Digital Data Storage Program

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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.

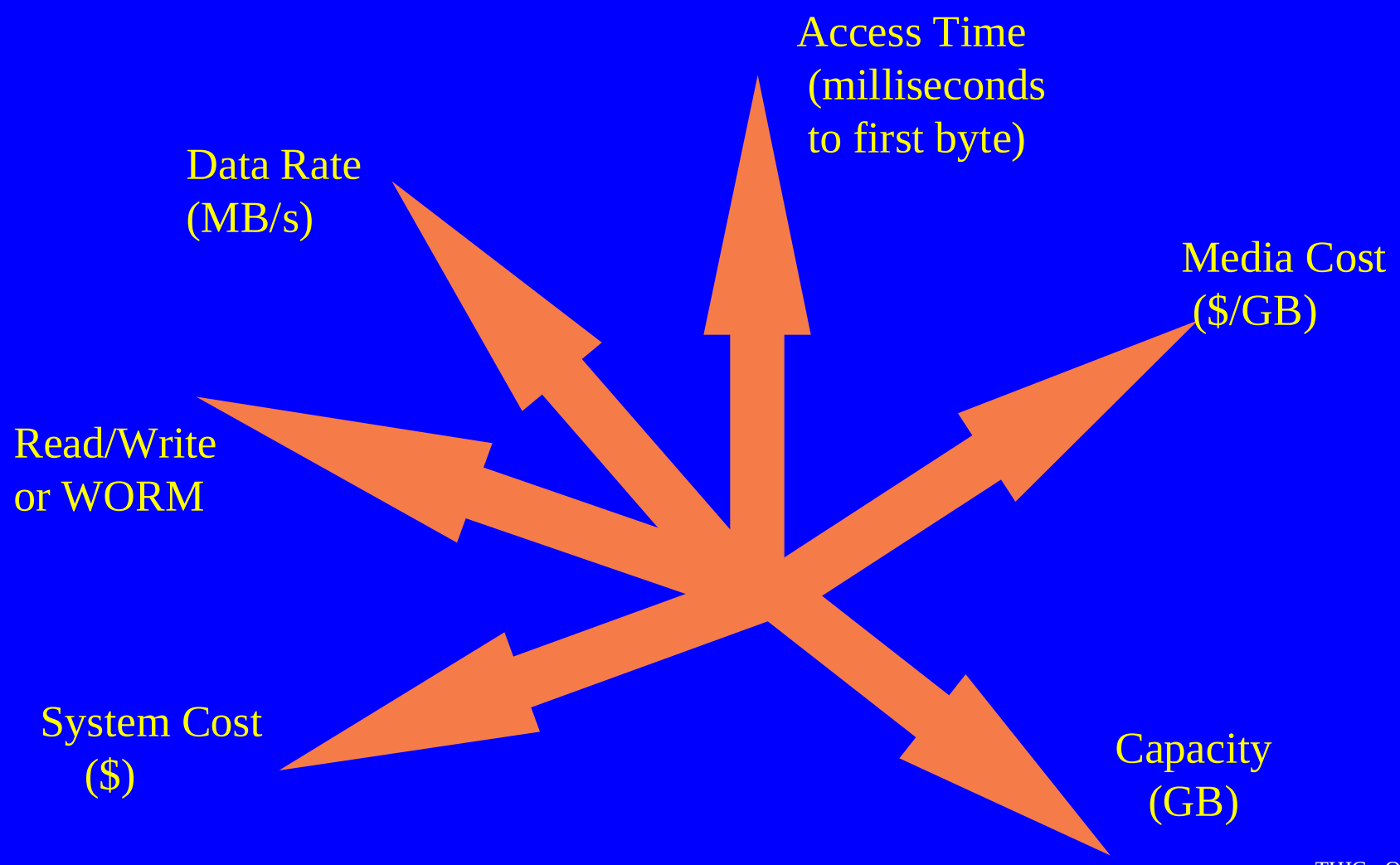
NIST Laboratory Support to ATP Projects

Picture of Kodak Camera CD-ROM here

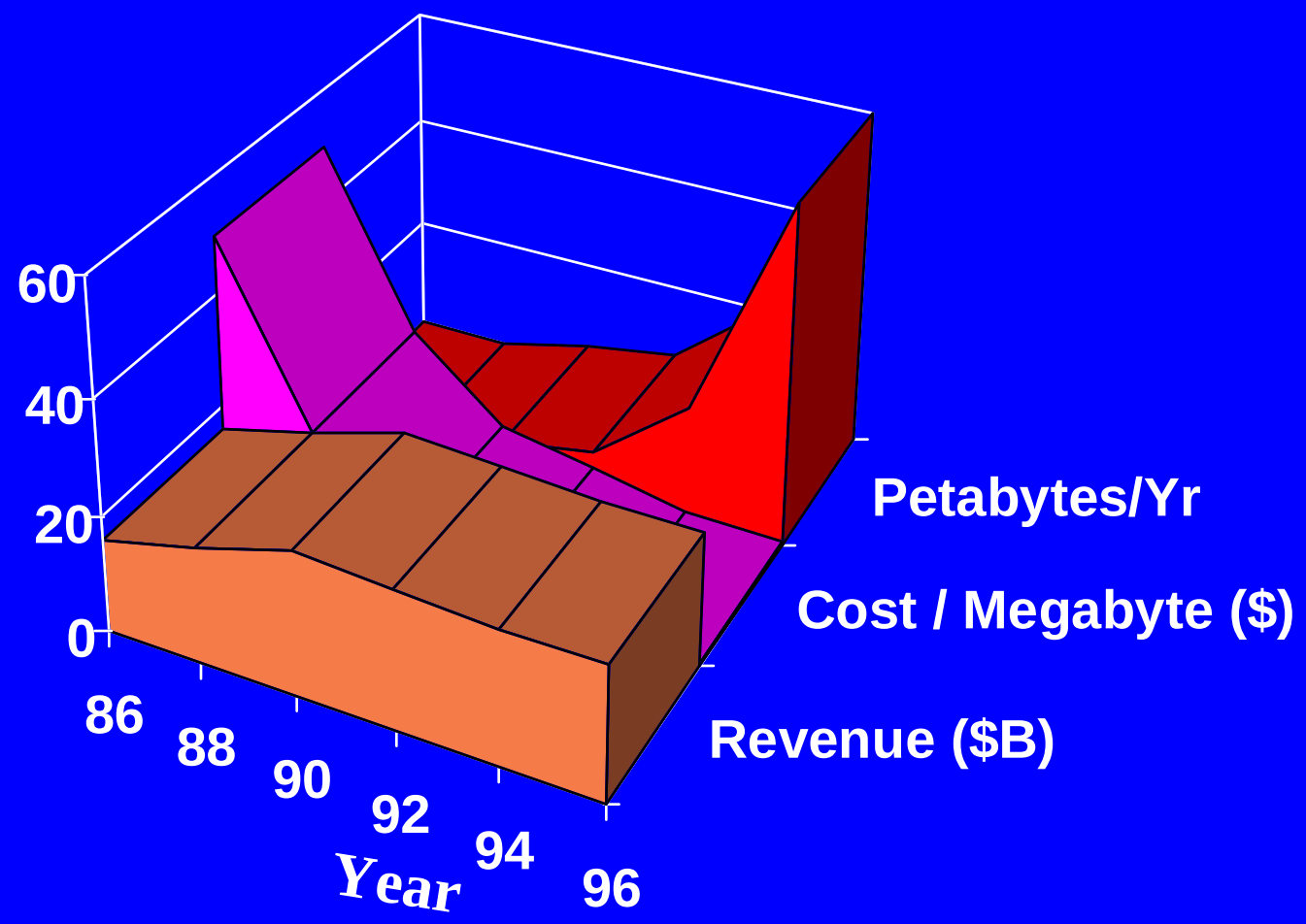
