The Premier Advanced Recording Technology Forum

THIC Inc.

2002 NSIC Tape Roadmap

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Boulder CO 80305-5602

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Outline

- NSIC Overview
- The storage hierarchy
- Tape roadmap team and approach
- Tape applications and systems conclusions
- Technical roadmap review
- Technical challenges
- Conclusions

NSIC (National Storage Industry Consortium) Overview

- **Founded in 1991**
- **Membership:**
  - **20 storage companies**
  - **32 universities and government labs**

- **Activities**
  - **Create an information storage industry technology roadmap and research strategy**
  - **Work with government to gain support for the information storage industry**
  - **Foster the establishment of pre-competitive joint research projects, involving collaboration among its members**

NSIC Project Overview

- *Extremely High Density Recording* - 6 Companies, 15 Universities - began 11/96 - Sponsored by Companies and NSF
- *Network Attached Storage Devices* - 5 Companies, 1 University - 1/97 to 12/99 - Sponsored by Participants
- *Multiple Optical Recording Enhancements* - 3 Companies, 2 Universities - 11/97 to 2/02 - Government Sponsor: NIST/ATP
- *Advanced Magnetic Tape Storage Technology* - 6 Companies, 4 Universities - began 12/99 - Sponsored by Companies
- *Heat Assisted Magnetic Recording* - 4 Companies, 2 Universities - began 11/01 - Government Sponsor: NIST/ATP

