

---

# Digital Data Storage Program

Thomas Leedy

NIST

Advanced Technology Program

# Need for Data Storage Focused Program

---

## Two Themes:

- ✓ Audio, video, and graphical information is being converted from analog formats to digital formats to meet massive information demands.
- ✓ Digital document storage and retrieval is big business ... but traditional ways of doing data storage R&D in US won't be adequate to meet market needs.

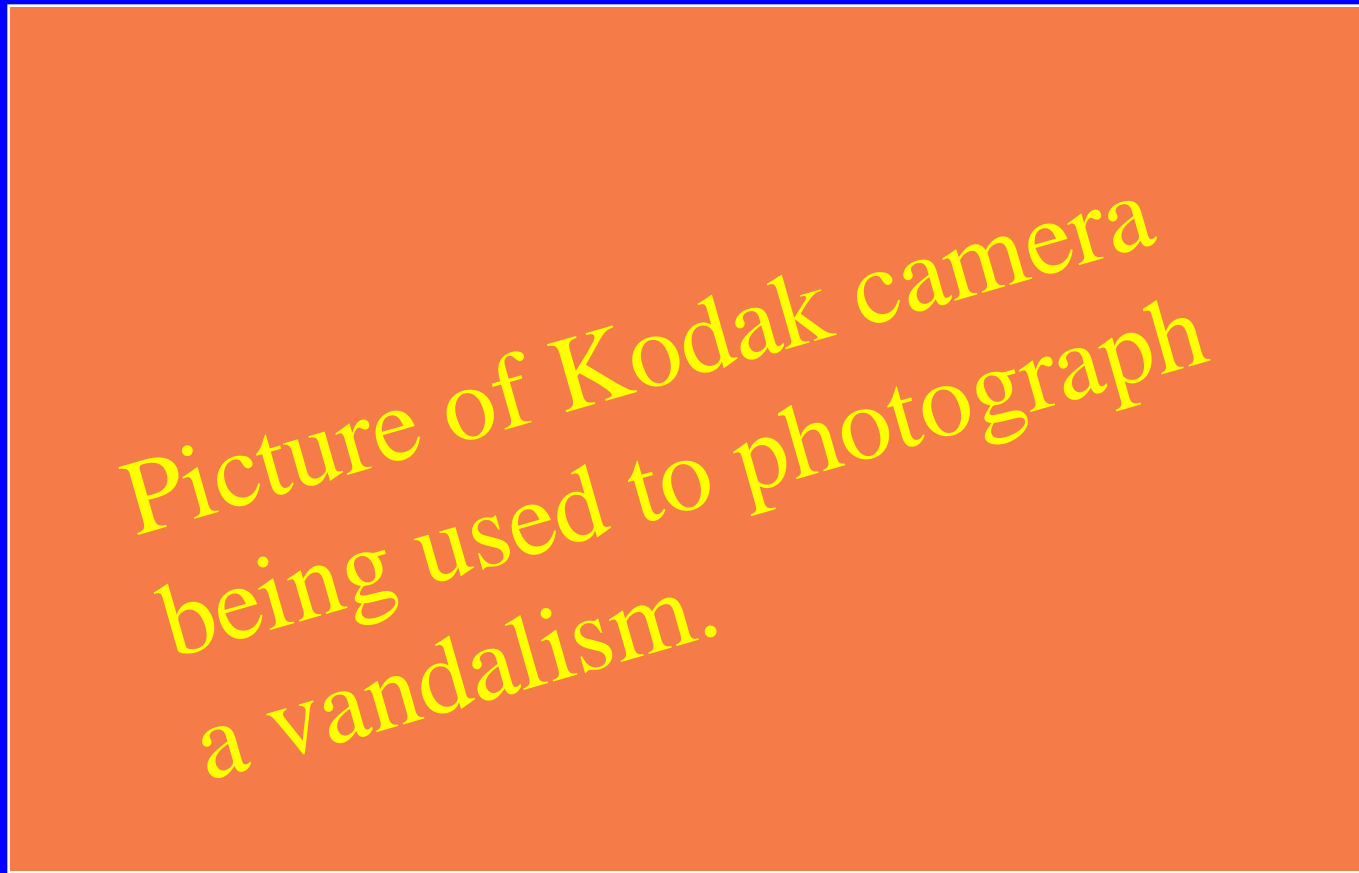
# NIST Laboratory Support to ATP Projects

