



## **Tape Directions for the New Millennium**

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# Tape Directions for the New Millennium



# Outline

- Technology Objectives
- Data Rate vs. Channels and Tape Speed
- Cost Trends
- Density Trends
- Migration Chart
- Data Rate/Capacity Paradox
- Tape Head Mechanics
- Track Density Keys
- Summary

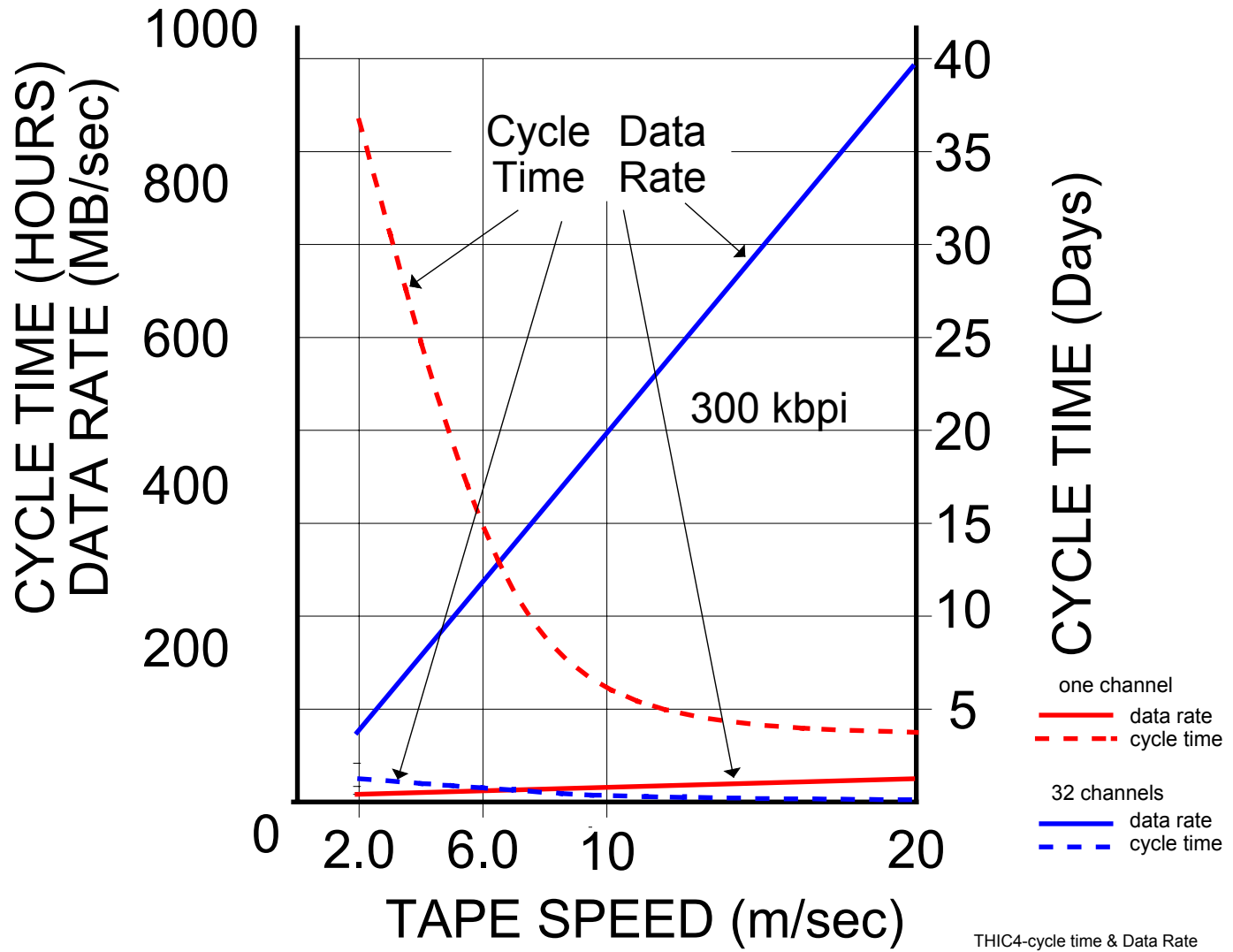


# Technology Objectives

track density:	20,000	tpi	787.40	t/mm
linear density:	300,000	bpi	11,811.02	b/mm
<b>areal density:</b>	<b>6.00</b>	<b>Gb/in<sup>2</sup></b>	<b>9.30</b>	<b>Mb/mm<sup>2</sup></b>
layer density:	5,000	Lpi	196.85	L/mm
<b>volumetric Density:</b>	<b>3.8</b>	<b>TB/i<sup>3</sup></b>	<b>228.84</b>	<b>MB/mm<sup>3</sup></b>
LTO type Cartridge -				
tape width:	0.50	in.	12.7	mm
tape length:	5,511.80	ft	1,680	m
total area:	33,070.73	in <sup>2</sup>	21,336,000	mm <sup>2</sup>
total area:	229.66	ft <sup>2</sup>	21.34	m <sup>2</sup>
volume:	4.71	i <sup>3</sup>	77,222	mm <sup>3</sup>
Efficiency:	70	%	70	%
<b>Capacity:</b>	<b>12.4</b>	<b>TB</b>	<b>12.4</b>	<b>TB</b>