NSIC Roadmap Activity

1993-94: Storage Technology Roadmaps

Workshops:	April 1993; March 1994; April 1994
Report:	September 1994

1996-97: Optical Disk Storage

Workshop:	April 1996
Report:	June 1997

1997: Hard Disk Drive Technology

Workshop:	February 1997
Report:	Incorporated in July 1997 Proposal

1997-98: Magnetic Head Metrology

Workshop:	June 1997
Report:	February 1998

1997-98: Magnetic Tape Storage

Workshop:	September 1997
Report:	June 1998

1999: International Workshop on Holographic Data Storage

Workshop:	March 1999
Executive Report:	December 1999

1999-2000: Optical Disk Storage

Workshop:	November 1999
Report:	February 2000

2001-2002: Magnetic Tape Storage

Workshop:	June 2001
Report:	February 2002

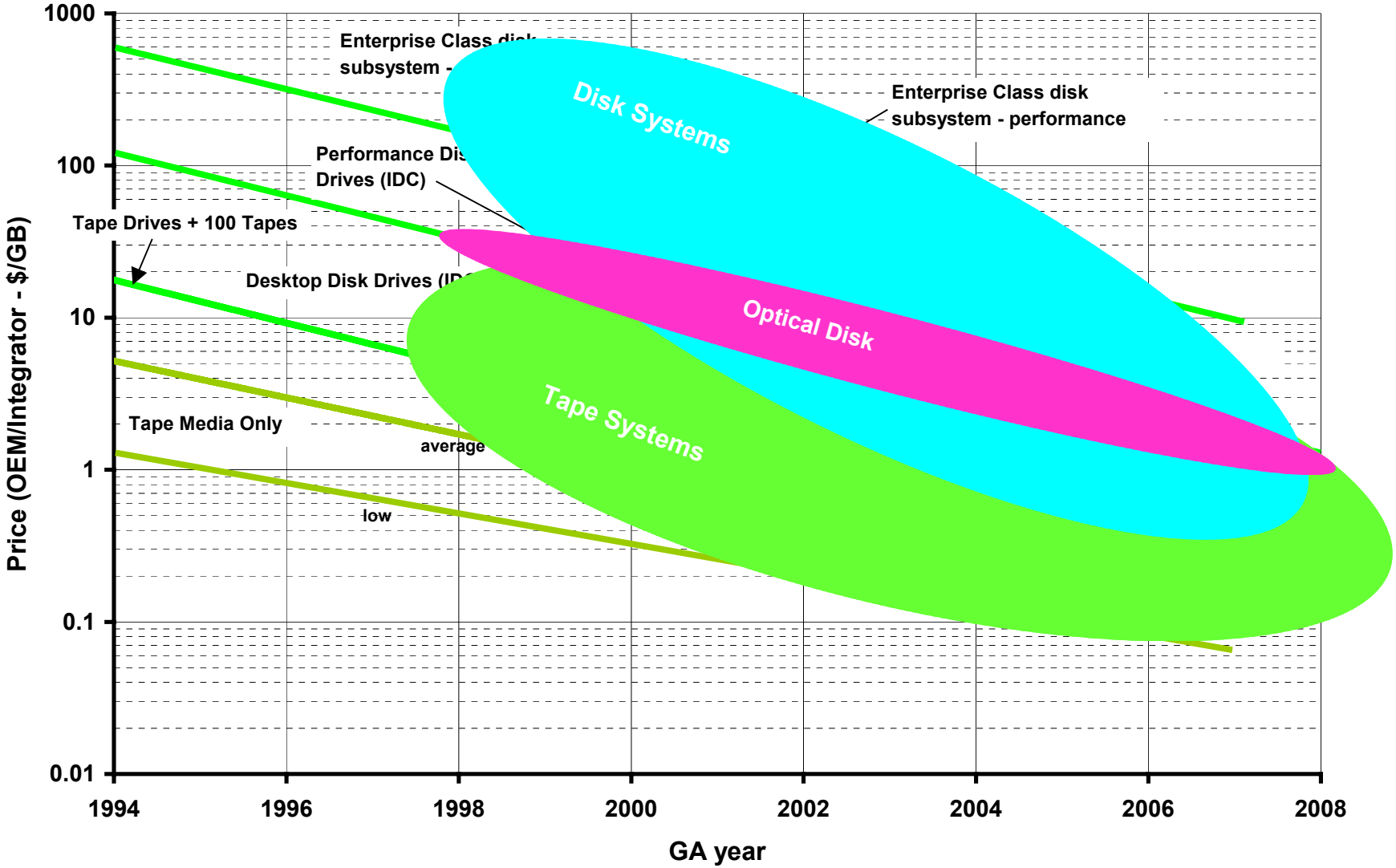
2002 NSIC Tape Roadmap

Team Leaders

NSIC:	**C. Denis Mee, Barry Schechtman**
Applications Section:	**Bill Phillips**
Technology Section:	**Bob Raymond (StorageTek)**
Heads:	**Richard Dee (StorageTek),**
	Jim Bain (CMU)
Media:	**Mike Sharrock (Imation)**
Channel:	**Richard Barndt (HP)**
Drive:	**Durkee Richards (Imation)**
Helical:	**John Woelbern (SONY)**

Storage Subsystem Price Trends

(OEM price/equiv. unless otherwise noted; no capacity compression or utilization factors)



