N93-13133

OPTICAL DISKS BECOME ERASABLE

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Discussion

* Optical Recording
* How Does it Work?
* Why All the Fuss?
* State of the Industry
* Sample Applications
* Future Directions

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OPTICAL DISK AND TAPE TECHNOLOGY

Dr. Robert Freese

DR. FREESE: Thank you. Good morning. Does everyone want to stand up and take a quick break?

(Participants stand up and stretch)

DR. FREESE: Okay. Now, it is 10:00 and let's begin. Just a quick fix.

What I would like to do today is spend a few minutes talking about and giving you an overview of the status of the optical recording industry.

(Showing of slides)

DR. FREESE: I have titled this particular overhead optical disk "become erasable." "Rewritable" is a technical term.

(First slide)

In today's presentation, I would really like to take an end user perspective, not so much of a technology perspective; and I would also like to take a more practical approach to the status of the industry, which is to say we have all sat through presentations and talks like this over the last decade and heard about all the wonderful things coming up.

But I would really like to take a more practical approach: What can I buy now? How do I use it? Why do I use it? And what am I going to see in the immediate future?

I would like to focus first of all just on the status of the optical recording industry, review how it works, talk about why all the interest and why all the fuss, go through a few sample applications and a few future directions.

(Change of slide)

DR. FREESE: Of course, everybody always asks me. There are three types of optical recording systems: the so-called read-only, the so-called write once, and the erasable.

(Change of slide)

DR. FREESE: Read onlys, just like the name implies: You can read the disks, but you can't record on them, and you can't write on them. The first implementations of this were like video disks; and in fact, I believe that you at NASA have used as data distribution mechanisms in the laser disk format.

(Change of slide)

More recently, CD ROM and CDI have been introduced in the smaller format and are starting to see widespread acceptance.

(Change of slide)

DR. FREESE: Probably the most questions I get are relative to WORM, or the write-once optical disks. WORM stands for "write once/read many times." These were introduced in 1982, 1983, and 1984--this type of time frame. Their marketplace is extremely small; we have seen that. It is really a precursor to the rewritable marketplace.

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Optical Recording Systems

Three Types:

- **Read Only**
- **Write Once (WORM)**
- **Erasable**

Read Only Optical Disks

Introduced:	**1979**
Function:	**Read (only)**
Markets:	**Music, Publishing**
Application:	**Compact Disk (music)** **CD-ROM (data)** **CD-I (data)** **Interactive Videodisc**

Write Once Optical Disks

Introduced:	**1983**
Function:	**Read and Write**
Market:	**Precursor to Re-writable Marketplace** **Other ??**
Applications:	**??**
Standards:	**No**

Applications for WORM. Now that rewritables are here, there are very, very few. People constantly misunderstand the fact that a WORM is for "archival purposes." A WORM just doesn't last as much as an erasable disk. And you can give me a WORM disk today, and I can alter the data for you--really simply--and you will never know.

(Laughter)

DR. FREESE: So, in terms of the market and in terms of the applications, a very, very small market--very, very, very small. And many companies have found that out, like STC, and got out of that business.

(Change of slide)

DR. FREESE: Erasables tend to be a little bit new, introduced officially in 1988. Of course, with an erasable optical disk, you can do all the things that you normally associate with magnetic disks, floppy disks, hard drives, Winchesters.

There is an extremely wide variety of markets, and the applications we will go through in just a second. But you can use them just like magnetic disks. A lot of people say they are erasable or rewritable compact disks; and every once in a while, somebody will use the term: It's just like a random access tape.

(Change of slide)

DR. FREESE: Optical disks all work the same. You start out with some sort of laser source--a laser diode or whatever--take that light, put it into an optical head, and focus it onto a rotating disk memory.

You use that same laser beam to go back and read the information off the disk.

(Change of slide)

DR. FREESE: Well, that was simple enough. Why all the fuss? Why all the fuss is because it combines-- uniquely combines--these particular attributes. You get a large storage capacity, which we will talk about in a minute. The disks are removable. You have increased reliability; every time you talk about more data and more capacity, reliability gets more and more and more important.

I am reminded of the time that I lost my business plan on a floppy disk, and I can't tell you why; but anyhow, I just lost it. The disk got corrupted somehow. And I was really mad and angry for about a day because it took me about a day to redo the business plan from my memory back onto the computer.

Suppose that was a little optical disk; looks just like a floppy disk, about that big *[demonstrating]*--only that it is going to hold 1,000 floppies. So, now, if you lose the data on that disk, that's not one day that you are going to be upset; it's 1,000 days.

So, we'll talk a lot about reliability associated with optical recording systems.

You get a random access feature associated with the disk; we will talk about the archivability and key features associated with archivability--one of the main reasons why NASA is using these disks today for some of their archival storage.

We'll talk a little bit about erasability, and I want to concentrate also a great deal on international standards.

(Change of slide)

Erasable Optical Disks

Introduced: 1988

Function: Read, Write and Erase

Markets: Medical
Imaging
Engineering
Security
Accounting/Banking
more...

Applications: "Just Like Magnetic Disks"
"Erasable CD's"
"Random Access Tape"

Standards: Yes

How Does It Work?

