Terabytes, Petabytes and Beyond -- Data Storage Strategies

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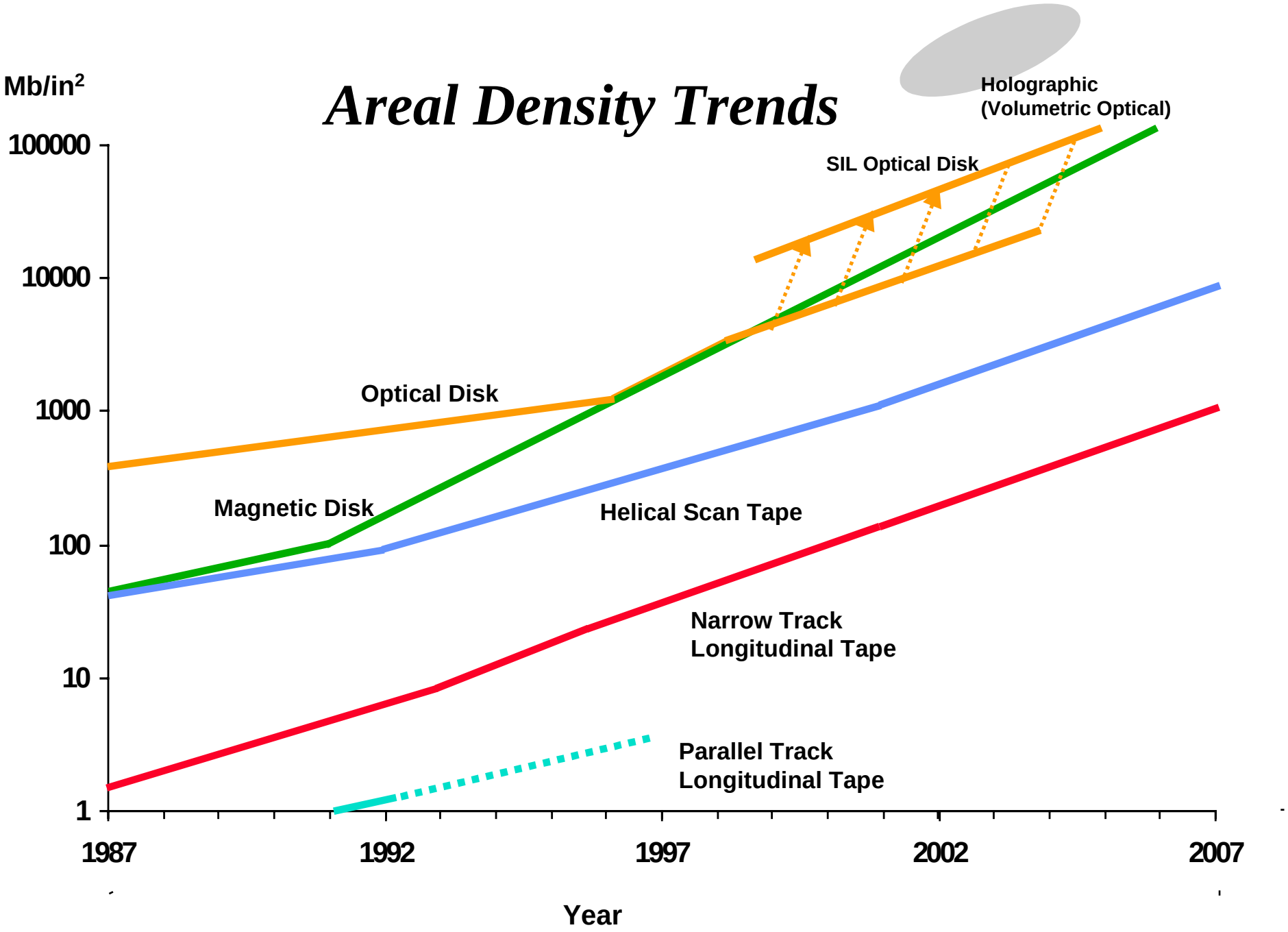
Presented at the THIC meeting at the Amberley Suite Hotel, Albuquerque, NM
April 21, 1998

Outline

- Data Storage Building Blocks
  - Storage Technology Overview
  - Magnetic Tape
  - Magnetic Disk
- Data Storage Archive


Areal Density Trends
Mb/in2
100000
10000
1000
100
10
1
1987
1992
1997
2002
2007
Year
Holographic
(Volumetric Optical)
SIL Optical Disk
Optical Disk
Magnetic Disk
Helical Scan Tape
Narrow Track
Longitudinal Tape
Parallel Track
Longitudinal Tape

Storage Trends

- Magnetic disk is the areal density leader with 60%/year growth
- “Optically assisted” approaches are in development to continue magnetic disk’s growth past “2003 technology limit”
- Optical disk using “near-field” technology (e.g.SIL) could regain areal density lead
- Distinction between magnetic and optical recording will become “blurred”
- Major technical challenges remain for holography
- Tape’s “third dimension” gives it a volumetric storage efficiency advantage (30-50%/year growth)