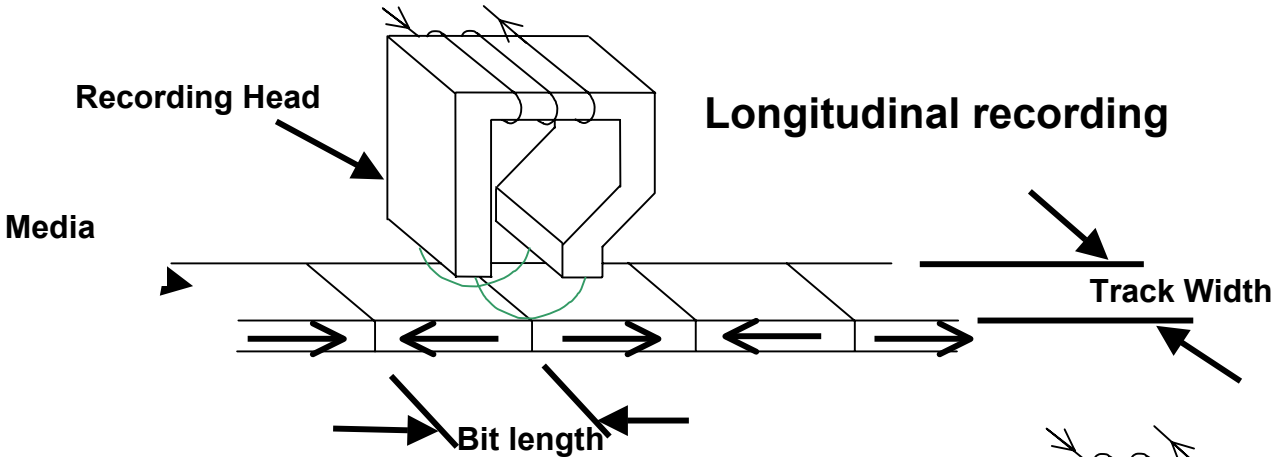
2001 NSIC Tape Roadmap

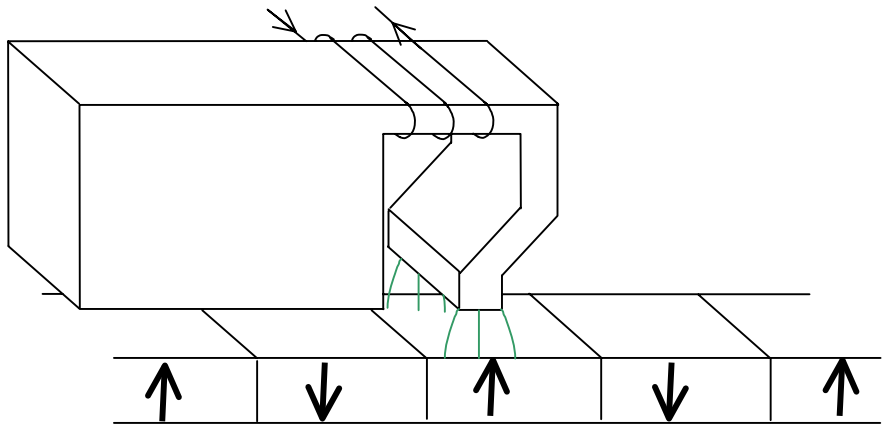
- 10 year roadmap.
- Consensus of over 40 researchers
  - Representing virtually every large tape drive manufacturer, tape media and substrate supplier, many of the leading research universities.
- Primarily focused on linear tape (helical section by Sony).
- Goal to remain competitive with disk ($/MB) *and* be technically feasible.
- Keep the ratio of the capacities of a tape cartridge to a single 3 1/2 disk platter constant. (Ratio = 3.3 at time of roadmap)
- Assume:
  - Disk capacity growth will be 60%/year
  - Disk data rate growth will be 26%/year

Tape Applications and Systems Conclusions

- Tape use is migrating away from the desktop to the data center.
- The most prevalent applications for high capacity high data rate tape are backup and restore as well as archive in an automated open systems environment.
- In these applications tape must continue to remain cost competitive to magnetic disk.

Magnetic Recording Definitions



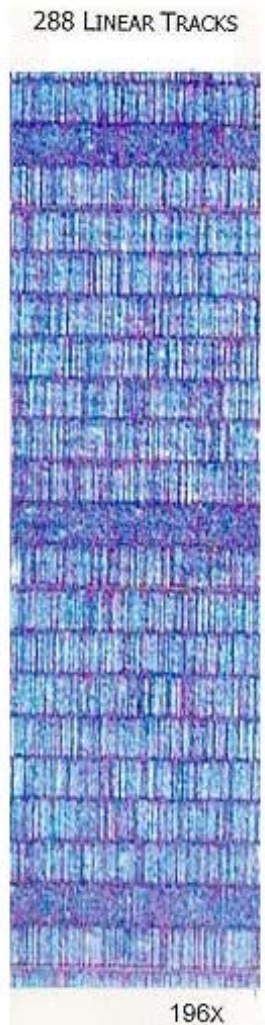


Tracks per inch (tpi) = $(\text{Track Width})^{-1}$

Bits per inch (bpi) = $(\text{Bit Length})^{-1}$

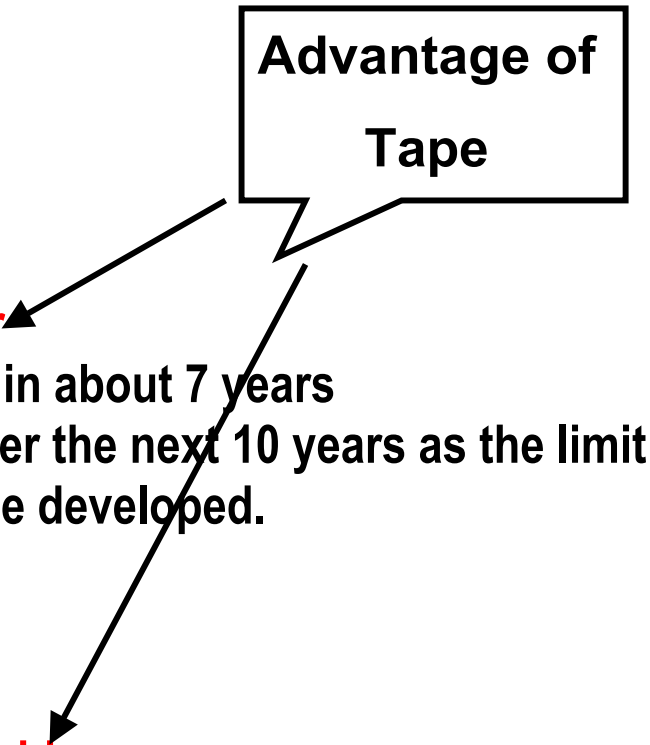
Areal density = (Tracks per inch) X (Bits per inch)