---

Picture of Kodak Camera  
CD-ROM here

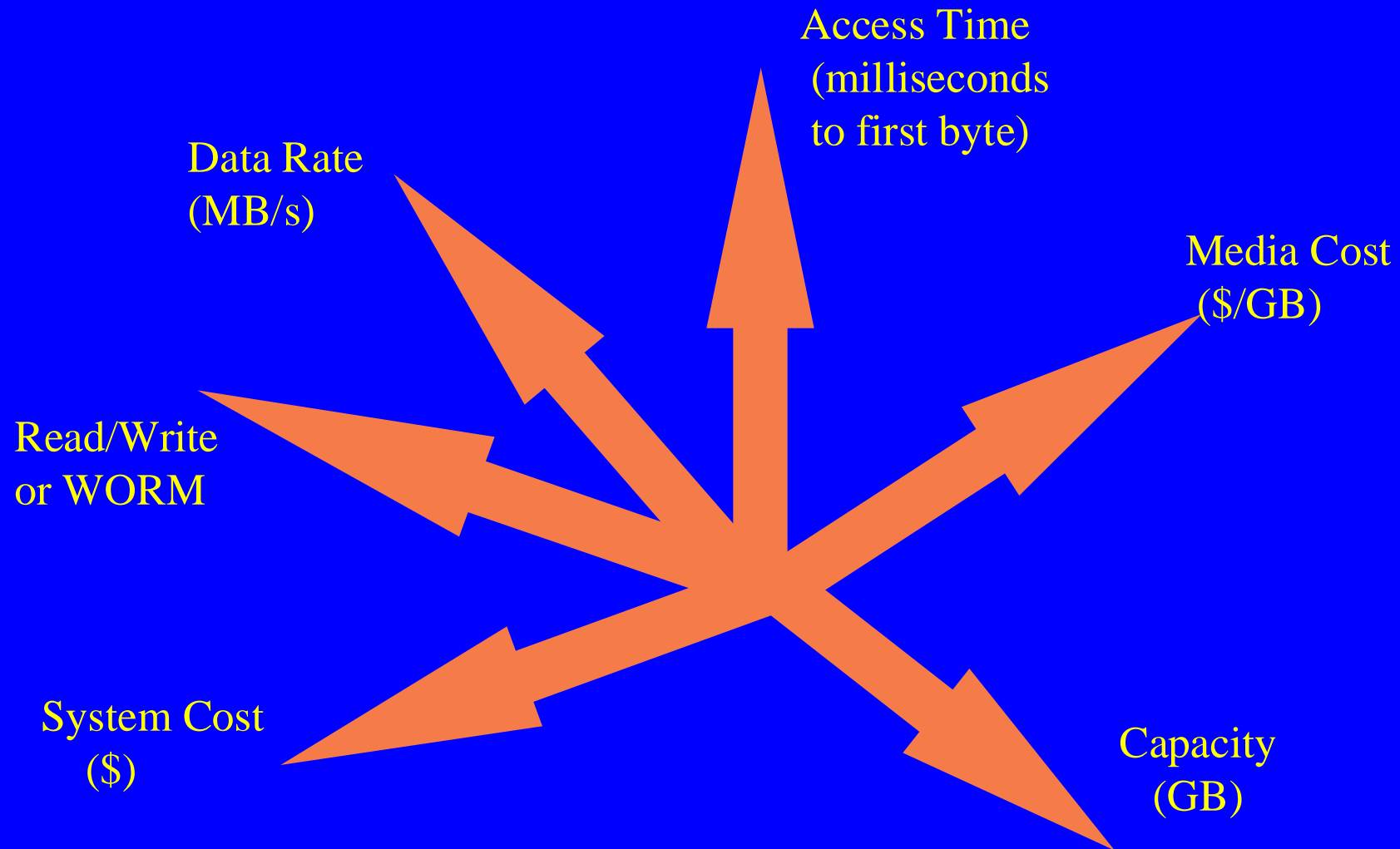
# NIST Laboratory Support to ATP Projects

---

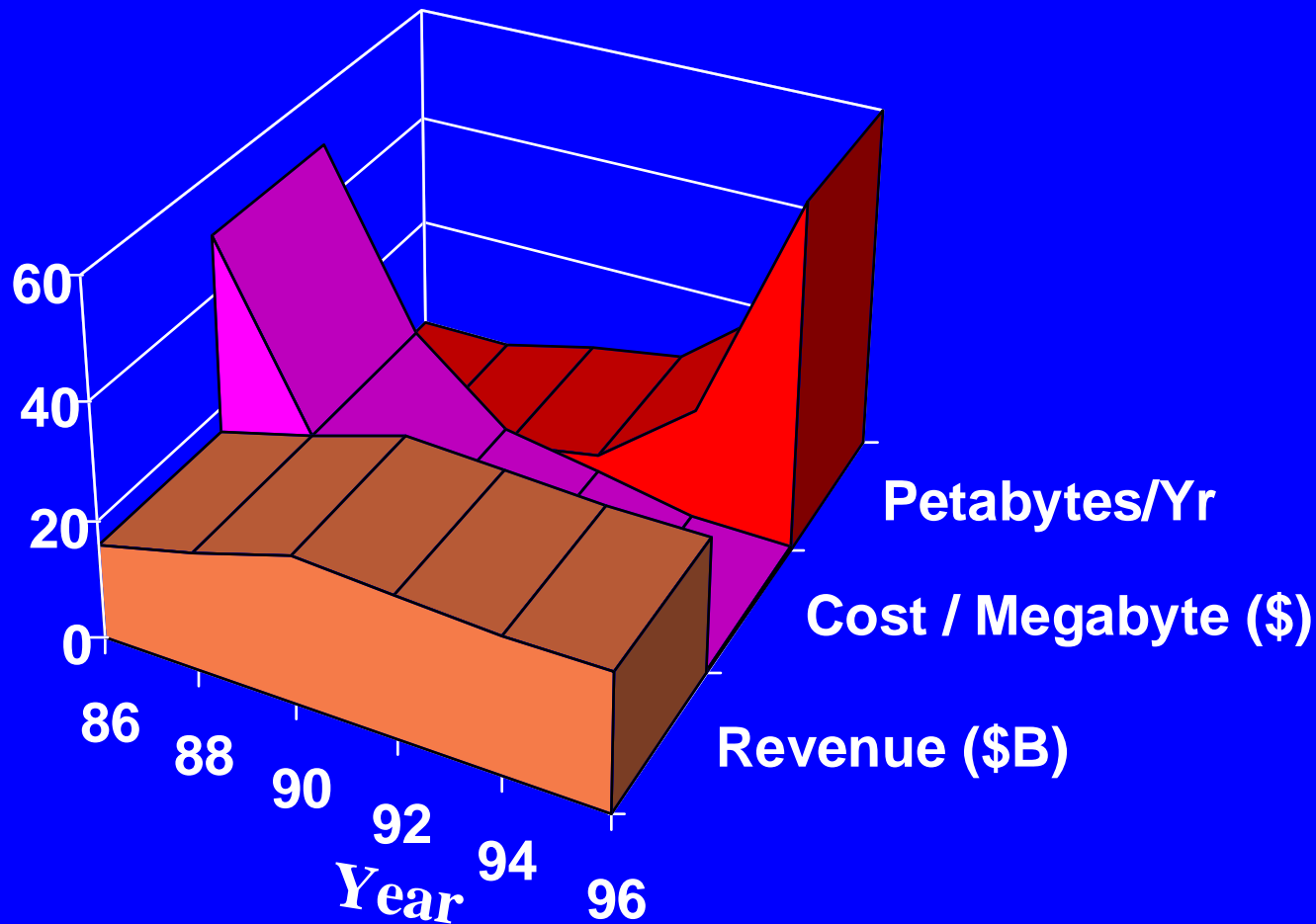


# Data Storage Parameters are Multidimensional

---



# Trends in Hard Disk Drive Market - Worldwide



Source:  
National Storage  
Industry Consortium  
"The U.S. Recording  
Industry"

