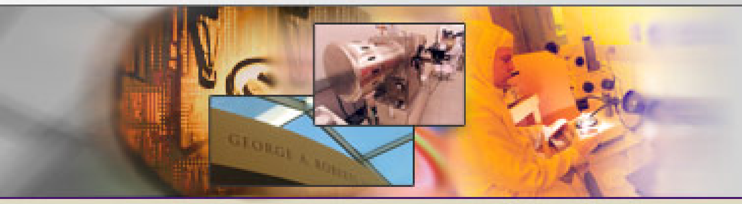
Nanotechnology, Information Storage, and Applied Physics

T.E. Schlesinger
Director, Data Storage Systems Center
Carnegie Mellon University
Pittsburgh, PA, USA



DSSC
The Data Storage Systems Center

Electrical & Computer ENGINEERING

30 November 2004

Carnegie Mellon

Outline

- *Limits in information storage systems and IC fabrication technology are being approached THESE ARE REAL but are not fundamental in the sense of insurmountable laws of nature.*
- *Information storage today is an application of nanotechnology.*
- *Further advances in nanotechnology will bring unprecedented storage capacity that will fundamentally change the way we think about information.*
- *The integration of information storage and information processing will create a new paradigm to take us beyond CMOS technology.*

A Report from the U.S. National Science Foundation
Blue Ribbon Panel on Cyberinfrastructure

Daniel E. Atkins
The University of Michigan
Chair, NSF Panel on Cyberinfrastructure
January 2003

"….cyberinfrastructure refers to infrastructure based upon distributed computer, information and communication technology. If infrastructure is required for an industrial economy, then we could say that cyberinfrastructure is required for a knowledge economy….. The base technologies underlying cyberinfrastructure are the integrated electro-optical components of computation, storage, and communication that continue to advance in raw capacity at exponential rates."

The Need for Storage

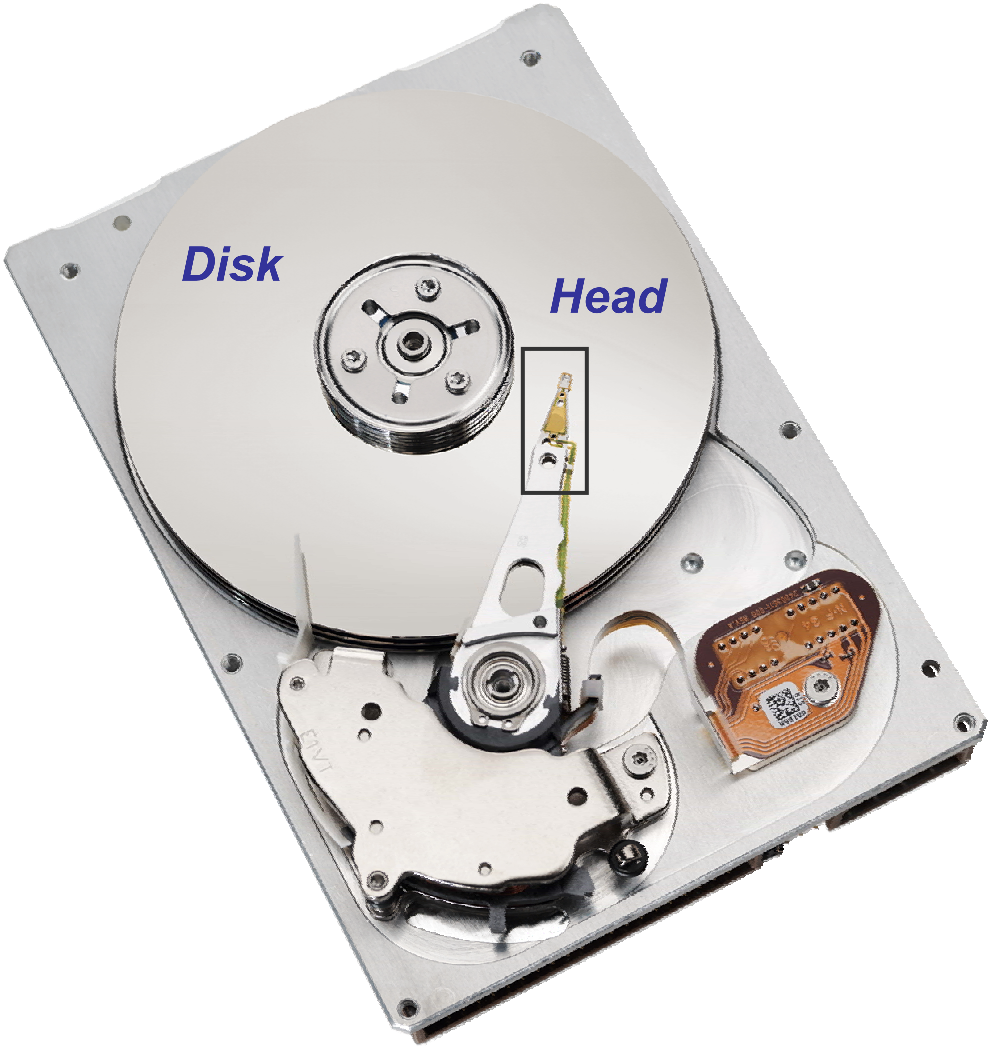
- *New stored information grew about 30% a year between 1999 and 2002.*