* Magneto Optic Technology

* Erasability of Magnetic Recording with the High Density, Reliability, Removability of Optical Recording

Why All the Fuss?

Combines:

* Large Storage Capacity
* Removability
* Increased Reliability
* Random Access
* Archivability
* Erasability
* International Standard Media

Large Storage Capacity

* 650 to 1,000 MBytes per 5.25" Disk
* 16,000 to 93,000 MBytes per Jukebox System
* "Gigafloppy"
* Mainframe Storage on Desktop -- Removable

DR. FREESE: In terms of the large storage capacity, typically you are looking at 650 megabytes on a 5.25 inch disk; that is user available storage capacity. Within the last year or year and a half, there are robotic systems, near-line storage systems; and they will provide you up to about 100 gigabytes per storage system by as many systems as you want.

A lot of people who use these disks refer to them as a "gigafloppy." The people at NASA Goddard, for example, use the disks to store the VOYAGER I and VOYAGER II data. Imagine sitting at a work station with VOYAGER I and VOYAGER II data--all the data, I understand--on just a few disks on the desk-top.

Any time you want to access any of that data, just pull down the disk, pop it in, and away you go.

(Change of slide)

DR. FREESE: The disks are removable. This is the part everybody always forgets. In fact, I can't tell you how many times a customer has come back and said: By the way, did you know these things are removable?

(Laughter)

DR. FREESE: It's a disk; you use it just like a floppy disk in that respect. They'll say: Sure, yes, I sold you the system. I knew they were removable, and it says so right there in the literature.

But people aren't used to removable data storage; so, think of it. You are sitting there are your work station; you need disk access, disk storage. So, you fill up your optical disk, or you fill up your hard drive. What are you going to do next?

Well, you can go out, and you can buy another hard drive. That is sort of an expensive solution. Or you can pull the optical disk out and just pop a new one in and set the other one aside.

(Change of slide)

DR. FREESE: So, at a work station level, what you find is virtually "infinite" storage sitting at your fingertips. Write a system once; just feed cartridges in and keep them right in front of you.

Beyond that, people discover once again the disks are removable. If you can keep them on your shelf, you can keep them on your title shelf. You can keep them in your salt mine vault in the mountains in the western region of the U.S. if you want.

(Laughter)

DR. FREESE: You can even take your data and say that university up in Michigan or a university in Ohio wants to take a look at that data, do a disk copy. Federal Express it; send it to them. If the guy happens to be on your local area network, then you can send it across the network if you wish.

My experience is that most of the time they are not linked to you. So, just do a disk copy and mail it overnight to them.

You have got the message in terms of the use; and by the way, if you stop by tomorrow, you can see one of these devices and play with it all you wish. You have, in essence, a removable hard drive.

(Change of slide)

Removability

* Portable Cartridge
* On-line Storage
* Off-line Storage
* Back-up
* Archival
* "Removable Hard Drive"

Increased Reliability

* Non-contact "soft" Laser Beam
* No Head Crashes
* No Wear
* No Tribology Issues

Eliminates #1 Failure for Conventional Media

Increased Reliability

* Active Layer Buried Within Glass Substrate
* Dust and Dirt Out of Focus
* Reduced Susceptibility to Contaminants in Environment
* Protective Cartridge

DR. FREESE: It is random access. I spent an hour on the phone yesterday with a guy saying: Exactly what does this thing look like? He was a PC user. And I said: Gee, it looks just like a Drive A. You plug it in. My secretary can take a system out of a box, not even reading the instructions, install the thing, get it up and working in 20 minutes. The worst part about it was that she had to teach herself which end of the cartridge goes in the slot and where the button is to push it out, to get the cartridge back out again.

It's a disk; it's a regular disk. You use it just like a regular disk. There is nothing for the user to learn or to forget. There are no new commands for you to learn; there are no new commands that you need to forget. Can you do disk copy on it? Sure.

DR. FREESE: It is rewritable. I find that people in the marketplace use the term erasability; but the technical term is rewritable, which is to say that you can delete a file and recover that space.

You can delete a file on the WORM systems, but you don't get the space back and the file will go on. And if you give me about two minutes, I can delete a file so that you never even knew it was there; there is no traceable record associated with the WORM system. All that is done on the software side.

And so, if you wish, you can put together a so-called rewritable system such that you can only record it once, and you can't ever record that spot again. So, you can have all the functionality of WORMs without any of those disadvantages.

People constantly ask me: How many times can I erase this thing? Or: How many times can I rewrite this thing? We actually know of no limit. The highest number that I know of that has ever been tested on a single track is 30 million times of rewrite/erase cycles.

You typically don't get that many cycles with tapes, floppies, or hard drives today; but the limitation is not the recording mechanism, it is associated with the tribology. You get a head crash, or you get some friction. You get some dust on a disk.

DR. FREESE: Everybody knows that optical disks come in sandwiches, like a peanut butter and jelly sandwich; you use the peanut butter and jelly layer as the recording layer. So, the actual physical recording layer is buried; it is buried underneath either glass or it is buried under bullet-proof glass. That makes it pretty tough. It doesn't make it totally perfect.

You can give one of these disks to your dog, and your dog can chew it up; and you'll lose your information. However, what this means is that the information surface is buried and that things in the environment which play a role--dust, dirt, fingerprints, sea water, whatever--stay off the information surface.