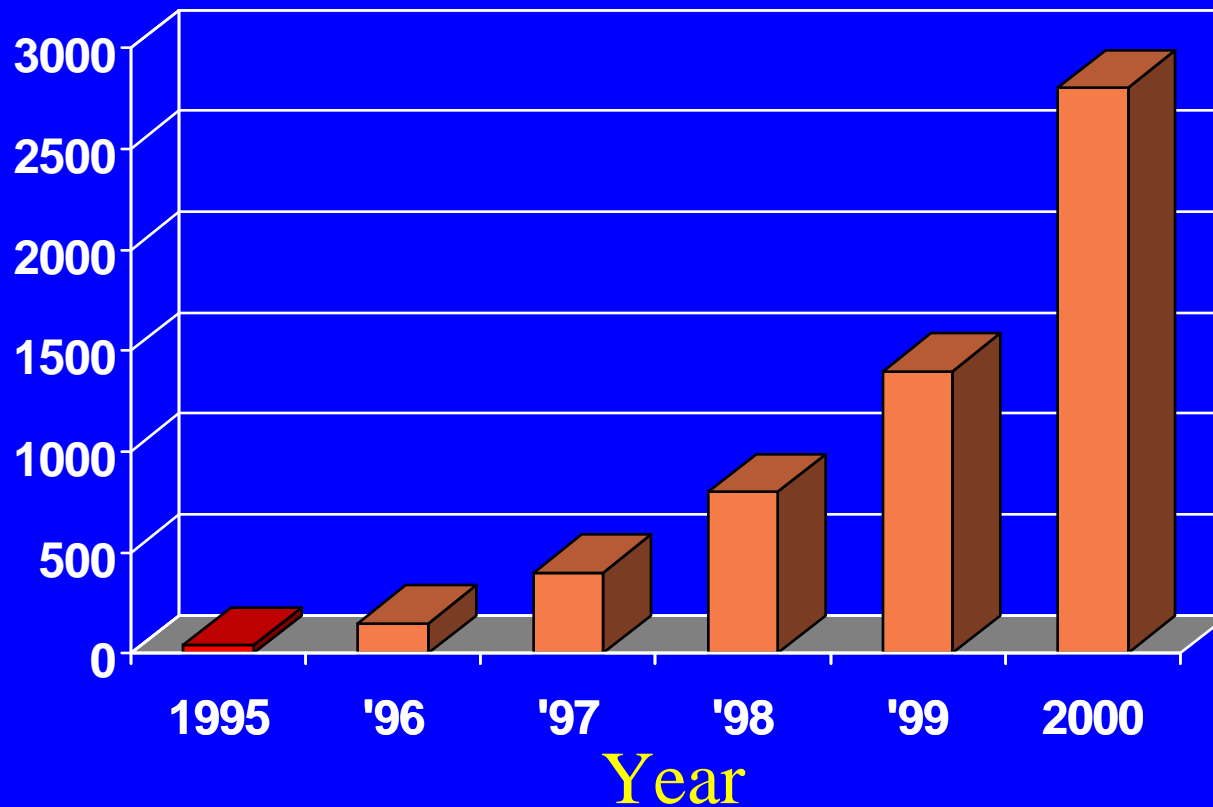
Note: Petabyte =  
1000 Terabytes

Note: Not all data for all years available; some data points interpolated

THIC - Oct. 1996

# The Computer Storage Market - Worldwide

## Petabytes Shipped

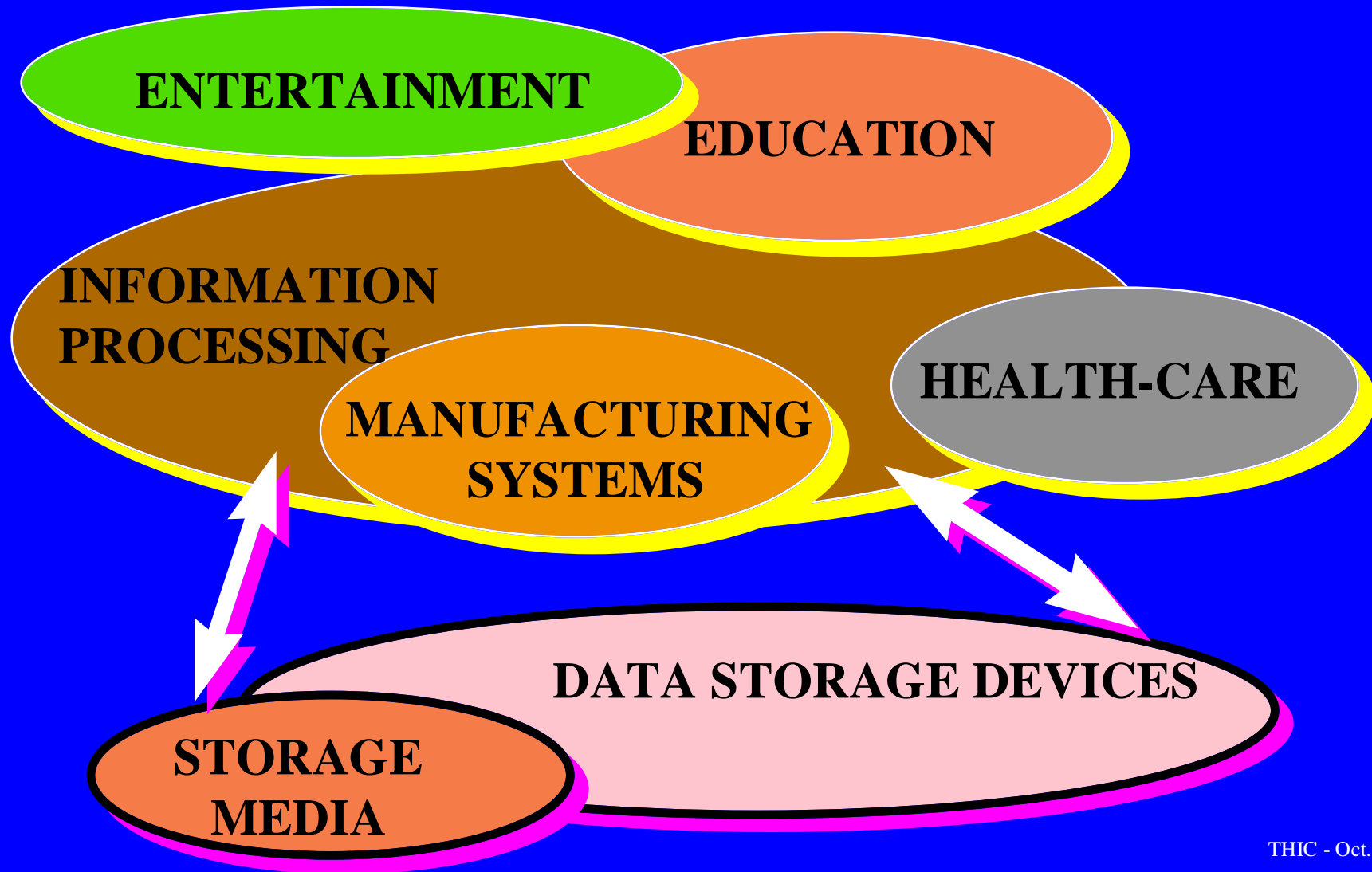


Data for 1995, actual;  
remainder, estimated

Source:  
International  
Data  
Corporation

# Current U.S. Products in Markets Affected by Digital Data Storage

---





# Digital Data Storage: Examples of Present and Future Markets

Users are asking for higher capacity and higher performance:

---

## ◆ Entertainment:

- Time Warner: Move photos on-line with an initial 500 gigabyte database; scheduled to grow to over 2 terabyte in a year for a 10 terabyte ultimate size.

## ◆ Scientific:

- Shell Oil has seismic data on 900,000 cartridges and one million reels of stored data.

# Digital Data Storage: Examples of Present and Future Markets

---

## ◆ Commercial Transactions:

- Wal-Mart: 6 terabyte data warehouse storing all POS transactions; growing 30%/year.
- Pacific Bell: records 200 million-plus daily phone calls in a database of more than 5 terabytes.

## ◆ Human Services:

- State of Wisconsin: 350 gigabyte database for 5 million people.

# History of ATP Focused Program in Digital Data Storage

---

*General Competition Projects  
Establishes Industrial Interest*

*'White Papers' Received  
from Industry*

*Digital Data Storage Workshop*

*Digital Data Storage  
Program Chosen*

*Competition Held  
Project Work Starts*

'90

'91

'92

'93

'94

'95

'96

Year

# Program Scope

---

- ◆ To address specific technical barriers in optical and magnetic data storage:
  - Optical: e.g.: new light sources; improved performance for optical tape
  - Magnetic: e.g.: new heads to achieve a 10 to 100 times in areal data density
- ◆ To develop integrated systems solutions for diverse data storage applications.

# Technical Goals

---

## ◆ Magnetic Recording:

- Magnetic modeling and analysis
- New materials for new magnetoresistive heads
- Microtribology
- Advanced tape mechanics
- Magnetic metrology and imaging

## ◆ Optical Recording:

- Waveguide-based optoelectronics
- Integrated optical heads
- Blue-sensitive super-resolving storage media
- Multi-channel modulation and error correction coding

# ATP Projects in Data Storage

---

## ◆ From the General Competitions:

- *A High-Density and High-Speed Read-Only Optical Data Storage System* -- (SA) Calimetrics