Typical Tape Data Tracks



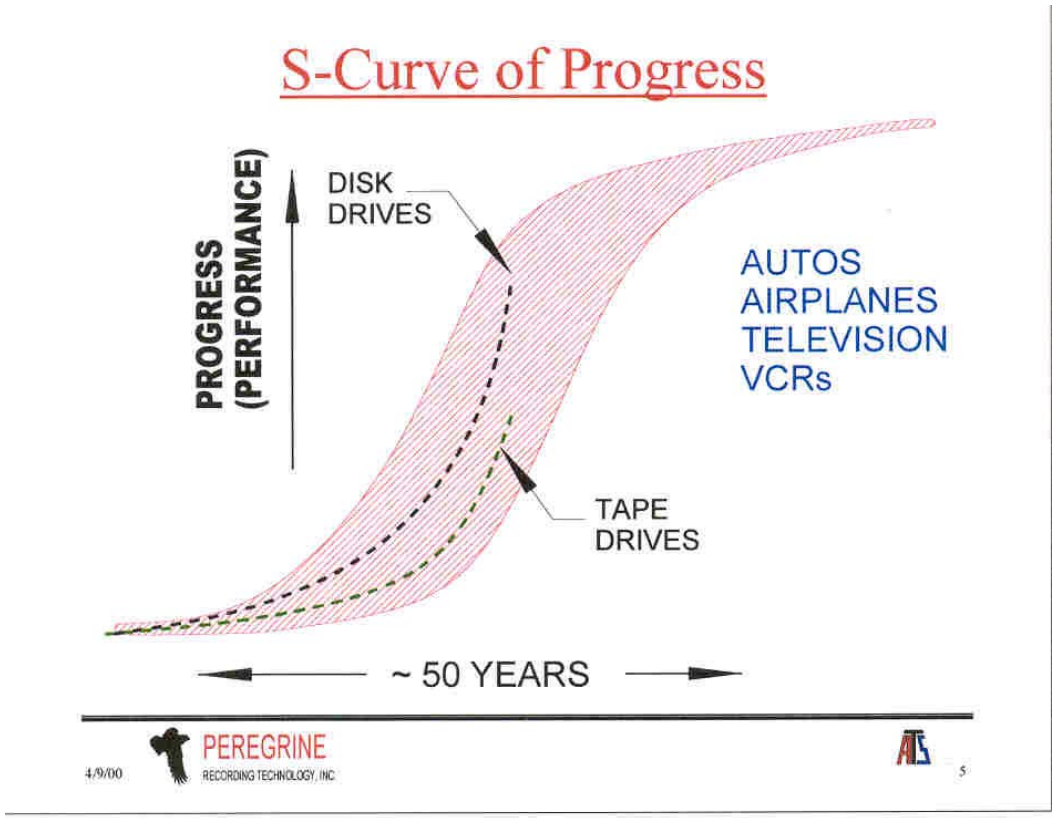
Will Disk Areal Density Growth Slow

- Super-paramagnetic effect
  - Limit ~1Tbit/inch^2 *
- Disk
  - Disk is at ~0.050Tbit/inch^2 today
  - 14 inch^2 recording area on 3 ½ inch platter
  - At 60%/yr growth the limit will be reached in about 7 years
  - =>Disk capacity growth will slow down over the next 10 years as the limit is approached and new technologies must be developed.
- Tape
  - Tape is at ~0.0001Tbits/ inch^2 today
  - 14,000 inch^2 recording area on ½ inch cartridge
  - At 60%/yr capacity growth tape will reach 0.005Tbits/inch^2 in 10 years
  - =>Tape will not reach any fundamental limits



