DETERMINATION OF RADIATION LEVELS

- LEVEL CRITERION: S-110 "OPTIMAL NUCLEAR RADIATION CRITERIA FOR AERONAUTICAL SYSTEMS"; VHSIC OBJECTIVES; PRESENT SYSTEM REQUIREMENTS

LEVELS (BASED ON CRITERION)

- TOTAL DOSE: 1 TO 10 KRAD (Si)
- DOSE RATE: $10^8$ TO $10^9$ RAD(Si)/S & 20ns
- NEUTRON FLUENCE: $10^{12}$ TO $10^{13}$ N/CM$^2$
- EMP CONSISTENT WITH ABOVE LEVELS

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Figure 131. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SCOPE AND METHODS OF TESTING AND ANALYSIS

DISKS

• SCOPE

- BOTH WORM AND M-O DISKS TO BE TESTED
- TOTAL DOSE AND NEUTRON FLUENCE TO BE PERFORMED
- DOSE RATE SYSTEM PERFORMANCE DIFFICULT (DRIVE MUST OPERATE DURING EXPOSURE)

• METHOD

- EVALUATE SYSTEM PERFORMANCE (DISK/DRIVE ERROR RATES) FOR VARIOUS EXPOSURES
- EXPOSE DISKS OVER TOTAL DOSE RANGE
- EXPOSE DISKS OVER NEUTRON FLUENCE RANGE

Figure 132. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182."
SCOPE AND METHODS OF TESTING AND ANALYSIS
HEADS

• SCOPE

- BOTH WORM AND M-O HEADS TO BE EVALUATED
- DIFFICULT TO OBTAIN SEVERAL HEADS (NECESSARY FOR RADIATION TESTING)
- RADIATION EFFECTS DATA AVAILABLE FOR OPTICS
- HEAD ANALYSIS PERFORMED BY MATERIALS STUDY

• METHOD

- IDENTIFY OPTICAL COMPONENTS/MATERIALS IN HEADS
- PERFORM RADIATION MATERIALS ANALYSIS

Figure 133. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
- Investigate application of optical disk technology to existing computer memory complexes

- Define overall computer/memory system requirements for both hardware and software

- Definition of present system

- Definition of architecture based upon "Practical" optical disk technology defined in OMS study
  - Functional description
  - Performance requirement
  - Interface parameters

Figure 135. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SYSTEM DEVELOPMENT DECISIONS

- SYSTEM TECHNOLOGY
  - WRITE ONCE
  - ERASEABLE
  - COMMON

- TRANSPORTABILITY LEVEL
  - MEDIA
  - CARTRIDGE
  - DRIVE

Figure 137. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
SYSTEM CONCLUSIONS

WRITE ONCE SYSTEM

- REQUIRED DEVELOPMENT PROGRAMS
  - W/O MEDIA
  - OPTICAL HEADS
  - SERVO MECHANISMS

- SHORTEST SCHEDULE TO PRODUCTION
- LOWEST COST
- INTERIM SYSTEM

ERASABLE SYSTEM

- REQUIRED DEVELOPMENT PROGRAMS
  - ERASABLE MEDIA
  - OPTICAL HEADS (MORE COMPLEX)
  - SERVO MECHANISMS (MORE COMPLEX)

- LONGER SCHEDULE TO PRODUCTION
- HIGH COST
- ULTIMATE SYSTEM

NOTE: COMMON DRIVE CAN BE REALIZED WITH ADDITION OF W/O MEDIA DEVELOPMENT

Figure 138. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown, MD 20874-1182.
ASSUMPTION - OPTICAL COMPONENTS MUST BE SEALED FROM ENVIRONMENT

CHOICE

- SEAL COMPLETE DRIVE AND REMOVE AS A SUBASSEMBLY
- DEVELOP A SEALED CARTRIDGE THAT CONTAINS ELEMENTS OF SPIN MOTOR ASSEMBLY
- TRANSPORT MEDIA ONLY, BUT DEVELOP DRIVE SYSTEM WITH ENVIRONMENTAL CONTROL SYSTEM

Figure 139. "Optical Memory System Study Presentation," Tim Rogers, Fairchild Communications and Electronics, 20301 Century Boulevard, Germantown MD 20874-1182.
END
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