  2 - 10x over disk drives

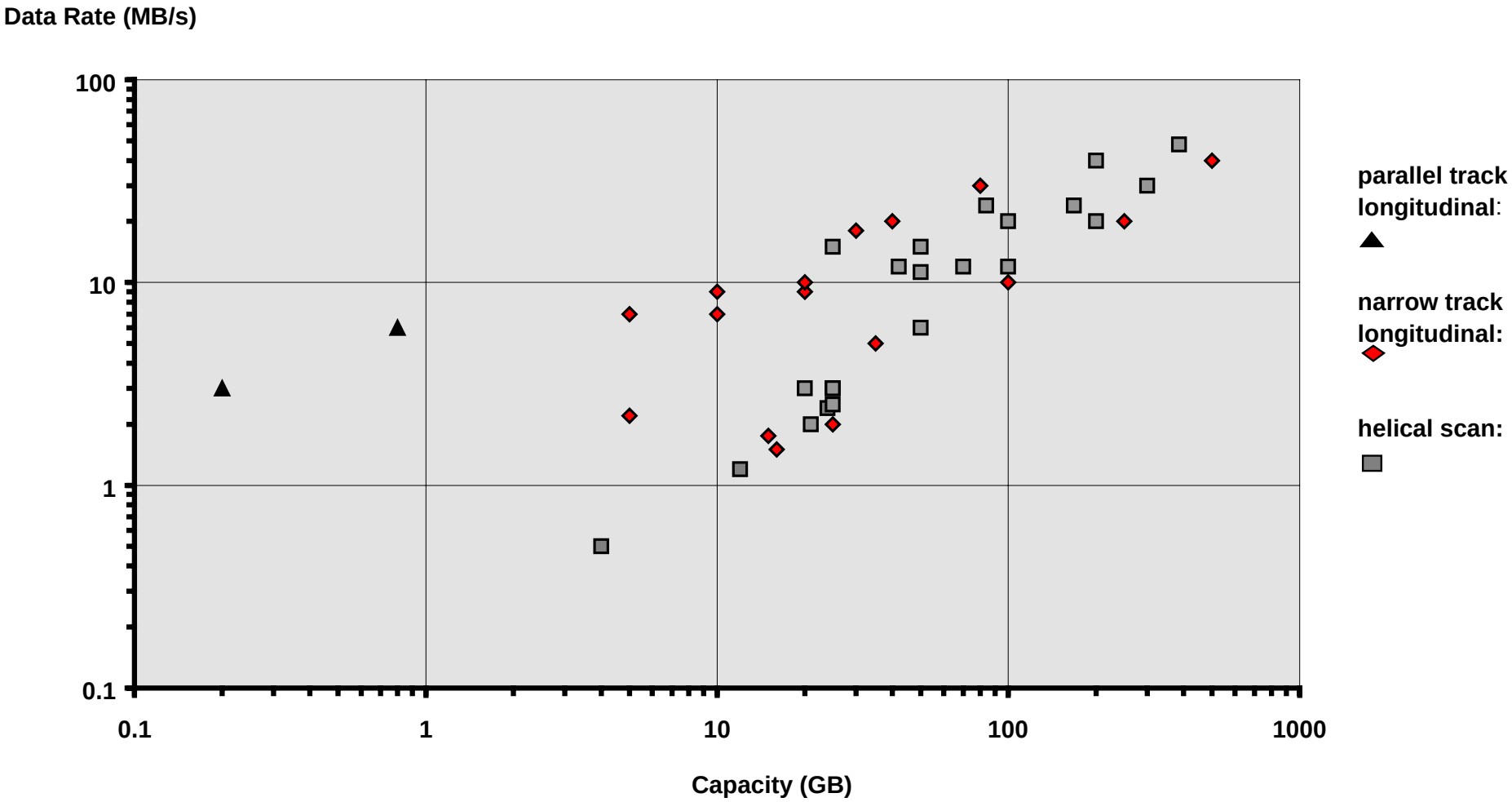
  > 3x over optical media

- Magnetic tape vendors will get (are getting) more aggressive

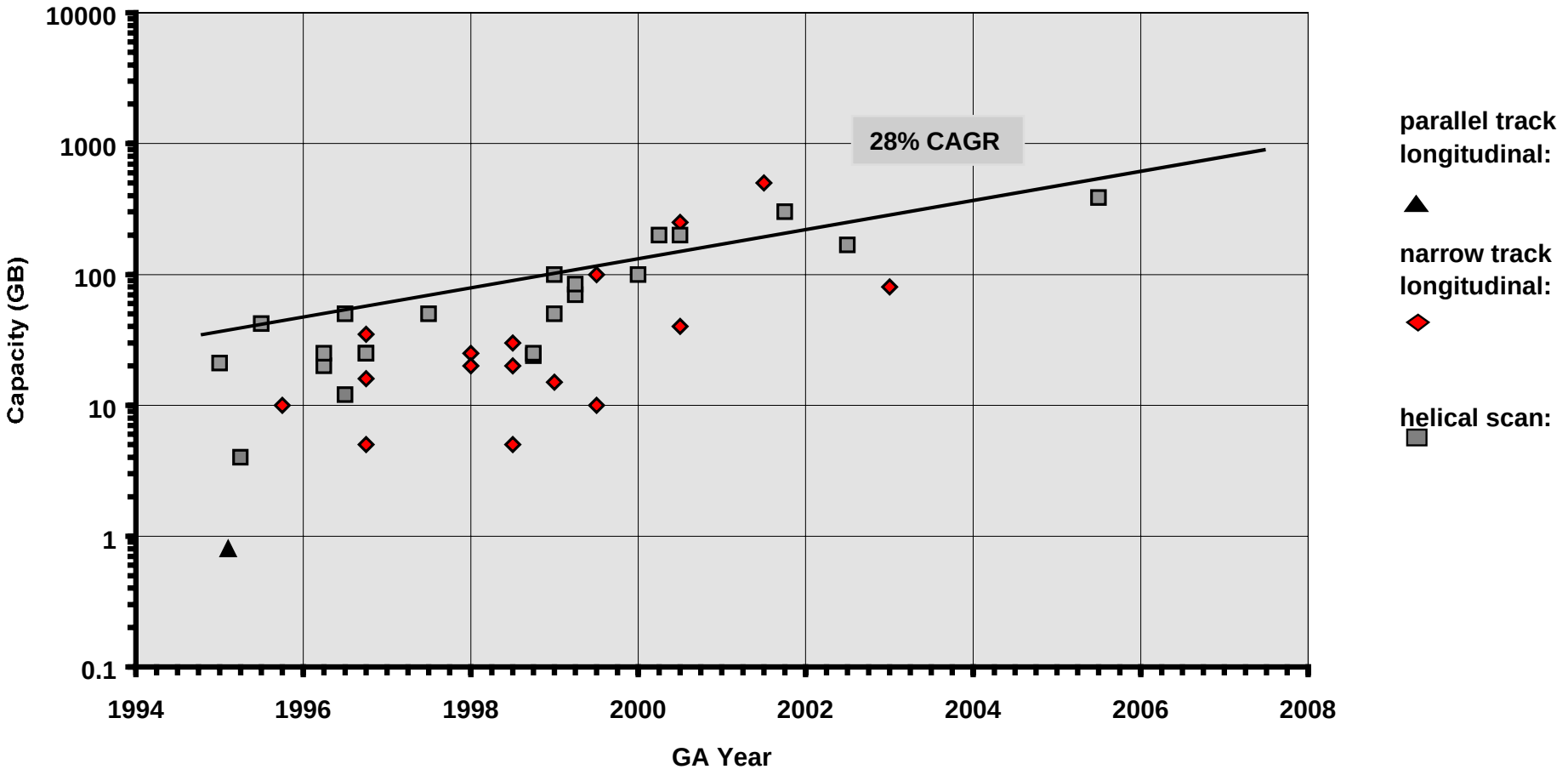
  Recent announcements - more expected

Magnetic Tape Technology Trends

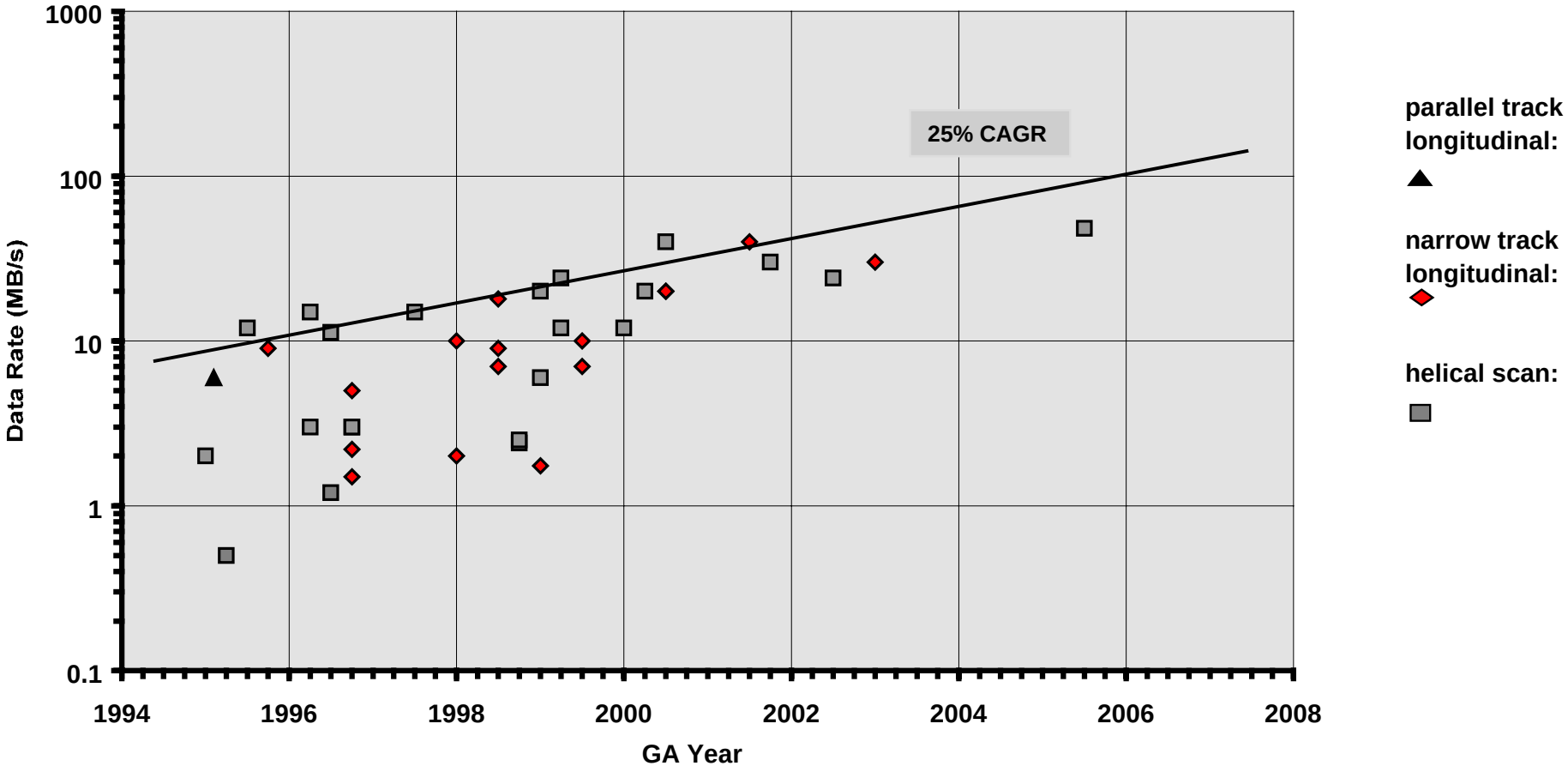
Data Rate vs Capacity



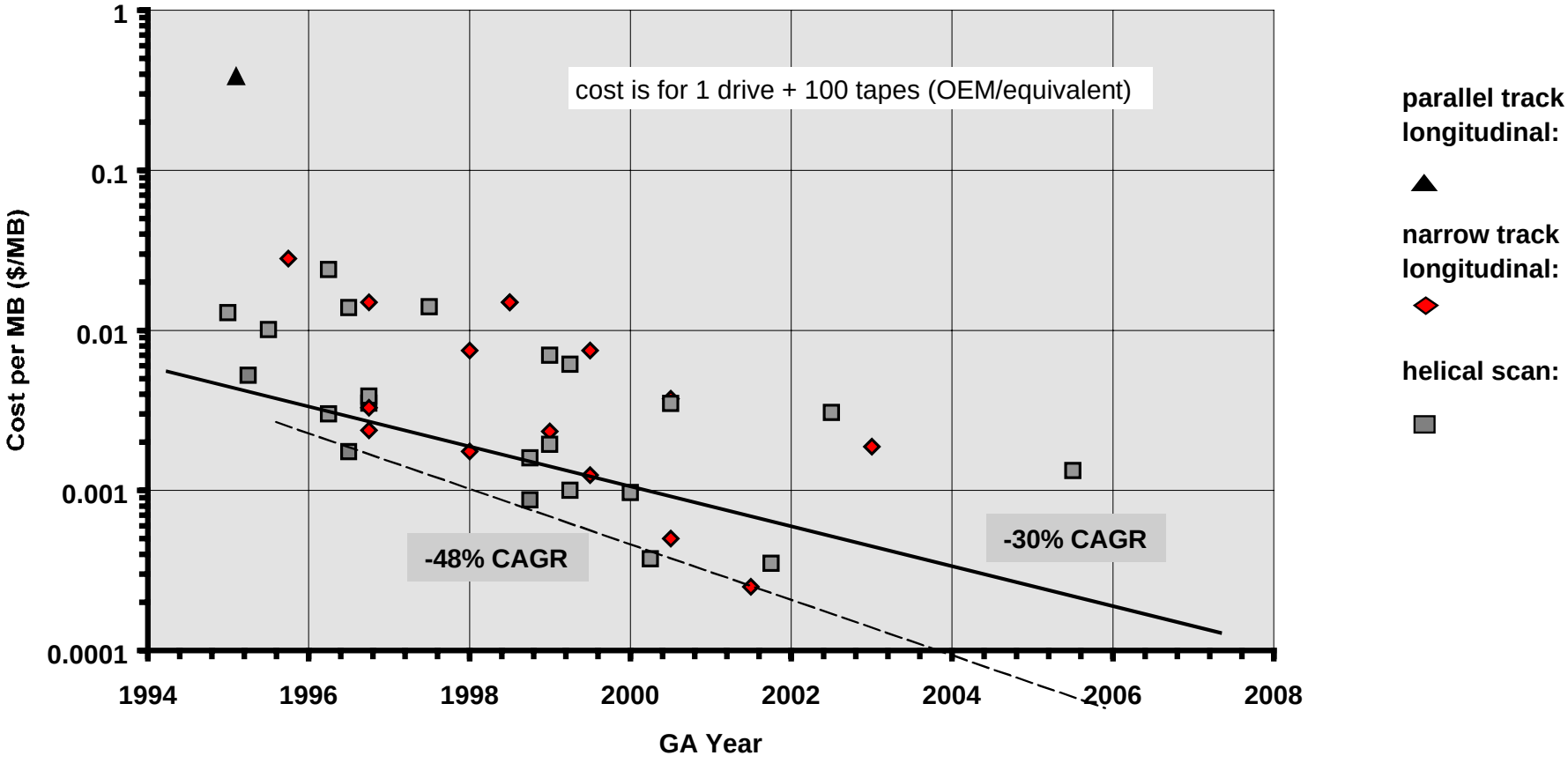
GA Year vs Capacity



GA Year vs Data Rate

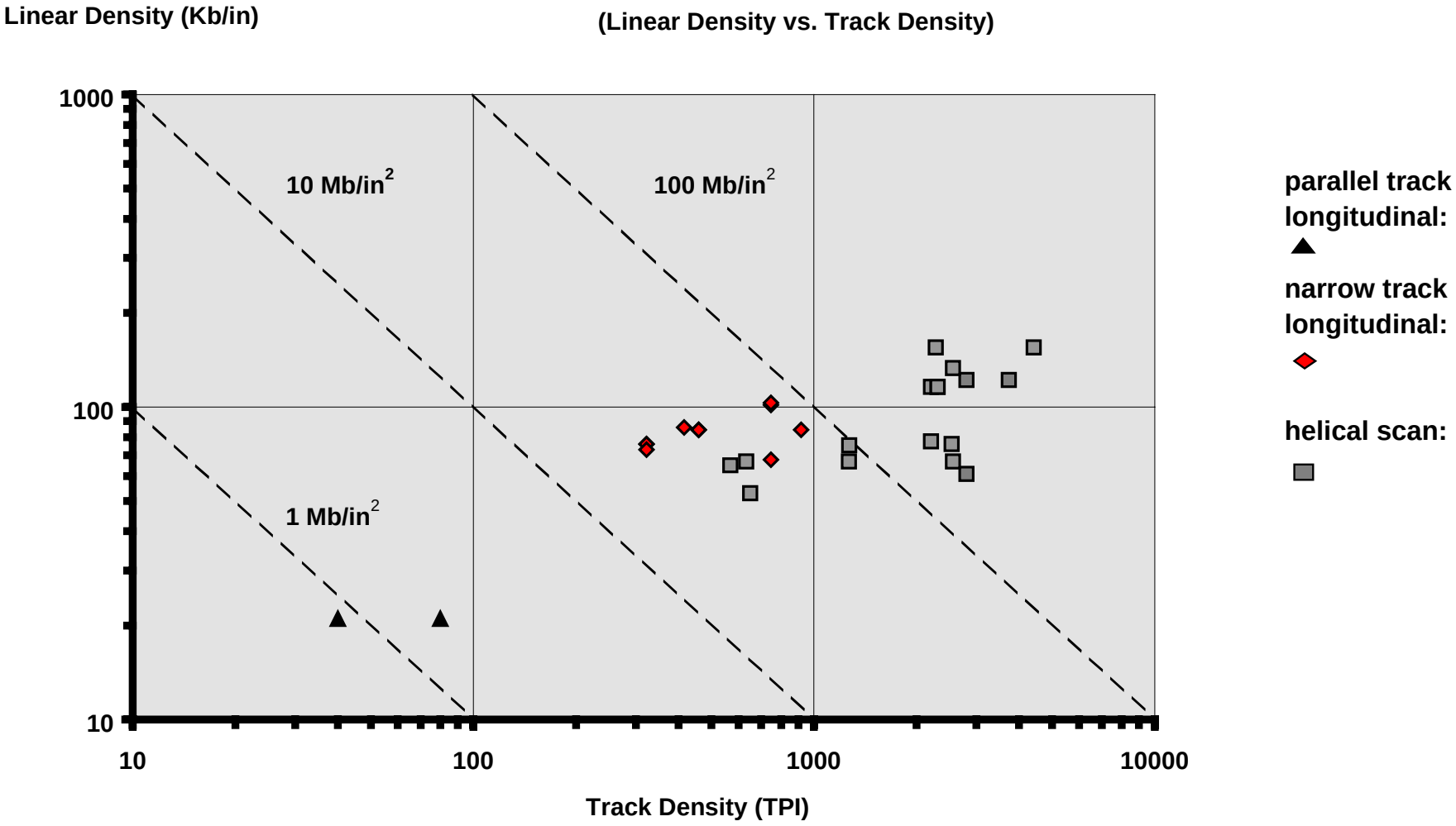


GA Year vs Cost per MB

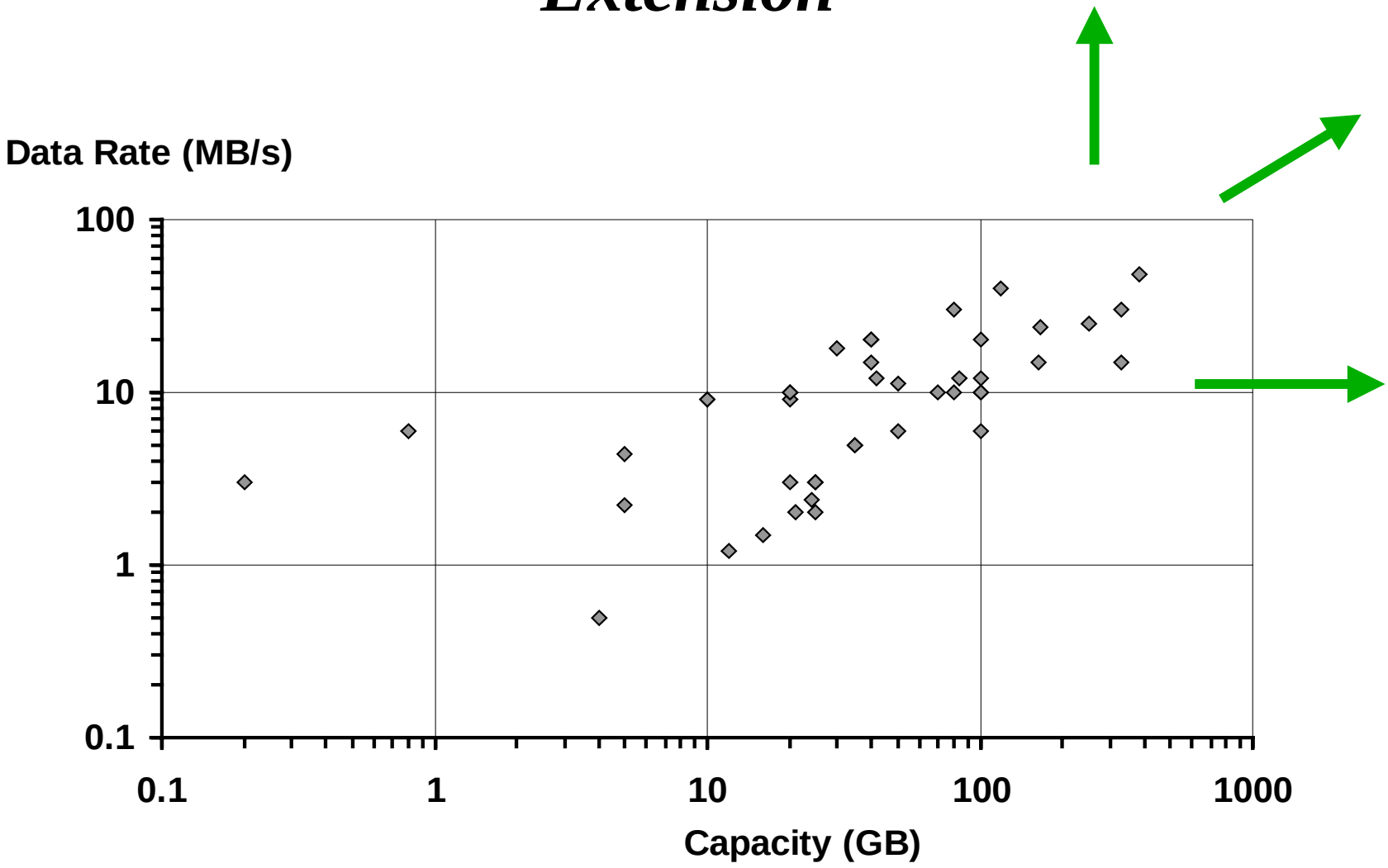


Areal Density

(Linear Density vs. Track Density)



Storage Architecture as a Tape Technology Extension



Tape Array Background

Fuctions

- Capacity multiplying
