THIC Inc. The Premier Advanced Recording Technology Forum

Magnetic Tape as the Mass Storage Medium

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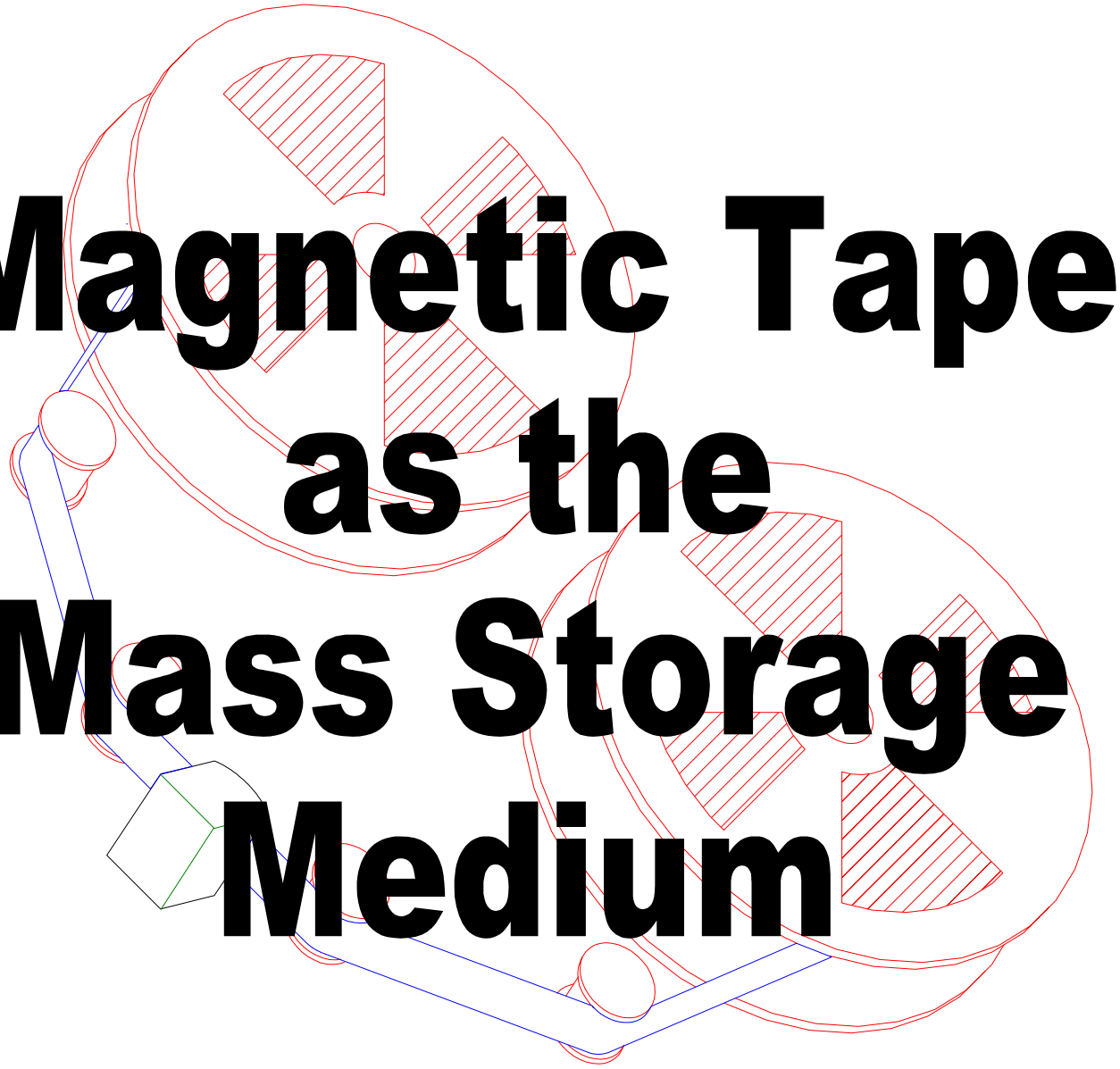
Englewood CO 80112
on June 27, 2000



Magnetic Tape as the Mass Storage Medium

Outline

- Density/Capacity
- Cost
- Performance (Data Rate)
- Key Technologies
- Summary

Mass-Store Metrics

1. Magnetic Disk Drive Cost/bit
2. Total Volumetric Density
   - Not Areal Density
   - Archival Storage Density
3. Thru-put

Density Migration

Today

100 kbpi

750 tpi

3000 lpi

75 Mb/in^2

28 Gb/in^3

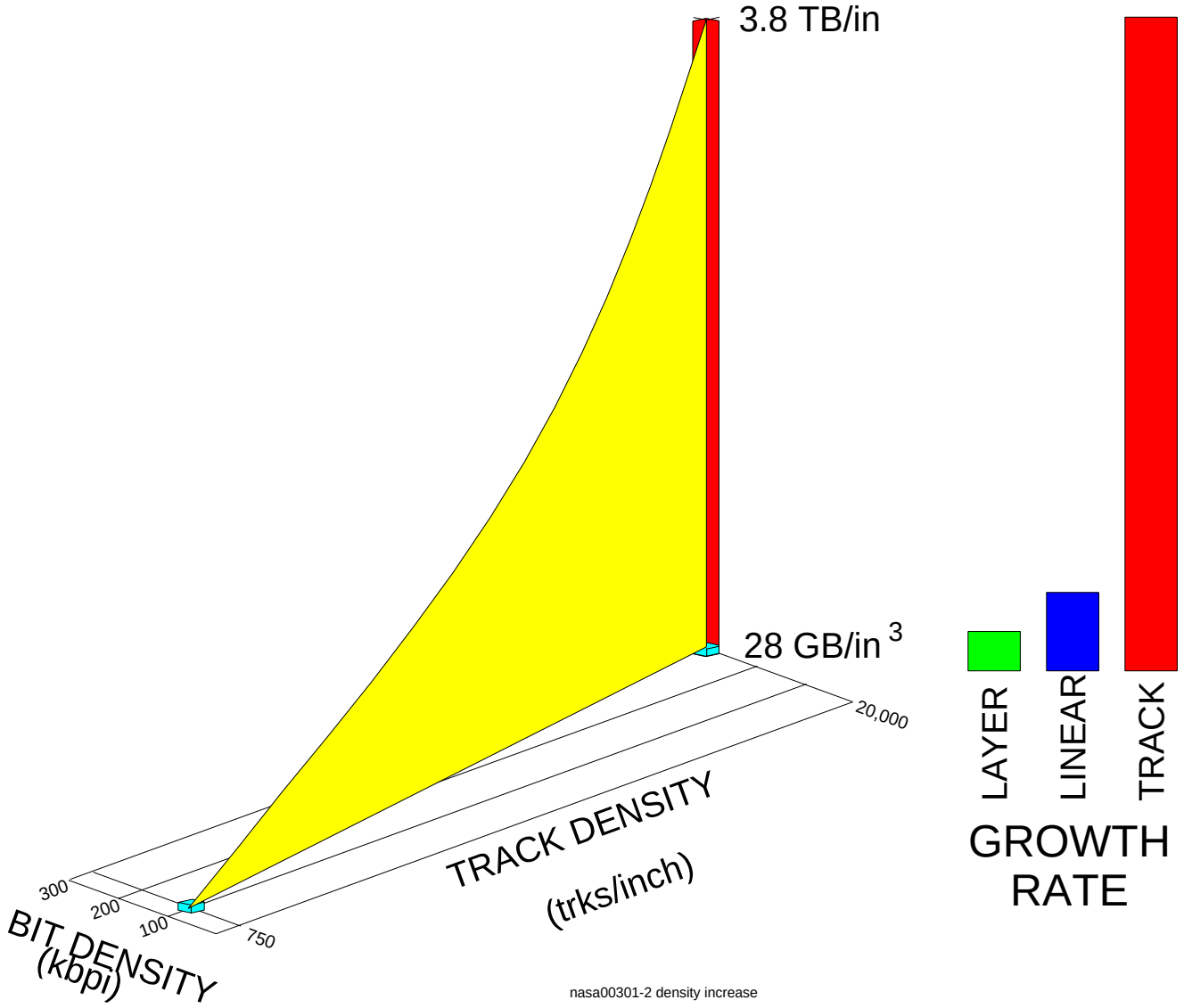
Density Migration

Today		ATS
100 kbpi	→	300 kbpi
750 tpi	→	20 ktpi
3000 lpi	→	3000 lpi
75 Mb/in^2	→	6.0 Gb/in^3
28 Gb/in^3	→	3.8 TB/in^3
		(2 b/um^3)