- *Electron-Trapping Optical Memory for Digital Recording Applications* -  
- (SA) Optex Communications Corporation
- *Short-Wavelength Sources for Optical Recording* -- (JV) National Storage Industry Consortium (NSIC) (Lead) with Carnegie Mellon University, Eastman Kodak Company, IBM Corporation, and Uniphase, Inc.
- *Ultra-High Density Magnetic Recording Heads* -- National Storage Industry Consortium (NSIC) (Lead) with Applied Magnetics Corporation, Carnegie Mellon University, Censtor Corporation, Digital Equipment Corporation, Eastman Kodak Company, George Washington University, Hewlett Packard Company, IBM, Quantum Corporation, Read-Rite Corporation, Seagate Technology, Stanford University, University of Alabama, University of California, San Diego, University of Minnesota, and Washington University.

# ATP Projects in Data Storage -

(continued)

---

## ◆ From the Focused Competition:

- *A Revolutionary, High-Density, High-Speed, Low-Cost Optical Information Storage Technology* -- (SA) Optex Communications Corporation
- *Digital Data Storage Technology via Ultrahigh-Performance Optical Tape Drive Using a Short-Wavelength Laser* -- (SA) LOTS Technology, Inc..
- *Technology Development for Optical-Tape-Based Rapid Access Affordable Mass Storage (TRAAMS)* -- (JV) Terabank Systems, Inc. (Lead) and Carnegie Mellon University, Energy Conversion Devices, Motorola, NASA/Goddard Space Flight Center, Polaroid Corporation, University of Arizona.
- *Ultrahigh-Capacity Optical Disk: Multilayer Short-Wavelength Write-Once and Erasable Optical Disk Recording System* -- (JV) National Storage Industry Consortium (NSIC) (Lead) and Eastman Kodak, SDL, and Carnegie Mellon University.
- *Enhanced Rigid Disk Drive Technology: High Resonance Suspension* -  
- (SA) Hutchinson Technology, Inc.
- *High-Performance, Variable-Data-Rate, Multimedia Magnetic Tape Recorder* -- (JV) Imation (spinoff of 3M) (Lead), 3M (original company), and Seagate Tape Technology Inc.

# ATP Competition 95-03: Digital Data Storage

(Total Number of Awards: 6)  
(Total Amount Awarded: \$28 M)

## UNIVERSITY PARTICIPATION

	Joint Venture Participants	Subcontractors
Number of Award with University Participation	2	3
Number of Universities	3	8
ATP Funding Amount, \$K	2,637	2,952
Participating Universities	Carnegie Mellon U. (2 awards) U. of Arizona	Arizona State U. Carnegie Mellon U. (2 awards) Ohio State U. Stanford U. University of Alabama University of California University of Minnesota