- Data rate multiplying -- cost-performance benefits
  - Emulation
  - “Super-performance”
- Fault tolerance
  - Enhanced archive data integrity
- Data reconstruction

Enabling Events -- Magnetic Tape

- Magnetic disk drive development “spin-off” technologies
  - Head, media, channel, servo, system architecture
    - MR, GMR, thin film heads
    - PRML (partial response-maximum likelihood) recording channels
    - Track following servo systems
    - ME (metal evaporated) thin film media
    - RAID (array) configurations
- Greatest opportunity for areal density growth is in track density
  - Magnetic disk track density is 4-12x tape track density
  - Media, head, servo, tape path, channels issues to overcome
- Array configurations (RAIT) as a technology extension
- Consumer product driven technologies
  - Helical scan tape from VCRs, camcorders
  - Competition from Digital Versatile Disk (DVD), recordable CD’s

Magnetic Disk Technology Trends

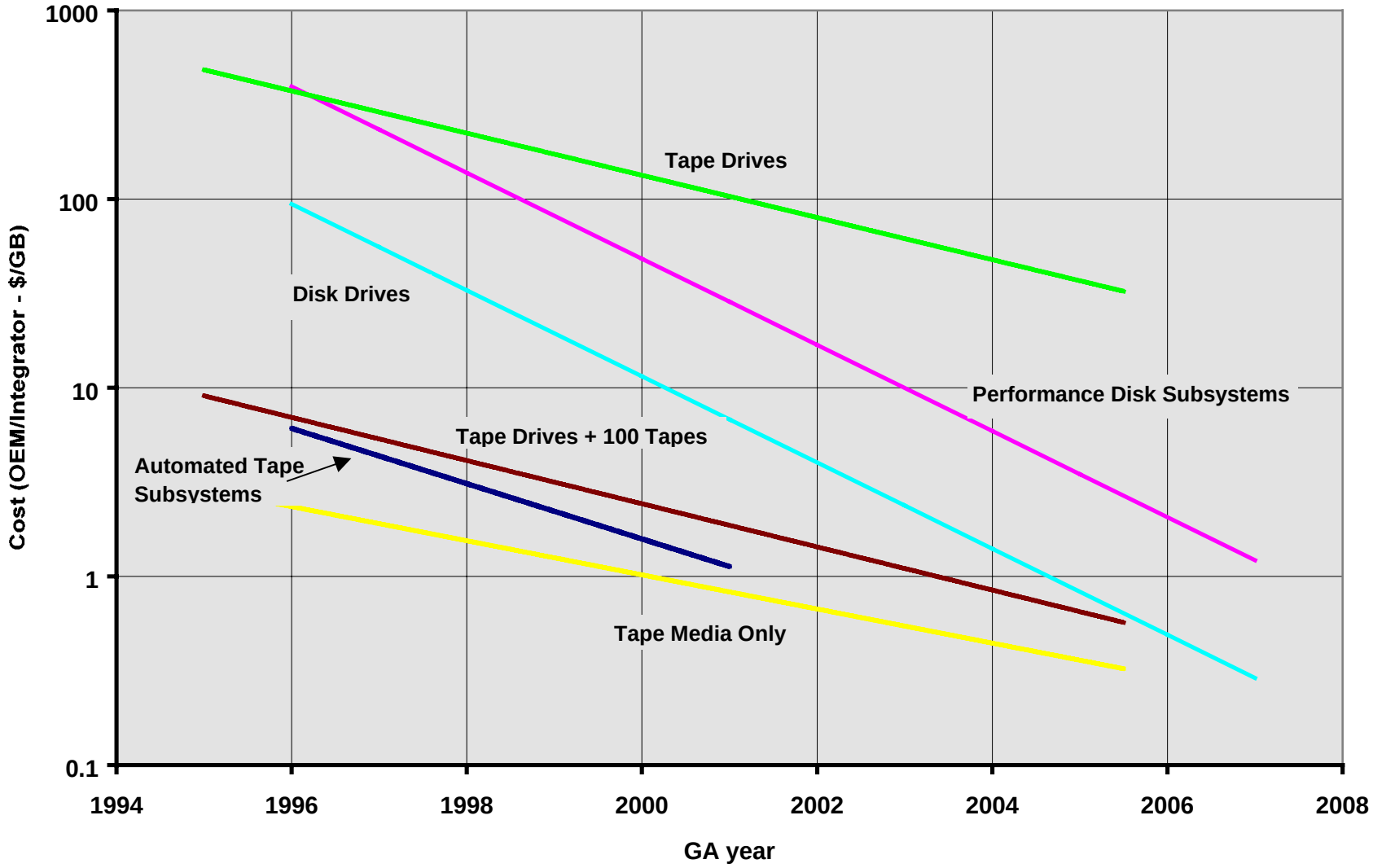
Disk Storage Issues

- Disk areal density growth continues at 60% per year and drives the storage technology infrastructure.
- Will disk run out of steam?
  - Super paramagnetic limit will cause data retention problem by year 2003 if 60% areal density growth continues
- Solutions
  - Manage data, i.e. backup to tape or cycle data
  - Patterned media or new magnetic material
  - Thermally assisted write technologies
  - Other new technologies (holographic, probe)