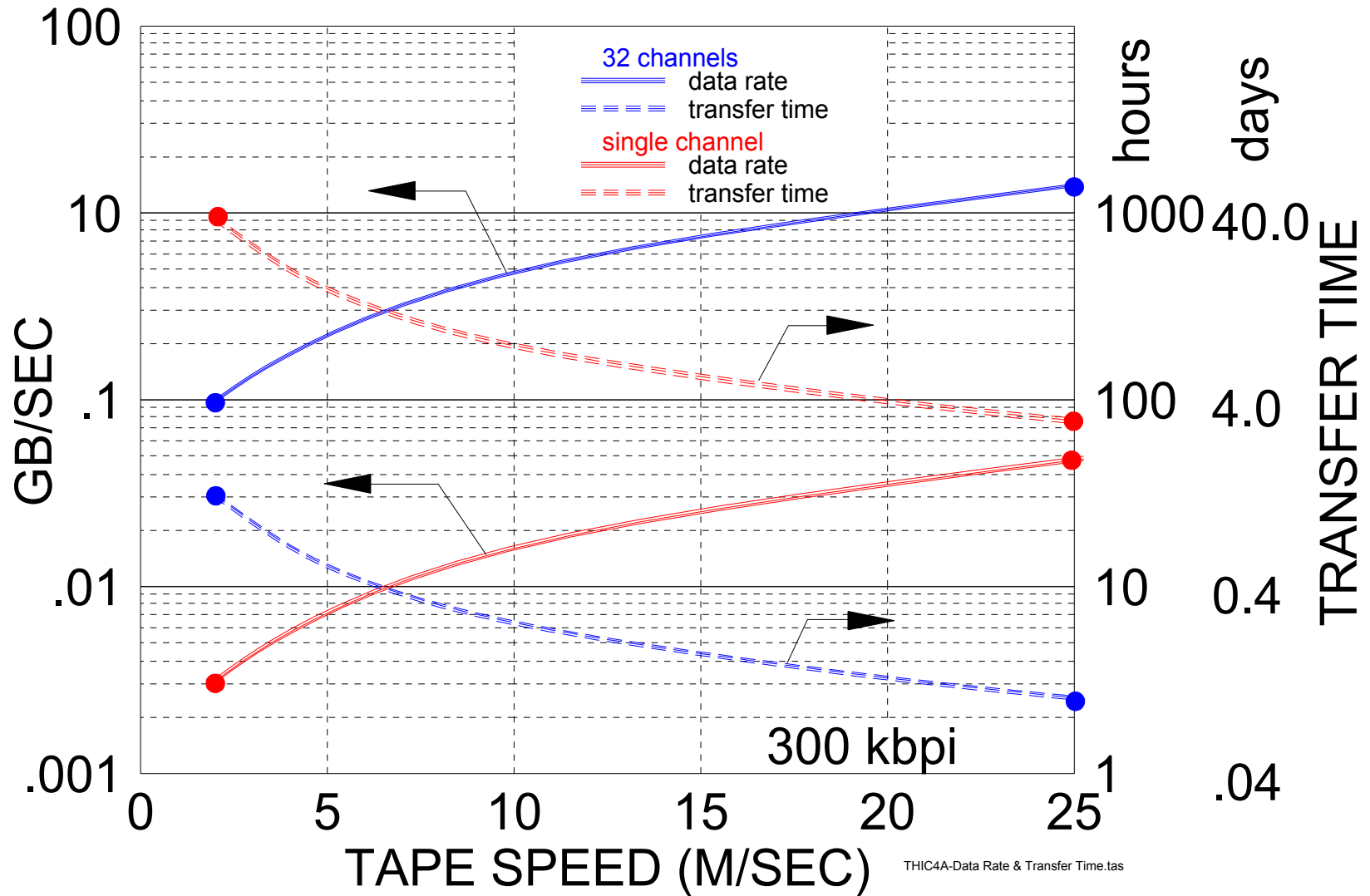


# Data Rate & Transfer Time for 10TB of Data



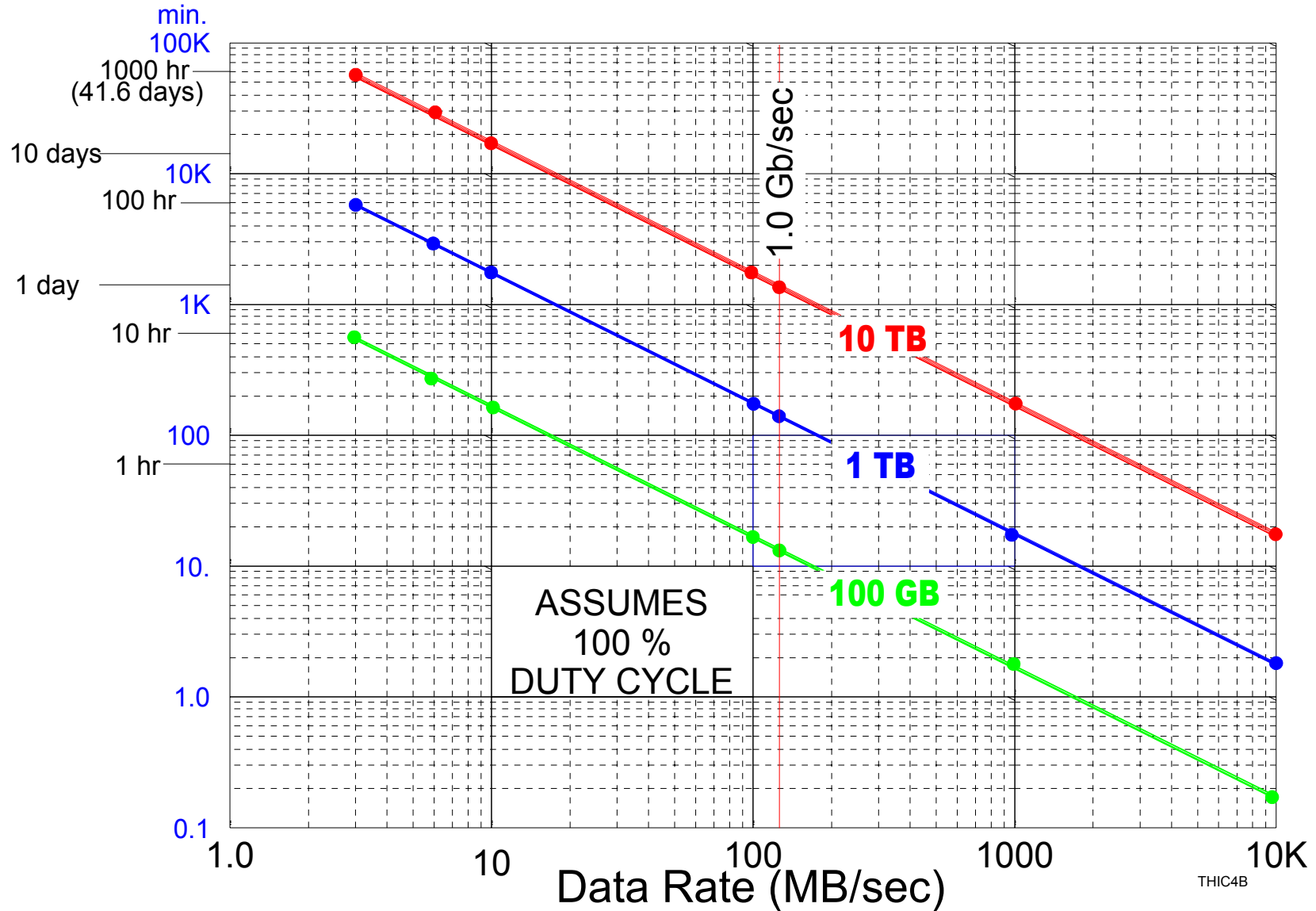
THIC4-cycle time & Data Rate

# Data Rate & Transfer Time for 10 TB of Data

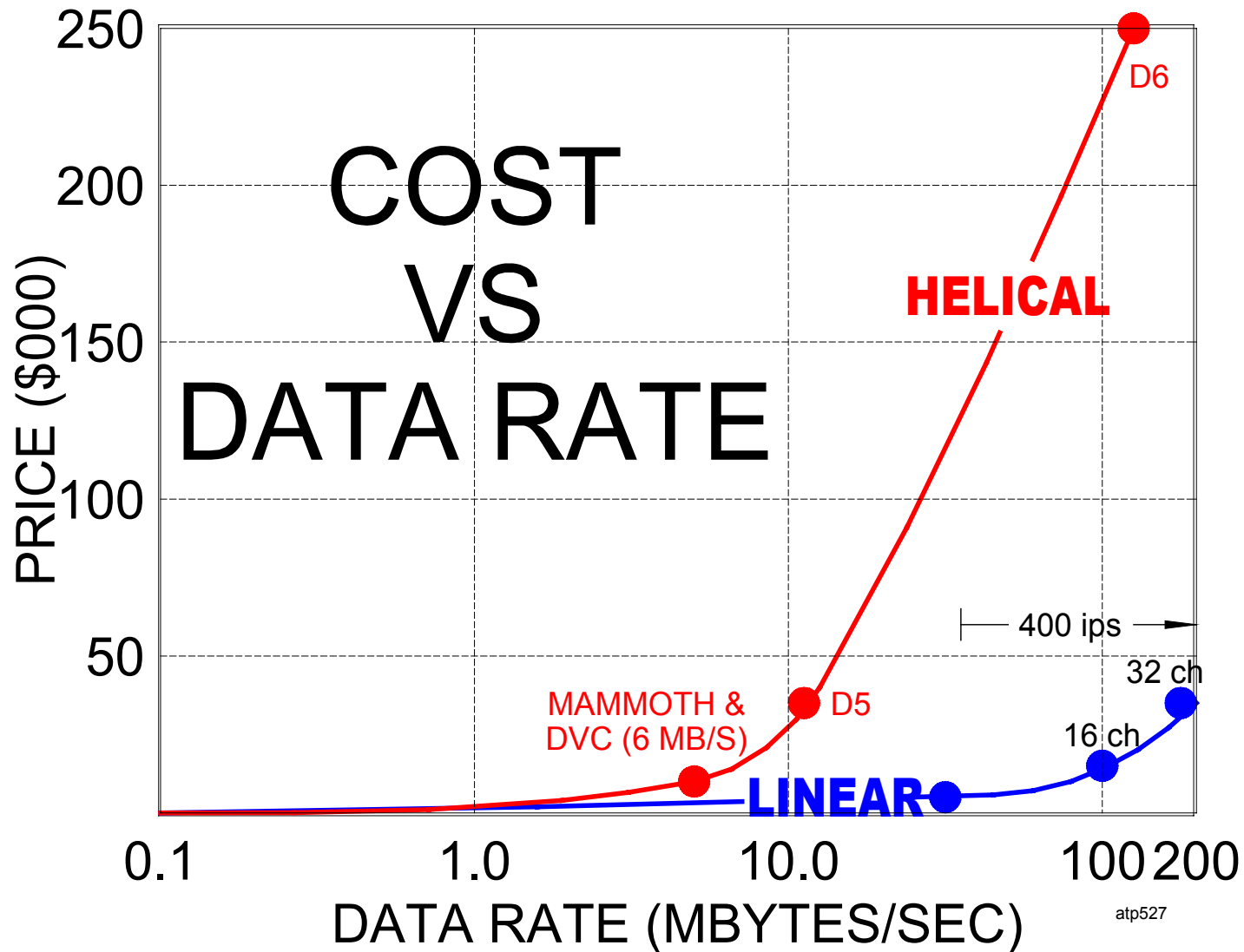


THIC4A-Data Rate & Transfer Time.tas

# Transfer Time vs. Data Rate



# Argument for Linear Systems





# Data Rate/Capacity Paradox

Large Capacities

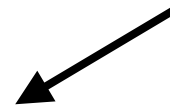
Require High Data Rates  
for Reasonable  
Transfer Times