# Methodologies

---

## Recording Media

Calimetrics, LOTS Technology  
Optex

## Error

## Detection/Correction

NSIC/Ultra High Capacity Optical Disk

Terabank Systems / TRAAMS

## Tribology

NSIC Heads Project

3M Magnetic Tape Recorder

## Materials Science

NSIC Heads Project

NSIC Short Wavelength Source

## Advanced Mechanical

## Design

Hutchinson Technology

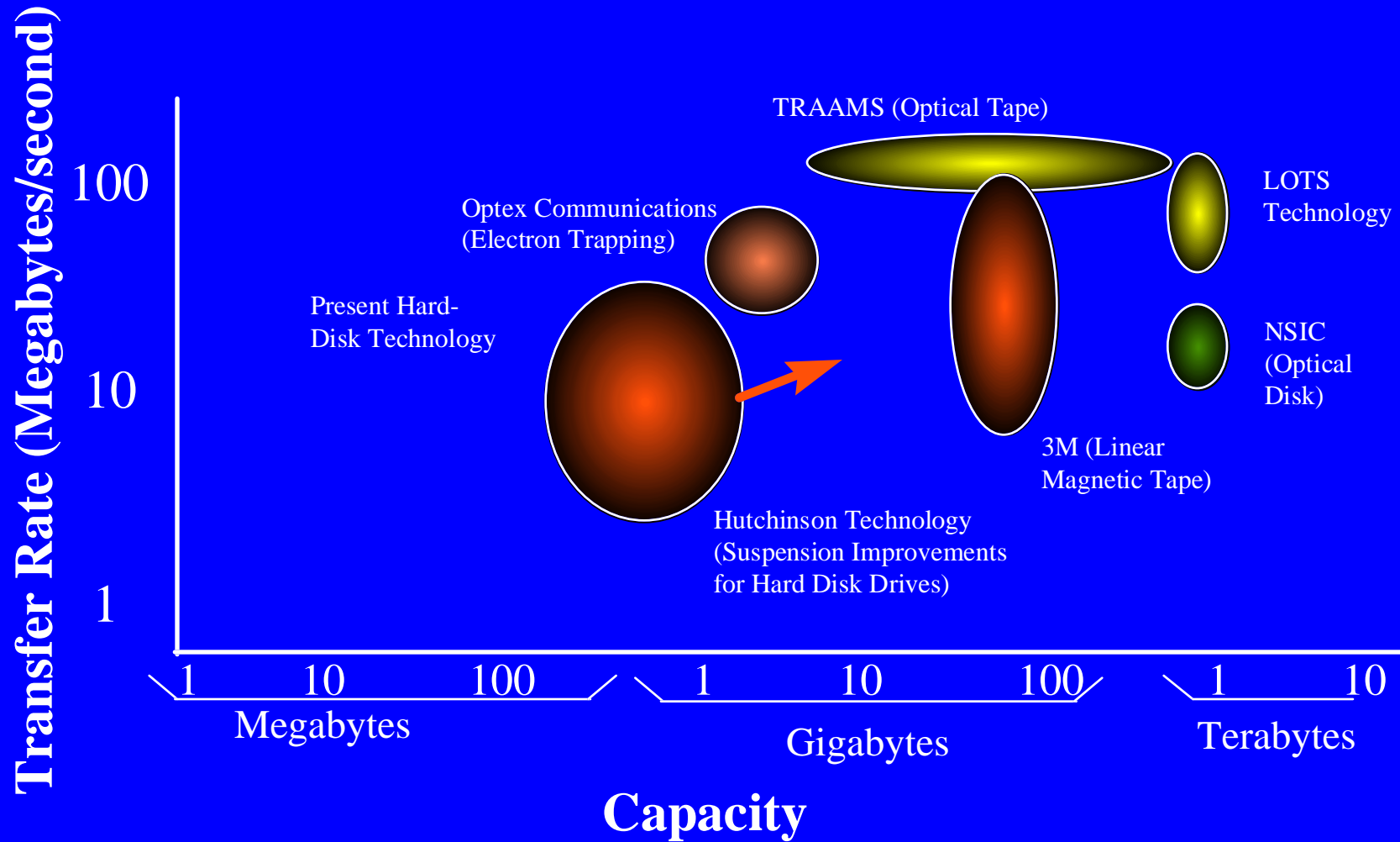
LOTS Technology

## Systems Integration

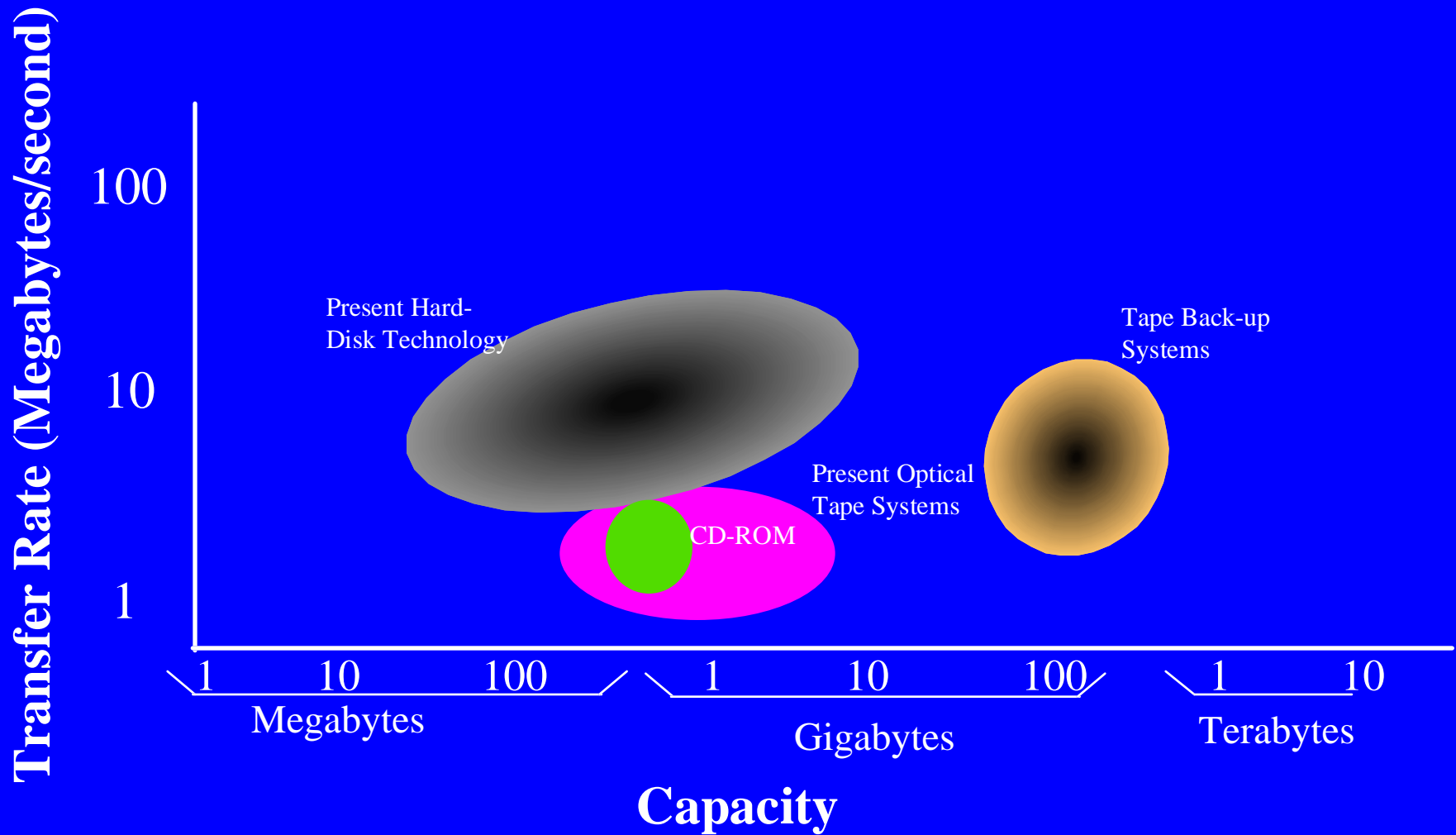
NSIC/Ultra High Capacity Optical Disk

Terabank Systems / TRAAMS

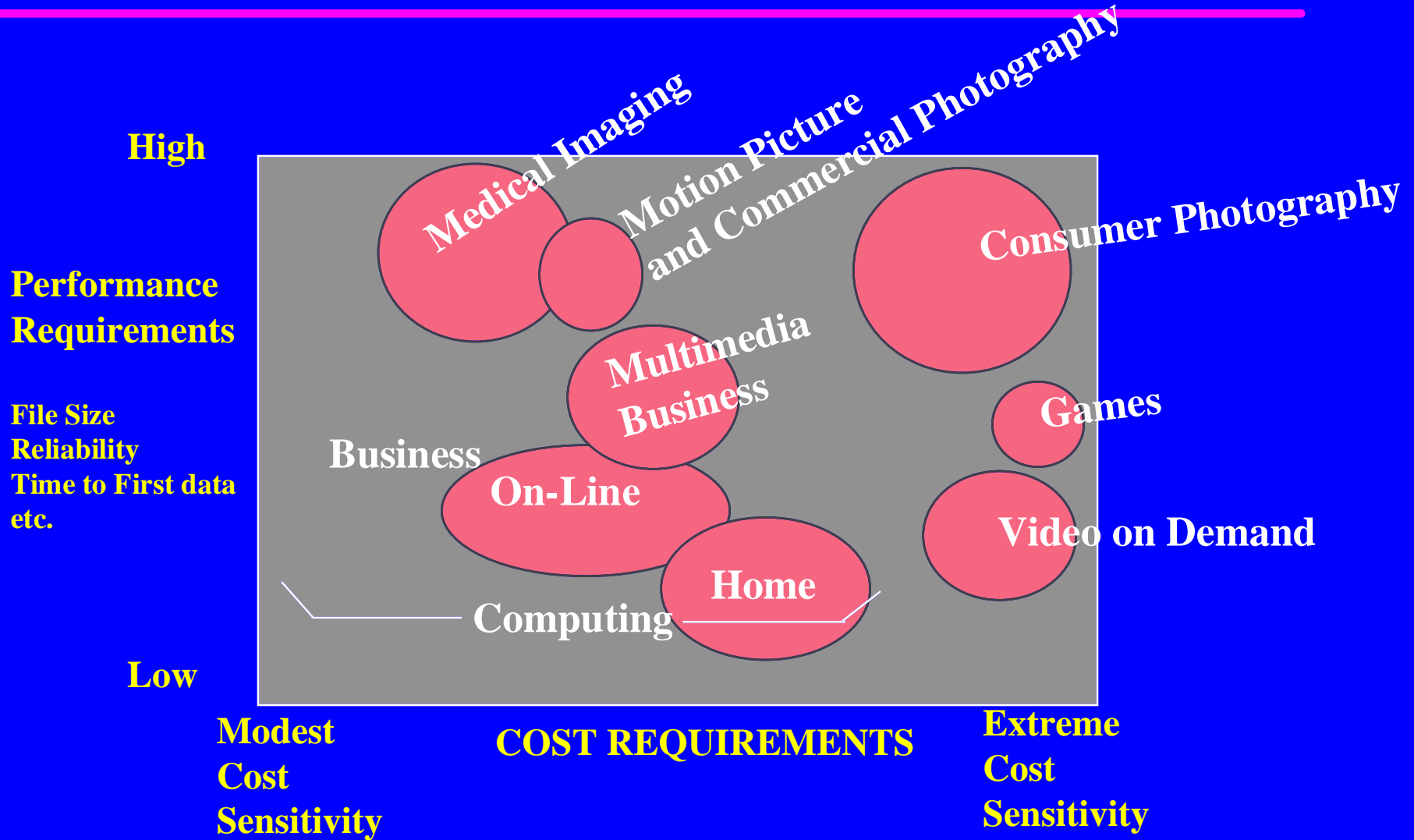
# Speed/Capacity of Digital Data Storage Projects