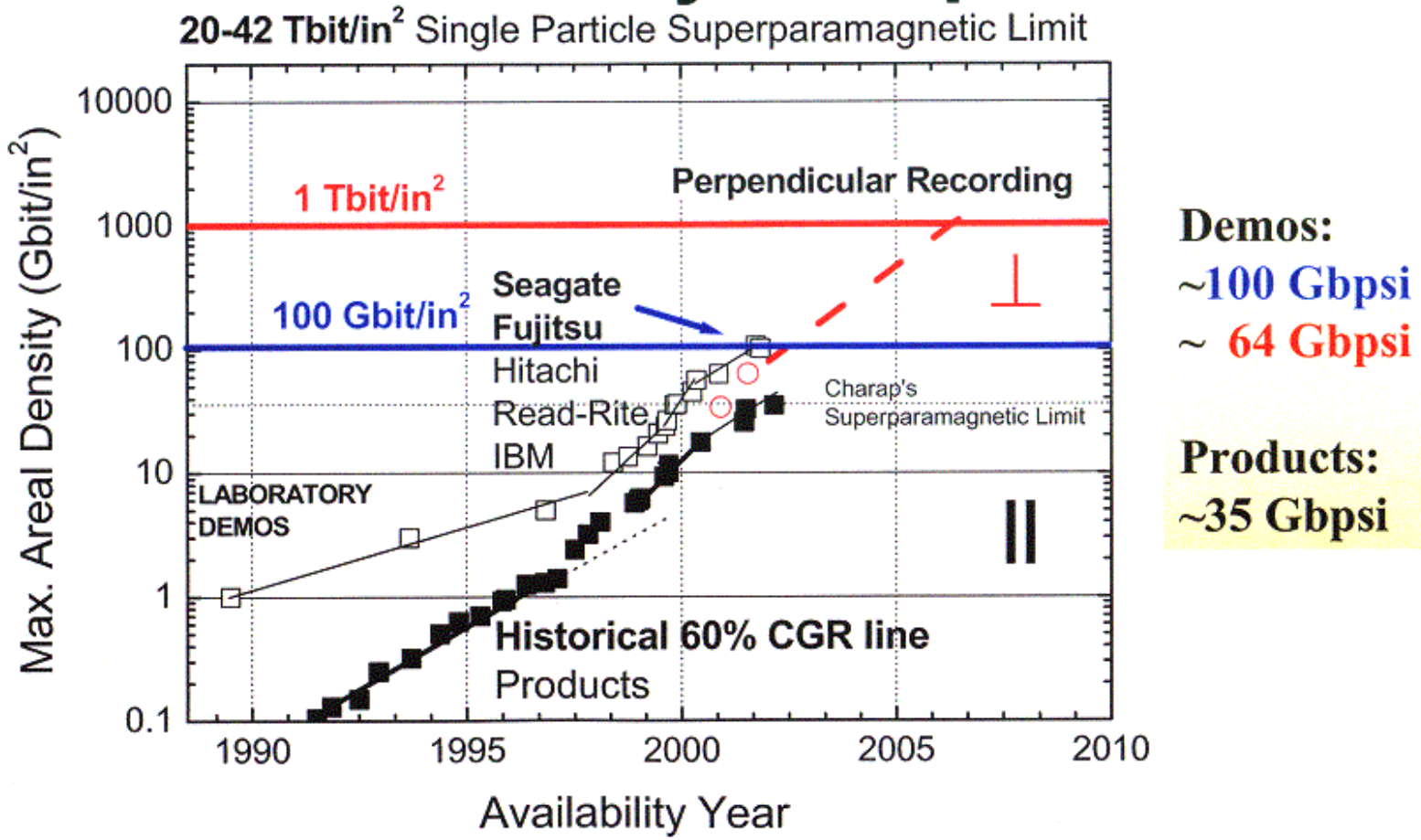
*"A Hard Disk Drive Using Magnetic Recording at One Terabit Per Square Inch," Roger Wood (IBM), presented at the NSIC Alternative Storage Technologies Symposium, June 26, 2001. Proceedings are available from NSIC, nsic@nsic.org or 858-279-7230.

Tape technology is accelerating to head them off at the pass!



From "Magnetic tape as the mass storage medium" T. Schwarz, IEEE/NASA Goddard Mass Storage Systems Conference (2000)