NIST Laboratory Support to ATP Projects

Picture of Kodak camera being used to photograph a vandalism.

Data Storage Parameters are Multidimensional



Trends in Hard Disk Drive Market - Worldwide



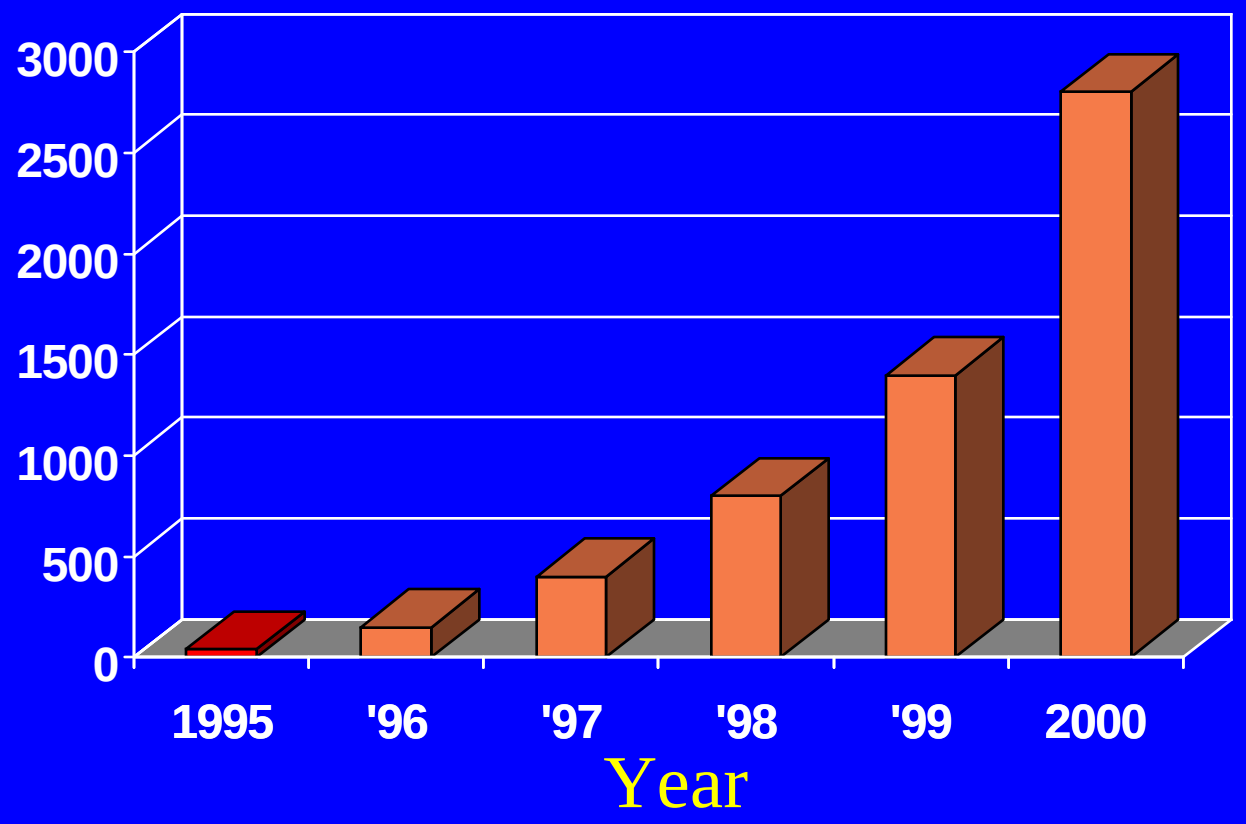
Source:
National Storage Industry Consortium
"The U.S. Recording Industry"