# Present-Day Storage Performance



# Performance / Cost for Different Applications



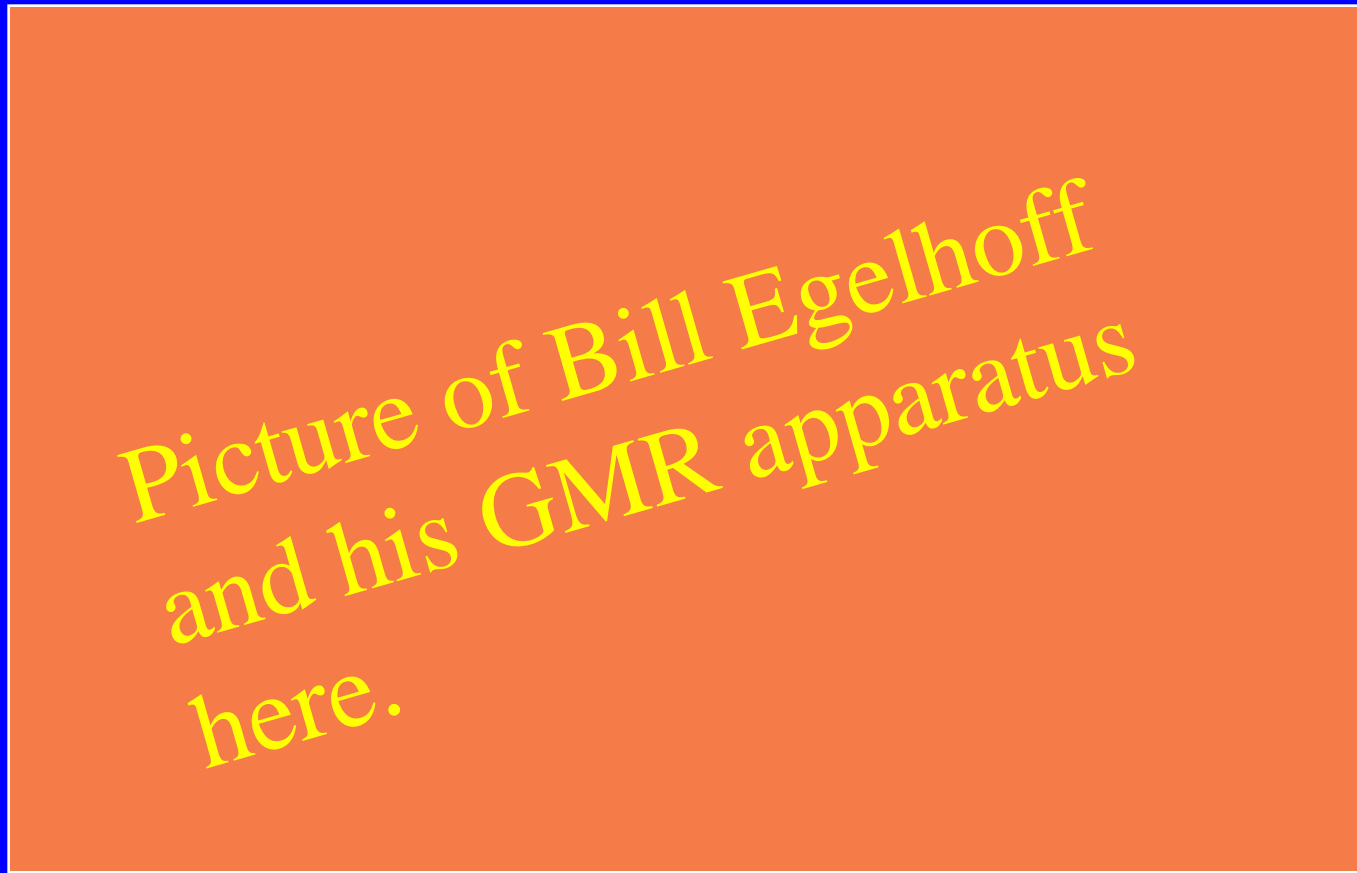
# NIST Laboratory Support to ATP Projects

---

- ◆ **Magnetic Materials and Measurements**
  - **Materials and basic physics of GMR and spin valve sensors (CSTL - NSIC/HEADS).**
  - **Precision magnetic measurements and imaging (PL - 3M Variable Data Rate Tape Recorder).**
- ◆ **Reliability Issues**
  - **Thin-film reliability issues (electromigration) (EEEL - NSIC/HEADS).**
  - **New lubrication systems for use between heads and data media (tribology studies) (MSEL - NSIC/HEADS Project).**
- ◆ **Standards**
  - **Standards that promote interoperation of data storage systems (ITL - LOTS Technology).**