- *Information flows through electronic channels -- telephone, radio, TV, and the Internet -- contained almost 18 exabytes (exabyte=10^{18} bytes) of new information in 2002, three and a half times more than is recorded in storage media. Ninety eight percent of this total is the information sent and received in telephone calls - including both voice and data on both fixed lines and wireless.*

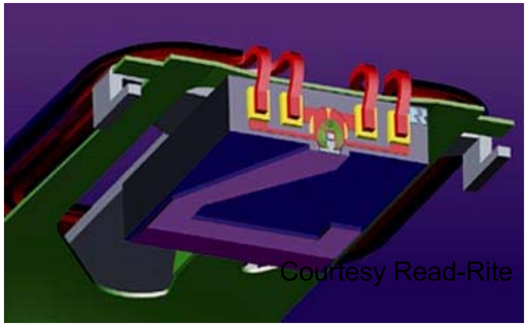
- *The World Wide Web contains about 170 terabytes of information on its surface; in volume this is seventeen times the size of the Library of Congress print collections.*

http://www.sims.berkeley.edu/research/projects/how-much-info-2003/printable_report.pdf

Inside a disk drive

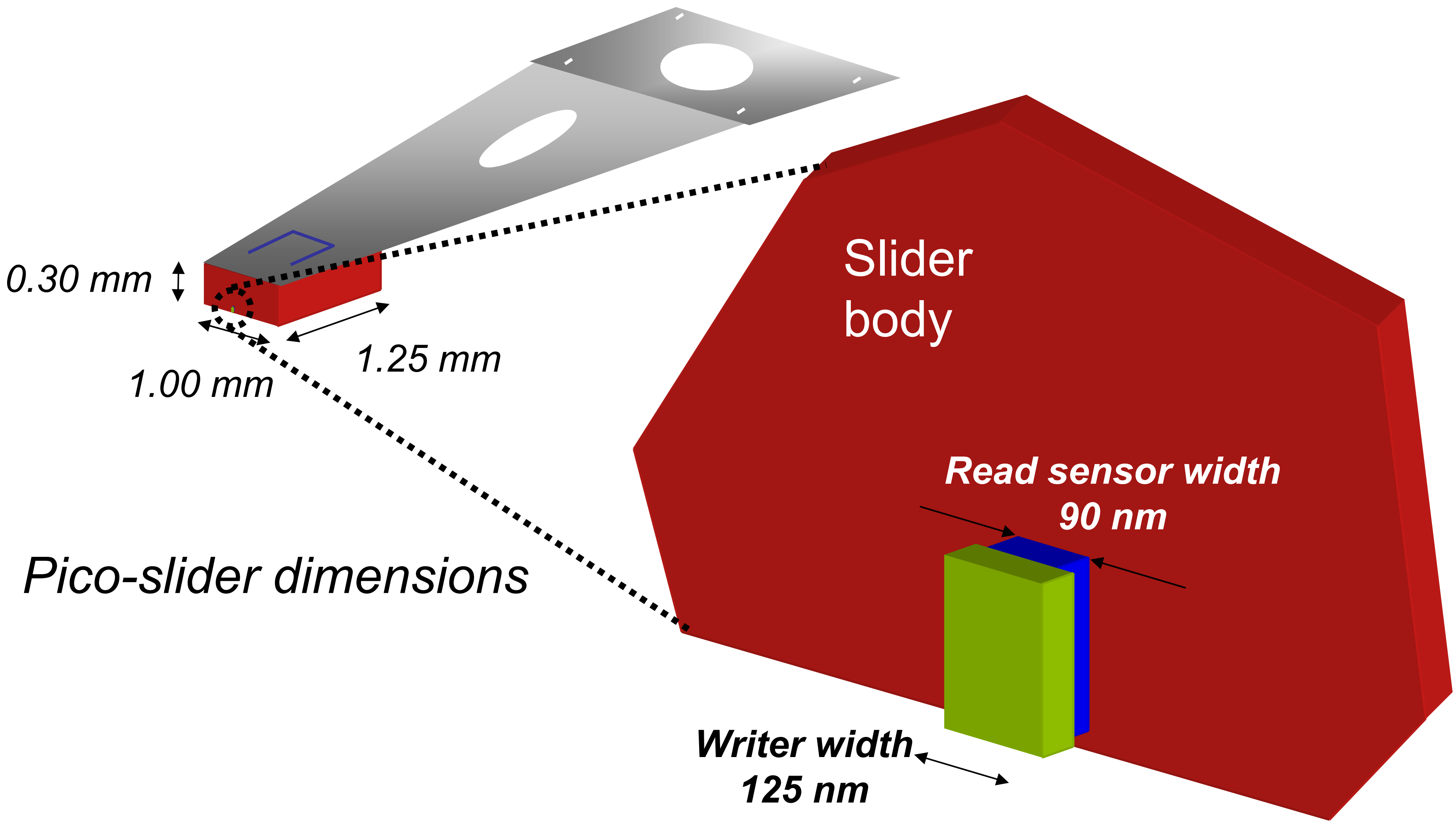


Seagate Barracuda ATA II



Head

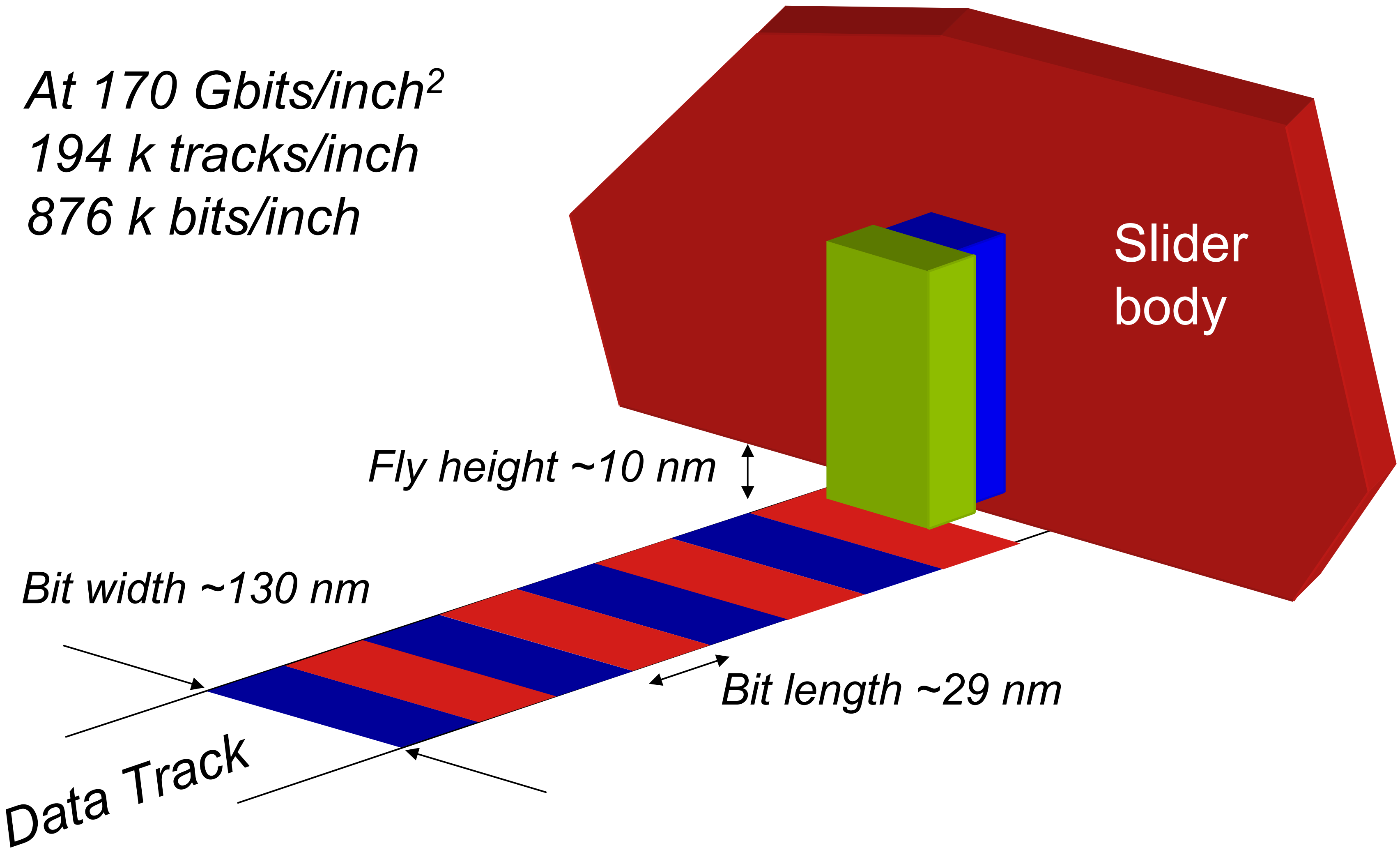
State-of-the-art industrial demo 170 Gbit/inch^2



Pico-slider dimensions

This is nanotechnology...

