Wheels Keep Spinning – Disc Drive Research

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Seagate Research
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Seagate
We turn on ideas

Company Overview

Seagate Technologies (NYSE: STX)

Seagate is the world's leading provider of hard disc drives

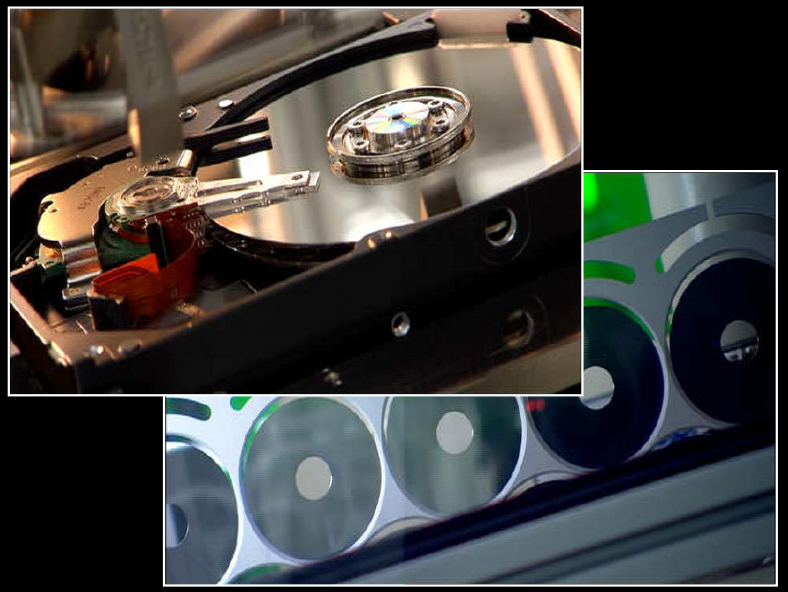
- All-time record shipments of 98 million drives in FY05
- Over 250,000 drives (over 7 PB) each day (!)

Market share leader in Desktop, Enterprise and Consumer Electronics

Vertical integration of core technologies: heads, media, motors, and printed circuit boards

Revenues of $7.55 billion in FY05

40,000 employees worldwide

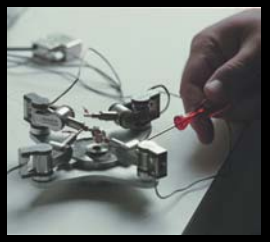


Seagate Research

The Research Center currently has a total of 150 employees, all in Pittsburgh, Pennsylvania

About 120 technical staff from 22 countries; 90 staff with Ph.D. degrees from over 50 universities.

Up from two people in just over five years.