Optically Assisted Magnetic Recording

- “Optically assisted” magnetic write -- thermal assist
- Not “near field” optical
- Optical track following servo -- factory optical servo patterns on disk
- Maintains magnetic disk’s areal density growth path
- High track density
- First products expected within a year

Storage Subsystem Cost Trends



Storage Outlook

- Magnetic Tape -- largely maintaining $/MB advantage over other storage types
  - Disk subsystems = 6-30x performance tape subsystem costs
  - Arrays -- data rate performance, archive enhancing fault tolerance, data reconstruction
- Magnetic Disk -- technology leader, aggressive growth
  - “Optical assisted” magnetic technology extension
  - Watch for removable media product advances
- Optical Disk -- costs down, performance up
  - Watch for DVD, CD-R driven products
  - Watch for “near field” (e.g. solid immersion lens) progress
- Holographic -- potential storage efficiency but...significant inventions required
- Optical Tape -- no drive, media products; limited development

Removable Media Archiving

Data Archive

- Media lifetimes
  - Environmental control
  - Data migration
  - Role of data storage fault tolerance (e.g. array architecture)
  - Management
- Technology lifetimes typically < media lifetimes
- Lifetimes are economics driven
  - Magnetic tape has lifetime potential > 30 years

Recommended Storage Conditions for Magnetic Tape

September 1997 by National Technology Alliance

"With moderate care, most magnetic tapes used for digital data storage will last for 10 years. With special storage and handling [see chart] **digital magnetic tape formats can reliably store information for 30 years or more**. The longevity of magnetic tapes can be significantly increased by storing the tapes at lower temperatures and humidities"

ref: http://www.nml.org

Agency/Researcher	Year	Temperature	Relative Humidity
Cuddihy	1982	65° F ± 3° F (18°C ± 2° C)	40% ± 5%
SMPTE (RP-103)	1982	70° F ± 4° F (21°C ± 2° C)	50% ± 20%
NARA	1990	65° F ± 3° F (18° C ± 2° C)	40% ± 5%
SMPTE (RP-103) Operating [1]	1995	63° F to 77° F (17° C to 25° C)	30% to 70% ± 5%
Storage <10 years [1] (medium term)		59° F to 73° F ± 4° F (15° C to 23° C ± 2° C)	40% to 55% ± 5%
Storage >10 years (long term)		63° F ± 4° F (17° C ± 2° C)	30% ± 5%
ANSI/AES Medium Term	1996	73° F (max) ± 4° F [3] (23° C (max) ± 2° C)	20% to 50% ± 10% [4]
Extended Term [2]		68° F (max) ± 4° F [3] (20° C (max) ± 2° C) - or - 59° F (max) ± 4° F [3] (15° C (max) ± 2° C) - or - 50° F (max) ± 4° F [3] (10° C (max) ± 2° C)	20% to 30% ± 5% [4] 20% to 40% ± 5% [4] 20% to 50% ± 5% [4]

[1] For operating or storage less than 10 years, the center point for temperature and humidity can be selected anywhere within the allowable range, but the variation cannot exceed the allowable range.
[2] For ANSI/AES Extended-Term Storage, a lower storage temperature can compensate for a higher humidity to provide the same life expectancy and a wider relative humidity range can be tolerated. For this reason, several relative humidity-temperature combinations can be used for an extended-term storage environment as specified above.
[3] Storage of tape below 8° C (46° F) may cause lubricant separation from the tape binder. The manufacturer should be consulted to determine if this is a potential problem.
[4] The moisture content of the tape to be stored shall not be greater than the tape in moisture equilibrium with these relative humidities.

Archive Strategy

Goal:

- **Archive 1 exabyte of data (10^{18} bytes)**
- **Capture 1 petabyte/day (10^{15} bytes)**

Scale of the Problem -- 1 Petabyte/day - Today

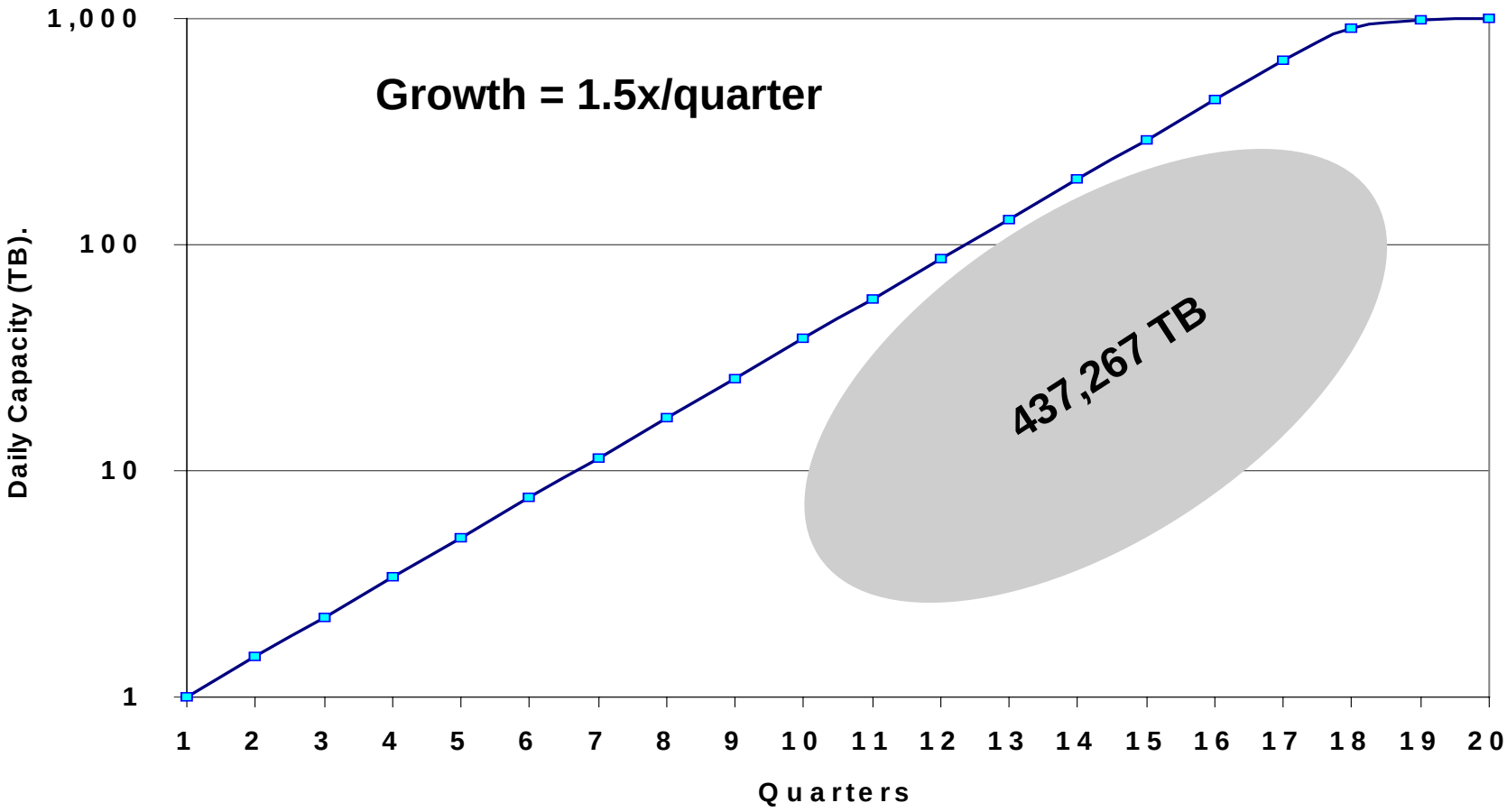
RedWood drives, Powerhorn libraries

Capacity (TB)	
Daily	1,000
Quarterly	91,250
Yearly	365,000
Cartridges (50GB)	
Daily	20,000
Quarterly	1,825,000
Yearly	7,300,000
Silos (5600 Slots)	
Daily	4.0
Quarterly	326
Yearly	1,304
Floor Space (Sq.Ft)	
Daily	576
Quarterly	46,929
Yearly	187,776
Floor Space	
Daily	Lg. Room
Quarterly	FootBall field
Yearly	4 Acres