High Data Rates Require  
Multi-Channel Heads



MultiChannel Heads  
Have Wider Spans



Wider Spans Mean  
Lower Track Density



Lower Track Density



# Head Life-

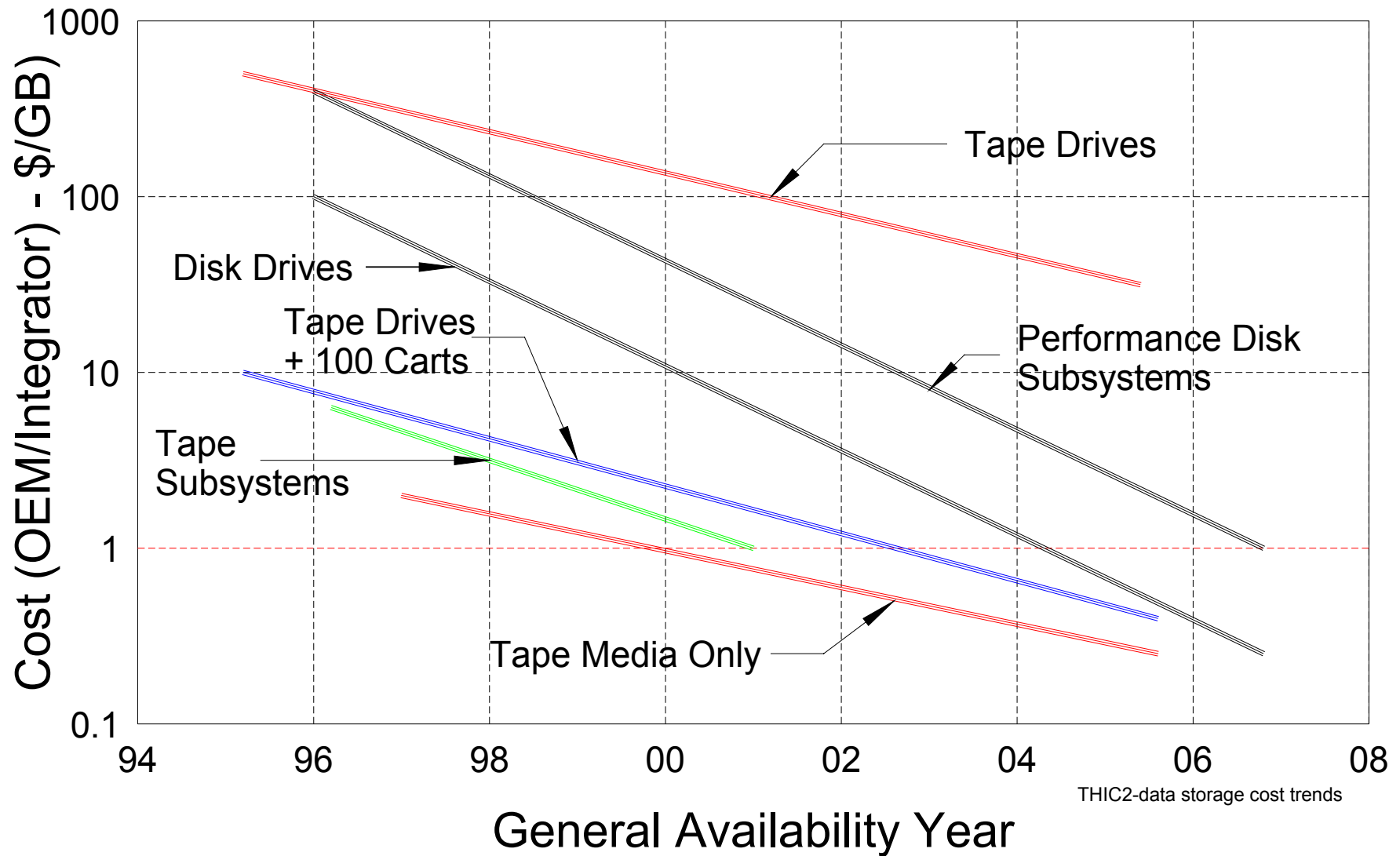
## Tape Sliding Distance

6.0 m/sec	10 m/sec	25 m/sec
708 Million feet	1.2 Billion feet	2.9 Billion feet
216,000 km	360,000 km	900,000 km
134,000 miles	224,000 miles	560,000 miles