Seagate Research
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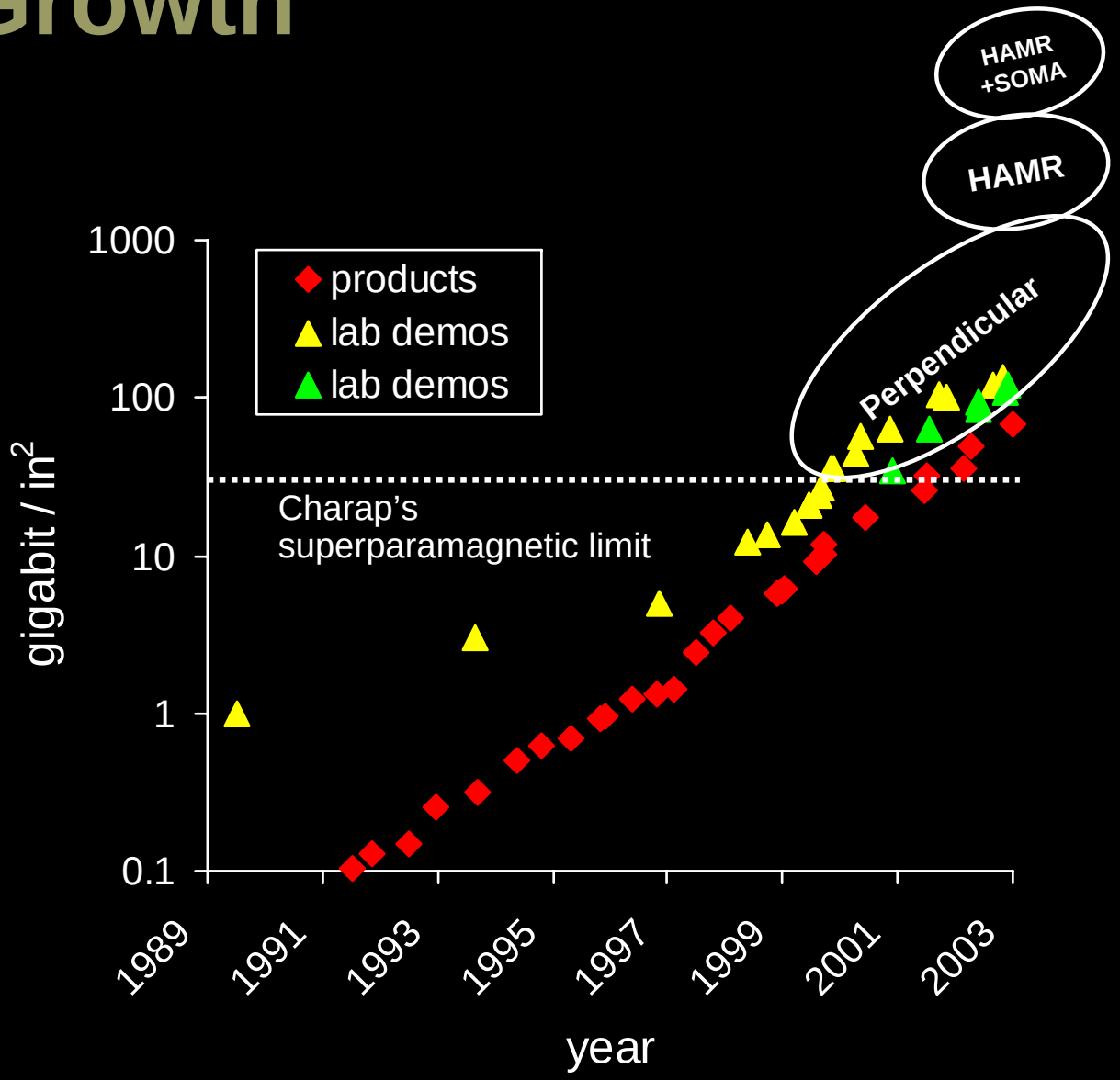
Pittsburgh, PA

Technical Specs – Then and Now

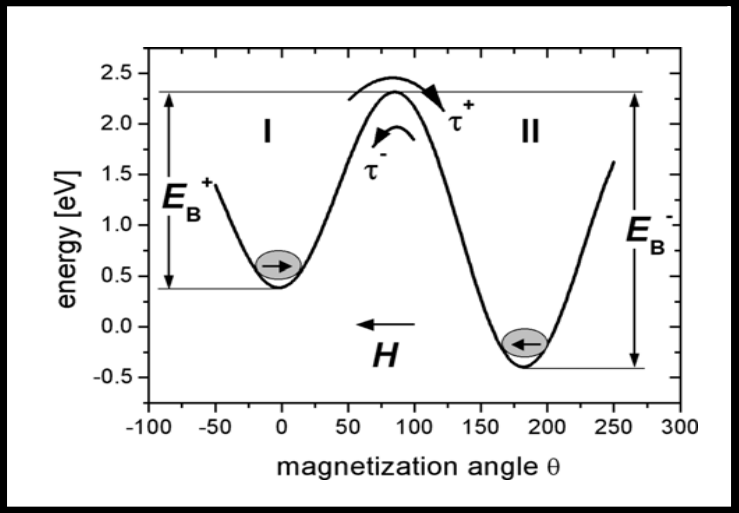
	IBM RAMAC (1956)	Savvio 10K.1 (2004)	Delta
Capacity	~ 5 MB	73.4 GB	15,000 x
Areal Density	2000 bits/in^2	68 Gb/in^2	34,000,000 x
Disks	50 @ 24” dia	2 @ 2.5” dia	240 x
Price	$50,000	<$1000	x / 50
Price/MB	$1,000	<$0.02	x / 730,000
Spindle Speed	1,200 rpm	10,000 rpm	8.3 x
Seek Time	600 ms	4.1 ms	x / 140
Data Rate (burst)	10 KB/s	94 MB/s	9,400 x
Power	5000 W	12 W	x / 740
Weight	~ 1 ton	1.9 lb	x / 1,800

Areal Density Growth

- Late 1990s – general fear that media would be unstable beyond the *superparamagnetic limit*
- Longitudinal recording now expected to extend above 100 Gb/in^2
- Perpendicular expected to extend to 1 Tb/in^2
- Additional innovations required at that point
  - heat-assisted recording
  - self-organizing media