Req'd BandWidth;		
GB/Hr.;	8 Hr	125,000
	16Hr	62,500
	24Hr	41,667
MB/Sec.;	8hr	34,722
	16Hr	17,361
	24Hr	11,574
Transports (11.1 MB/s)		
	8Hr	3,129
	16Hr	1,565
	24Hr	1,043
Power		
kwH	8 Hr	17,522
	16Hr	17,528
	24Hr	17,522
Power		
Cost	8 Hr	$998.78
	16Hr	$999.10
	24Hr	$998.78

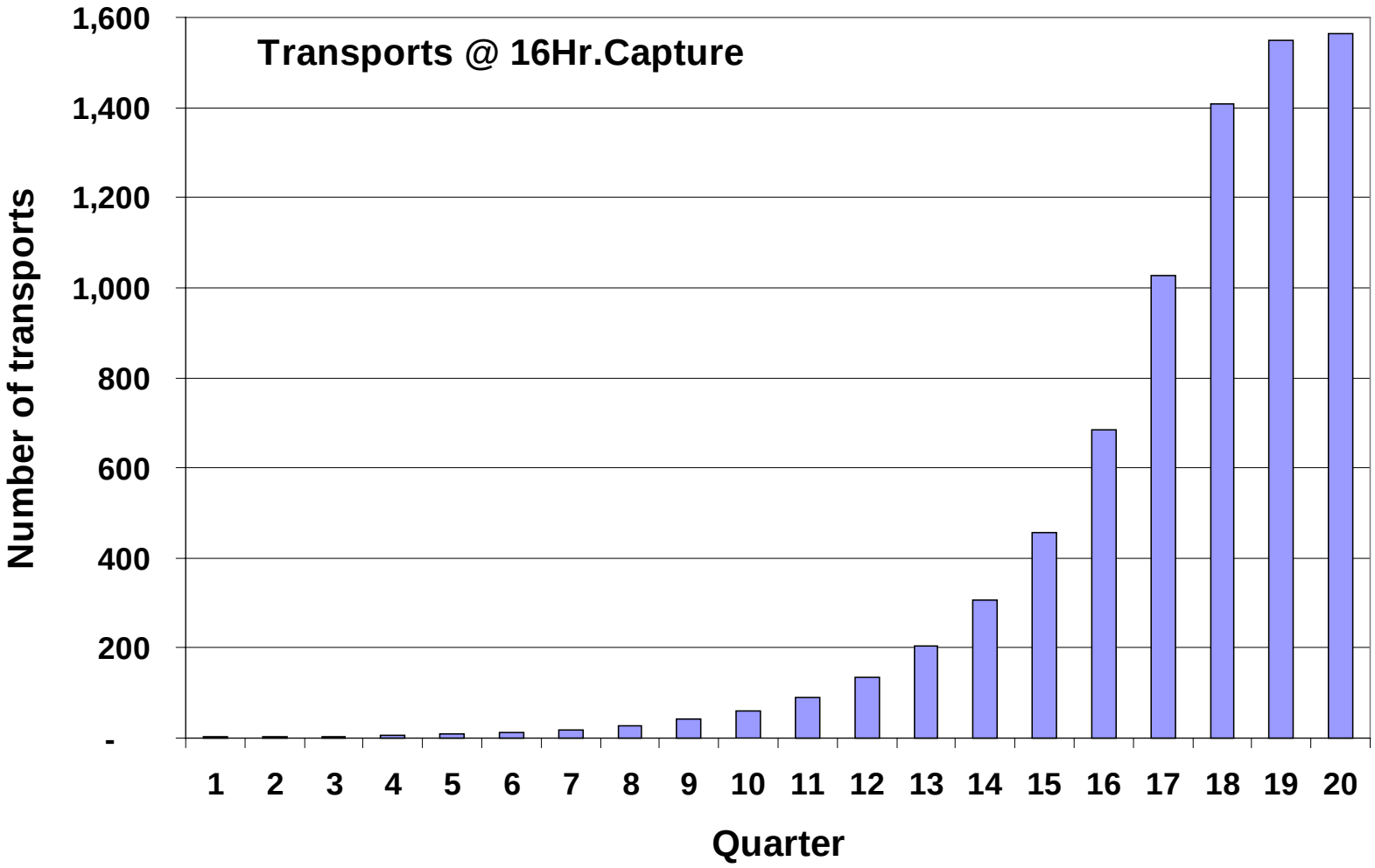
Data Capture Rate Ramp

to 1 petabyte/day