The information surface remains buried and protected; and this has great implications relative to our data storage. Put a disk on the shelf for ten years and you still want to access that data--great. In this particular case, you might even have to blow off some dirt if you want; but your data will still be there.

DR. FREESE: If you have got all this data and you have spent a lot of money obtaining that data in the first place, you want it to last for a while. You don't want it to last just a couple minutes or even a couple years. You want it to last for a very, very, very long period of time.

So, let's talk about the archivability or the stability of these types of disks and where you may end up using these instead of some other type of technology.

The first thing is what we just talked about. I don't know what a soft laser beam is, to tell you the truth; but you have a noncontact method of recording. You are not rubbing any two things together; you are not rubbing any two surfaces together.

And so, because of that, you don't have any head crashes; and you don't have any wear. You totally get rid of the tribology issues, for which there is an entire panel--I believe either later today or tomorrow--to discuss. Those issues are gone.

But those are your number one issues associated with conventional magnetic recording systems today. Because those are gone, you have increased reliability associated with these systems.

DR. FREESE: In the magnetic-optic approach, which is pretty much the standard approach today, people always ask: How about accidental erasures? In fact, the people in Washington, D.C. are always asking me: Can you take the media on the subway?

And in fact, in 1984, I had to do some tests, where I actually carried the media on the subway for a few governmental agencies.

It is important to realize that in the magnetic- optic approach, it's true that the disk has magnetic properties; but the coercivity of that disk, or how stable those domains are--how much force it takes to accidentally erase your disk--is extremely high.

(Change of slide)

Your typical, conventional magnetic recording media today is somewhere between 300 Oersteds and maybe a little over 1,000 Oersteds. My son's magnet is stronger than that. And if my son sets his magnet on top of my video tape, the information is gone.

With erasable optical disks, you have coercivities that are in the hundreds--or I should say, in the tens of thousands of Oersteds, or tens of thousands of Gauss. Those types of magnetic fields, ladies and gentlemen, don't exist in the normal environment.

There are a few Government agencies you can go to that can produce a field that strong; but typically, you can't run into this in the environment. So, you can indeed take this disk and set a magnet on it if you want; and it won't do anything. It is very, very, very stable.

And yes, it can be sent through the mail; and yes, it can be sent through the airport security checks.

(Change of slide)

DR. FREESE: Those of you who are familiar with the removable media systems, or removable Winchesters, that were a little bit more common at the beginning of the 1980s, are familiar that you could take and remove the disk pack and set it on the shelf. And if you did so and then took that and put it back in three months later or six months later, you couldn't retrieve the information.

That issue also is addressed in the optical recording systems. You couldn't retrieve that information because you got some misalignments in the head, and the tracks no longer lined up again.

With the optical disks, the optical disks are all pregrooved--little tiny grooves, just like your record album grooves--sitting in each disk. With that groove, you can have servos which follow precisely on that groove. Now, big deal--what's the importance of this to the end user?

The importance is that these disks are removable, remember. They are removable--if you want to put them on the shelf, if you want to put them in an archival vault, if you want to potentially send them to a guy in Ohio, you can. He has a different system than you do; and now, you have to deal with system to system and media to media fluctuations.

Increased Reliability

* Extremely High Coercivity Media
  (5,000 to 50,000 Gauss)

* Most Magnets too Weak to Affect

* Accidental Erasure Due to Magnetic Fields Difficult

* Can be Sent Through Mail and Airport Security Checks

Increased Reliability

* Each Disk Hard Sectored with Physical Grooves
  (tracks)

* Tracking Servo Maintains Alignment to .1 μM

* Focus Servo Maintains Alignment to .1 μM

* Track to Track, Disk to Disk Variations Corrected by Servos

* "Mirror" Block Corrects DC Servo
  Position 2400 Times/Minute

* No Long Term Drift

* Enables Media Interchangeability

Well, with these pregrooves, you can send them the media, which isn't perfectly to spec; and his system will go back and line up on that groove and store and retrieve the information in that reliable way.

Every once in a while, somebody in the audience is quite familiar with the servo mechanisms; and he says: That's great; servos will solve your problem, but your servo may drift after a while so that your laser beam isn't dead nuts on the groove any more; it's dead nuts on the edge of the groove. And isn't that a problem, too?

Well, that problem is solved also in the preformatted structure of the disks with what is called its "mirror block." What happens is: Once a revolution, the D.C. position in focus and tracking is corrected, so you get rid of long-term drift, too.

The bottom line is: You can remove these disks, and our customers do it all the time. Pull the disk out of your drive and pop it into somebody else's drive.

(Change of slide)

DR. FREESE: People always ask me about life; and to tell you the truth, the media has not been around long enough to actually quote field experience, other than for the past, say, four or five years.

People do extrapolation tests and determine the chemical stability of the disks and predict lifetimes as a result of this. Outcomes of the erasable optical disk are very, very good. I won't sit up here and quote you the numbers of the technical people because you won't believe them.