Note: Petabyte = 1000 Terabytes

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

The Computer Storage Market - Worldwide

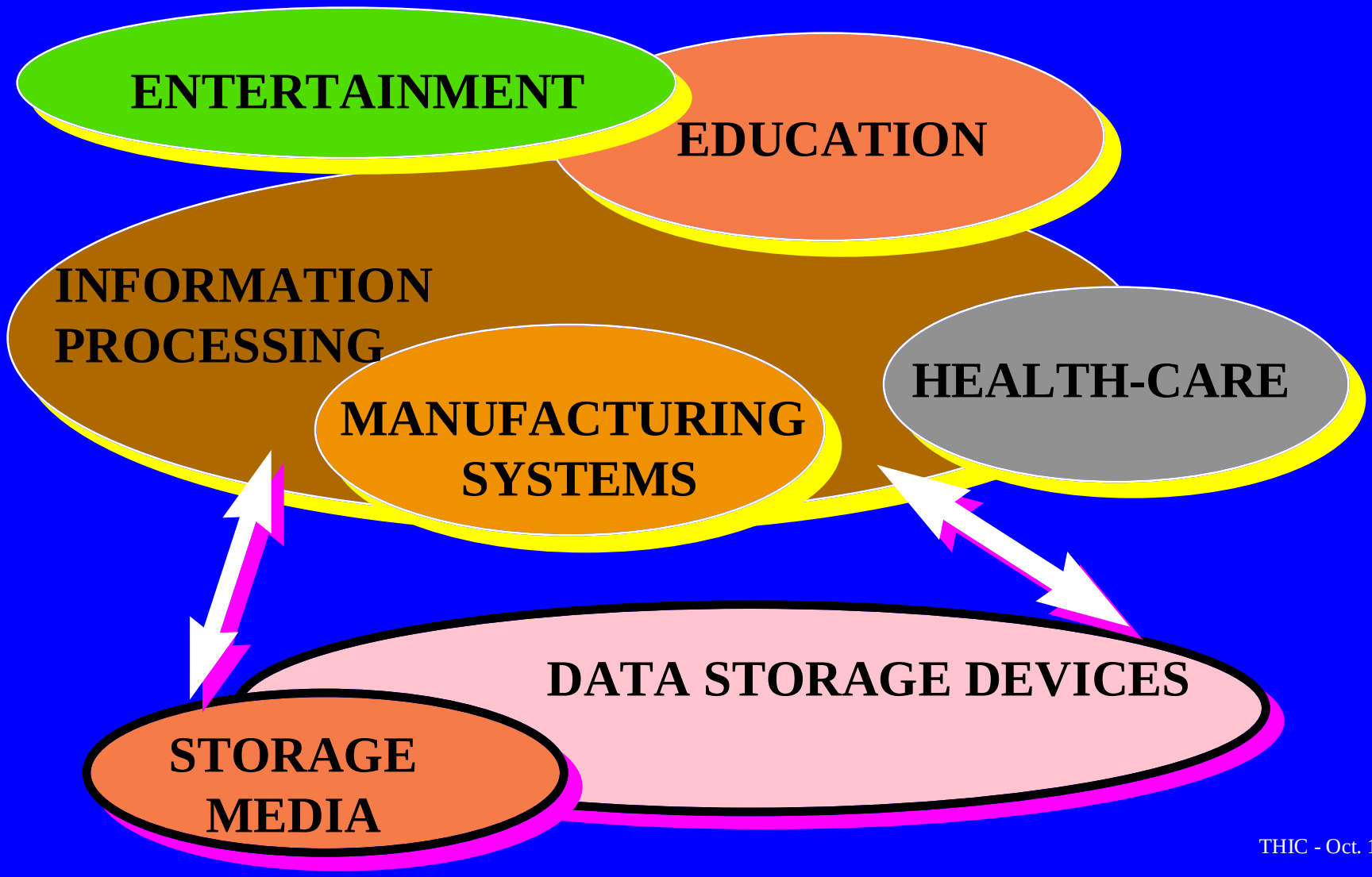
Petabytes Shipped



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

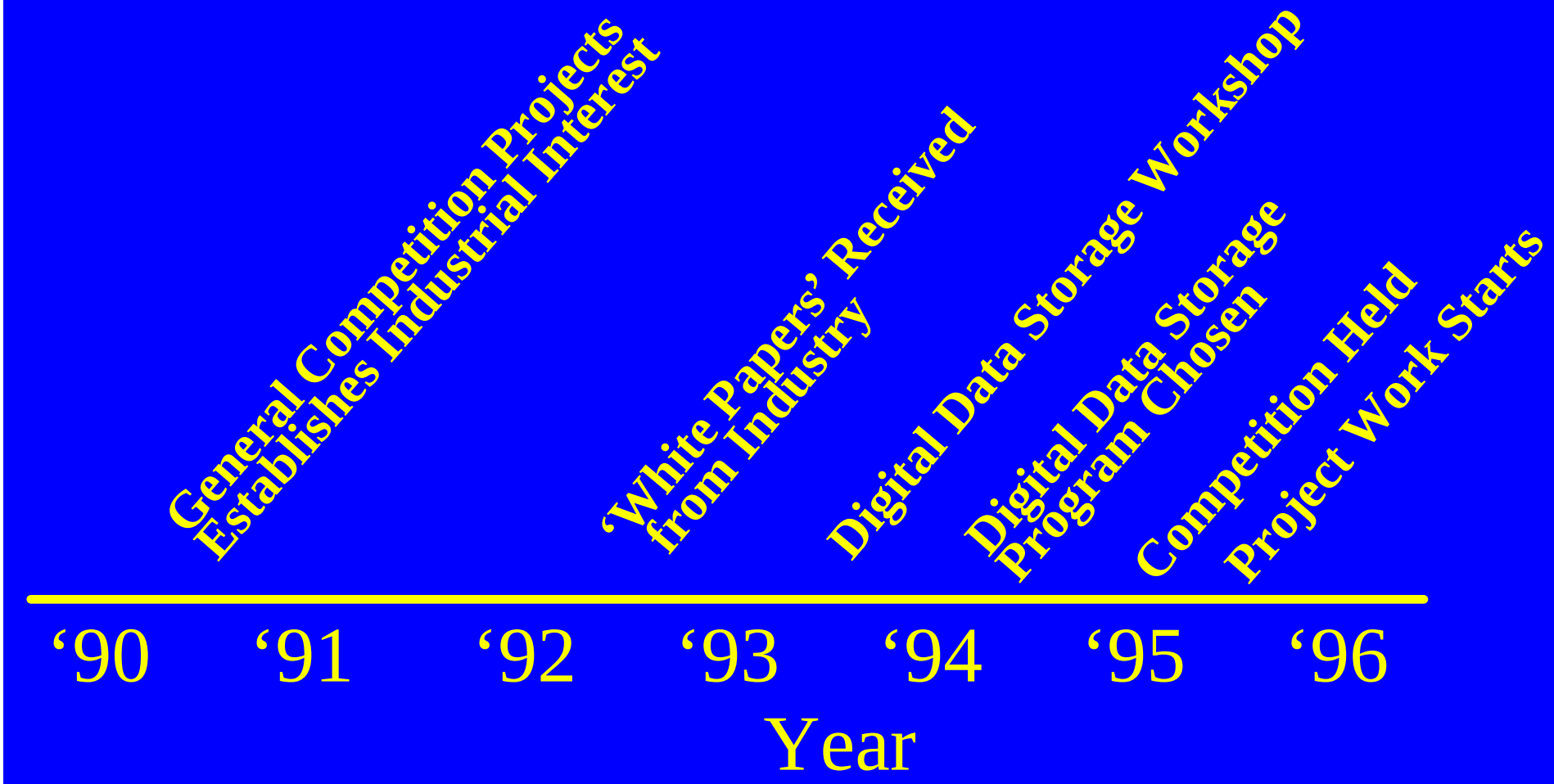
Users are asking for higher capacity and higher performance:

- 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



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

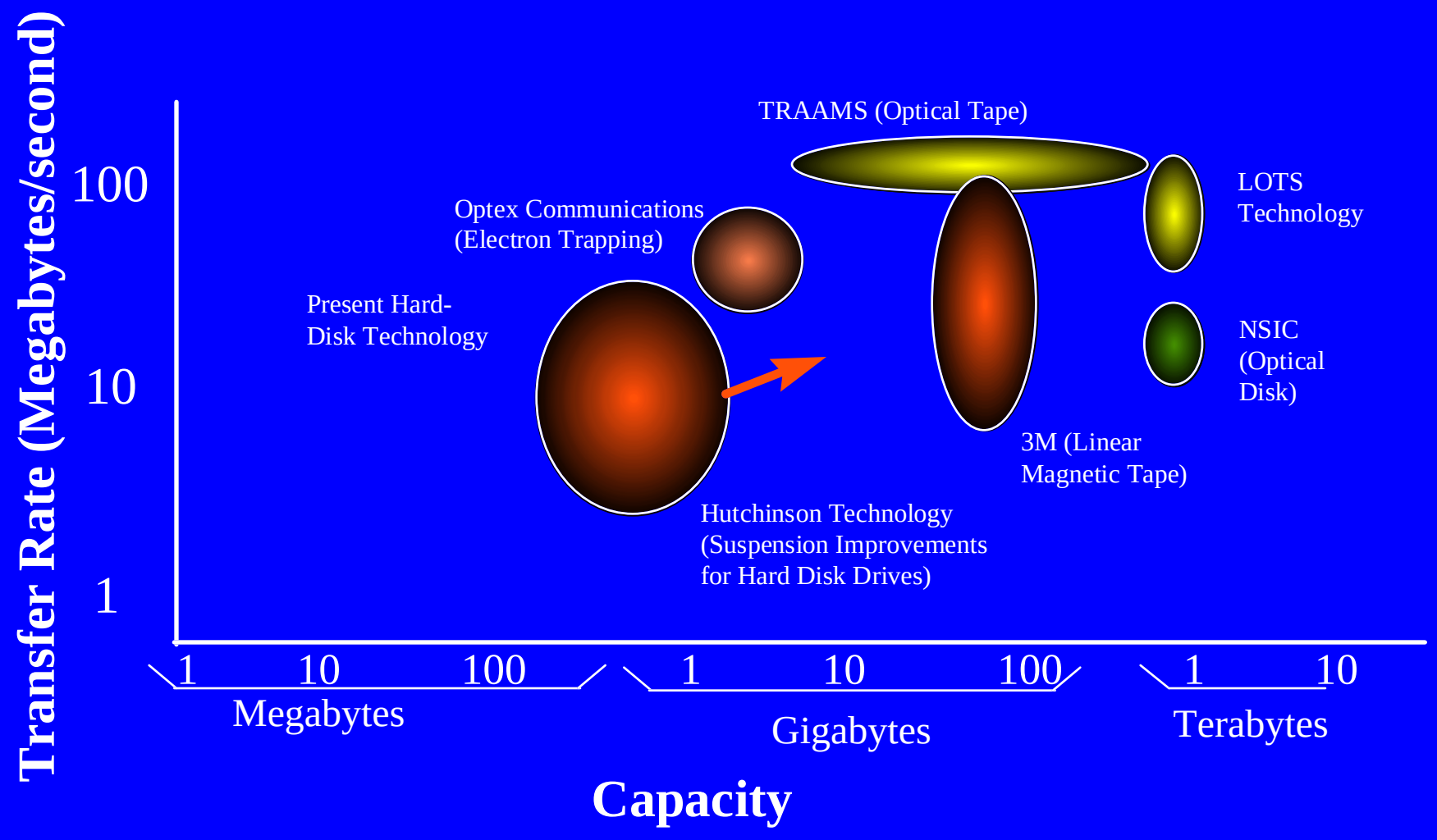
Tribology
- NSIC Heads Project