At 170 Gbits/inch²
194 k tracks/inch
876 k bits/inch

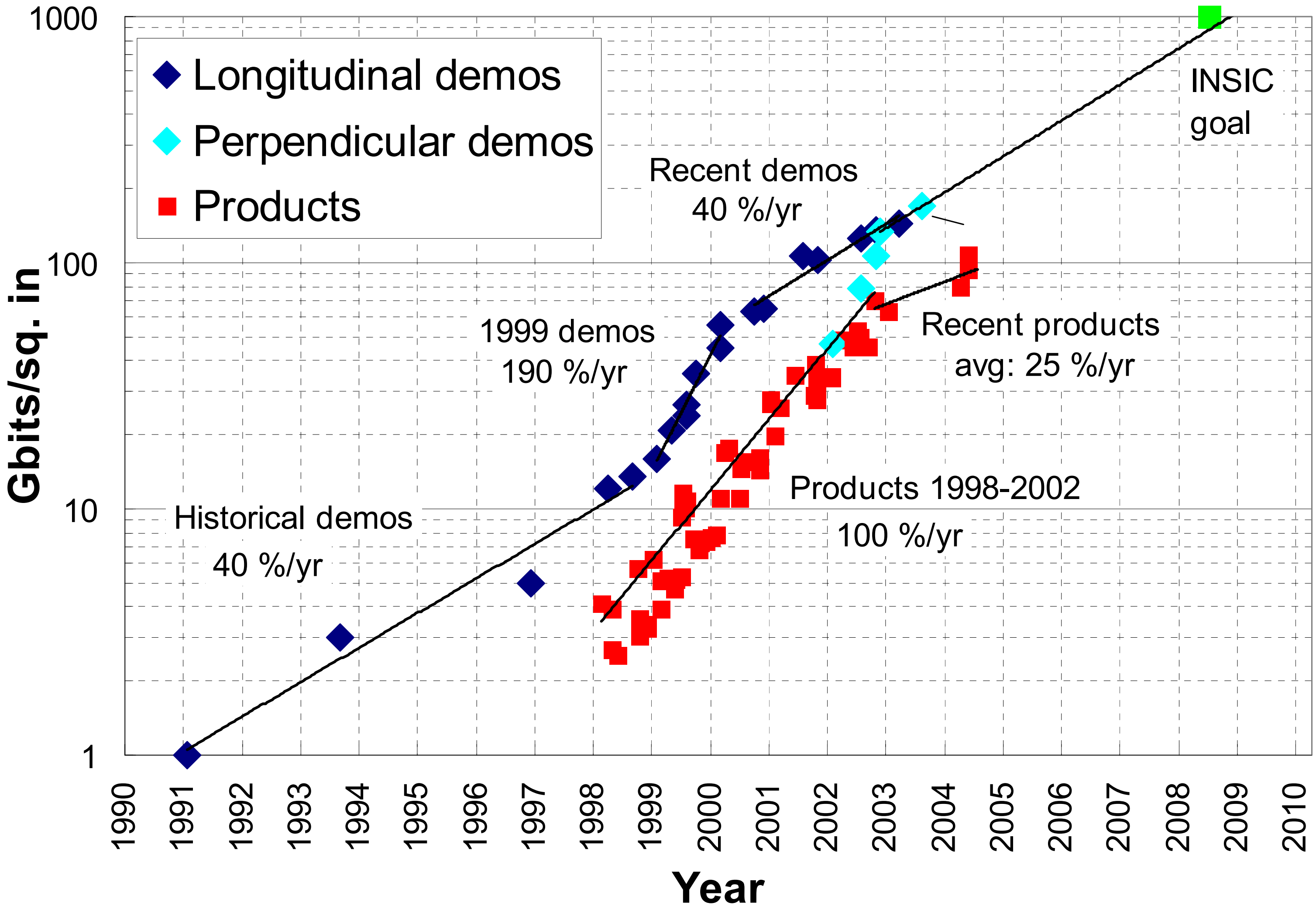


Nanotechnology

***Nano**; 1 - 100 nm the length scale at which groups of atoms begin to define their properties in aggregate*

Technology**; the* ***deterministic *manipulation of objects and materials rather than in an "average" sense.*

Magnetic Hard Disk Drives



Courtesy: J. Bain

What is a Tera-bit?

Technology goal today 1 Tbit/in^2

What does that mean?

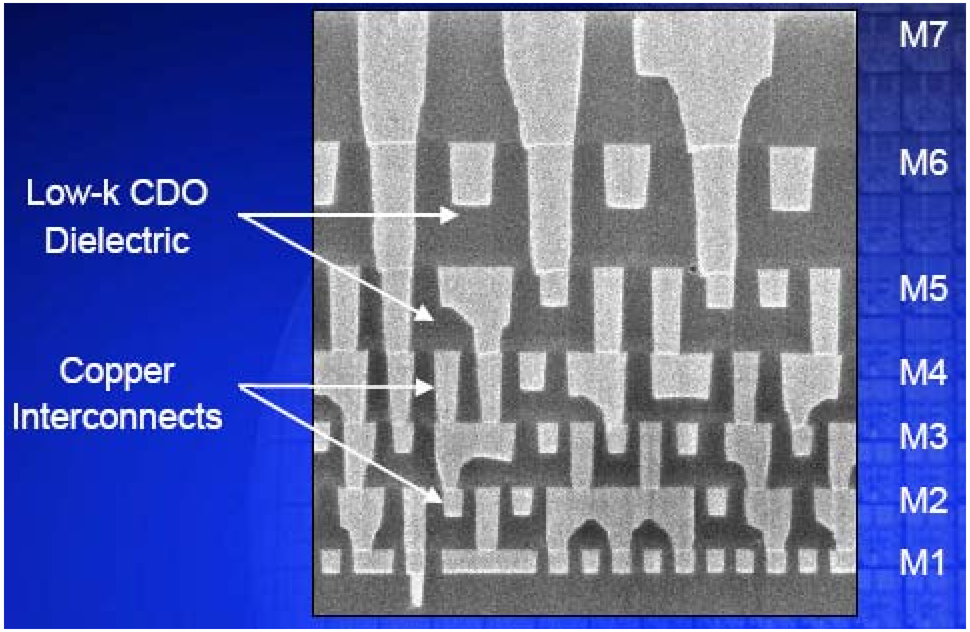
At 1 Tbit/in^2 you can save a picture of every man, women and child on earth on a disk the size of a Compact Disk