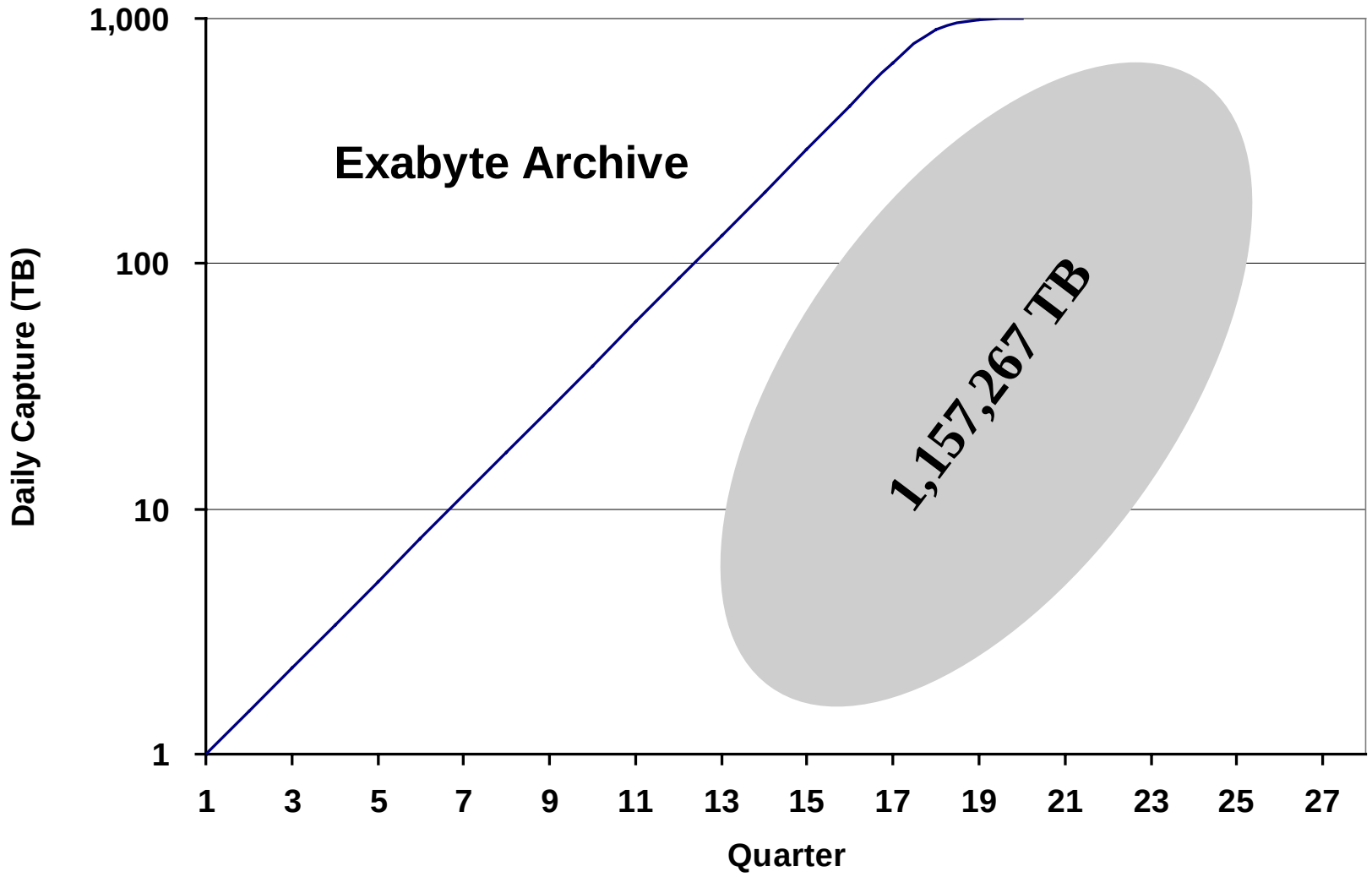


1 Petabyte/day - Today's Technology

Transports

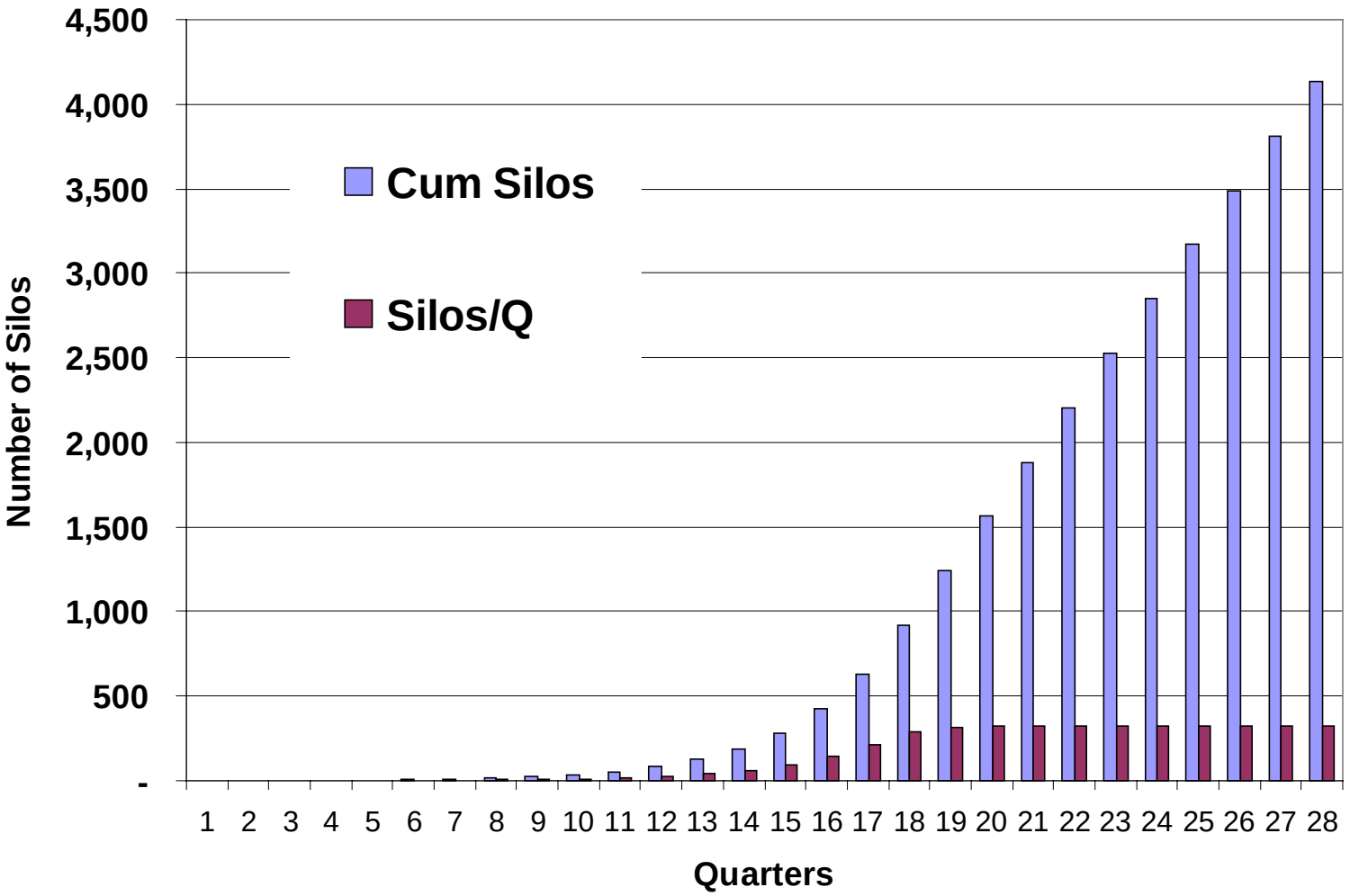


Data Capture Profile



Exabyte Archive - Today's Technology

Libraries

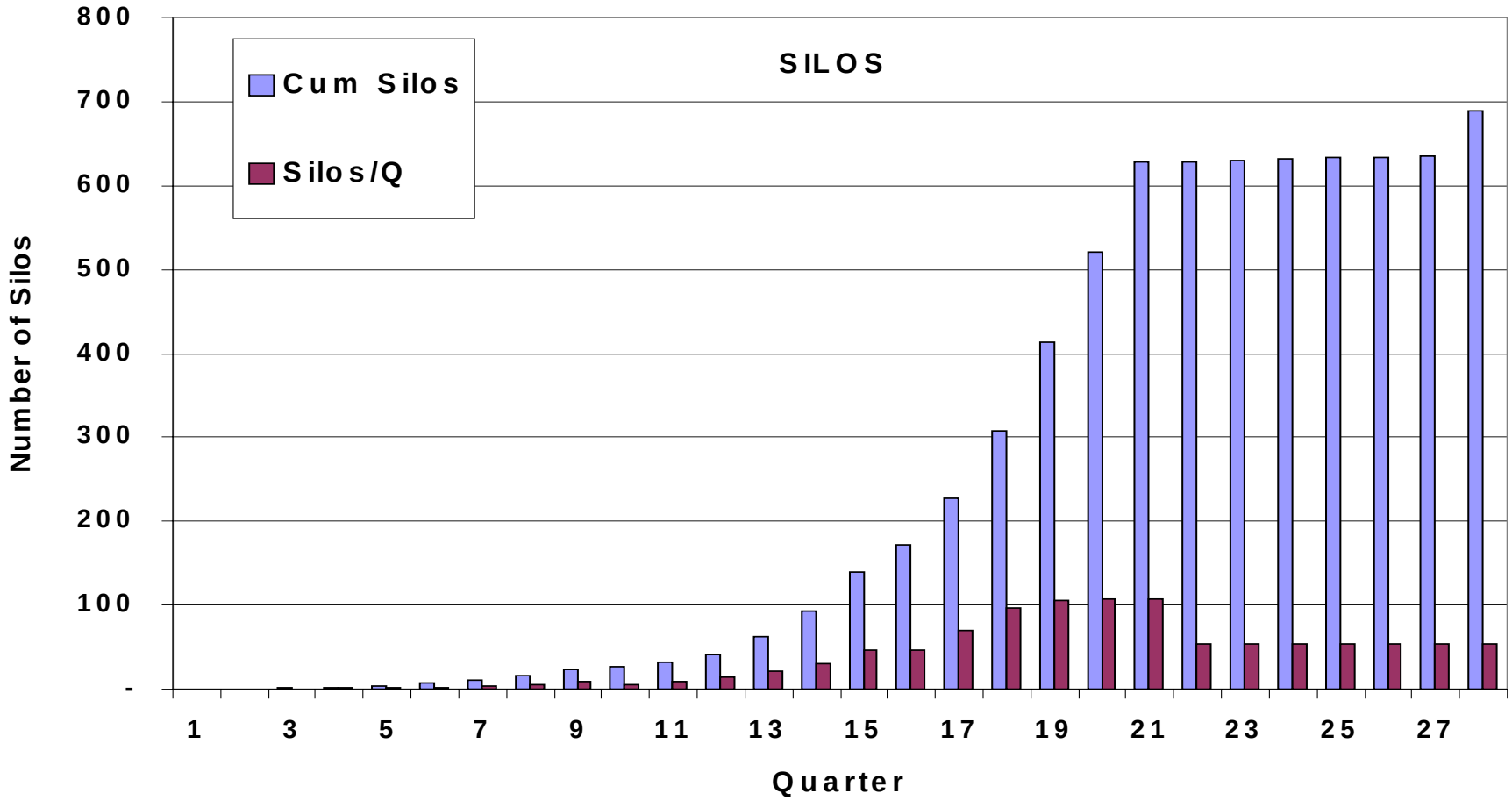


Projected Trend Tape Product Family

	Capacity	Data Rate	GA
RedWood	50 GB	11.1 MB/s	Now
PT1	100	25	3Q99
PT2	150	40	1Q01
PT3	250	50	3Q02
PT4	400	70	1Q04