- 3M Magnetic Tape Recorder

Materials Science
- NSIC Heads Project
- NSIC Short Wavelength Source

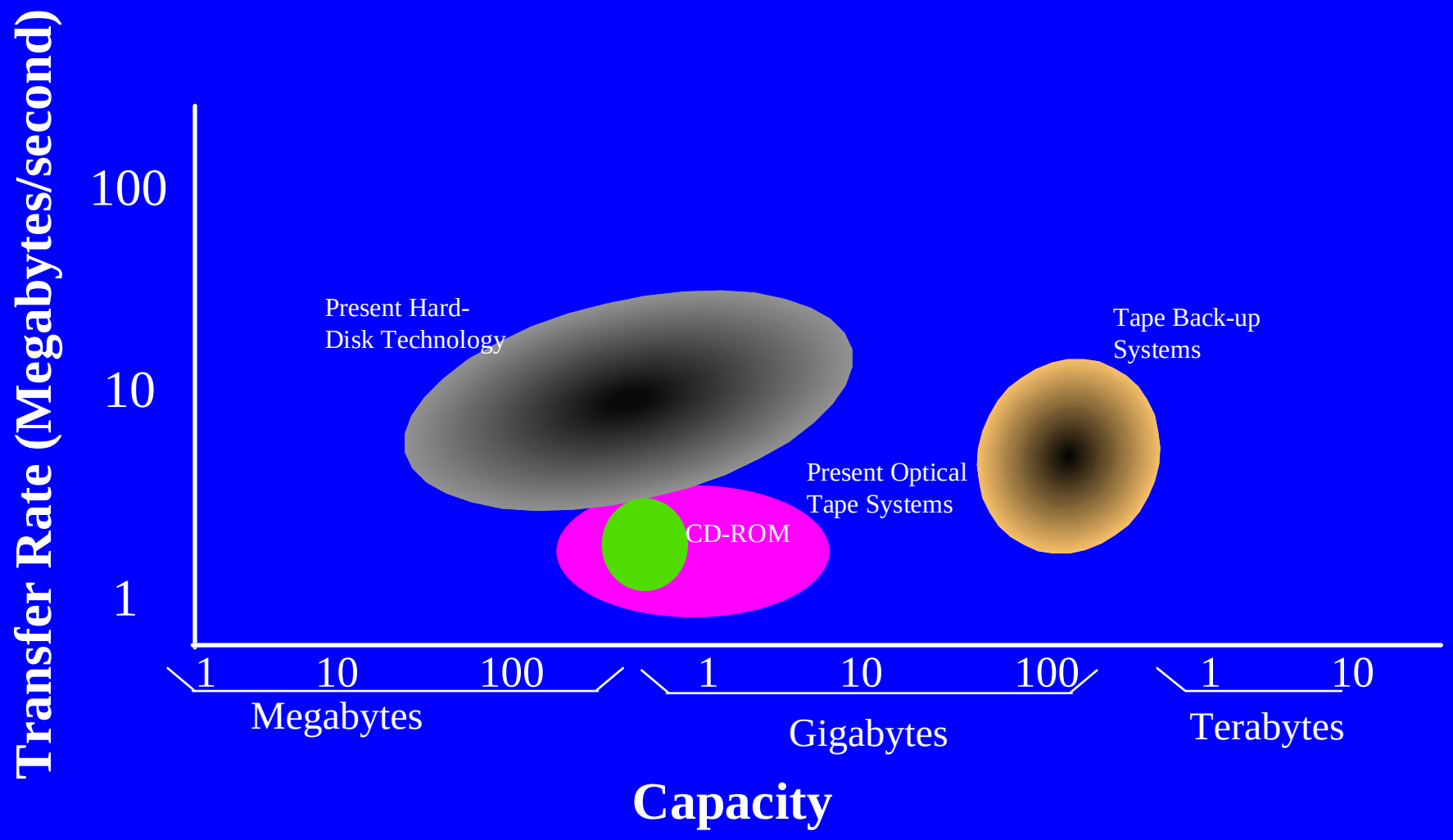
Advanced Mechanical Design
- Hutchinson Technology
- LOTS Technology