Libraries of information

750 byte
30 x 30 pixel
8 bit grayscale
.jpeg image

Courtesy: T. Rausch

Today's State of the Art in CMOS



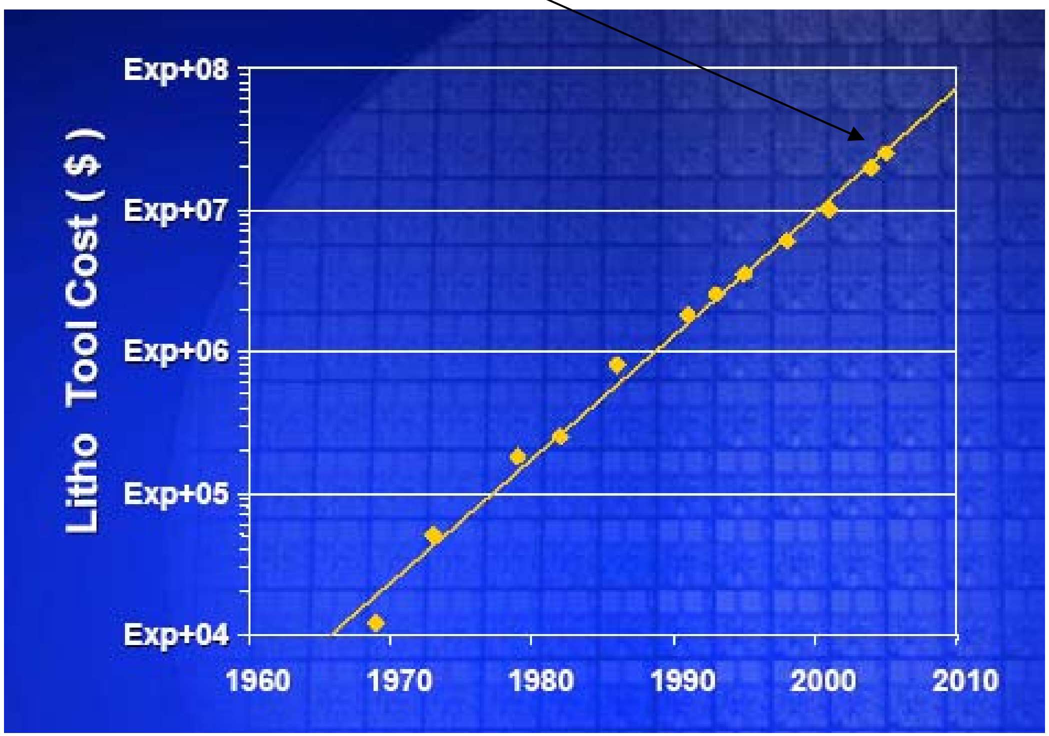
90 nm lithography

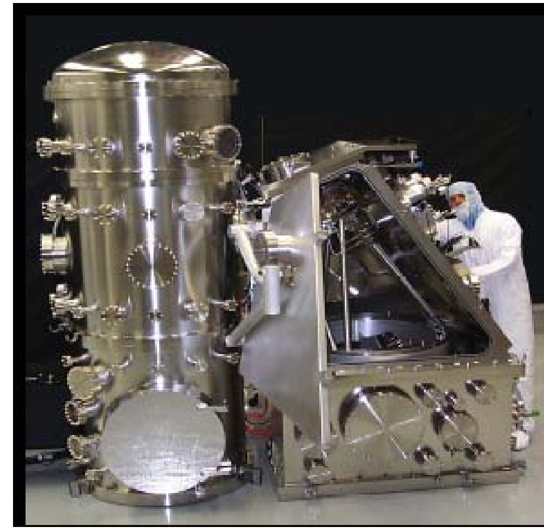
How long can physical limits on scaling be avoided?

Gordon Moore ISSCC 2003

Cost of Production

- $30 M/tool today
- $250 M/tool in ten years
- $1 B/tool in twenty years!





Extreme Ultraviolet Lithography (EUV)

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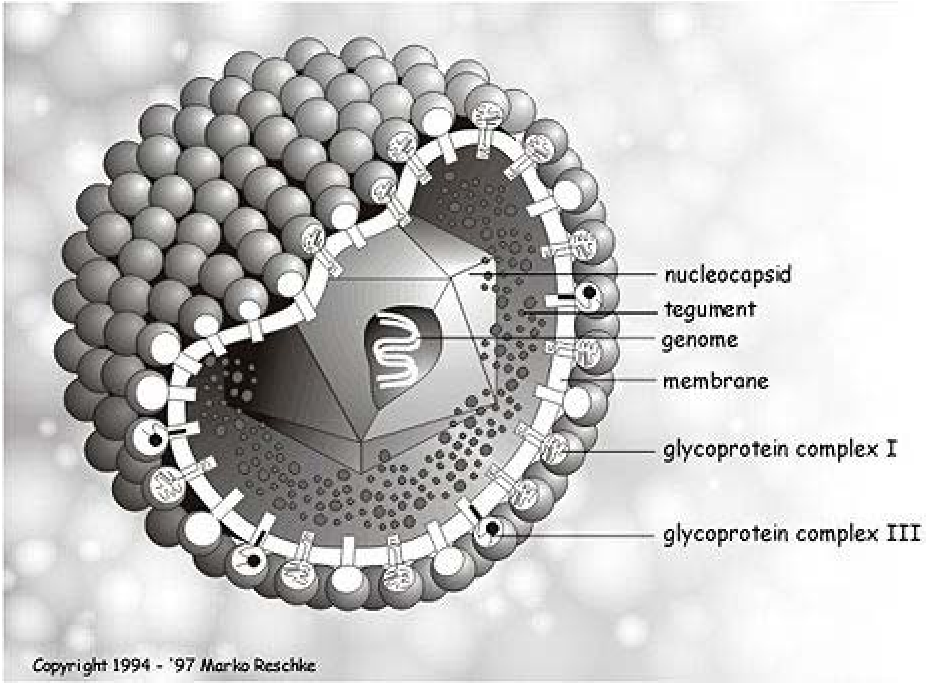
Human Cytomegalovirus (CMV):