# NIST Laboratory Support to ATP Projects

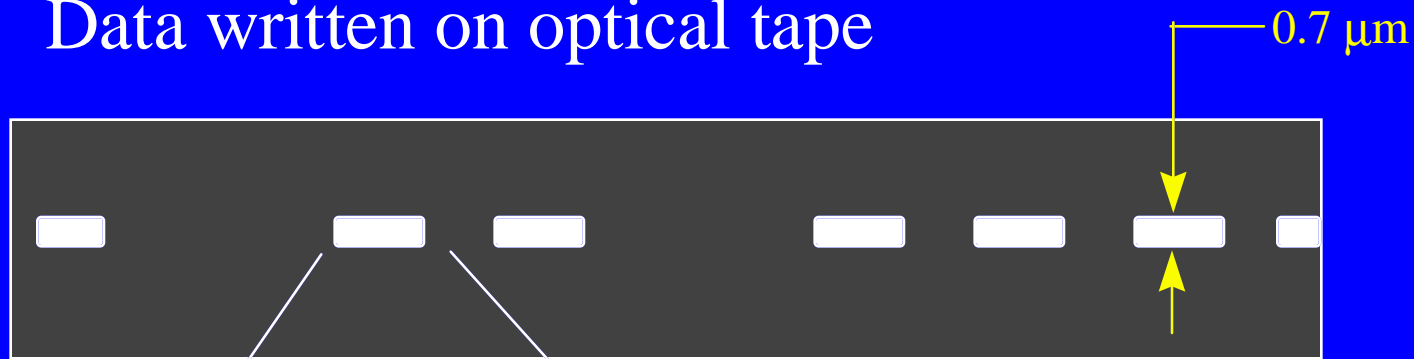
---



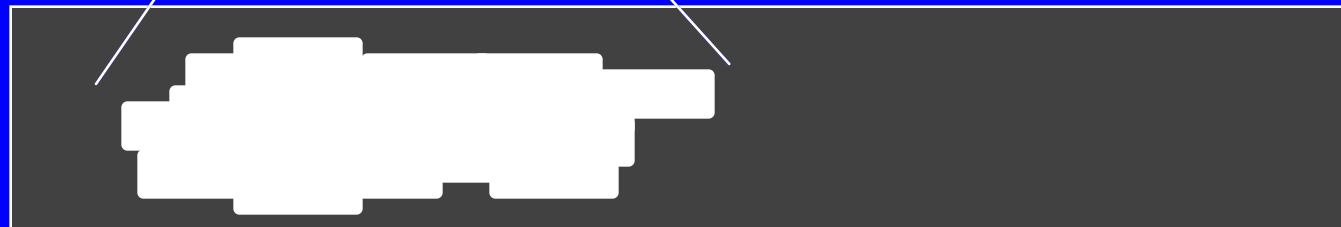
# Early Successes - LOTS Technology

---

Data written on optical tape



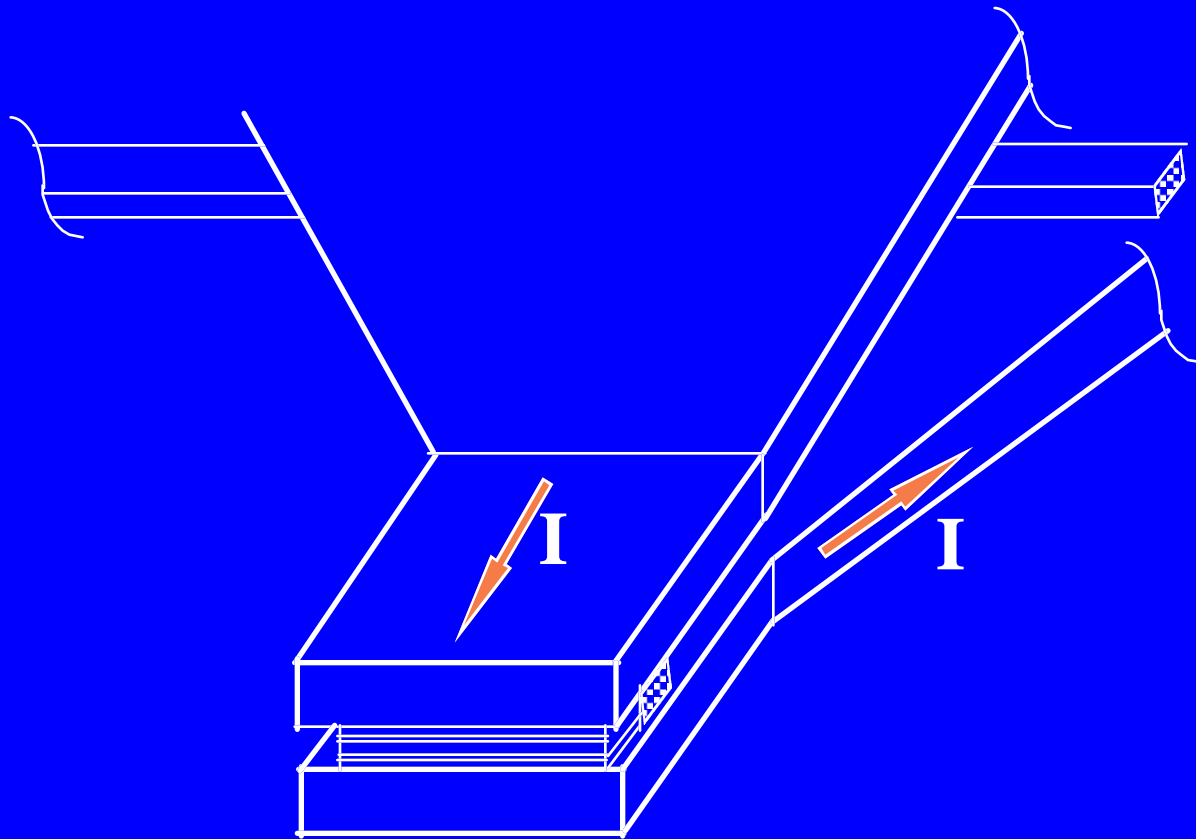
Written line 0.7 micrometers wide at 3 meters/s



8X Magnification of written line, above

# Early Successes - NSIC / HEADS Project

---



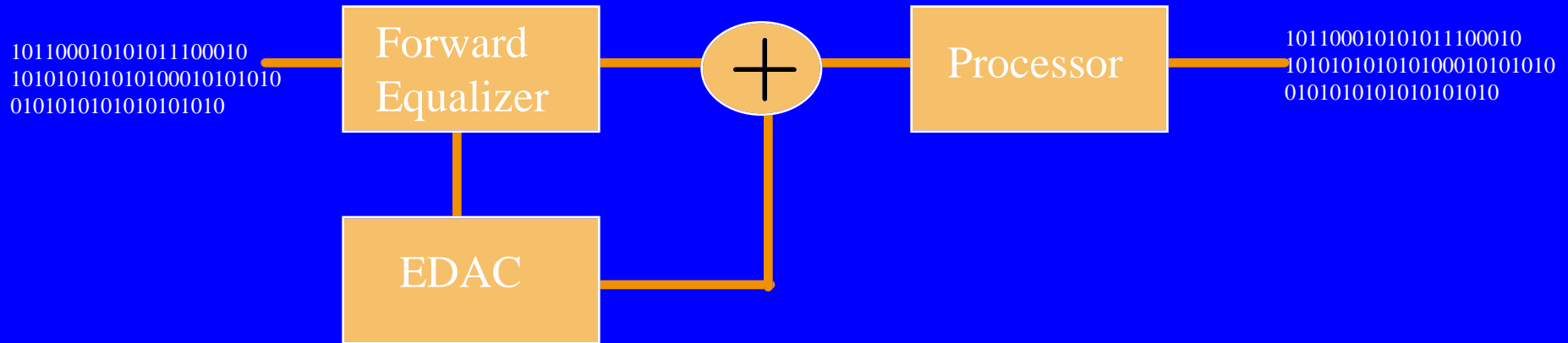
**Fundamental  
Understanding  
of GMR Physics**

**Advanced Models  
for Prediction of  
Performance**

**Microfabrication  
Methods  
Developed**



# Early Successes - NSIC / Ultra High Capacity Optical Disk



**Significant Progress Toward Modeling Bit Error Rate Using Partial Response Schemes**

**New Methods of Testing for High Performance MO or WORM Channels**

# New Industry Directions

---

- ◆ The National Storage Industry Consortium launched new emphasis on the business aspects of the data storage industry.
  - extended membership to suppliers and customers of data storage devices
  - featured promising future applications
  - facilitated networking among firms

# New Industry Directions

---

- ◆ National Media Laboratory (NML) provides center for activity for pooling resources and knowledge to advance new optical tape technologies.
  - LOTS and Terabank projects start dialog with NML on stability of optical tape as archival media
- ◆ American Association of Information Management (AIIM) starts standards activity devoted to optical storage.
  - industry standards will be needed to lower technical and non-technical barriers to system integration of optical storage