Systems Integration
- NSIC/Ultra High Capacity Optical Disk
- Terabank Systems / TRAAMS

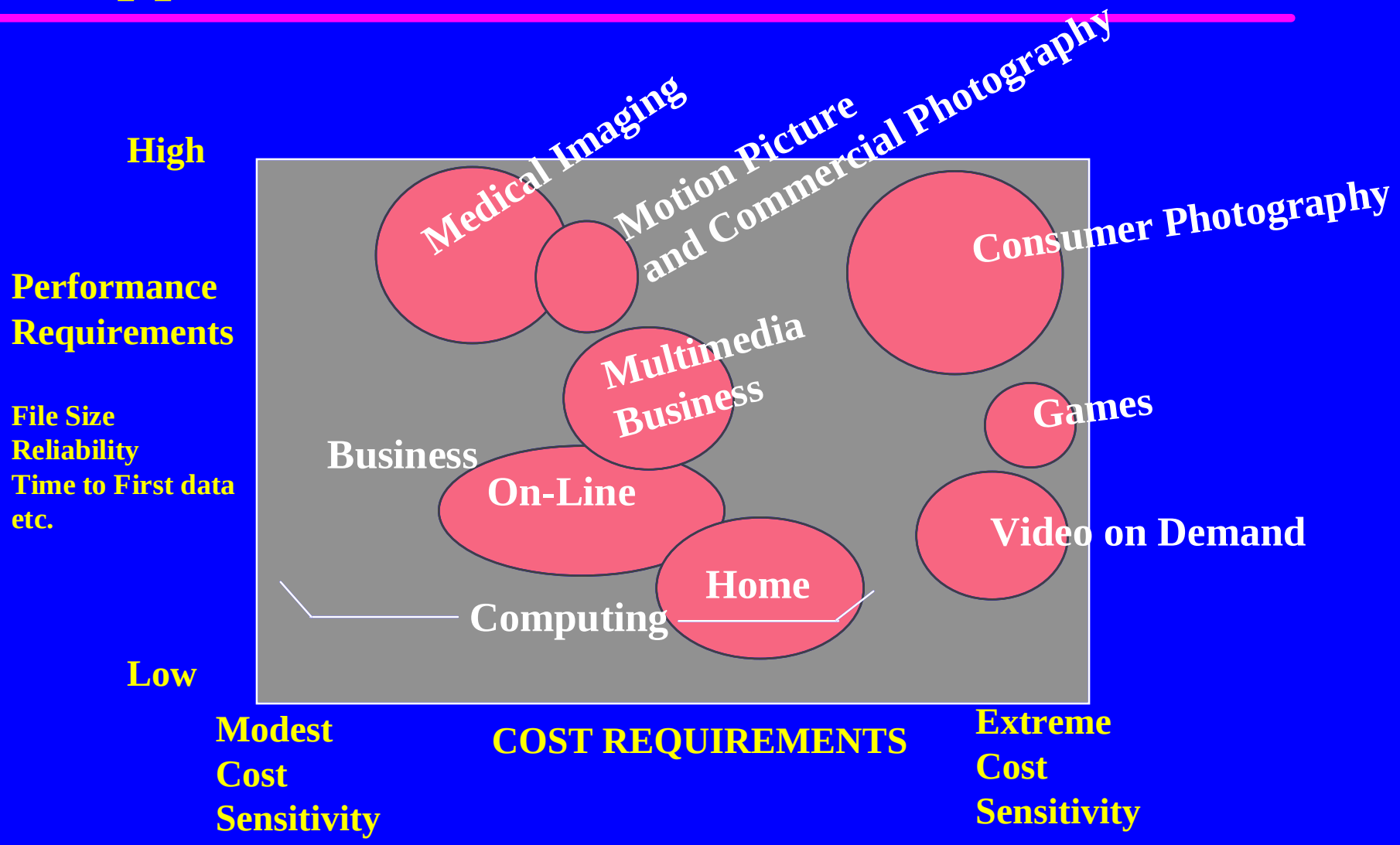
Speed/Capacity of Digital Data Storage Projects