200,000 base pairs
Nucleocapsid ~ 100 nm diameter

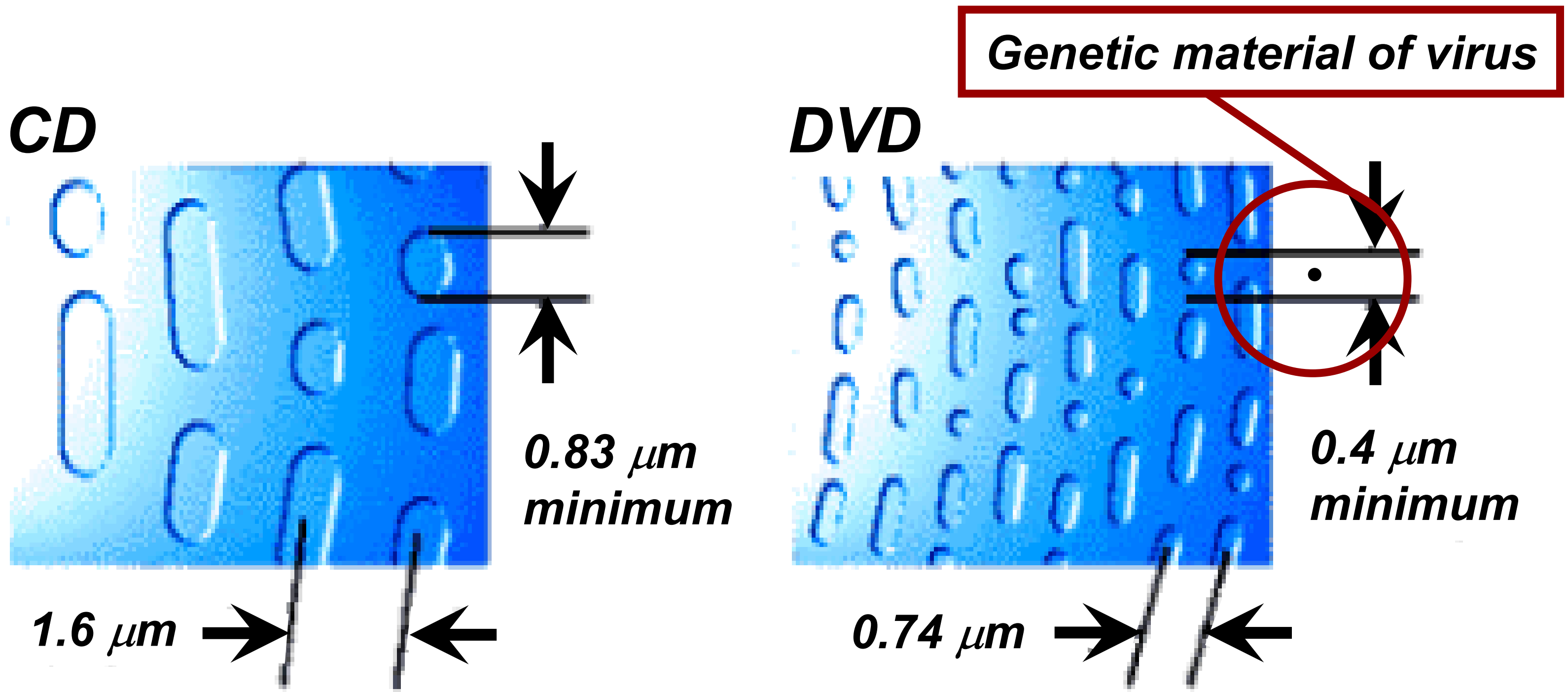
Information storage density $4x10^5$ bits per $\pi(50x10^{-9})^2$ m^{-2}

or about $3x10^{16}$ bits/inch^2

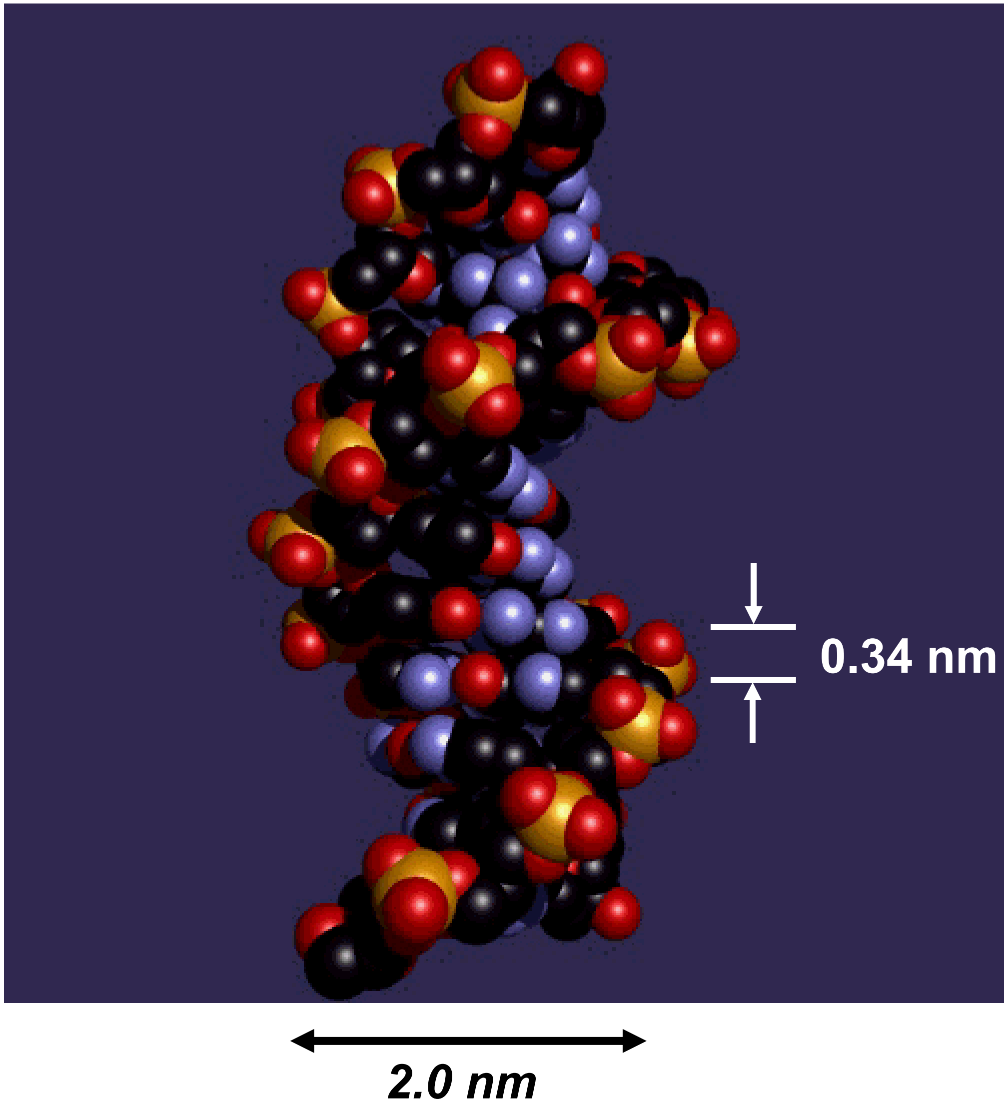
A factor of 10^5 times today's state-of-the-art