But I would like to give you a feel for what is a little bit different in the optical disks. I think you heard in the introduction that I used to be in charge of 3M's WORM activity at one point in time; and we used to do comparisons between the WORM disks and the erasable disks. The erasable disks almost always won in terms of their longer life, and usually by about a factor of 10. They did so because the erasable disks are self- passivating. What this means is that if you took a WORM disk and drilled a hole in it and put it in a very corrosive environment, eventually that corrosion would eat up the whole disk. STC constantly saw those tests.

If you do the same thing with an erasable optical disk, you can cut a hole in it and the corrosion will grow for a couple microns and will stop; it will stop growing. It is because of this self-passivation mechanism. You are familiar with them: your car bumper.

Your car bumper is made out of chromium, and chromium is a really reactive metal. It is right up there; it is one of the most reactive metals known to man. So, how come your chrome bumper stays around for so long? It does so because as soon as that chrome bumper is formed, there is a layer of chromium oxide which is formed on the outside; it oxidizes and forms chromium oxide.

Chromium oxide is really tough stuff. It's right up there with cubic zirconium in terms of stability. And so, that chromium oxide layer protects the rest of your bumper. Now, if you get in an accident and scrape that layer off, what happens? Well, a new layer forms immediately. And that same mechanism is present in the erasable optical disks. So, you have a very, very, very high or very long archival life; commercial people just say greater than ten years. At the same time, the magnetic domains are very, very stable.

If you are familiar with magnetic domains and the stability of magnetic domains, you know that on magnetic tapes, as an example, the domains move around. Well, when the domains move around, you are losing data.

Random Access

* File Directory Structure Stored
* "Random Access Tape"
* Instant Restore Applications

And if you have ever taken an audio tape, you can hear this. You hear the music right before it starts; that's the domains moving. That is bleeding.

The ability of a magnetic media to bleed or lose its domains or have the domains move, all else being equal, is inversely proportional to the coercivity. So, here you are talking about coercivities that are ten to a hundred times higher and more stable than your conventional magnetic disk.

(Change of slide)

DR. FREESE: But the biggest thing in our compatibility is standards; that is really the issue, ladies and gentlemen. It's not just the disk that will last because some other guy is going to get up here and say: Well, my disk lasts just as long as your disk. The issue is ten years from now, 20 years from now, 30 years from now, when you pull that disk off the shelf or out of your vault, or you are wanting to call back up the old APOLLO data, or my son is going to call up the old APOLLO data, the number one issue is going to be: (1) Is that disk still intact? Yes, it will be intact. (2) Is the information still on the disk? Yes, it's still on the disk. But hey, are the players going to be around?

Are any of the companies that sell you the systems today going to be around then? That's your number one issue. Now, if you are looking to store your data for a long period of time, what is your best bet against this problem? Nobody can promise that they are going to be here 30 years from now.

Your best bet is to build standards. So, if that company is not here, at least some other company is. You see this today in all the 1 inch tapes or the 1/2 inch tapes or the 3/4 inch tapes, you know, the 6250 BPI tapes and the 1600 BPI tapes.

Why do people still use these tapes for their standards? People sell equipment, and they maintain equipment, which enables you to play those tapes.

DR. FREESE: In the optical disk world, it took us eight years to get a standard. That's a long time, believe me. Anyhow, the standard is done. There is an international standard; it has been embraced by all four international standardization committees, and it is in the 5.25 inch form factor.

There are no standards for form factors larger than 5.25. So, if you are going to store your data for archival purposes and you are looking for standards, the 5.25 inch form factor standard is done; that has been done for two and a half years now, endorsed by all of the international bodies--ISO, ECMA, ANSI, and even the classic Japan Study Committee No. 23.

This not only gives you multiple sources of commodity media, but it addresses the main issue: standards and open systems architecture, which will potentially enable you to retrieve your data. Store it on the disks now; retrieve it ten years from now. Retrieve it 15 years from now; retrieve it 20 years from now.

DR. FREESE: There are disadvantages to raise about optical recording systems; they are not all things to all people. And I'm the last guy who is going to get up here and say these systems are going to wipe out tapes or are going to wipe out hard drives or wipe out DRAMs.

All these technologies are going to coexist. They each have their advantages; they each have their strengths. And the key will just be putting them together in a hierarchy. Disadvantages associated with this industry. The technology typically requires fairly high manufacturing tolerances. So, the cost for the home user, the clerical station, is too much; it's too high.

(Change of slide)

Archivability

* Self Passivation Mechanism
* Expected Life > 10 Years
* High Coercivity Stabilizes Magnetic Domains
* Short Term or Long Term Memory

#1 Failure: Cartridge Abuse

International Standard Media

* 5.25" Form Factor
* ISO, ECMA, ANSI, JC23 Ratified
* Multiple Sources of Commodity Media
* Random Access to Archival Data
* Mainstream User Acceptance

Erasability

"Just Like Magnetic Disks"

"How Many Erase Cycles?

SYSTEM	# CYCLES	LIMITATION
Tape	1,000's	Friction, Wear
Floppy	100,000's	Friction, Wear
Hard Disk	100,000's	Tribology, Head Crash
Optical	10,000,000's	???

Disadvantages

* Technology Requires High Manufacturing Tolerances
* Cost too High for Home User, Clerical Station
* New Technology, Long Implementation Cycle
* Not a Winchester Replacement
  (not fast enough for some applications)

The cost relative to a hard drive is not a valid comparison. You will hear speakers constantly sit there and say: Let's compare a hard drive with an optical drive. Okay. They are almost two different animals.