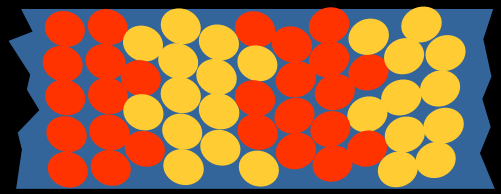


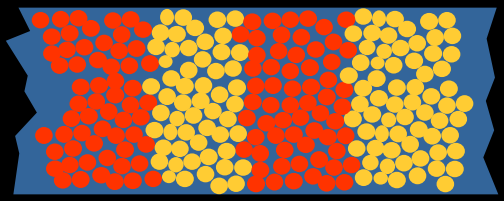
Media Design Constraints – Trilemma



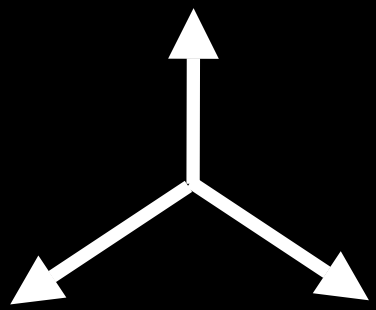
Readability

$SNR \sim \log_{10}(N)$





Small Grains (V)



Thermal Stability

$$E_B \cong K_u V \cdot \left[1 - \frac{|H_d|}{H_0}\right]^{3/2}$$

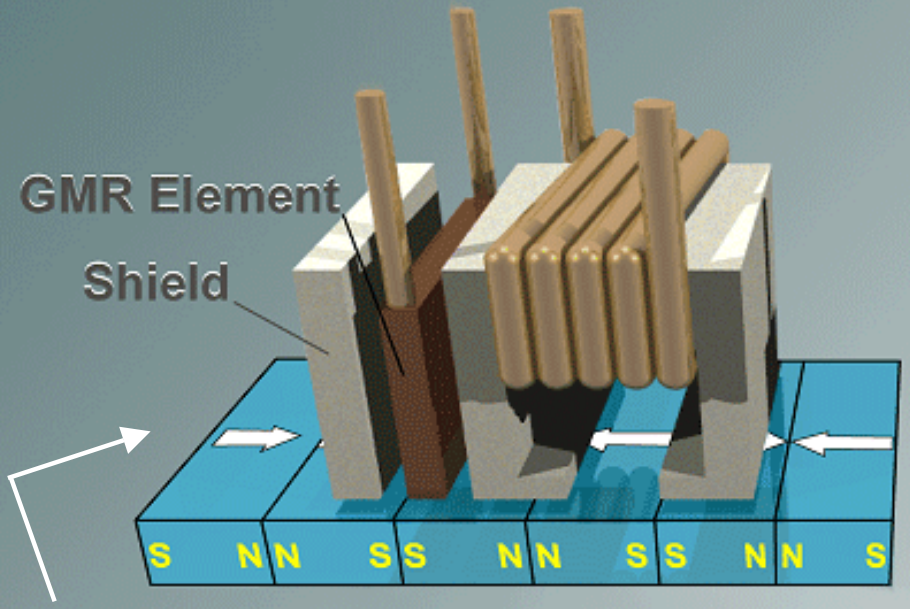
$K_uV = 40 - 60\ k_BT$