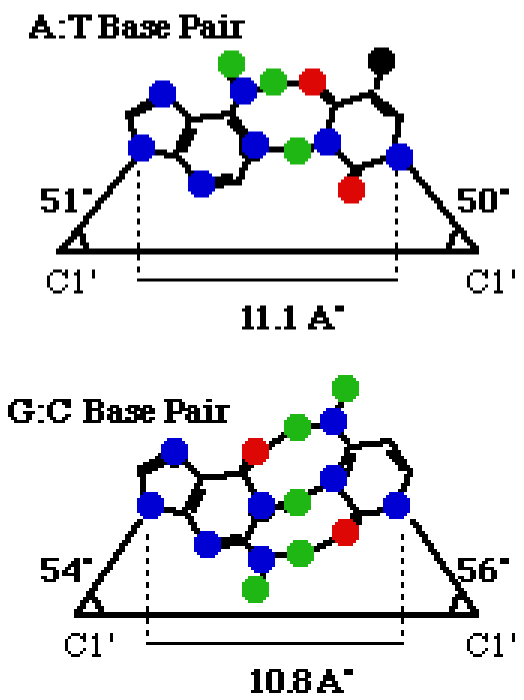
or equivalent to > 30 years of development

Relative Sizes



DNA Structure Defined at the Nanoscale





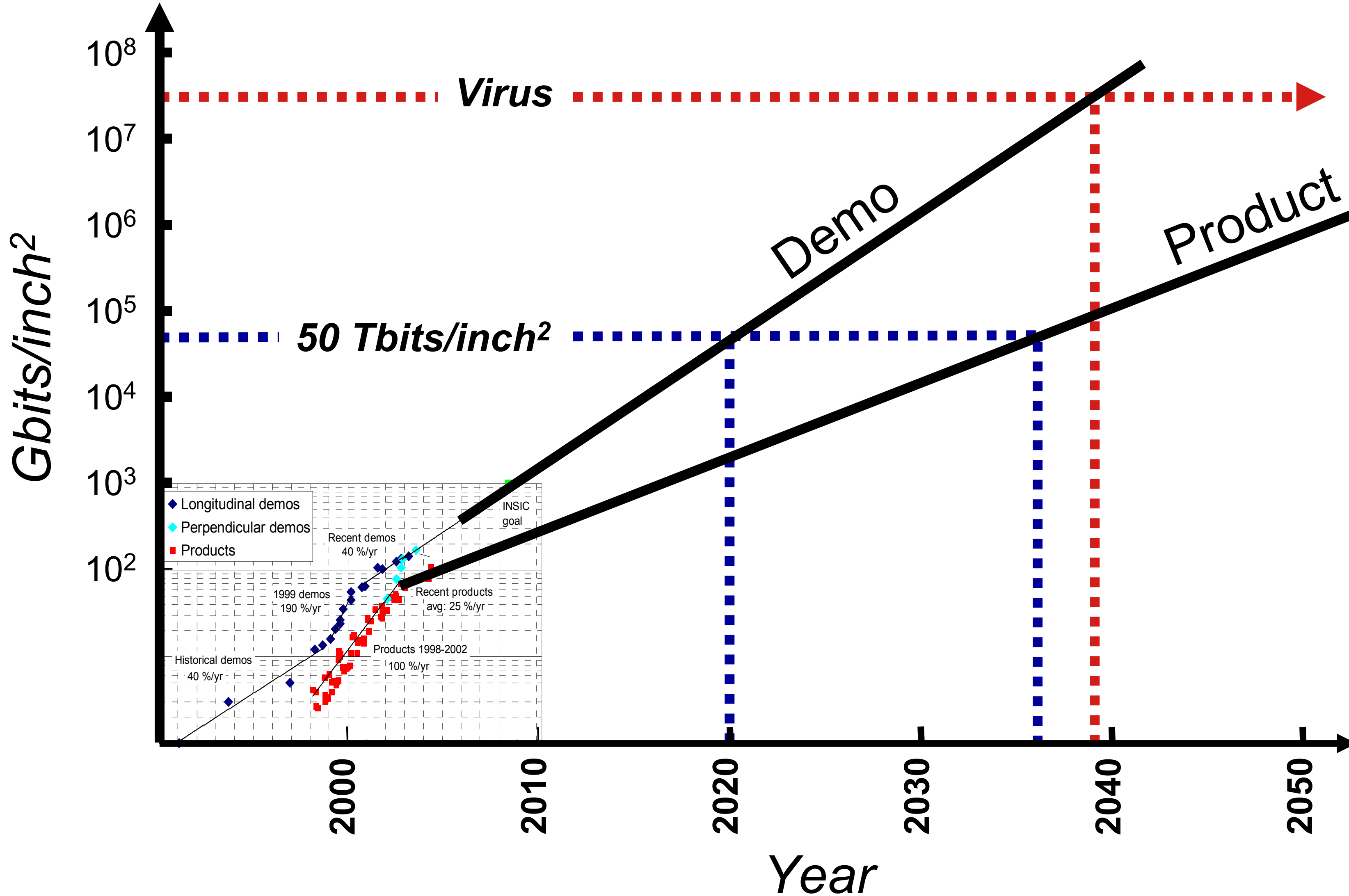
Can we learn too much from nature?