A hard drive comes with a fixed capacity; it's a high performance device. An optical drive comes with virtually infinite capacity; you just keep on feeding those cartridges in there. It's a removable device. They are both disks.

One is not going to replace the other; and the other is not going to replace the one. Those things are going to coexist.

But it is a new technology; the industry is just starting. And I would just like to remind everybody that the optical disks are not necessarily a Winchester replacement or a hard drive replacement, nor are they necessarily a tape drive replacement.

But they can combine the best features of all these creating "a random access tape" or a removable hard drive.

(Change of slide)

DR. FREESE: In terms of where the industry is today, I'll start off with the smallest size. 3.5 inch subsystems were just announced, and the media standards are in essence completed. This is a this year type of activity. 3.5 inch is going to hold 127 megabytes on a disk; it will be about $2,000 to $3,000 a subsystem. And really, this is aimed at the PC world.

Having addressed NASA audiences before, 127 megabytes a disk, I don't think, is quite enough capacity for most people sitting in the audience. But the 3.5 inch disks have just been introduced; and so, you have seen many announcements, I think, within the last three months associated with these.

(Change of slide)

DR. FREESE: In terms of system solutions, 5.25 inch and robotic systems, or so-called jukebox systems, offer really high capacity systems, and complete system solutions. You the user don't have to know anything about how this device works; but you simply use it on a PC just like a big Drive A. You use it on a DEC just like another DU device. You use it on a Sun microsystem just like another SD device.

It is totally transparent, no new commands to learn or old ones to forget.

You have solutions for almost all your popular computers nowadays, an entire line of DEC computers, the DEC network, all your Sun computers and Sun Sparcs.

DR. FREESE: The old Suns, the Sun NFS network, the new IBM RS6000s, all your PCs and their clones, the Novell networks; in the graphics industry, you often run into Scitex whisper stations, Macintosh, Appletalk.

(Change of slide)

So, you have got complete storage systems for almost all of your mainstream computer systems.

(Change of slide)

DR. FREESE: State of the industry for 5.25. Those standards are complete and being implemented worldwide. Commercial products began about two to two and a half years ago, where we talked about 650 megabytes as the increment on a cartridge. Put as many cartridges in your system as you want.

State of the Industry: 3.5" Subsystems

* Media Standards Complete
* Commercial Products Begin 91-92
* 127 MByte/Disk
* 5-10 MBits/sec
* 30-50 msec Average Access
* $2,000 - $3,000/Subsystem
* P.C.'s Only

State of the Industry: 5.25" Subsystems

* International Media Standards Completed
* Commercial Product Shipments Began 8/88
* 650 MBytes User Available/Cartridge
* 5-10 MBits/sec
* 30-100 msec Average Access
* $4,000 - $7,000/Subsystem
* First Applications Workstation Oriented

Present Status: 5.25" System Solutions

* COMPLETE SYSTEM SOLUTIONS EXIST FOR MOST COMMON COMPUTERS

  E.G., ALPHATRONIX INSPIRE SERIES AVAILABLE FOR :

  - DEC VAX COMPUTERS
  - DEC MICROVAX COMPUTERS
  - DEC VAXSTATION WORKSTATIONS
  - DEC DECSTATION (RISC BASED) WORKSTATIONS
  - DECNET NETWORKS
  - SUN SPARCSTATIONS, INCLUDING SPARC 1 AND SPARC 2

Present Status: 5.25" System Solutions (cont)

  - SUN 2,3,4 WORKSTATIONS
  - SUN NFS NETWORKS
  - IBM RS6000 WORKSTATIONS
  - IBM PC-AT AND PC-AT CLONES
  - IBM PS-2
  - NOVELL NETWORKS
  - SCITEX WHISPERSTATIONS
  - APPLE MACINTOSH COMPUTERS
  - APPLETALK NETWORKS

People who use Sun computers quite often sort of discover the removability aspect. Sun people, in particular, are constantly running out of disk space. So, when you run out of disk space, pop it out and put a new cartridge in; and you have another 650 megabytes.

Looking at about 5 to 10 megabits a second on our optical drive, 30 to 100 milliseconds of average access time; it costs about $4,000 to $7,000. And an awful lot of the 5.25 inch are really work station oriented. You see this in your Earth Resources in your NASA applications, where NASA may receive the information from some satellite orbiting; but there are an awful lot of people who do analysis on that information, universities in particular. So, NASA may pull the information down on DEC systems and then want to distribute these systems to their PC customers, if you will.

(Change of slide)

DR. FREESE: So-called jukebox systems or auto changers, robotic loaders. You can take these 5.25 inch disks and stick them in a rack essentially and have an auto changer, albeit a very, very fast one; and now you just simply expand by the number of cartridges the amount of on- line data you can get.

So, typically in a little box about yea big [demonstrating], you are looking at about 100 gigabytes or so of on-line disk random access storage.

Commercial products began shipping about a year and a half ago. You can get as small as you want I guess, but anyhow, almost up to 100 gigabytes, user available on the system.

The speed of the robot typically is quoted in a few seconds.