Technology Objectives

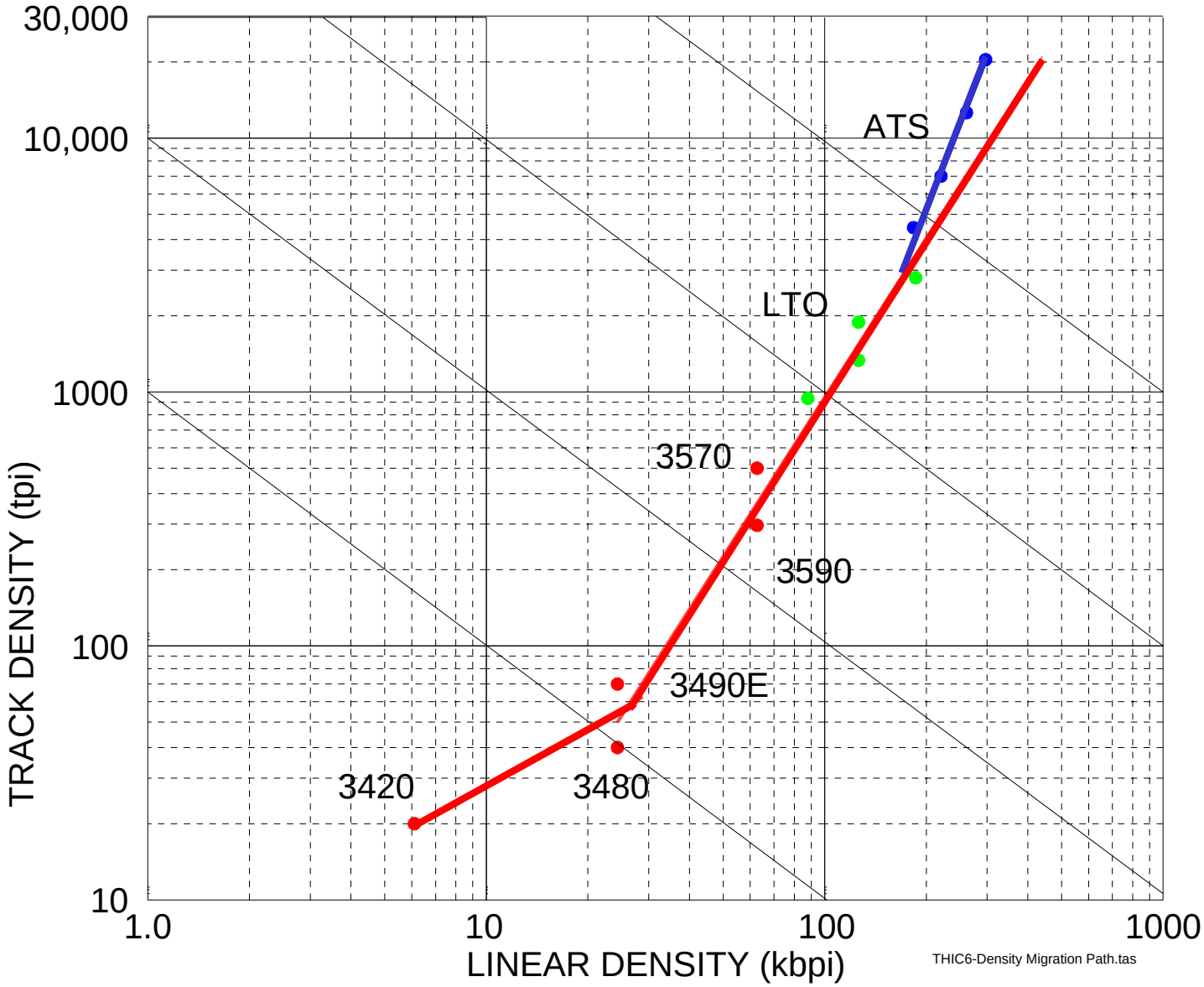
track density:	20,000	tpi	787	tpmm
linear density:	300,000	bpi	11,811	bpmm
areal density:	**6.00**	**Gb/in^2**	**9.30**	**Mb/mm^2**
layer density:	5,000	lpi	197	lpmm
vol density:	**3.80**	**TB/in^3**	**229**	**MB/mm^3**
LTO Cartridge:				
tape width:	0.50	inches	12.70	mm
tape length:	5512	feet	1,680	m
total area:	230	ft^2	21.34	m^2
volume:	4.71	in^3	77,183	mm^3
user efficiency:	70%		70%	
CAPACITY:	**12.53**	**TB**	**12.53**	**TB**
				THIC-0627.XLS