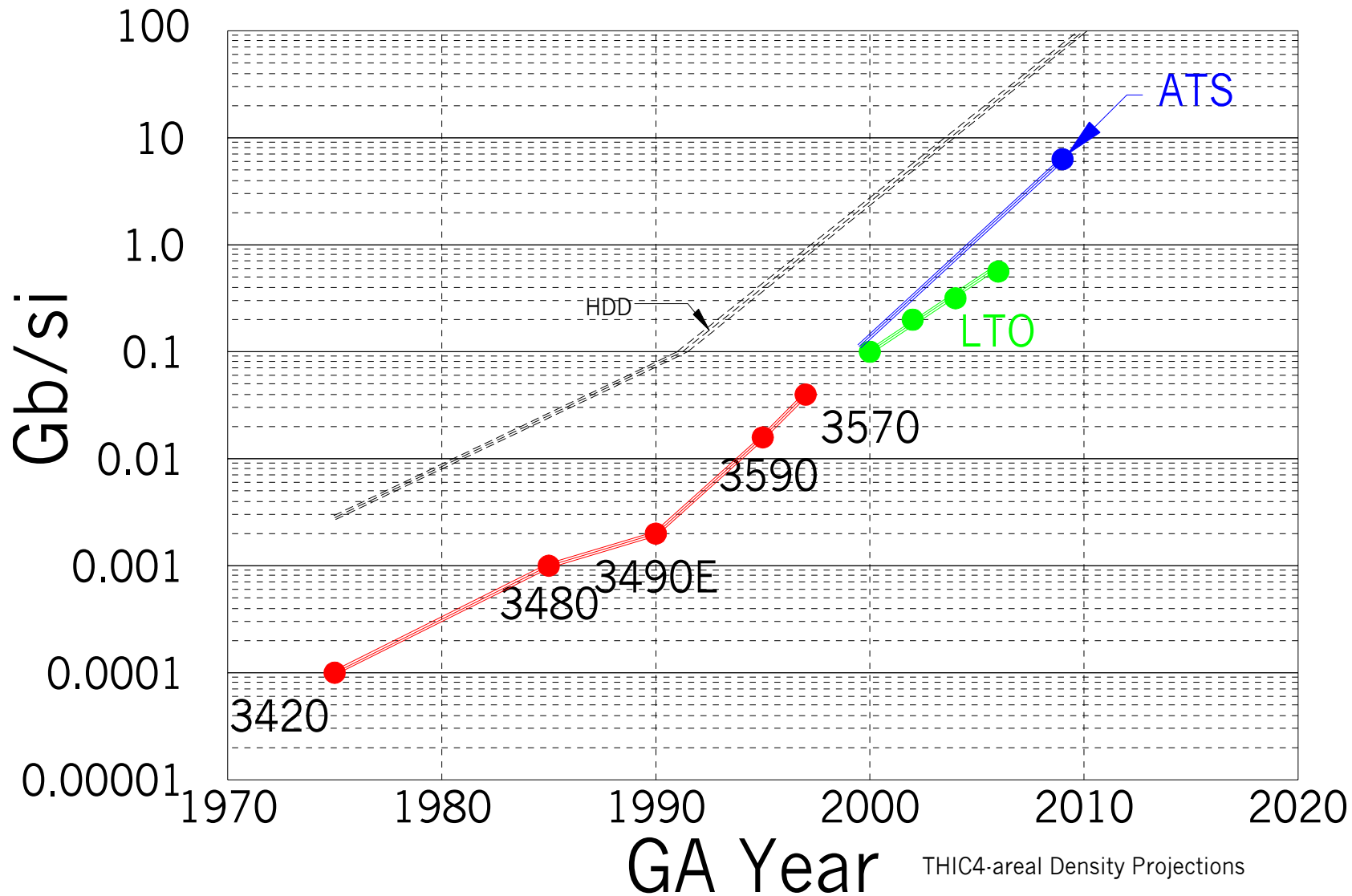
Assumes 10,000 hrs. tape motion



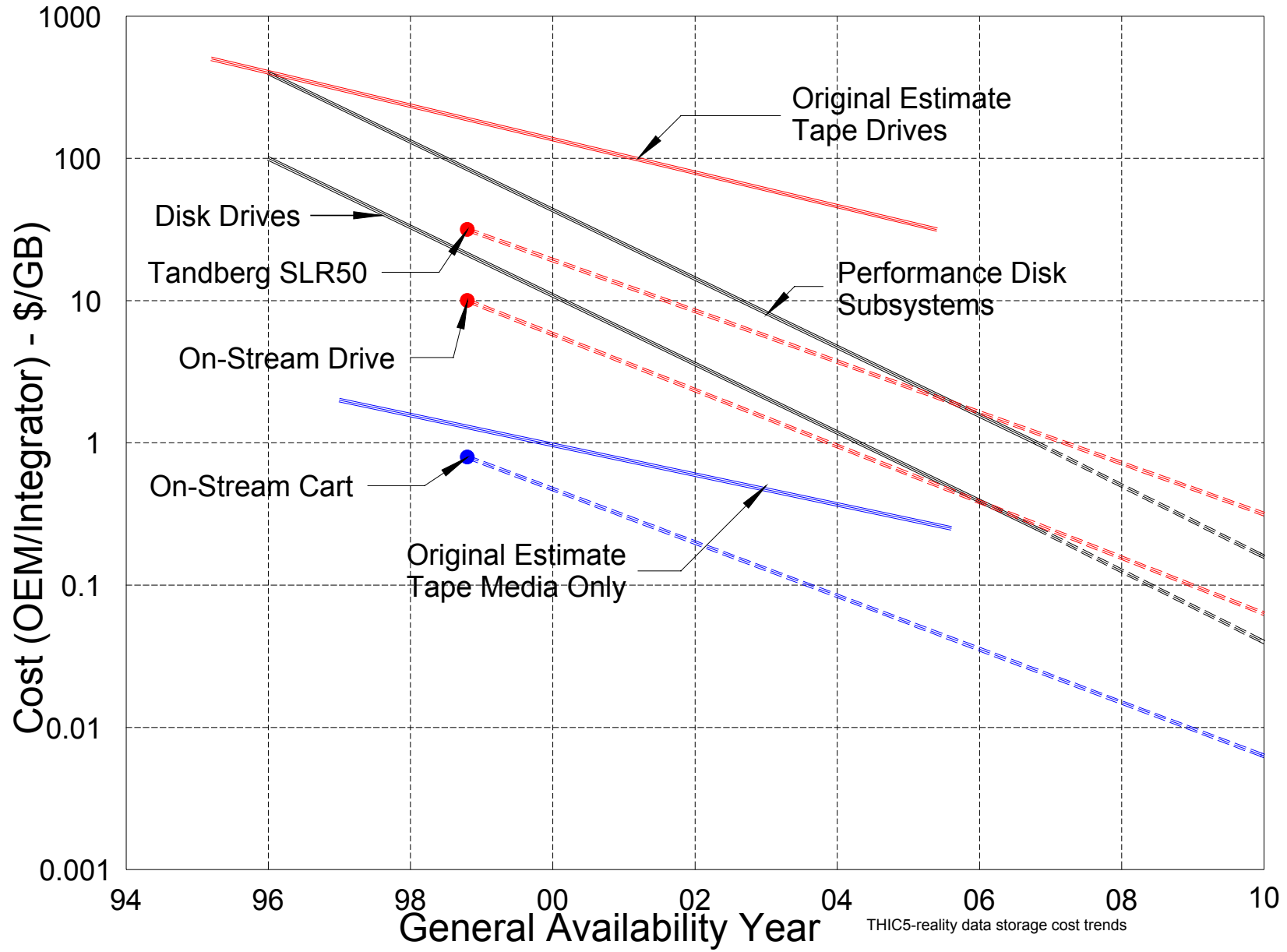
# Technology Cost Trends



# Areal Density Trends



# Revised Cost Trends



# Density Migration

100 kbp*i* → 300 kbp*i*