Today, there are mostly vendor unique solutions in the jukebox arena. Be very, very careful about this because if your application is archivally oriented, do you want to store your data on an ISO standard disk using nonstandard disk directory structures?

Do you want to bet your database on one company? Most people say no. If the answer is no, then make sure you have an open systems architecture solution. Make sure that that disk is always standard, not proprietary.

If you are on a DEC system, make sure your disk is always a standard DEC disk; it is not a vendor unique disk.

Make sure that you can take that disk and send it anywhere in the world you want, and anybody can read and write to it, following the standards. Again, you have got your most popular platforms.

Where is the state of the industry in optical tape? I didn't want to preempt the talk by Bob McLean tomorrow from ICI; but anyhow, let me review very quickly optical tape.

(Change of slide)

DR. FREESE: The advantages of optical tape are mainly optically derived; that is, there are very, very high densities that you get associated with optical recording and the fact that you are using a laser beam to rewrite and erase.

You can make tapes basically as long as you want. Optical tapes typically talk about gigabytes and sometimes even terabytes on a given reel of information.

(Change of slide)

State of the Industry: Jukebox Systems

* Commercial Product Shipment 89
* 6 to 93 GByte/System
* Disk Exchange - 2-3 Seconds
* Mostly Vendor Unique Solutions
* Some Open System Architecture Solutions
  e.g. "Alphatronix Inspire"
* Dec, Sun, PC, Macintosh, IBM Platforms
* Decnet, N.F.S., Novell, Apple Talk Networks

Optical Tape

* Advantages: Mainly Optically Derived
    - Same High Density as Optical
    - Higher Capacity: Gigabytes to Terabytes

Optical Tape

* Disadvantages: Mainly Tape Based
    - Tape Stretch/Break
    - Tribology/Friction
    - Contact Recording
    - Environmental Stability
    - Non-Random, Sequential Access

DR. FREESE: In a nutshell, the disadvantages are associated with the fact that it's a tape. Tapes are sequential access; tapes break; tapes are flexible. It is a contact method of recording because now you have got to spool your tapes. You have surfaces that are rubbing now. So, you have all the issues associated with tapes that need to be addressed.

(Change of slide)

DR. FREESE: In terms of applications, I would like to talk about two in particular; but having talked with NASA Goddard for a couple of years now, this is one of your most common issues that I have been able to discern.

And that is: Here you have this disk; it stores 650 megabytes. Great. You can put your VOYAGER I data on it; you can put your MAGELLAN data on it; you can put your shuttle data on it. You can put your images on it.

But you have so many people who want to analyze that data; and NASA has so many relationships with universities and private corporations and is constantly shuttling this data around. They have a really big problem, and that is that I may be NASA and I store my information on a DEC system; but the guy who is going to analyze that data is sitting on a Sun system. Well, the disks are portable; so, I can take my DEC disk and give it to my Sun guy. And say: Here, here's the data; go ahead and have at it. Except that's a Sun disk; he's on a Sun system, and that's a DEC disk. Those two things are incompatible.

Another example of that is: I'm NASA and I sit down at a DEC system, sending my data out to universities. The people at the universities are using PCs to analyze their data. Can you take a DEC disk and put it on a PC? The answer to that question obviously is: No, you can't.

See, now, the optical disk enables at least that possibility because you can store the information on that disk; it is high capacity, and you can ship it around because it's removable.

(Change of slide)

DR. FREESE: Bypass is a solution to that problem. Bypass is an application software program which has been designed explicitly for this problem. And what it enables you to do, just like the picture implies, is that you can sit on a PC machine using DOS and access standard DEC files or standard DEC disks.

And so, for the first time, you've got the possibility of a universal storage medium. You in NASA go ahead and store your information on either DEC, Sun, or PC systems; and that information can be distributed to anybody else who might be on a DEC, Sun, or PC system, at all times keeping the disk in standard file structure format.

So, you don't get any disadvantages.

(Change of slide)

DR. FREESE: So, with Bypass, you've got the potential application of a universal storage medium, adhering to the international standards, adhering to the file structure standards at all times. At no time do you have a unique disk--a unique NASA disk, a unique Alphatronix disk, a unique anybody's disk.

The cartridges are easily interchanged; just pull them out from one and stick them in the next. And there is nothing for the user to do; he just simply has access to those files.

DR. FREESE: Bypass then is available for VHF, Sun and DOS as of today--oops, I see we are going to do MAC in the future.

Optical Tape

Status:

See Wednesday Talk

Sample Earth Resources Applications

* Voyager I, II data analysis (NASA Goddard)
* Magellan Image Analysis (NASA Goddard)
* Space Shuttle Mission Photography
  (NASA Huntsville)(Hughes)
* Weather Satellite Photos/Analysis
  (NOAA)(Fleet Numerical)
* Oceanographic Mapping (Woods Hole, Oregon State)
* Data Distribution
  (Marshall SFS, USSD, JPL, TRW, Aerospace)

Rewritable Optical Disk: The Universal Storage Medium

* International Standards Adopted and Implemented
* Cartridges Easy to Physically Interchange Between Hosts
* Bypass Platform Dependent File Systems
* Requires No Modification to Access Data on any Host

Data Interchange Using Optical

A Solution Presents Itself:

* Rewritable Optical Technology
* 650 Mbytes per Cartridge
* Easily Portable

Relative to an archival application, this is also sort of interesting because there is a constant migration of computer systems, a trend that I think everybody in the room can identify. What a person used to do on a mainframe, he now does on a work station. What he used to do on a work station, he is now doing on a PC. So, tell me: Where do you store your information? How do you store your information? Do you store it in DEC format? Do you store it in Sun format? Do you store it in PC format? Which one do you think you ought to do?