Writability

$$H_0 = \alpha \cdot \frac{2 \cdot K_u}{M_S} - N_{eff} \cdot M_S$$

H_0 < Head Field

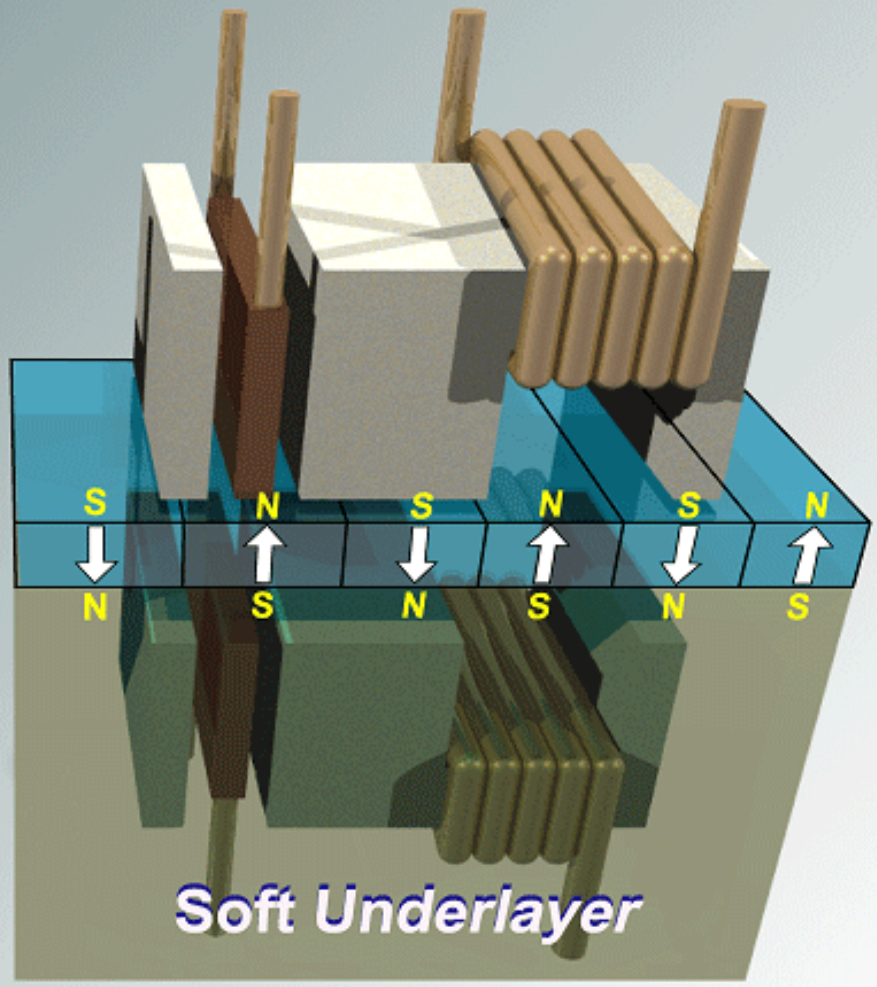
Longitudinal Recording



Magnetic domains oriented in the direction of travel of the head (much longer than wide/tall).

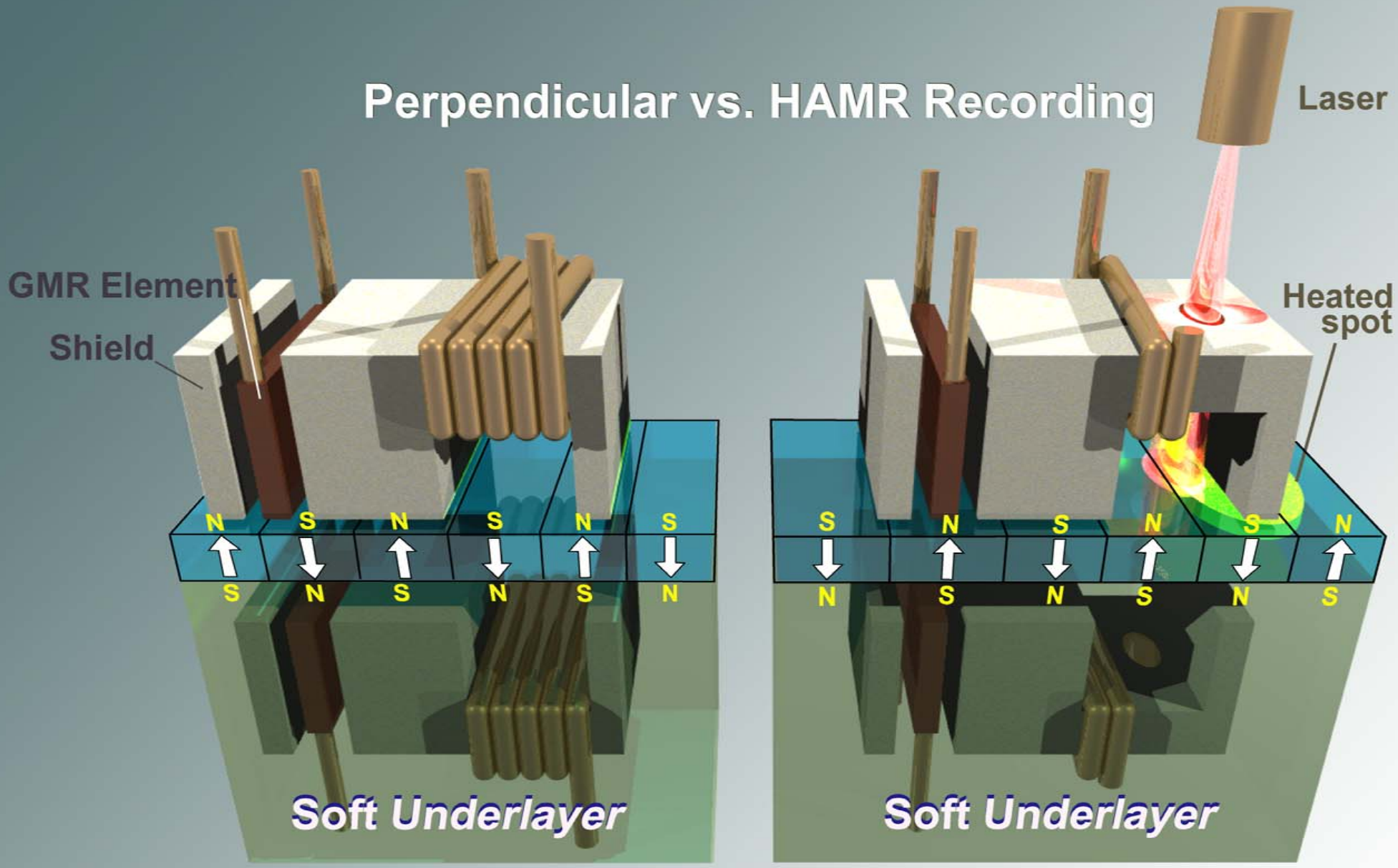
Soft underlayer "mirrors" write field and allows domains much closer together.