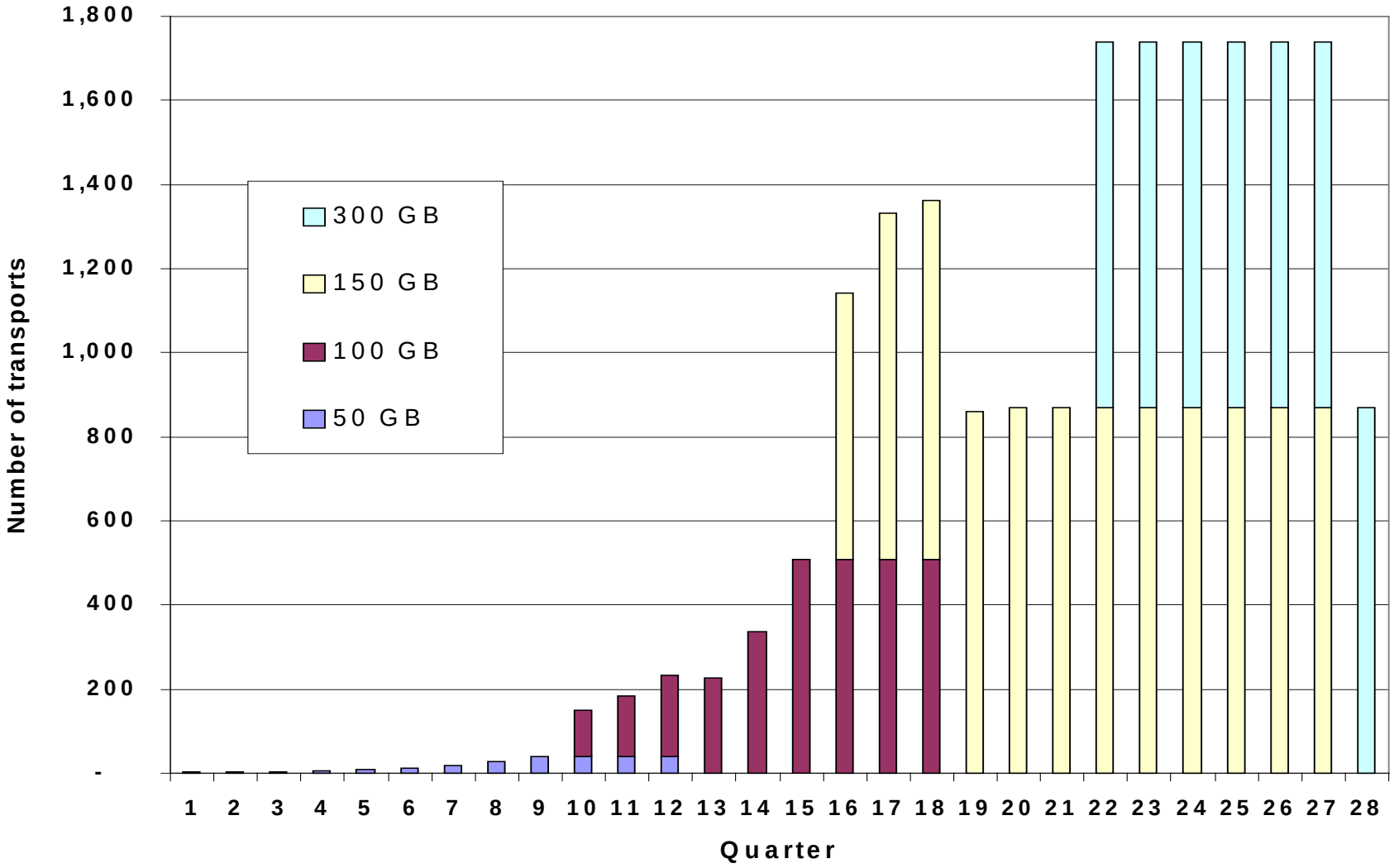
Exabyte Archive - Trend Technology

Libraries



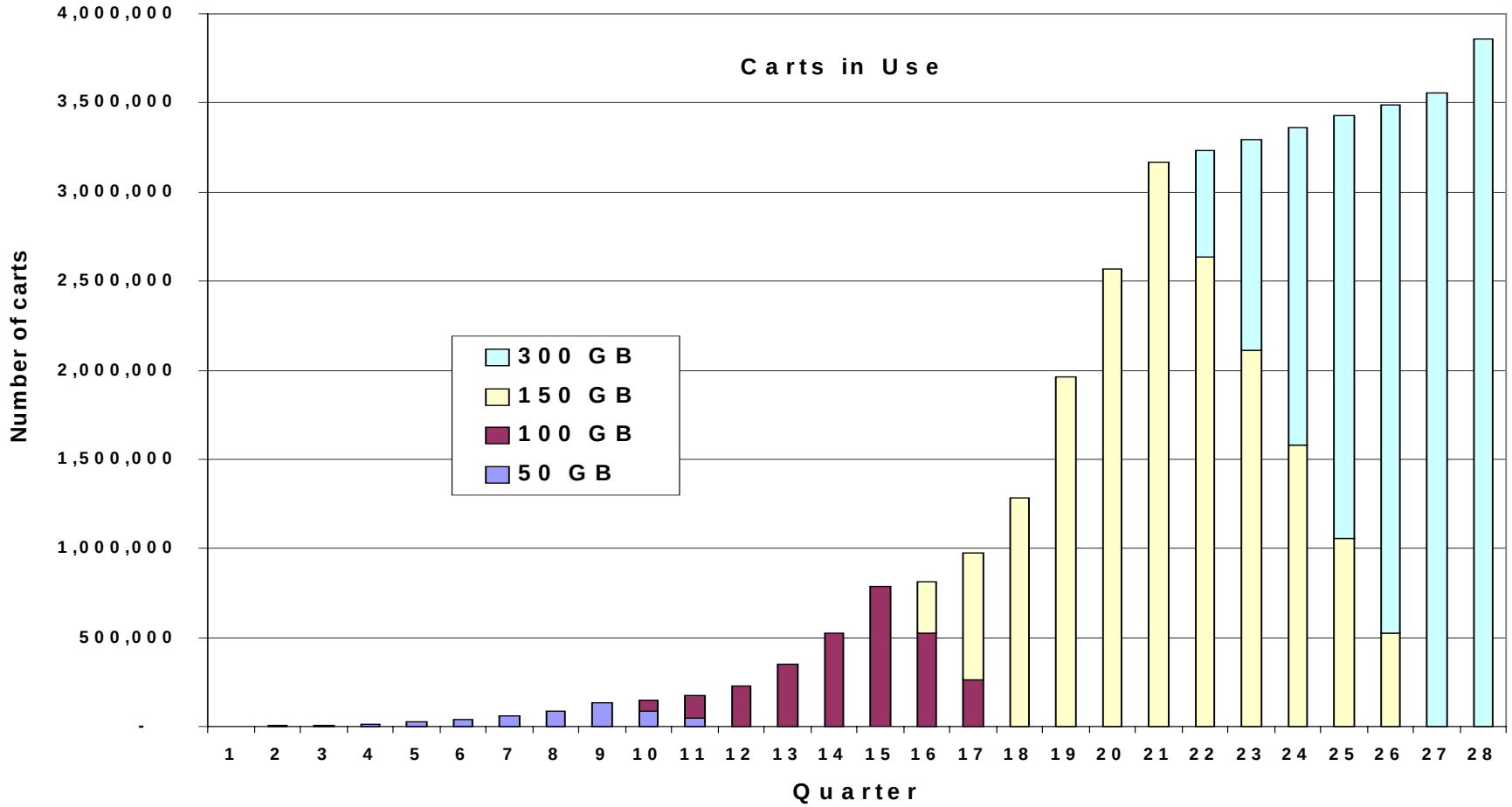
Exabyte Archive - Trend Technology

Transports



Exabyte Archive - Trend Technology

Media



Summary

Capacity 7 Years (TB)	1,157,267
GB/Hr.	62,500
MB/Sec.	17,361
Transports Capture	435
Capture Silos	27
Daily Carts (300 GB)	3334
Total Carts (300 GB)	3,857,557
Total Silos	689
Total Sq.Ft. (Silos)	99,216
	2 Acres

Conclusion

- Magnetic tape based data archive can meet exabyte capacity, petabyte/day rate goals
  - Offers cost advantage over other storage types
  - Media is “medium to long term” archive capable
  - Tape technology will support continual performance enhancements

- Questions remain for a comprehensive archive model
  - Transport-Library ratios
  - Recall activity
  - Usage patterns
  - Data retirement
  - Technology adoption