Data Density Growth

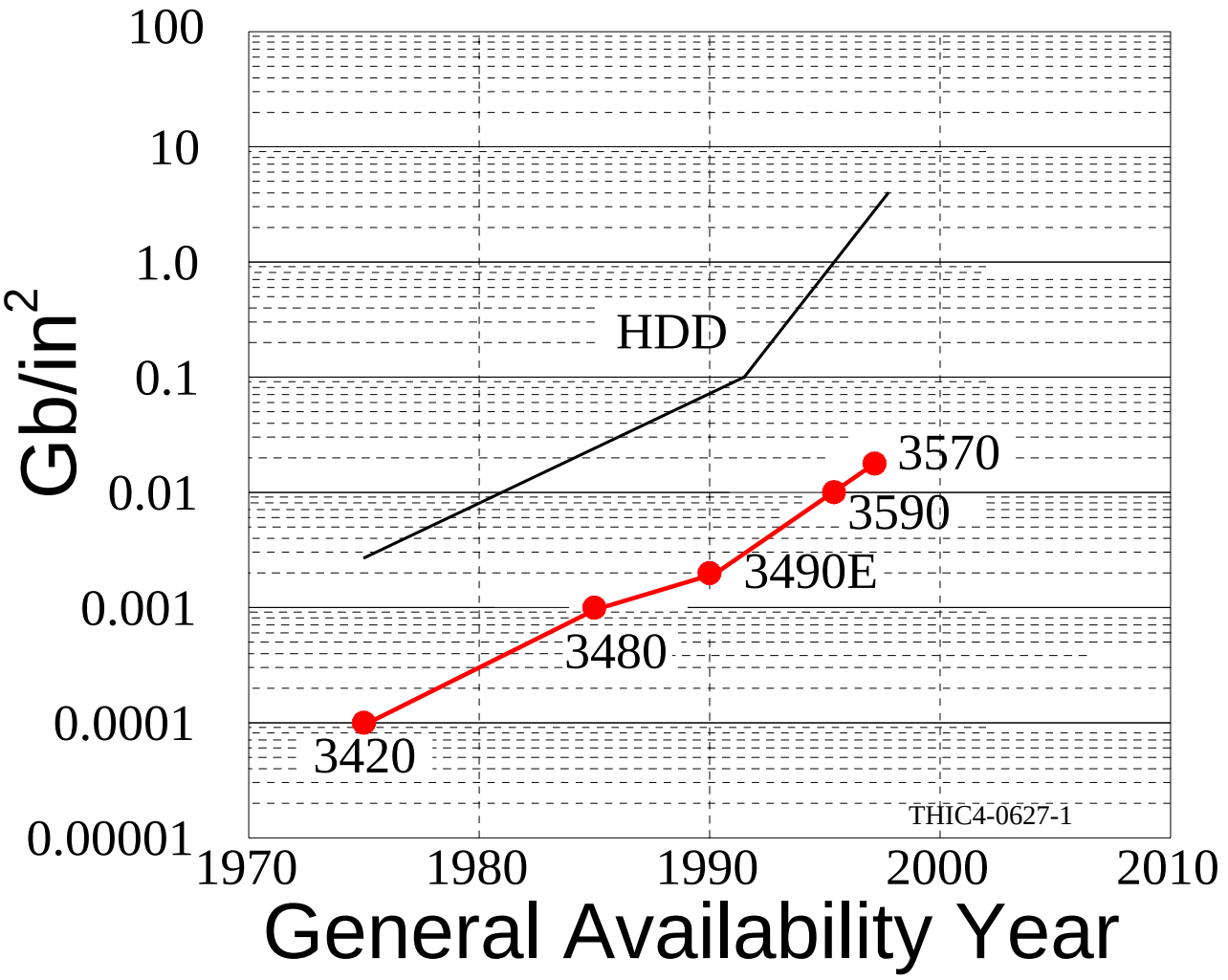


nasa00301-2 density increase

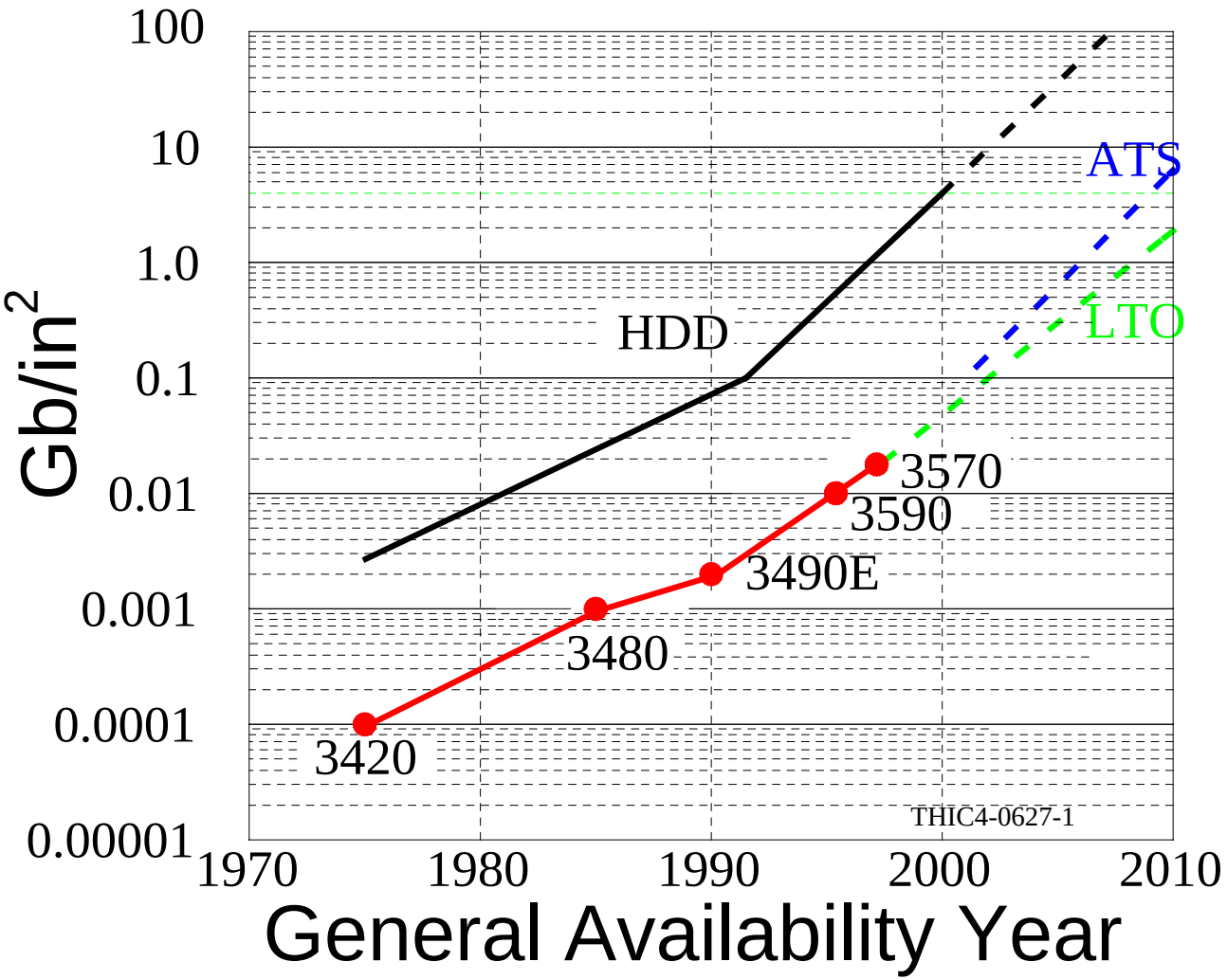
Tape Density Migration



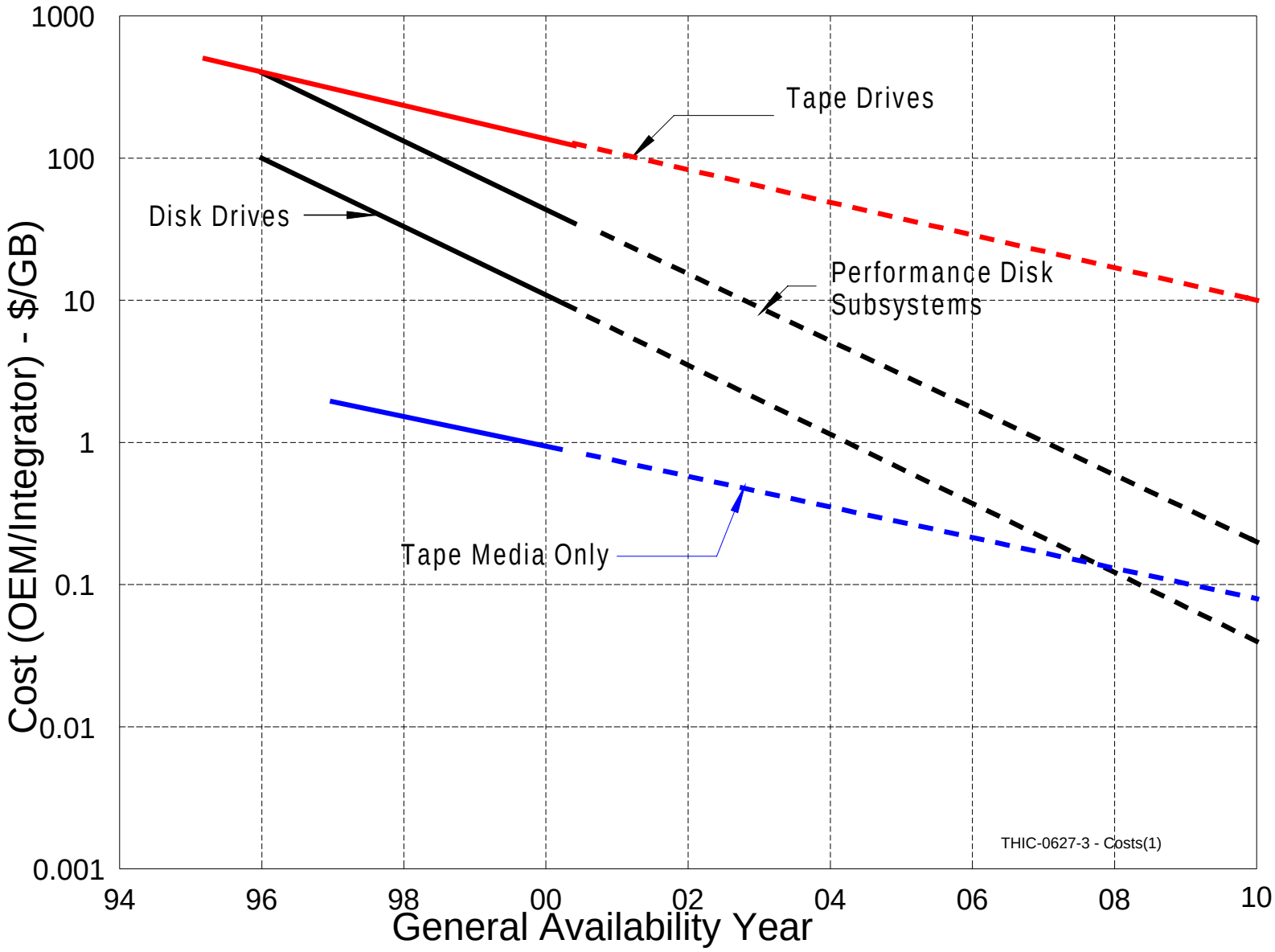
Areal Density Trends



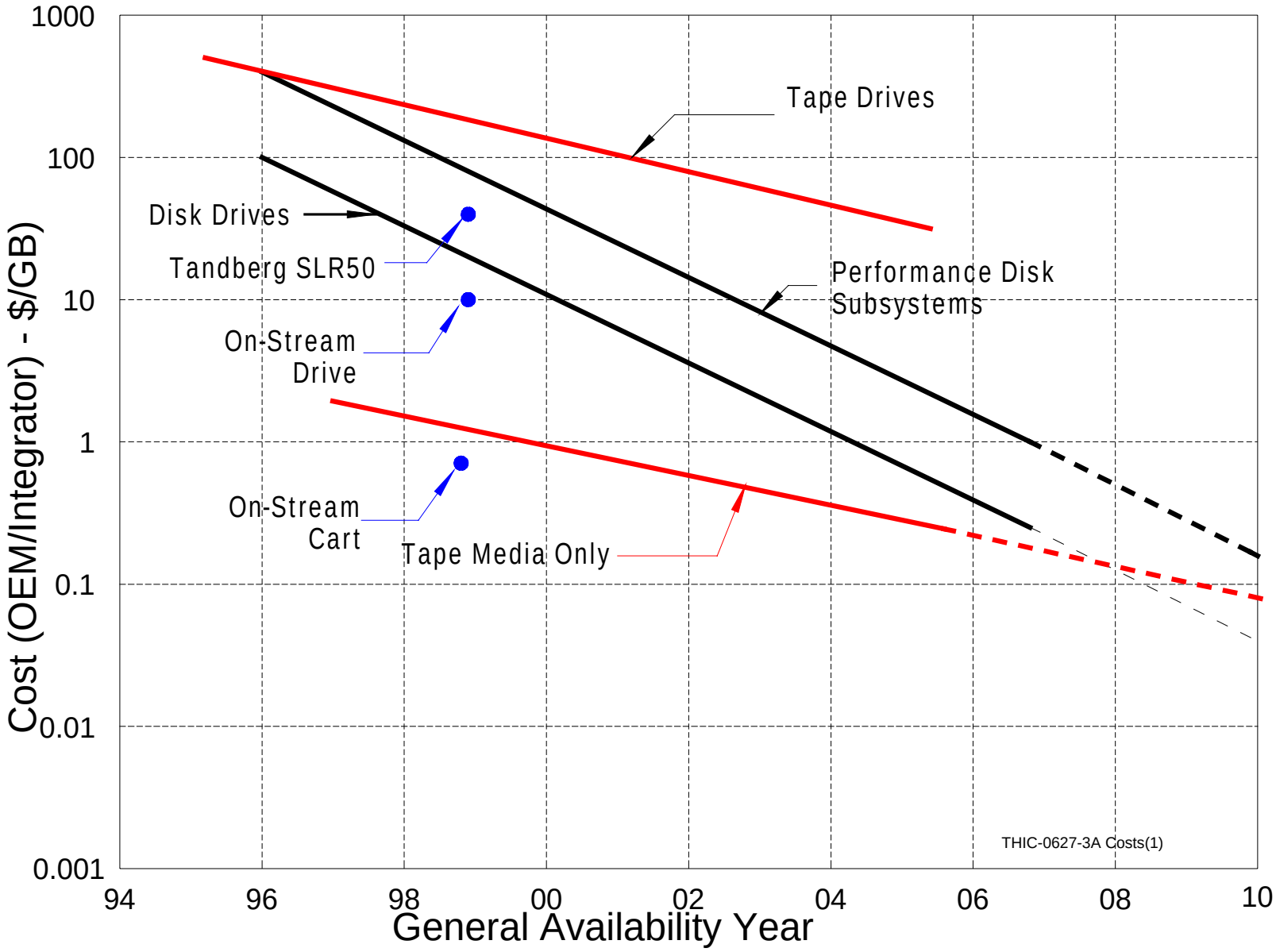
Areal Density Trends



Cost Trends


1000
100
10
1
0.1
0.01
0.001
Cost (OEM/Integrator) - $/GB)
Tape Drives
Disk Drives
Performance Disk Subsystems
Tape Media Only
THIC-0627-3 - Costs(1)
94
96
98
00
02
04
06
08
10
General Availability Year