Perpendicular Recording



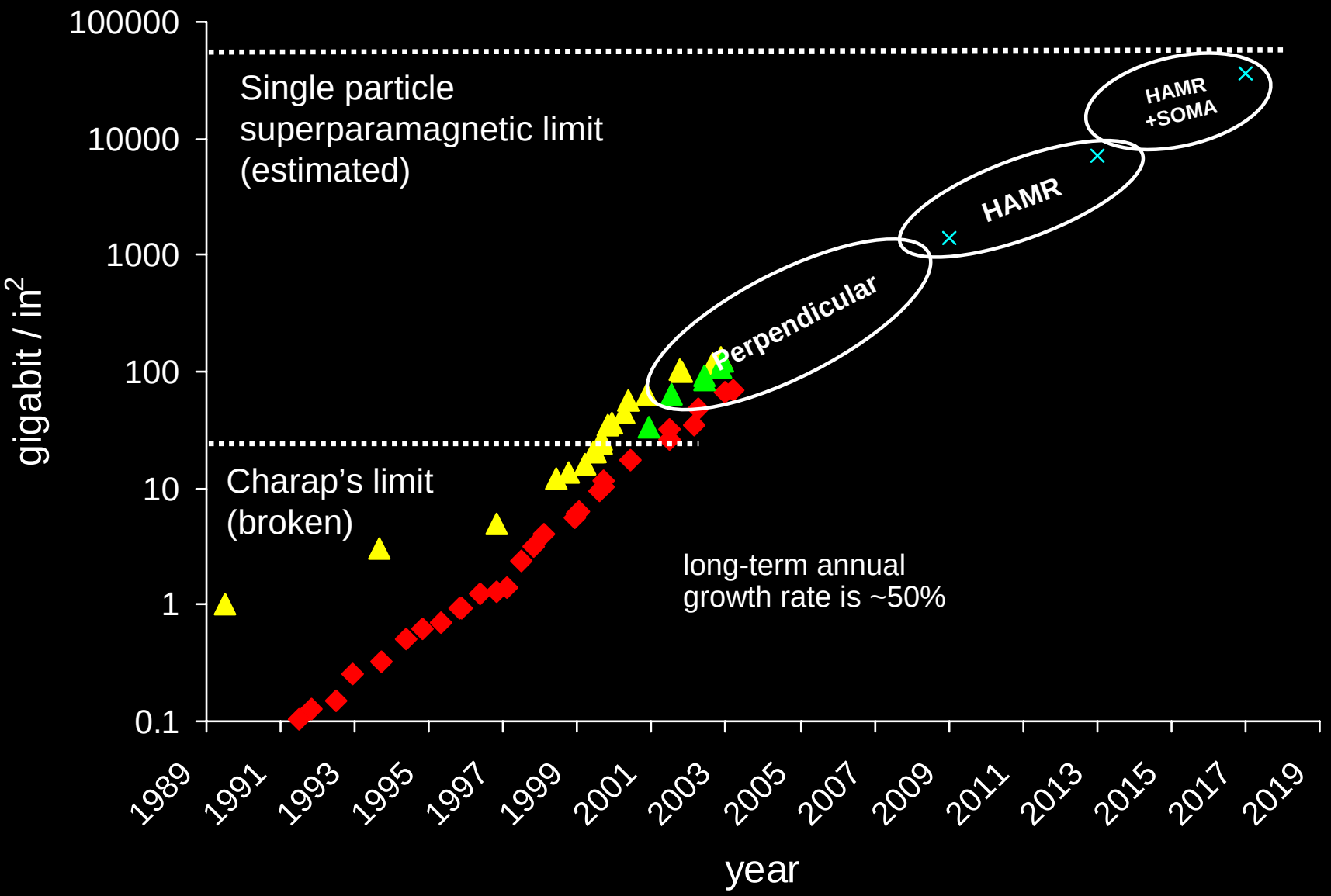
Perpendicular should take us to 1 Tbpsi

Perpendicular vs. HAMR Recording



HAMR can theoretically extend the density of recording to 10 Tbpsi

Areal Density Growth



The Extreme Sport of Technology

Core Teams
- Individual products

Platform Teams
- Interface
- Firmware
- Electronics
- Mechanical
- Servo
- Heads
- Media

new areas

core technology

Research Teams
- *Systems*
- Channels
- Integration
- Modeling
- Mechanical
- Servo
- Heads
- Media
- Materials

Disciplines

CS (*systems*)

CS (*security*)

CS (*signal proc)*, Math

CS (*simulation*)

Physics

Mechanical eng

Control theory, Mechanical eng

Physics, Materials

Chemistry

New Markets

* (IDC, 15 April 2004)
^ (Seagate estimate, 20 April 2004)

41 million PCs were sold in Q1 of 2004*

65 million hard disk drives were sold in Q1 of 2004^

- this is 700,000 disk drives produced **every day (!)**
- more than 20 PB of new disk storage **every day (!)**

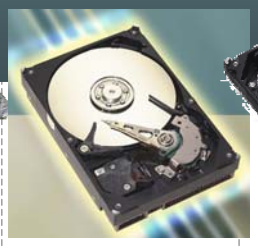
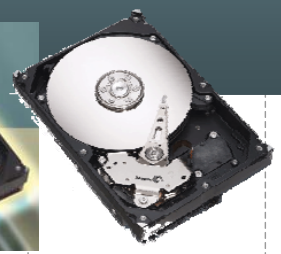
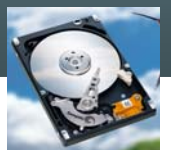
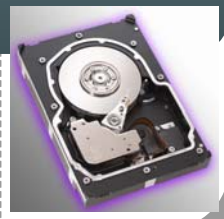
24 million disk drive didn't go into PCs

- they went into servers, archives, video recorders, game machines, audio players, …

This gap has been growing for several years

- more and more drives into non-PC uses

Disc Drives Today Cover the Widest Range of Users and Systems Ever