Present-Day Storage Performance



Performance / Cost for Different Applications



NIST Laboratory Support to ATP Projects

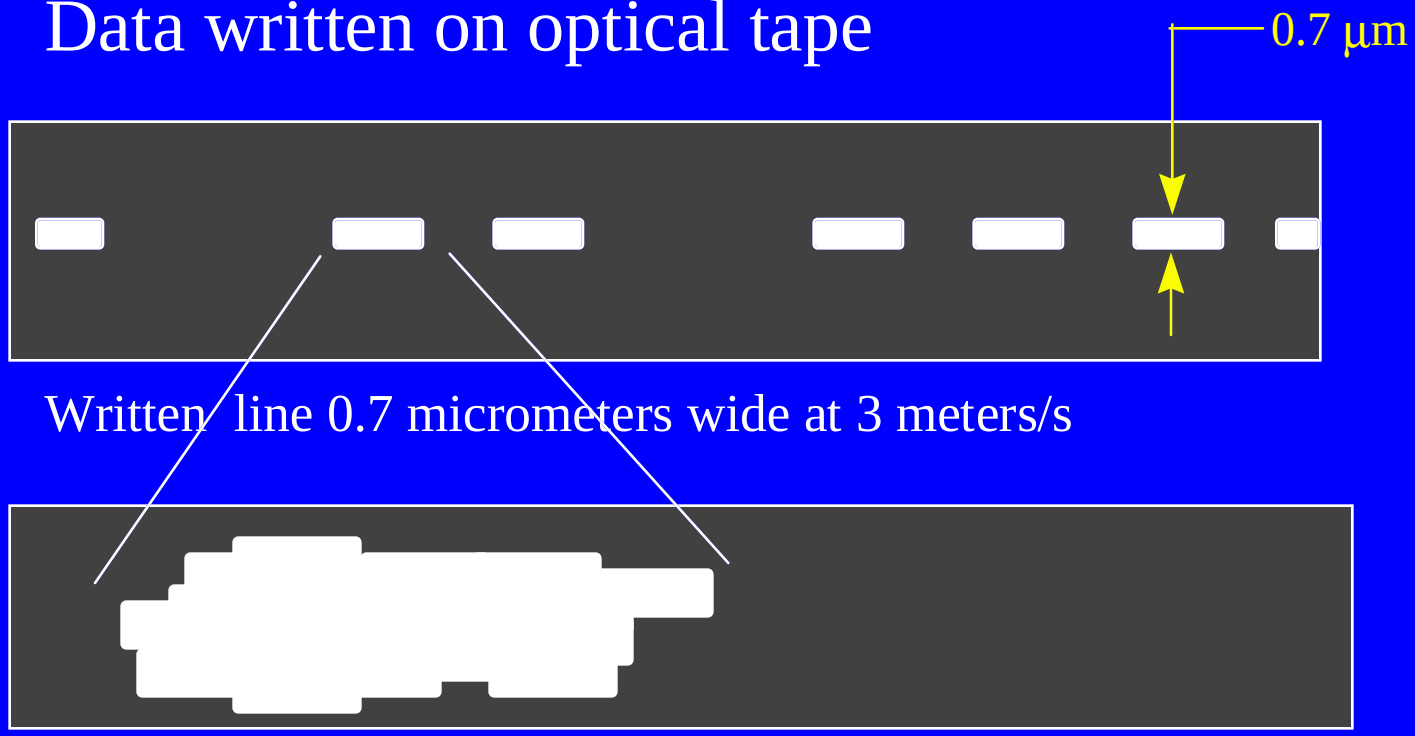
- Magnetic Materials and Measurements
  - **Materials and basic physics of GMR and spin valve sensors (CSTL - NSIC/HEADS).**
  - **Precision magnetic measurements and imaging (PL - 3M Variable Data Rate Tape Recorder).**
- Reliability Issues
  - **Thin-film reliability issues (electromigration) (EEEL - 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

Picture of Bill Egelhoff and his GMR apparatus here.