Areal Density Perspective

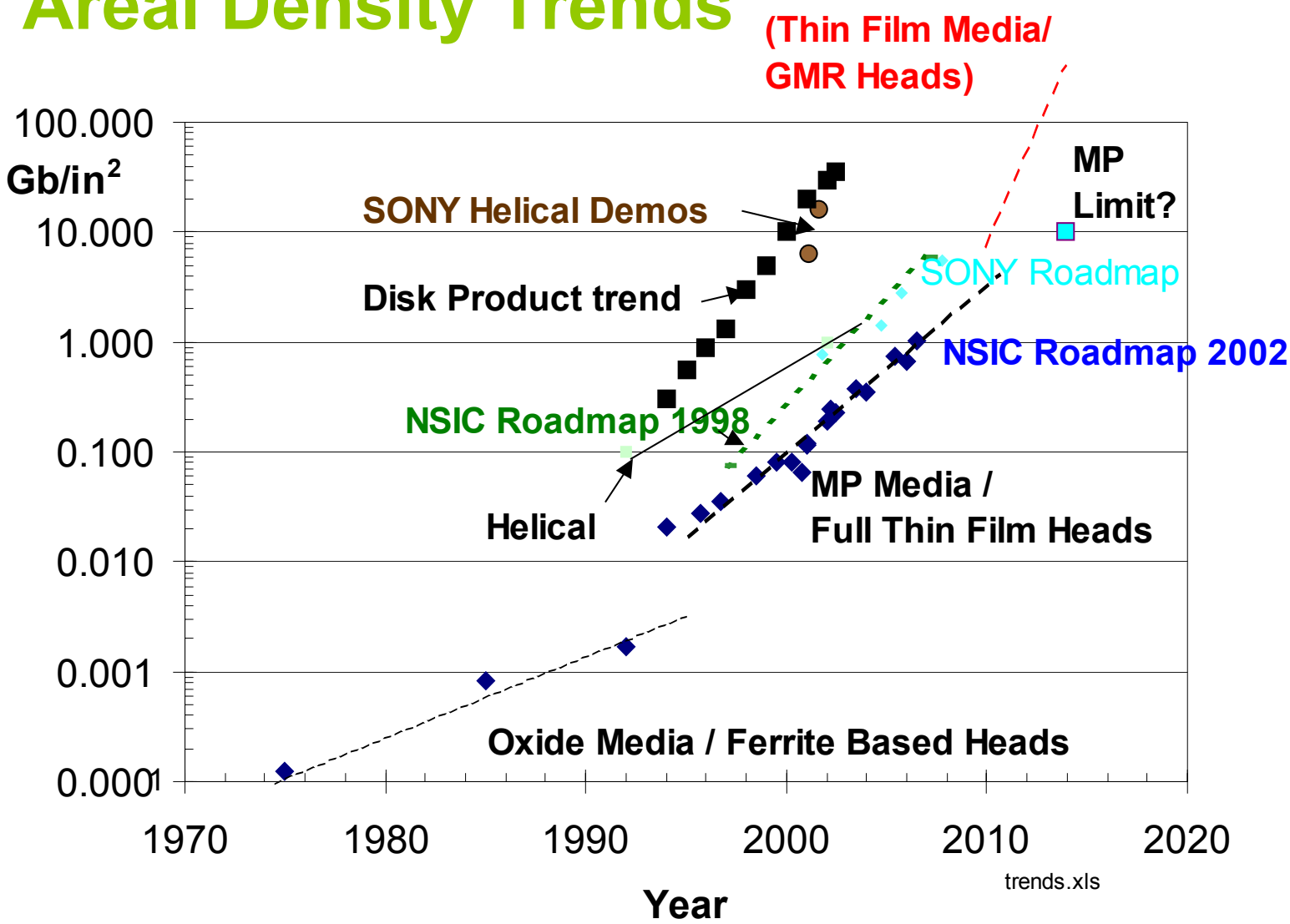


Demos:
~100 Gbpsi
~ 64 Gbpsi

Products:
~35 Gbpsi

Courtesy of Dieter Weller

Tape Areal Density Trends



Capacity and Data Rates

$$Capacity \sim (tpi)(bpi)WL\varepsilon$$

$$DataRate \sim n(bpi)v\varepsilon$$

tpi **= track density,** ***bpi*** **= bit density,** ***L*** **= length of tape,**