750 tpi → 20,000 tpi

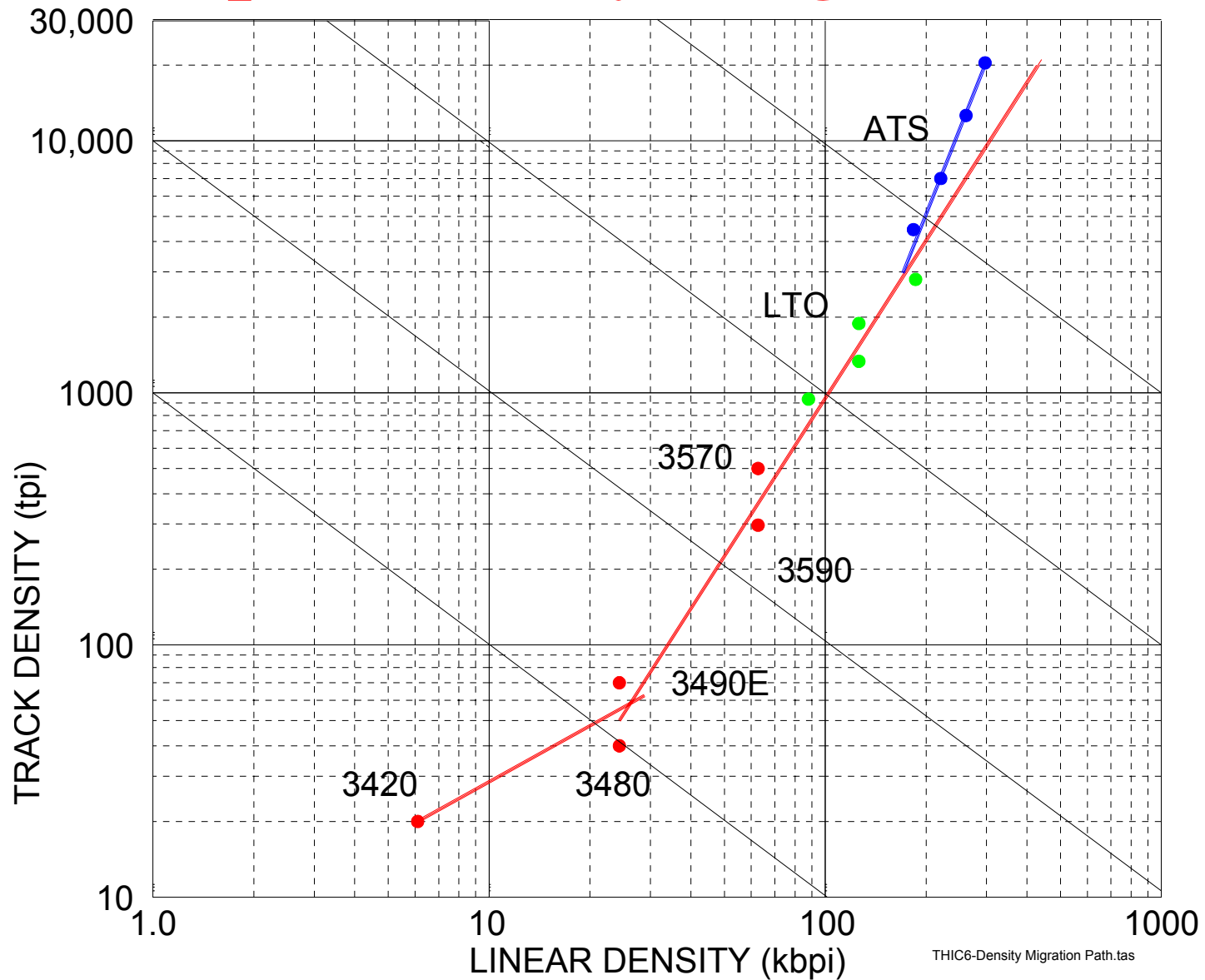
3000 lpi → 5000 lpi

75 Mb/in<sup>2</sup> → 6.0 Gb/in<sup>2</sup>

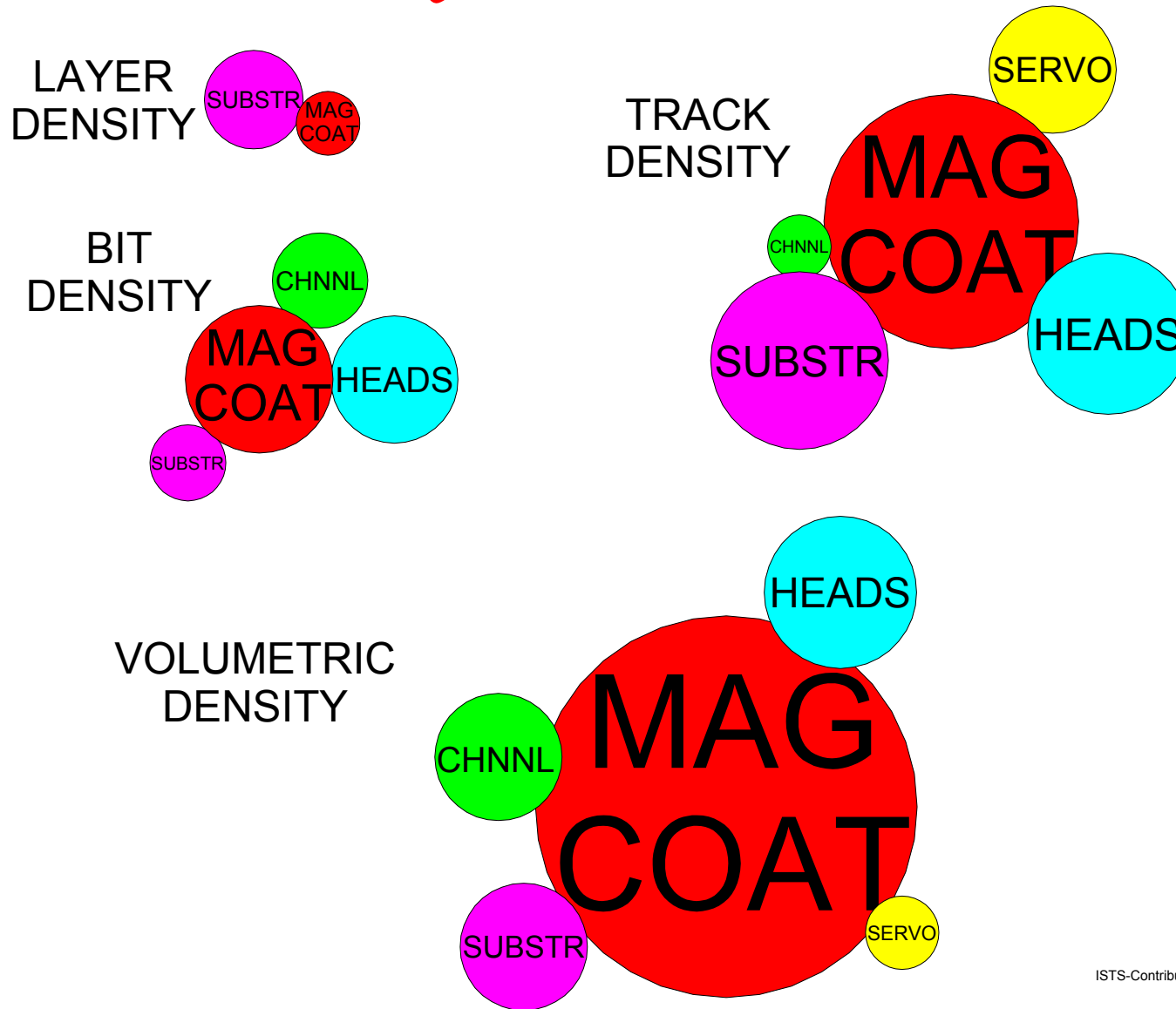
28GB/in<sup>3</sup> → 3.8TB/in<sup>3</sup>