With Bypass, it doesn't matter. Store it in one of the three, and you will be able to access one of the three at any time in the future.

DR. FREESE: Other sample applications. Some of the systems are Goddard; I'm aware of at least two of them. One is people who are doing the analysis on the VOYAGER I and VOYAGER II data; and actually, I was surprised, but very pleased, to find out that VOYAGER I and VOYAGER II actually are still sending us data. And it is under constant analysis.

The MAGELLAN program also uses various optical and storage devices. The space shuttle dumps its imagery to jukeboxes down in Huntsville.

(Change of slide)

NOAA has been using the optical storage systems for their weather satellite and weather image analysis, as does the Navy for their weather forecasting.

Woods Hole and Oregon State are a couple of examples where they are doing more photographic mapping, although in this particular case it is of the ocean. And the Marshall Space Flight Center, along with a few other people, are now really getting interested in the data distribution application, where you can take the disk--be it on DEC, Sun, or PC format--and distribute it across the country or across the world to anybody else on one of those three particular platforms.

And then, they can do their own analysis on the data and communicate that to the rest of the world.

These are a few of the classic applications associated with earth resources.

(Change of slide)

DR. FREESE: Other applications include anything to do with images whatsoever--scanned documents or images, CAD/CAM documents or images. If you have ever had a CAT scan or an MRI scan, they are used to store those particular images.

DR. FREESE: We already talked about satellites and geologic data analysis.

(Change of slide)

DR. FREESE: Data logging and analysis is sort of interesting. Here is an application where people used to use tapes, but they found that the tapes weren't archival. You couldn't keep your tapes around for a long time; the tapes had binders on them, chemicals and glues. The tapes stick after a while. You see that in your NASA tapes from the 1960s where, when you unreel the tape, particles fall apart; and the thing pulls apart.

Now, the pharmaceutical industry is converting over to erasable optical disks just to solve this problem mandated now by the FDA, where they have got to store all their data; and they must keep it on-line, and they must keep it for seven years. And they have to keep their original data.

That's an application where they decided, gee, archival life is the number one issue here; and so, therefore, we are going to store these things on standard optical disks.

The Bypass™ Solution

* Developed for Rewritable Optical Disks
* Works with Many Technologies
* Copies Information To/From Foreign Disk Types and Formats
* Uses Simple Commands
* Reads/Writes Cartridges From Any Supported System
* Easy to Add Other Hosts Quickly

Advantages of the Bypass Solution

* Allows Access to Data in Native File System Format
* All File System Commands Work Normally
* Requires No Modification to Native File Systems or Applications
* No Need to Intercept Requests and Translate

Bypass

* **Device Independent**

  VMS

  SunOS

  DOS

  MacOS (future)

* **Converts DOS 3.x to 4.0**

Bypass Applications

* **Share Data Between Field and Corporate Offices**
* **Data Distribution**
* **Move and Release Source Code and Programs**
* **Distribute Disks with Different Formats**

Archiving Applications

* Key Issues:
  - Ability to Retrieve & Store Data in Future
  - Systems Must Be Supported/Serviced
  - Media Life > 10 Years

Archiving Applications: The Inspire Solution

* Open System Architecture
* Adheres to All ISO/ANSI International Standards
* Adheres to all Native File Format Standards
* Media Life > 10 Years

Sample Applications

* On-line Data Storage
* Back-up Data Storage
* Archival Data Storage

Sample Applications

* CAD/CAM
* Image Processing
* Medical Imaging
* Scanned Document Storage

Sample Applications

* Computer Integrated Manufacturing (CIM)
* Geologic Data Analysis
* Satellite Image Analysis

Sample Applications

* Software Distribution
* Data Distribution
* Data Logging/Analysis

Sample Applications

- Government/Security
- Desktop Publishing
- Software Development

Future Directions - Now to '94

- 3.5" Media Standard Completed
  Products Announced
  ~150 MBytes/Cartridge
- 5.25" Disk: Two to Four x Present Capacity
  (1-4 GBytes/Disk)(Backward Compatable)(Standardized)
- 2 to 5x Increase in Transfer Rates
  (20 to 50 Mbits/sec)
- 15-25 msec Average Access
- Half-Height Drives

I should mention the issue of erasability since it was brought up by the prior speaker; but that's what this industry uses today. They use tapes; tapes are rewritable. Tapes are erasable; tapes are correctable.

Only microfilm and microfiche is considered not to be correctable.

So, for one to switch from tapes to optical disk was no issue whatsoever.

DR. FREESE: There are a tremendous number of systems in Washington, D.C. all associated with Government applications and all associated with the removability aspect of these cartridges. You can keep them on-line in your computer if you want; but when you are done with that data, you can pull it out and stick it on the shelf. You can keep your system right there. If you wanted to send it to somebody, you could.