W **= width of tape,** ε **= efficiency,** ***n*** **=number of channels,**

v **= tape speed**

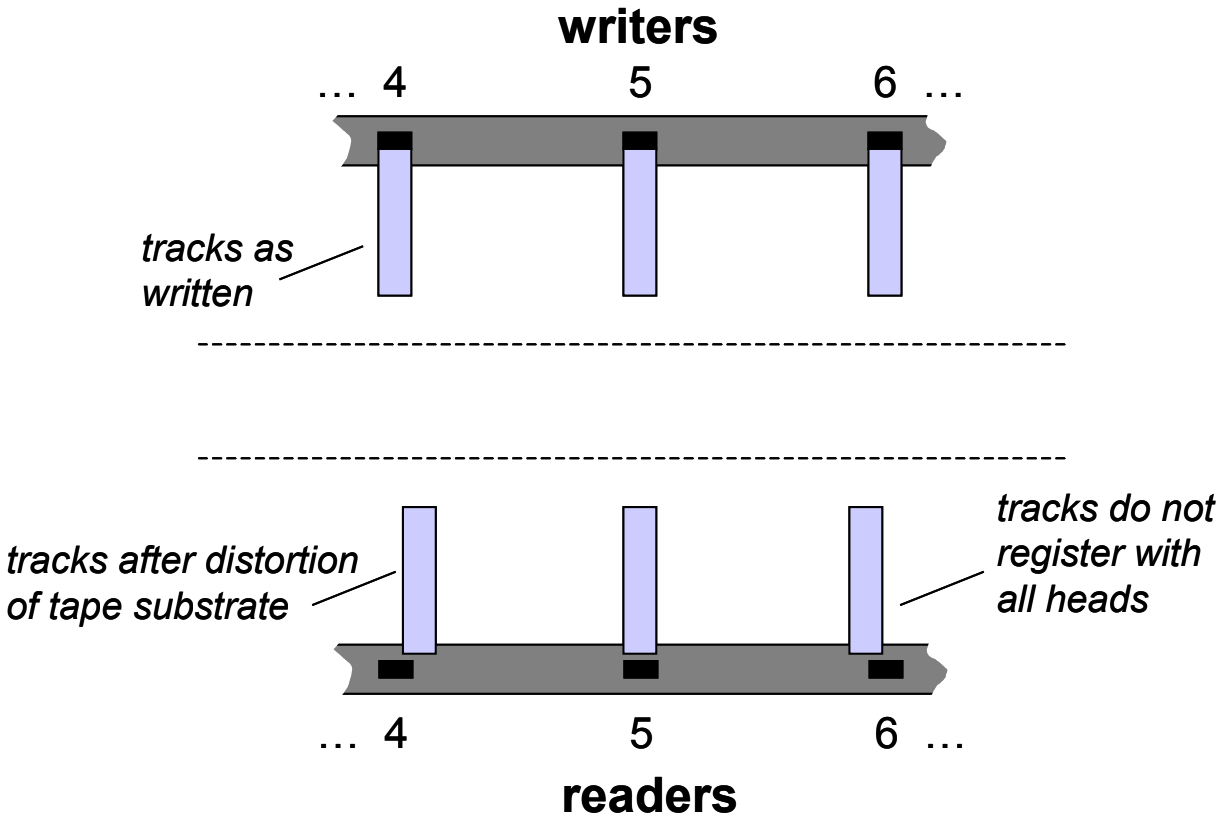
2001 NSIC Tape Roadmap

Year	2001	2006	2011	Unit
Tape Cartridge Capacity (User*)	0.1	1	10	TB
Tape Thickness	8.8	5.3	3.8	µm
Approx. Length of Tape	600	1000	1400	m
Linear Tape Track Density	900	2700	9800	TPI
Linear Tape Bit Density	125	250	500	Kbpi
Tape Speed	4	6.5	10	m/s
Data Rate/Channel (Raw)	2.5	8	25	MB/s
Data Rate/Channels (User*)	1.7	6	18	MB/s
* Assumes 15% Servo/Trk Layout OH and 29% ECC/Format OH				
Disk Drive Single Platter Capacity	0.03	0.3	3	TB
Disk Drive Data Rate	74	227	855	MB/s
Capacity Ratio (Tape/Disk)	3.3	3.3	3.3	
Data Rate Ratio (Disk/Tape)	30	29	34	

Technical Challenges Summary

- Media improvements are key
  - Particulate
    - Smaller particles
    - Thinner substrates
    - Improved stability
  - Evaporated thin-film
    - Thinner layers (beyond 30 nm)
  - Sputtered
    - Best long term potential, but new research needed.
- Tape paths
  - Higher speeds with thinner tape
- Recording channels
  - New techniques for higher errors (turbo codes)
- Heads
  - Technology is place with disk, must apply it to tape (GMR heads)
  - Reduce head media spacing 70nm -> 20nm
- New environmental issues