Cost Trends


1000
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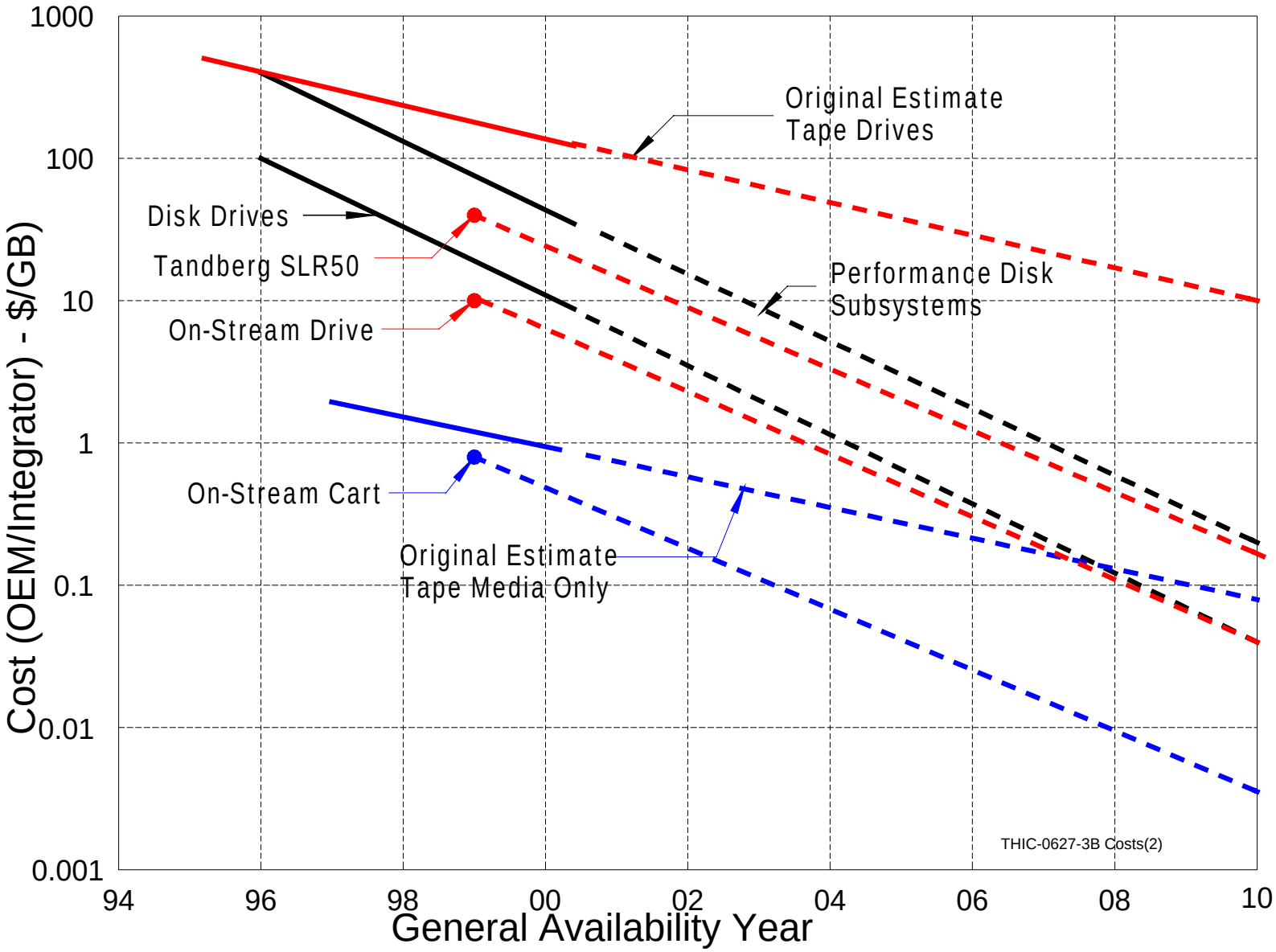
Cost (OEM/Integrator) - $/GB)
94
96
98
00
02
04
06
08
10
General Availability Year
Tape Drives
Disk Drives
Tandberg SLR50
Performance Disk Subsystems
On-Stream Drive
On-Stream Cart
Tape Media Only
THIC-0627-3A Costs(1)

Cost Trends


1000
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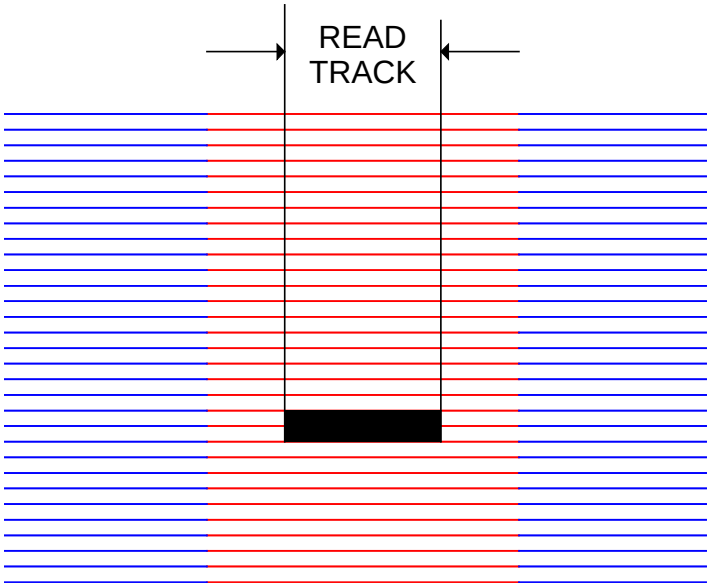
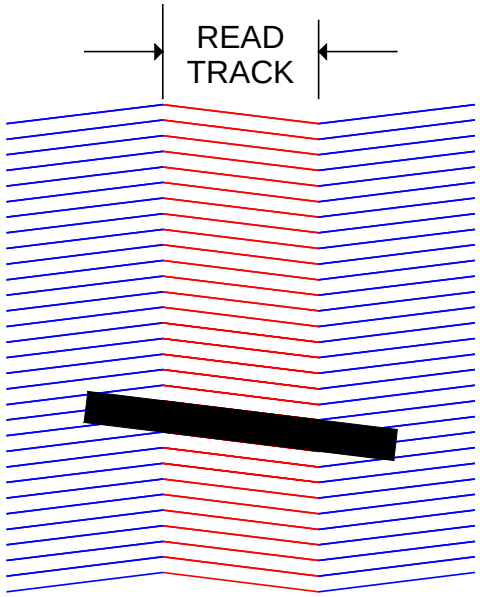
0.1
0.01
0.001
Cost (OEM/Integrator) - $/GB)
94
96
98
00
02
04
06
08
10
General Availability Year
Original Estimate
Tape Drives
Disk Drives
Tandberg SLR50
On-Stream Drive
Performance Disk
Subsystems
On-Stream Cart
Original Estimate
Tape Media Only
THIC-0627-3B Costs(2)

Recording Methods

LINEAR RECORDING



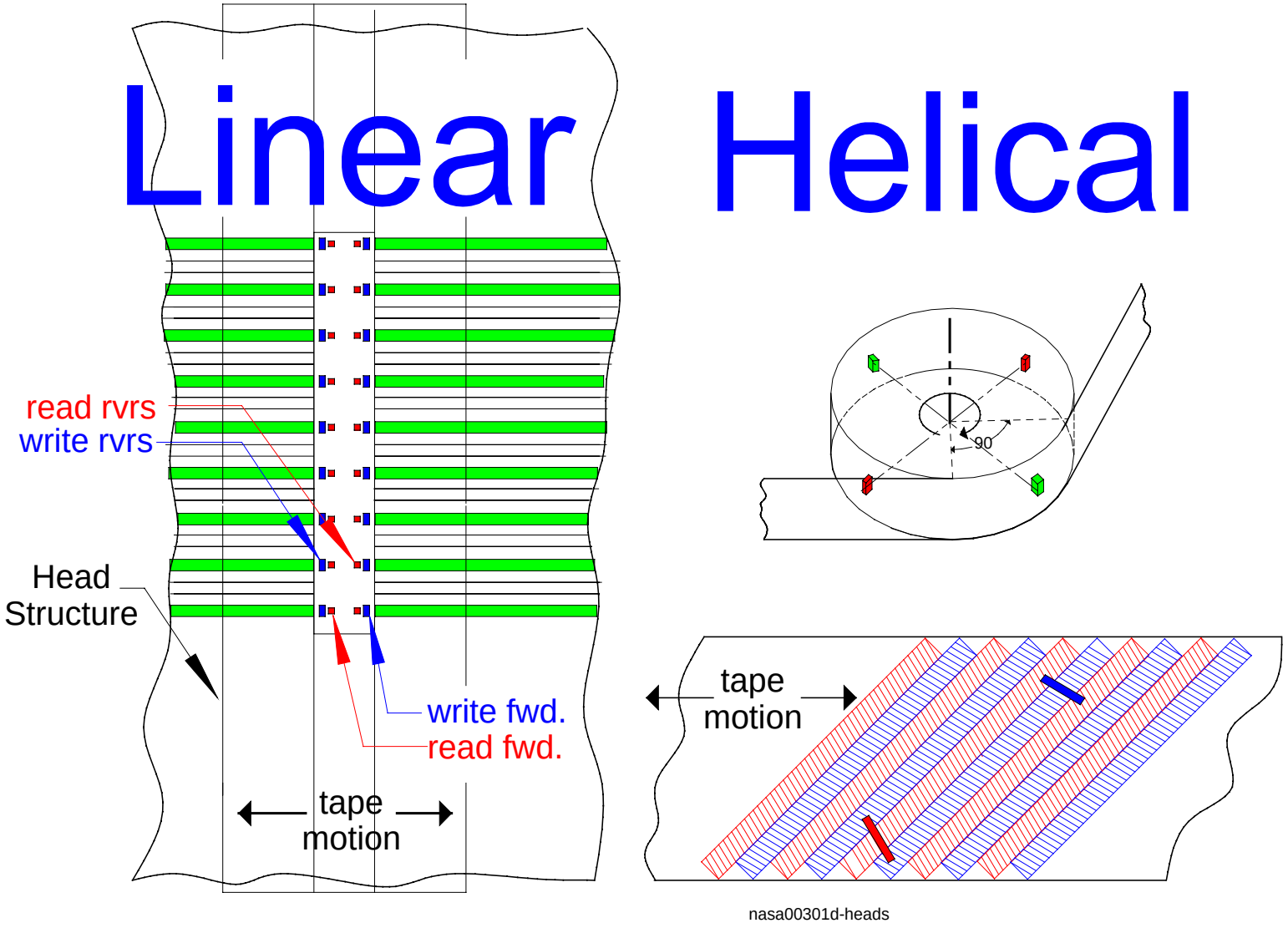
AZIMUTH RECORDING



FOR THE SAME READ TRACK WIDTH & PERFORMANCE, AZIMUTH RECORDING CURRENTLY HAS A 2:1 ADVANTAGE IN TRACK DENSITY. AS THE TRACK DENSITY INCREASES FASTER THAN THE LINEAR DENSITY AND THE TAPE SUBSTRATE DIMENSIONAL STABILITY IMPROVES THAT ADVANTAGE WILL SHRINK TOWARDS A 1:1 RATIO.