Early Successes - LOTS Technology

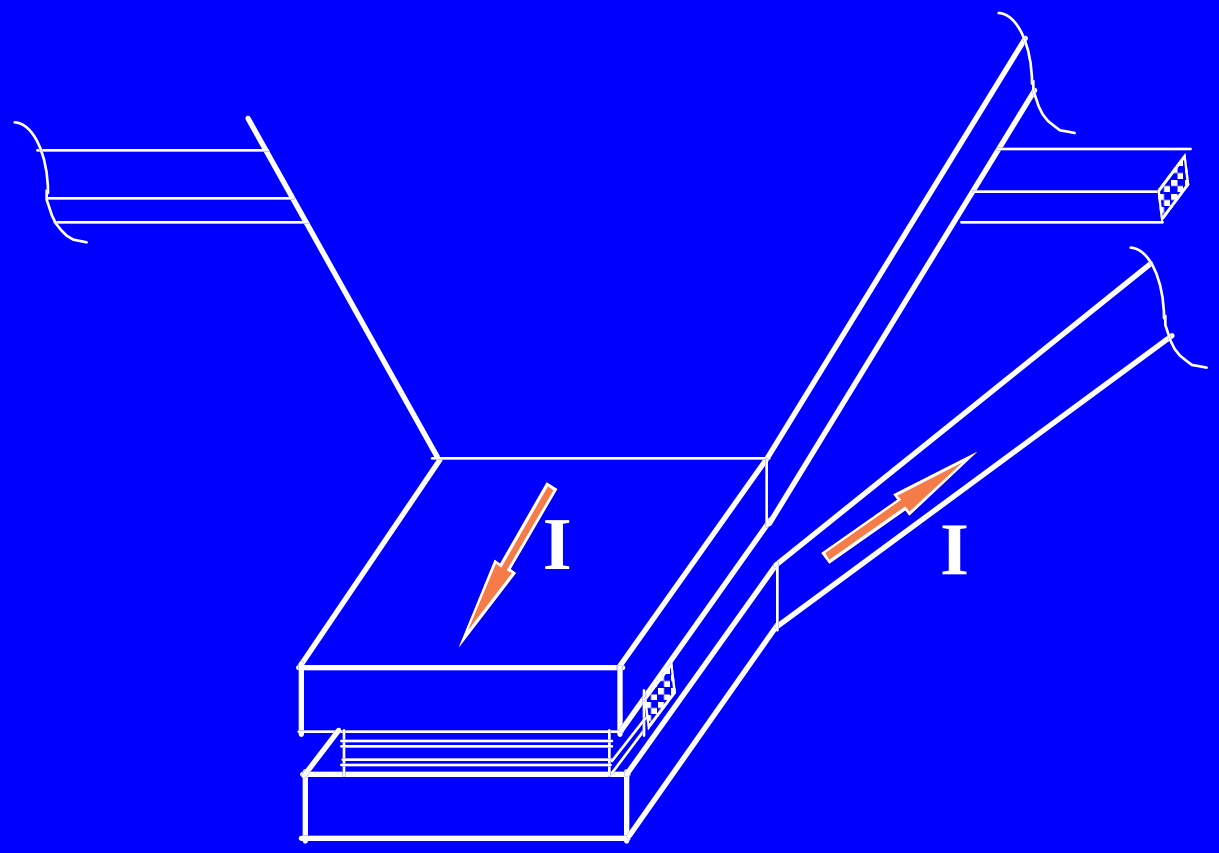
Data written on optical tape



Written line 0.7 micrometers wide at 3 meters/s

8X Magnification of written line, above

Early Successes - NSIC / HEADS Project

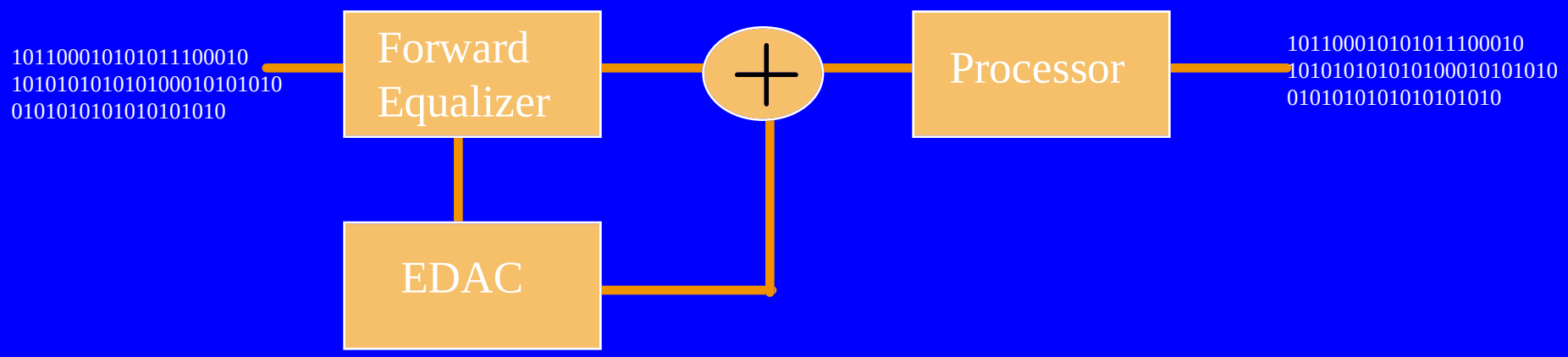


Fundamental Understanding of GMR Physics

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