Media Stability



Courtesy of NSIC and Jim Bain, CMU

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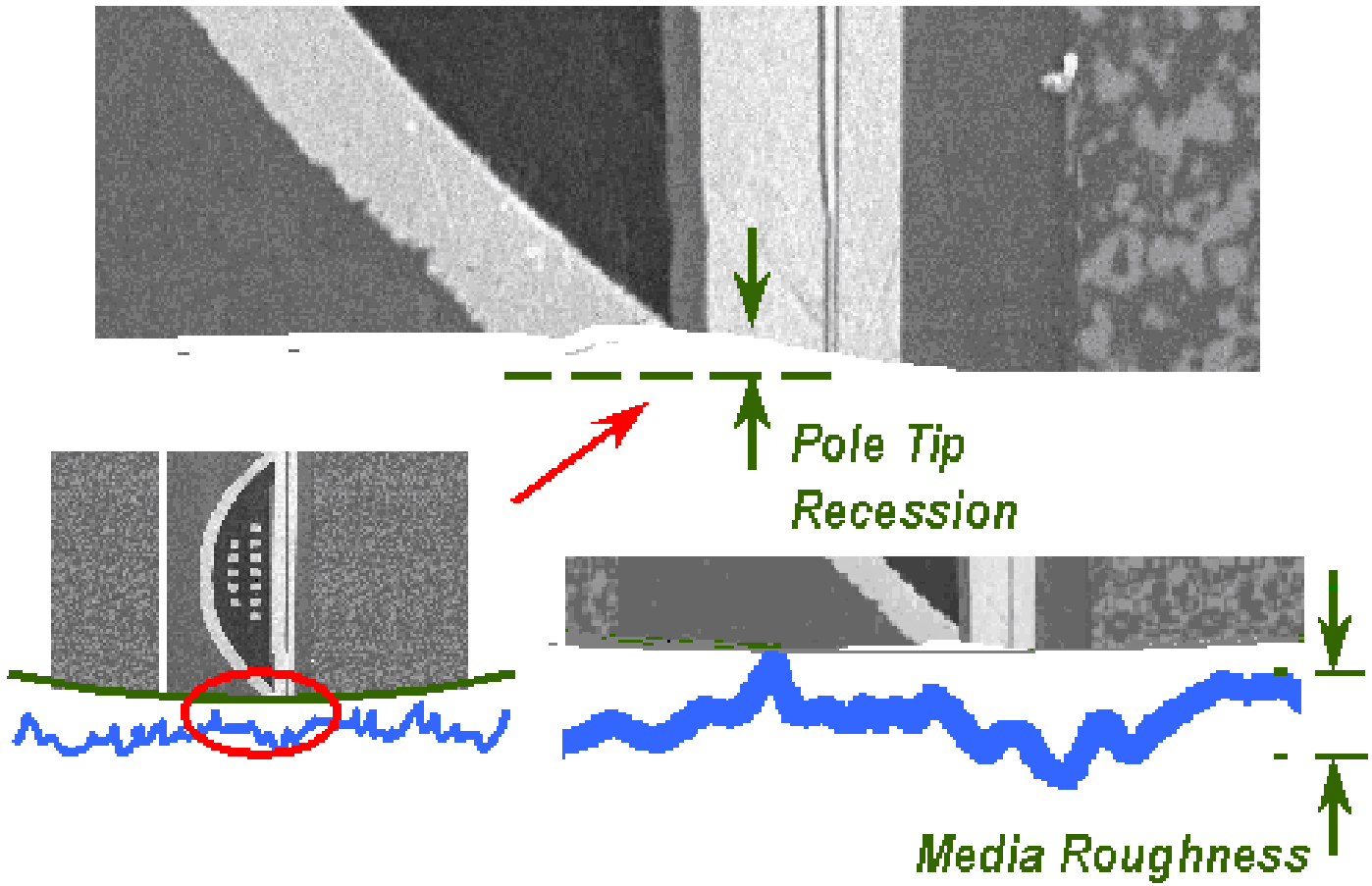
Head Media Spacing Challenge



Courtesy of NSIC and John Moore, Seagate

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Conclusions

- Tape can continue to remain the cost competitive solution over disk
  - NSIC roadmap illustrates this competitiveness
  - Roadmap is doable with helical and linear tape demos showing feasibility
- Disk is expected to slow its capacity growth over the 100% per year trend.

The NSIC Magnetic Tape Storage Roadmap (February 2002)…

- Is available for purchase from NSIC:
  - call Barbara Brittain at: (858) 279-7230
  - e-mail: barbara@nsic.org
  - or FAX: (858) 279-8591