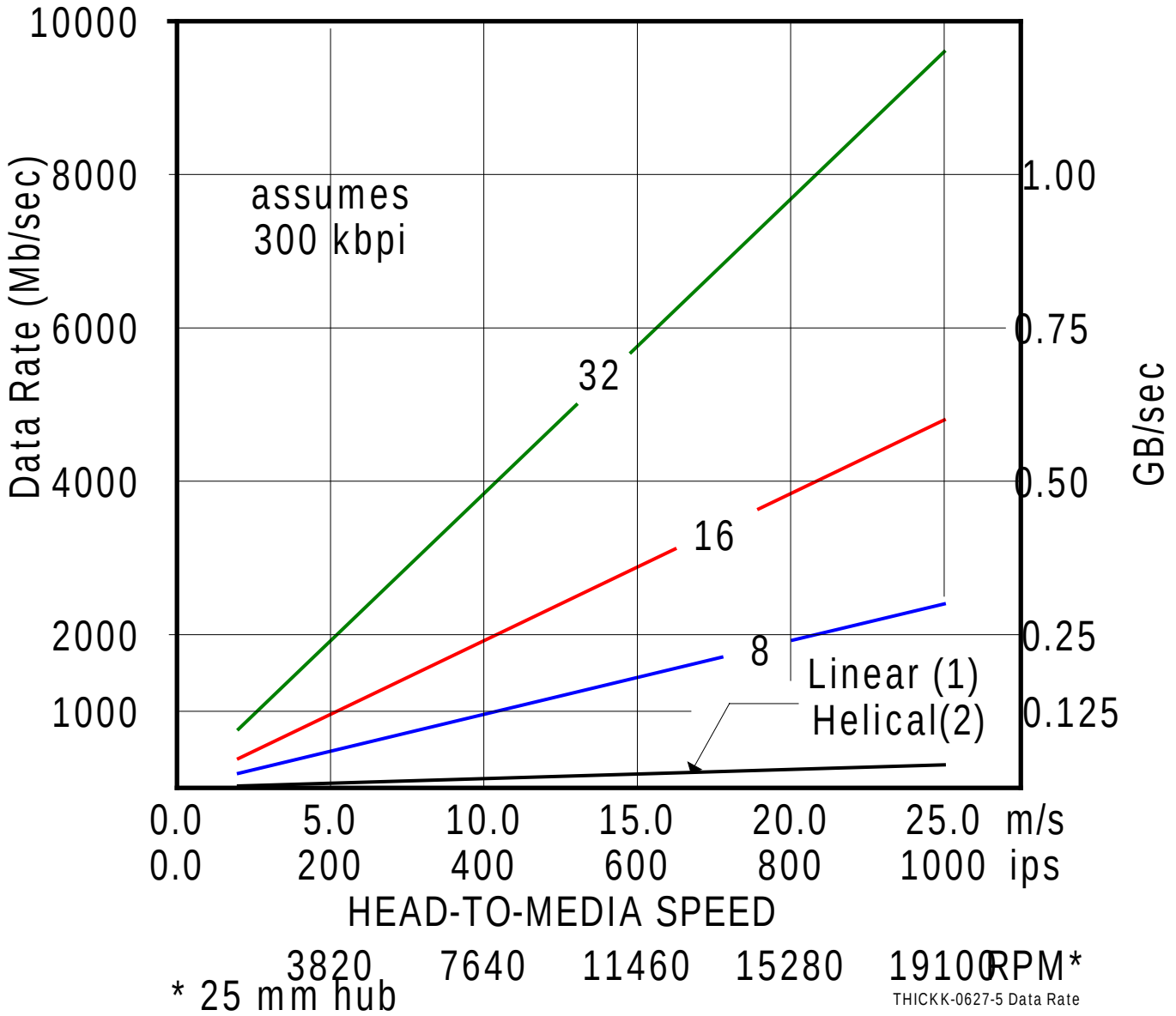
THIC-0627-4 Recording Method

Recording Methods



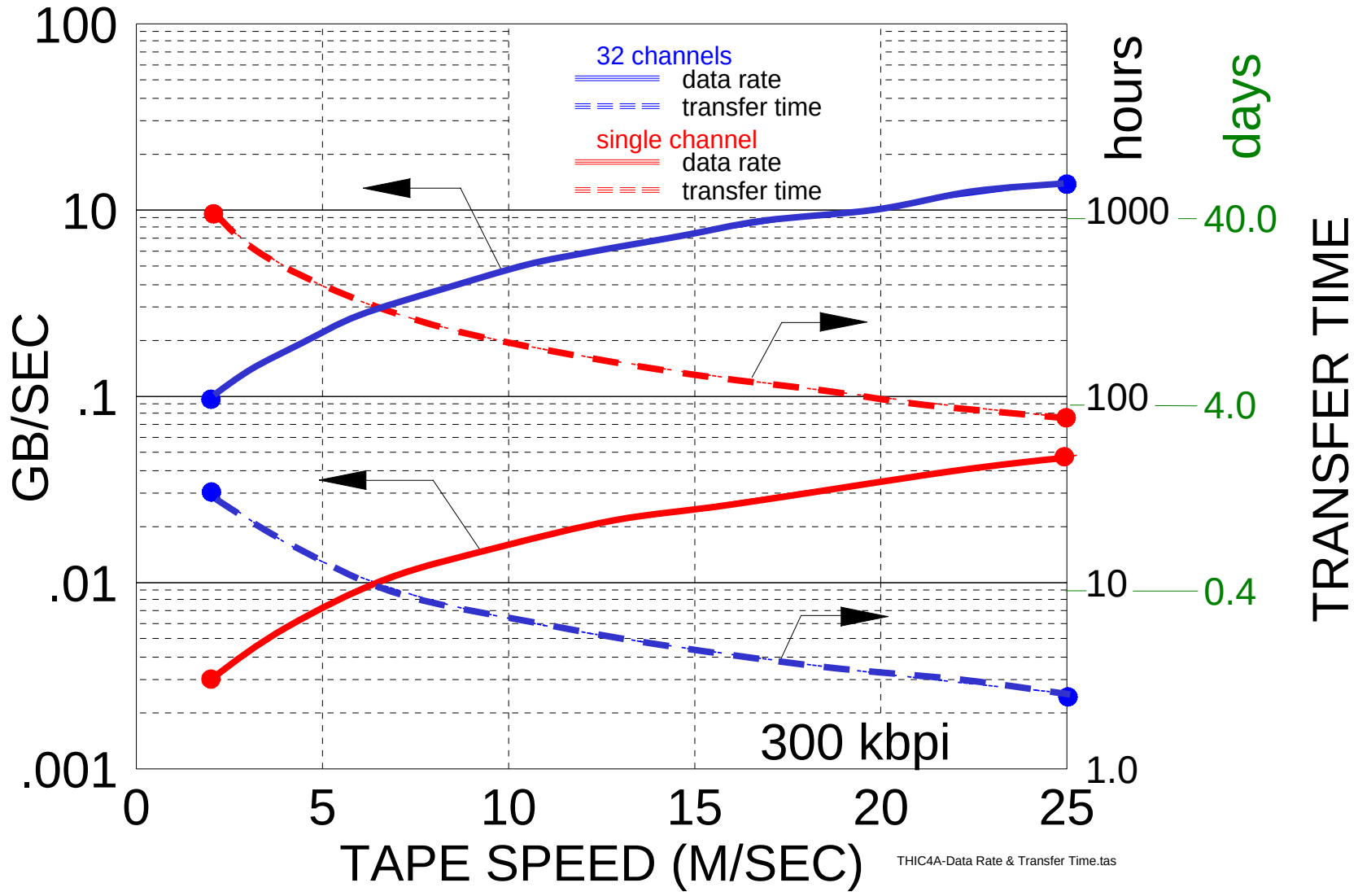
nasa00301d-heads

Data Rate vs. Speed and No. of Elements

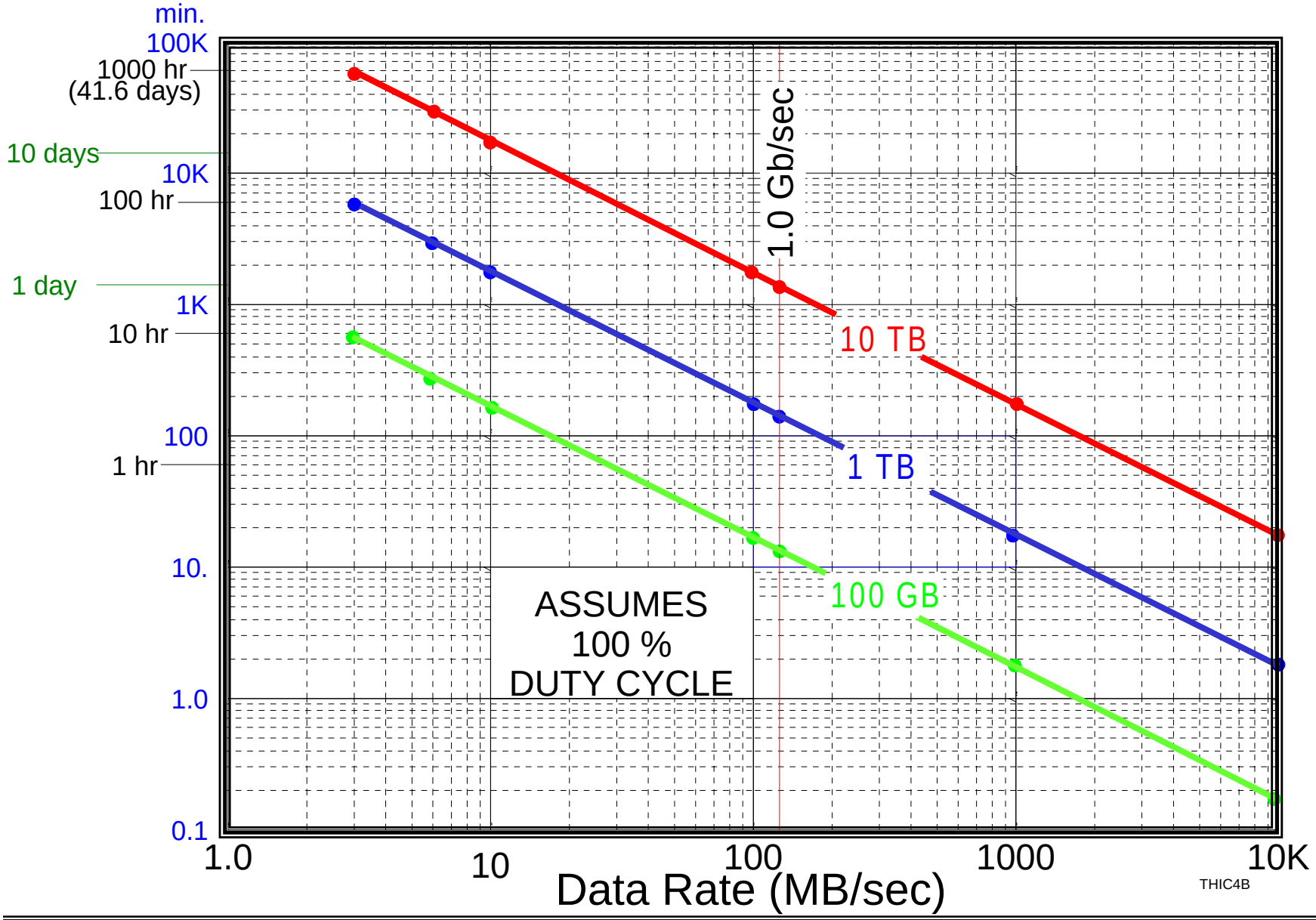


THICKK-0627-5 Data Rate

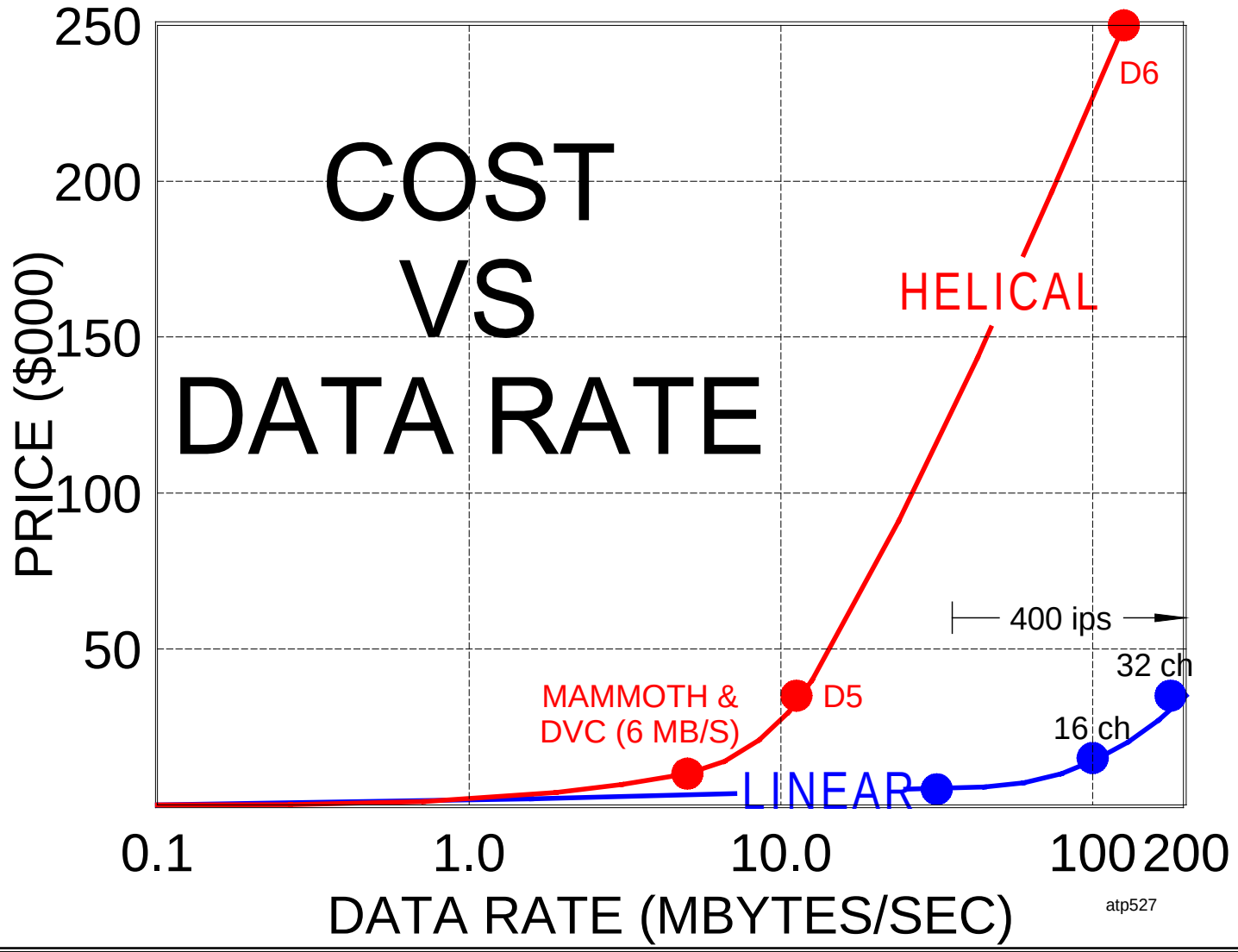
Data Rate & Transfer Time for 10 TB of Data