DR. FREESE: I would like to take the last few minutes and talk a little about future directions. I think it's important to realize that all technologies are advancing.

I remember at the beginning of the 1980s hearing somebody stand up at an optical disk conference and say: This stuff is just going to wipe out the hard drive industry. And I remember thinking: Well, I'm not too sure about that. I've seen just the opposite.

I've seen magnetic disk people stand up and say: You know, tape is going to wipe out the optical disk industry, or whatever. They are all different solutions. They all have different advantages. And it's a mistake to assume that the technologies aren't advancing; they are.

Five years ago, a lot of people rang the death knell for tapes, saying tapes just can't go much further. Yet at the same time, in our own laboratories, we were storing tapes in a helical scan format with densities a factor of 10, a factor of 20--higher than what anybody was talking about then.

So, we have to be very, very careful about industries that aren't advancing. I think it's a good assumption to assume that they all will advance.

What I would like to talk about here is advancements that you will see, I think, in the optical recording industry between now and the immediate future in a commercial sense.

I won't talk technology because technology isn't a solution to your problem.

Between now and 1994--in fact, the very first thing that is happening this year is your 3.5 inch formats are available; and in the coming years, what you will see is all your PCs that are coming out of Japan will have a 3.5 inch optical drive or optical drive option associated with them.

On the 5.25 inch, the issue isn't technology. I can think back to 1983 when, in the laboratories, we took a standard 650 megabyte optical disk and stored 4 gigabytes on that disk, just using the same system that we had back then. The issues are not technology driven in the optical world; they are standards driven.

It took us eight years to get a standard in erasable optical recording. It then took another four years to get a standard in the 3.5 inch form factor; and now, the standards committees are turning their attention right back again to the 5.25 inch.

The 5.25 inch will evolve then, and discussions right now are anywhere between two and four times the present capacity per disk. So, somewhere between 1 and 4 gigabytes per disk on the second generation erasable optical 5.25.

The key part of the standards is that it be backward compatible with your existing disks. And the good news, at least from our perspective and probably from this audience's perspective, is that everybody that we know of talking in the standards bodies is making the standard backward compatible.

So, whatever disks you have got today will be able to be played on the second generation systems coming up.

When this occurs is a standardization issue; it is not a technology issue. The technology to do this is getting to be about seven years old. That's good because it makes it good, hard, and stable. But this is an issue of standards.

In my own personal opinion, that standardization will take about two more years because it tends to be a little bit political.

Performance will increase in terms of transfer rates, average access times, and getting into 1/2 height types of form factors.

(Change of slide)

DR. FREESE: There is a lot of talk about blue/ green laser diodes and taking the existing technology and changing the head, changing the colors of the head, and getting a 4X increase in capacity. And all that's basically true.

The key issue relative to the green laser diodes, which will then give you somewhere around 6 gigabytes on a 5.25 inch disk removable is commerciality. There are such diodes, I understand; in fact, I've understood that they have been around for quite a while, but they are not reliable yet. They are not commercially available yet.

But between now and the year 2000, those things will become available; and when they do, you'll see the same disks--the same optical disks--take about a 4X leap in their capacity.

Some interesting work which has not progressed in the commercial world is multiple beams. All of our technologies today use a single beam to read, write, and erase. But in 1983, 1984, and 1985, we also sponsored work at RCA, where they took 18 beams and recorded all those beams in parallel simultaneously. Well, the media will do that; the technology will do that, as soon as laser diode arrays are available in that type of size. Then, you will see another quantum leap in the data rates.

Finally, between now and the year 2000, there is a great deal of work going on in lightweight heads--very, very compact heads, heads that look about the same size as a computer chip or as magnetic heads today.

So, you can expect between now and the year 2000 to see access times close the gap in the mechanical sense between today and whatever exists for hard drives. Now, hard drives will be moving; hard drives today are getting into the single digits of milliseconds, but so are these heads. There is no reason that they shouldn't.

(Change of slide)

DR. FREESE: So, summarizing, and in conclusion, the erasable optical recording industry is just starting. It is a new industry. We have found it so far to be a brand new tool for the work station user. It doesn't eliminate or supplant tapes; it doesn't eliminate or supplant hard drives or floppy disk drives.

What it is, is an additional option in the hierarchy of storage solutions for the user. There is a tremendous growth path for this particular technology; and usually, the main

Future Directions - Before Year 2000

* Green Laser Diodes
  Capacity up to 5-6 GBytes/5.25" Disk

* Multiple Beam Laser Diodes
  Data Rates 80-160 Mbits/sec

* Lightweight Heads (Holographic, Luneberg)
  Access Times Similar to Hard Drive

Summary

* Erasable Optical Industry Just Starting

* New Tool for Workstation; Networked User

* Significant Growth Path

* Wide Variety of Applications, Many New

reason why companies have gotten involved is for this particular growth path. And a lot of the applications which we are seeing for optical storage today are really just starting.

People are rediscovering the joys of removability, the joys of standardization and open systems architecture, and the joys of random access tape devices.

So, thank you very much for being a real patient audience. If you have any questions, do we have a few minutes for questions?