# Tape Density Migration



# Density Contributions

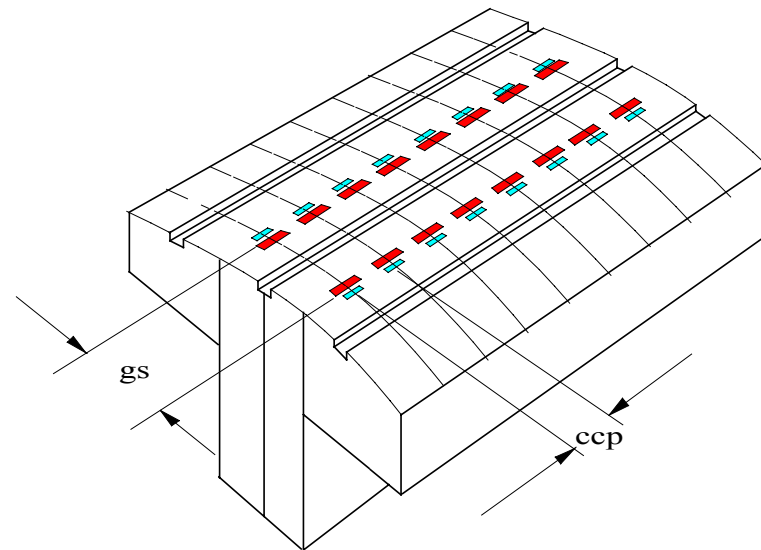
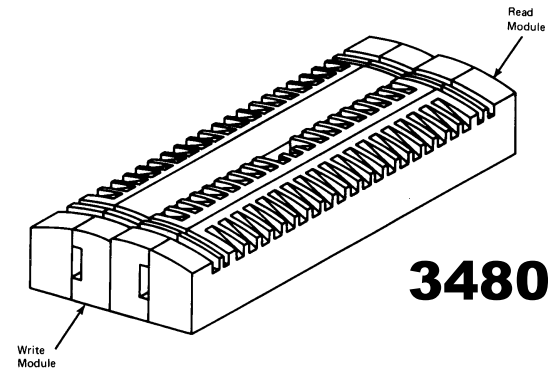
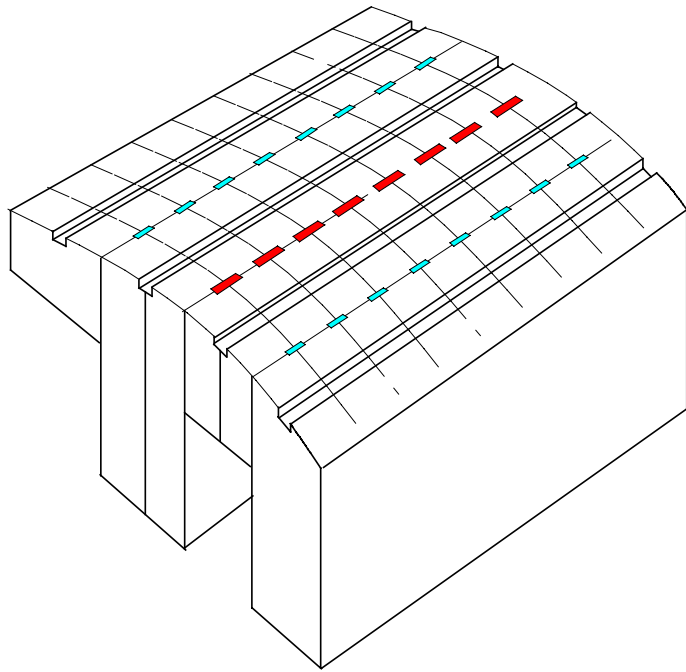