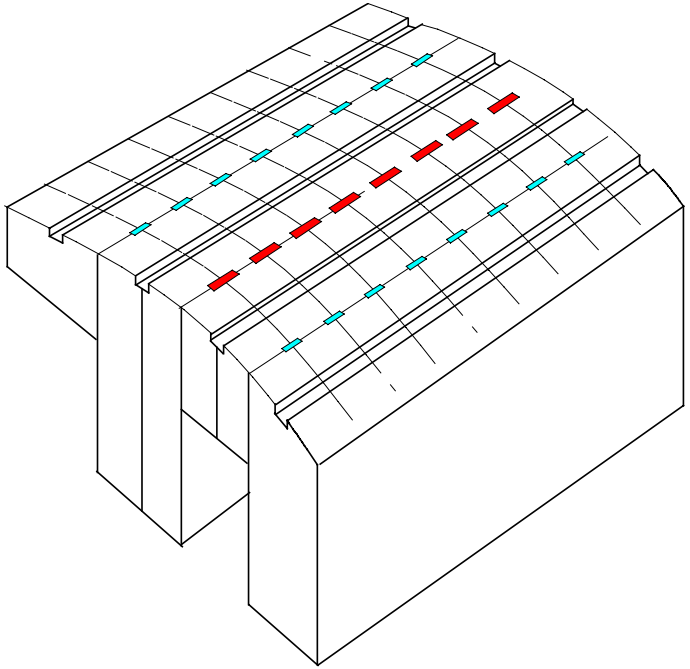
Transfer Time vs. Data Rate

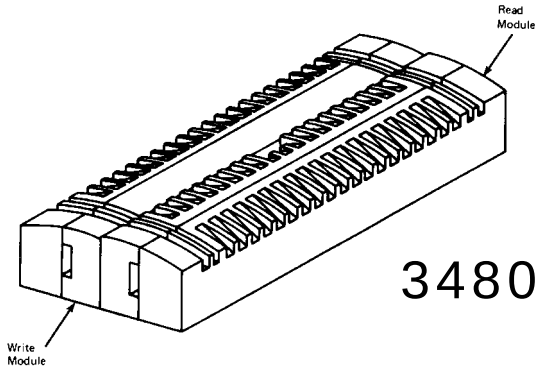


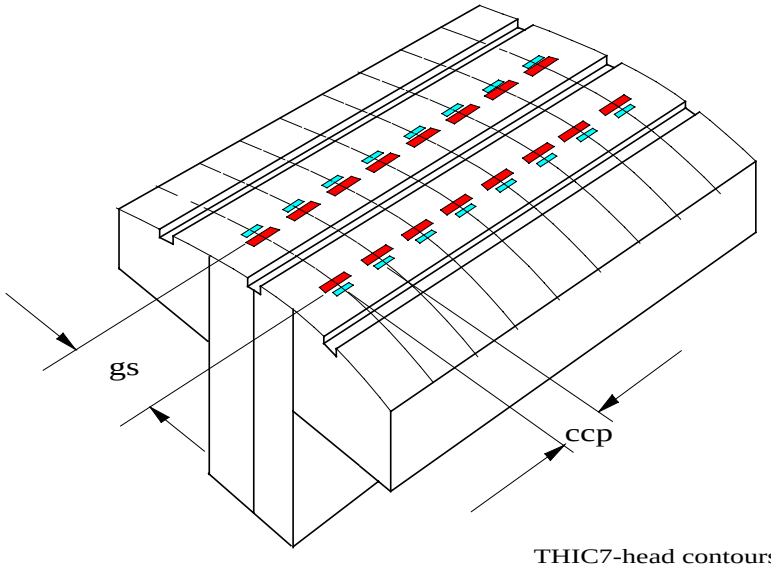
Argument for Linear Systems



Tape Head Contours

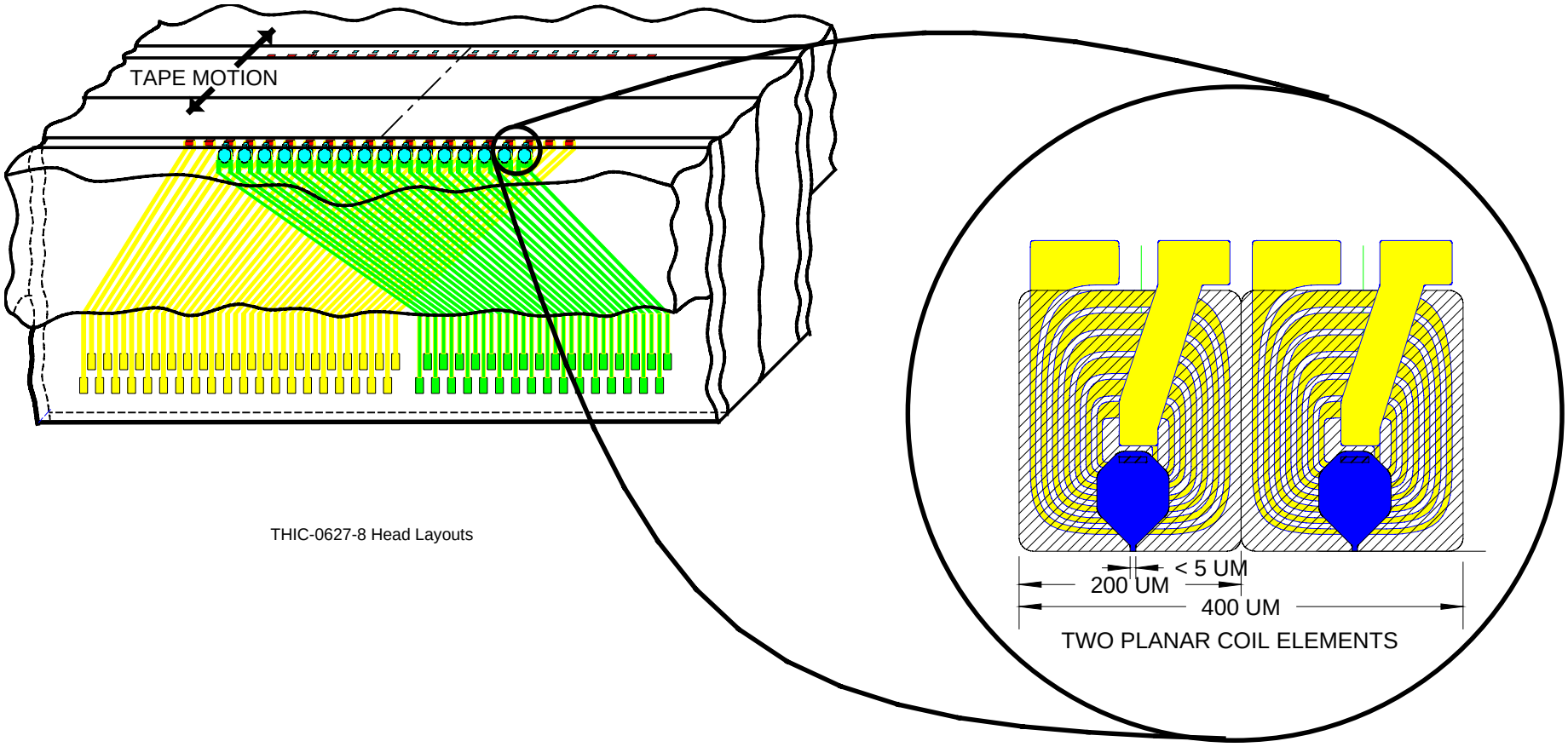






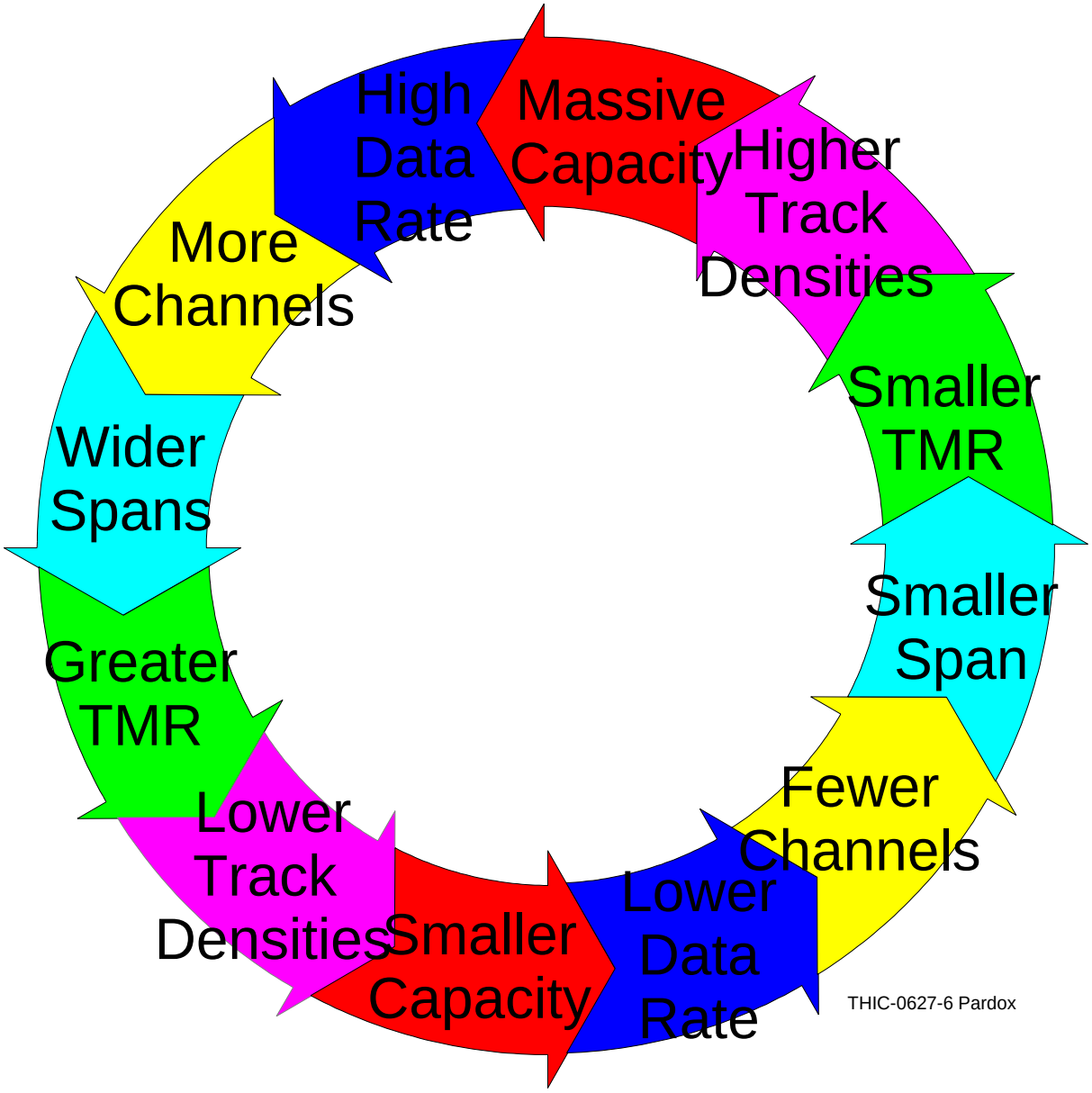
THIC7-head contours

Head Plan View



THIC-0627-8 Head Layouts

Data Rate/Capacity Paradox

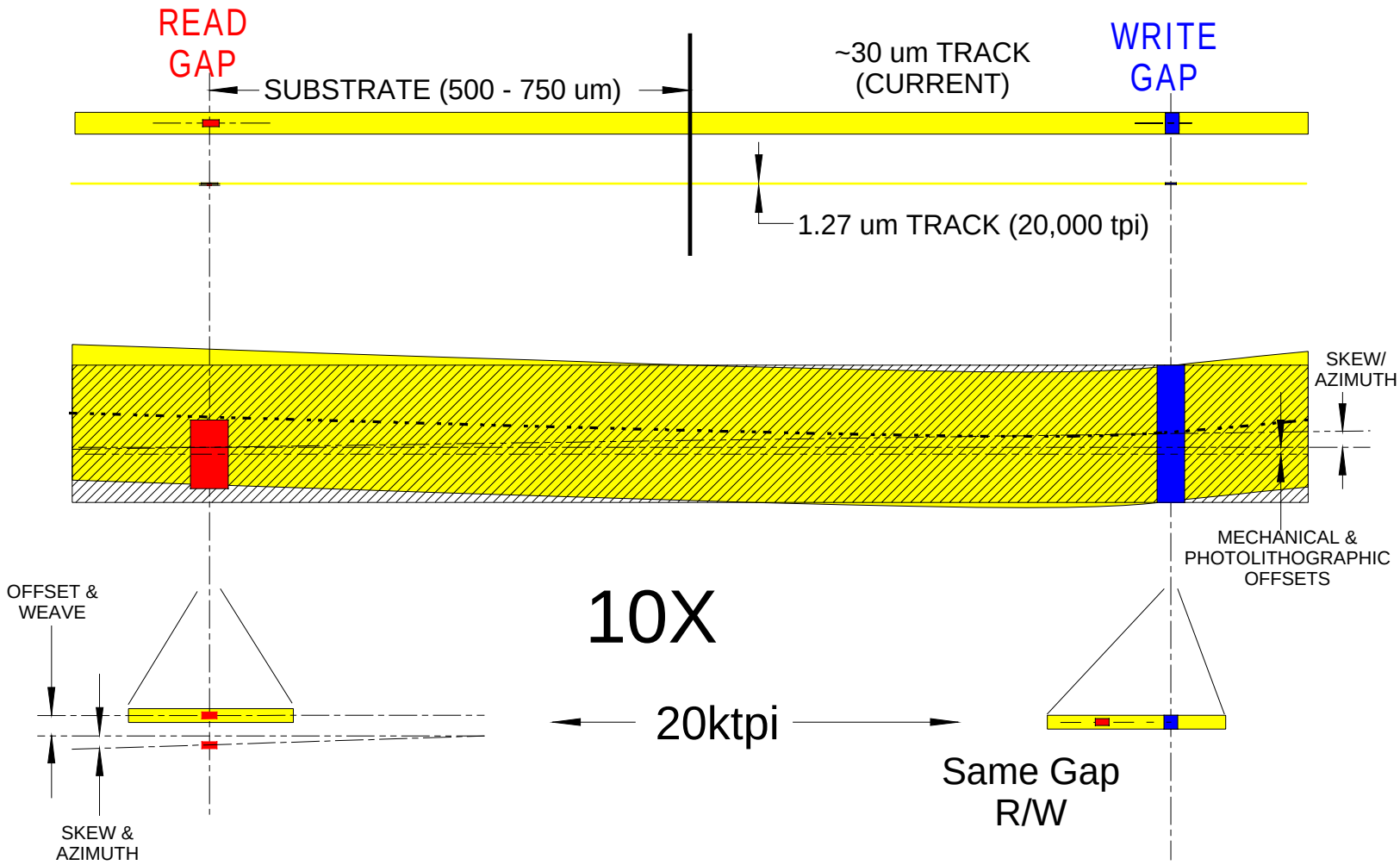


Density Key for Tape

Track Density

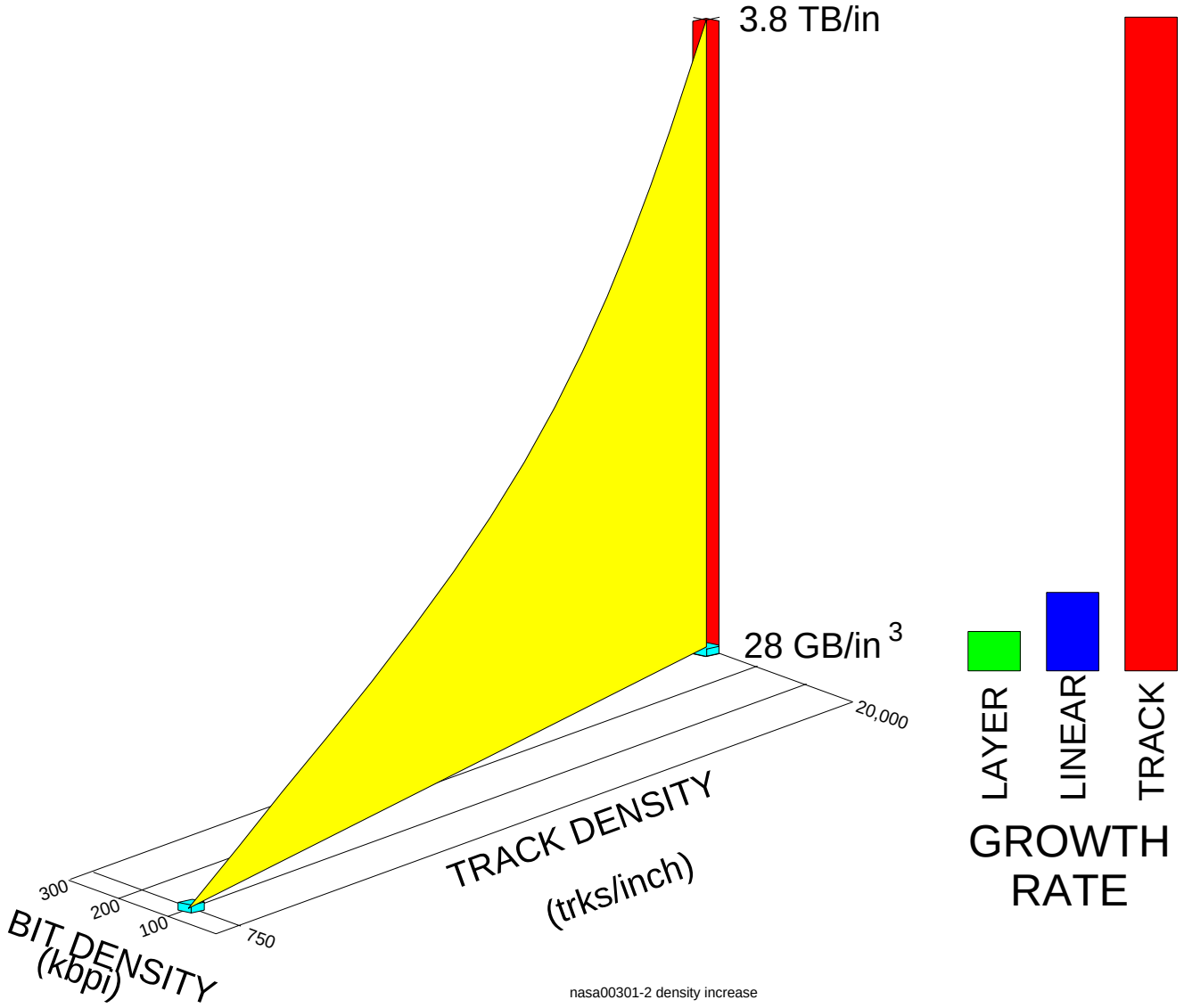
- Dimensionally Stable Substrate
- Closely Spaced Channels
- Low “noise” media
  - Maintain intrinsic SNR
  - Reduced surface roughness
- Mech. Alignment & Tolerance Compensation

Read/Write Separation



THIC-0627-9 R-W Separation

Data Density Growth



nasa00301-2 density increase

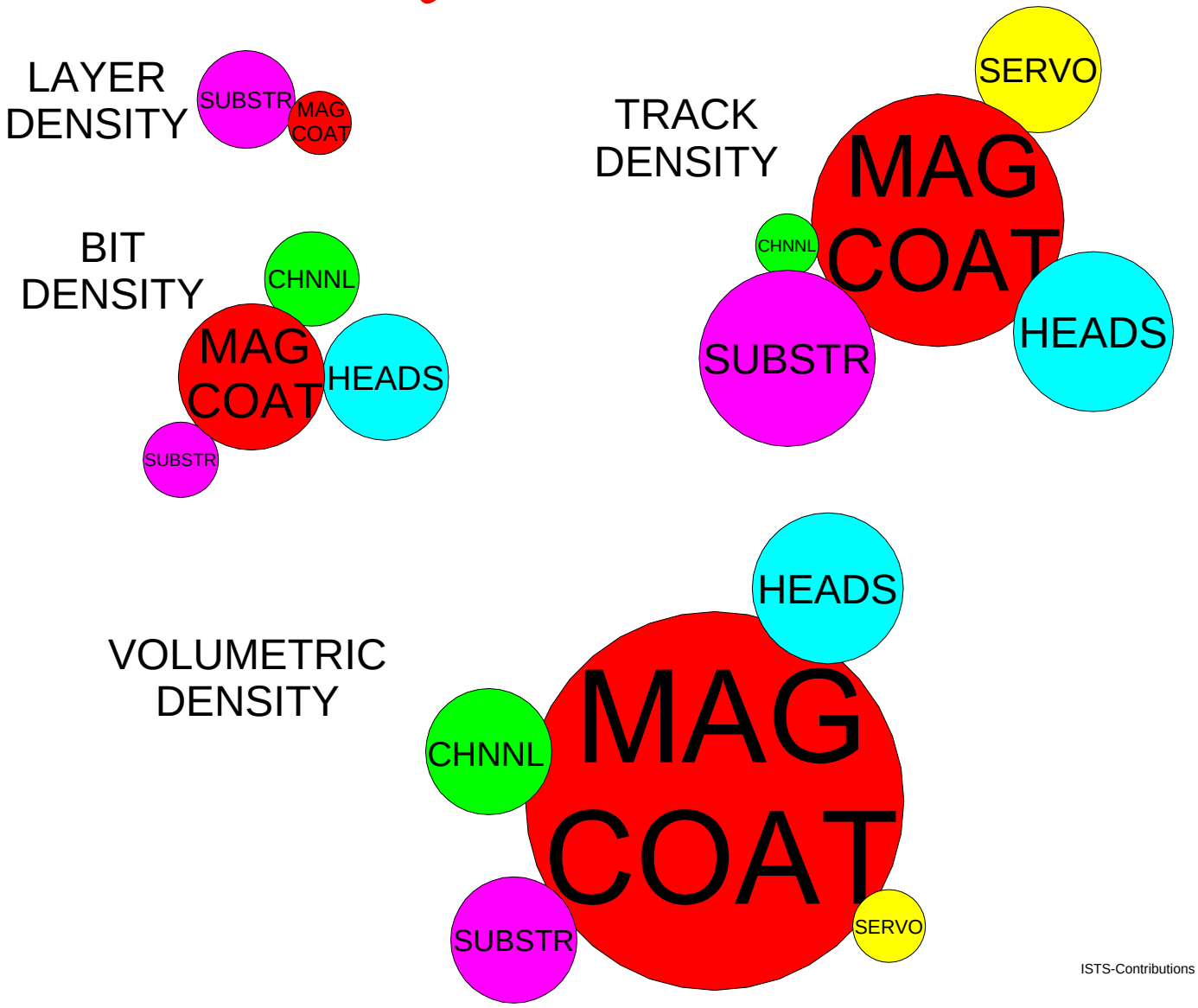
Media

- Higher Coercivity (> 2500 Oe)
- Improved SNR/unit width
  - Reduced Defects
  - Smaller Particles
  - Smoother Surfaces
- Thinner Magnetic Layer (<.05 um)
  - Multi-layers
- Metal Film
  - Perpendicular?

Substrate

- Reduced Dimensional Instability
  - 1000 PPM ⟶ 100-200 PPM
    - Humidity
    - Temperature
    - Tension
    - Creep/Compliance
- High T_G (For Metal Film)
- Thinner (4 um ⟶ 2 um?)
- Smoother
- Stronger

Density Contributions



ISTS-Contributions

Summary - Goals

6 Gb/in^2 ---- 3.8 TB/in^3

- 3X Bit Density
- ~25X Track Density

>10 TB/Large Cart

>200 MB/sec Data Rate

< 1 cent/GB per Cart (<$100/Cart)

< $0.5/GB per Drive (< $5000/Drive)

Summary - Challenges

- Data Rate
- Substrate Dimensional Stability
- Head Complexity/Span
- Mechanical Tracking
- Tape Speed
  - Head Wear
  - Handling
  - Tape Durability

Summary

“Tape Will Never Die!

-Jim Hughes – StorageTek

NASA Mass Storage Conference – April 2000