Handheld	Gaming	DVR	Notebook	Desktop	Enterprise
					 
5 GB	**400 GB**		**100 GB**	**400 GB**	**73 GB**	**400 GB**
ST1 Series **USB2 Pocket Hard Drive**	**CF Photo Hard Drive**	**U series X** **Barracuda 7200.8**	**DB35 Series**	**Momentus 5400.2** **Momentus 7200.1**	**Barracuda 7200.8** **External Hard Drive** **Portable External Hard Drive**	**Savvio 10K.1**	**NL 35 Series** **Cheetah 10K.7** **Cheetah 15K.4**
							

Metrics

enterprise-relevant metrics

Traditional metrics

- spindle speed (*rpm*)
- capacity (*GB*)
- seek time (*ms*)

=> more focus on IOPS/GB and system-level operations

New metrics

- acoustics (drives in living rooms)
- power (save battery, save cooling $)
- idle/standby modes (*W* saved, *s* to switch modes)
- shock and vibration (dropping, cabinets, jogging)
- reliability (end-to-end data protection)

=> for archives & large storage pools

=> security, long life

Research Topics – Systems

interface and API extensions

Over time, more semantic understanding at individual drives

- object storage is a first step (structure-aware storage)
- enables attribute-managed storage w/ metadata
- self-securing storage – protect against malicious damage
- autonomous storage devices (self-tuning, distributed)
- self-organizing, self-indexing (data-aware storage)
- system-level understanding & metrics

active storage devices

Open areas

- usable security and privacy
- organizing large data collections
- making sense out of data (data => information)