ISTS-Contributions





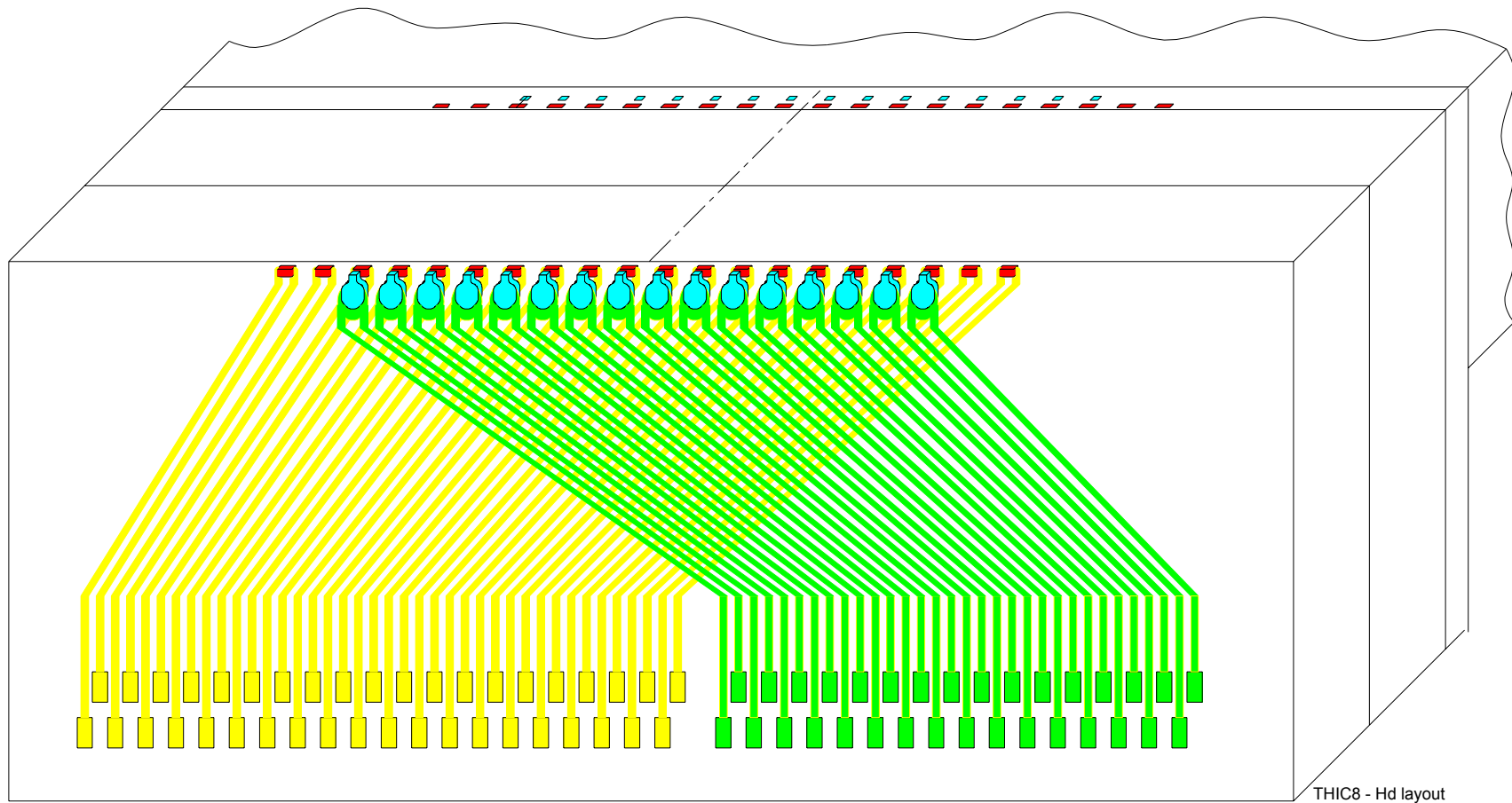
# Tape Head Contours



THIC7-head contours



# Head Plan View

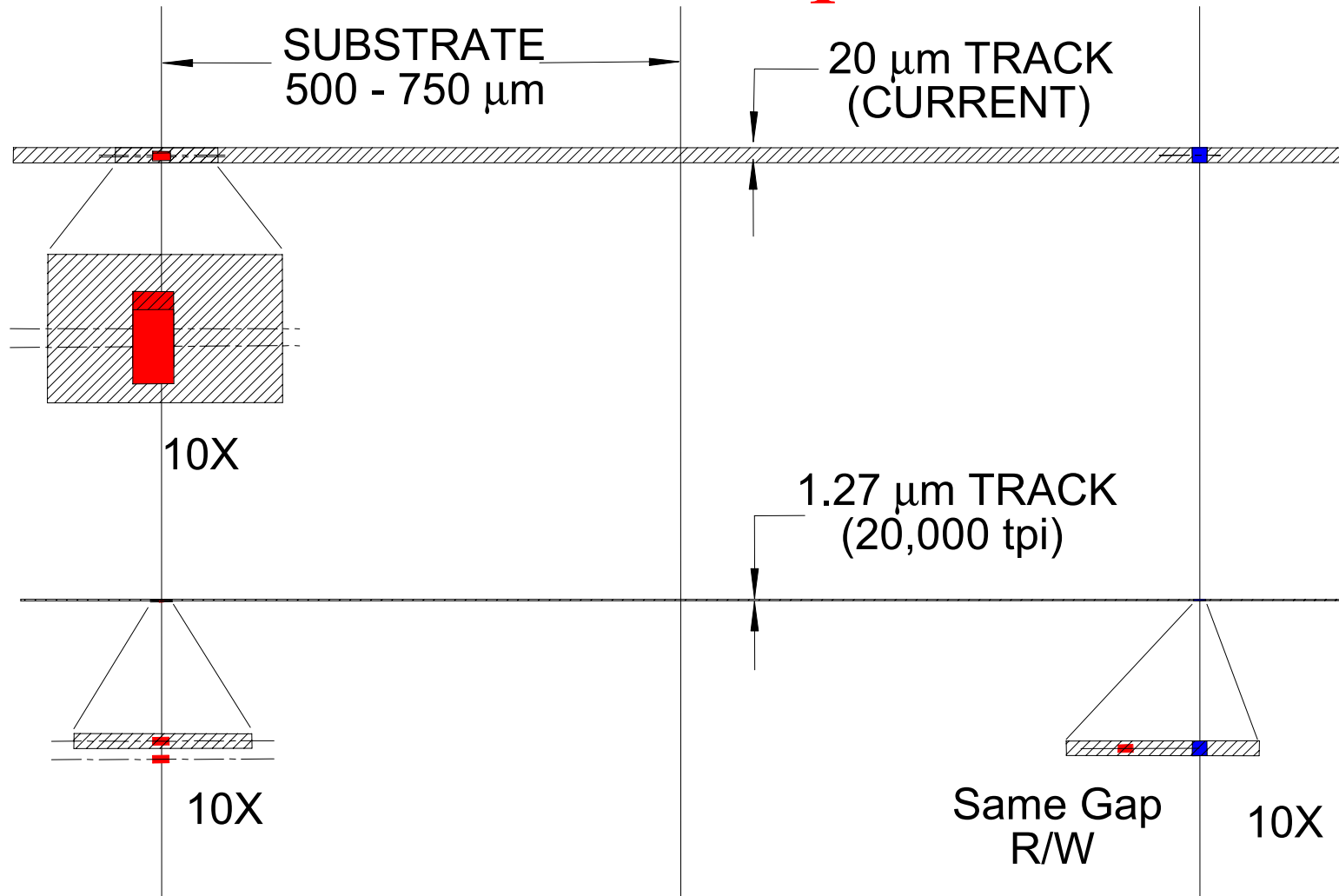


# Track Density Keys

- Substrate Stability
  - Strength
  - $dW/W$  vs Temperature/humidity/Tension
- Channel Spacing
  - No. of Channels vs Tape Speed
- Read/Write Separation
- “System” Azimuth



# Read/Write Separation



THIC9 R-W Separation



# Summary - Goals

6 Gb/in<sup>2</sup> ---- 3.8 TB/in<sup>3</sup>

– 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
- Head Complexity
- Tape Speed
  - Head Wear
  - Handling
  - Tape Durability