Bald Eagle in flight

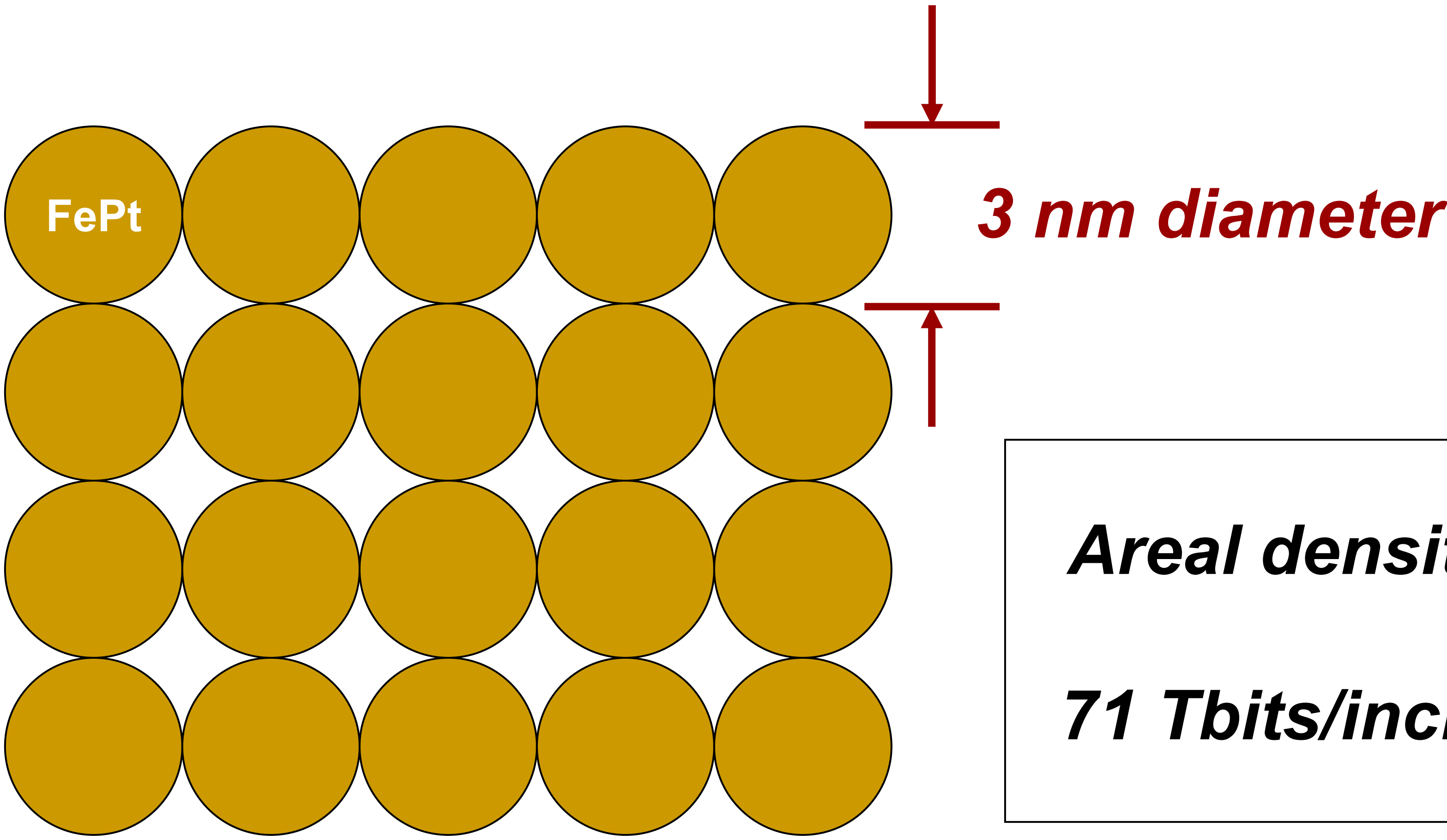
F-15 Eagle in flight

Heavier than air flight is possible…..

Competing with Viruses



Areal Density

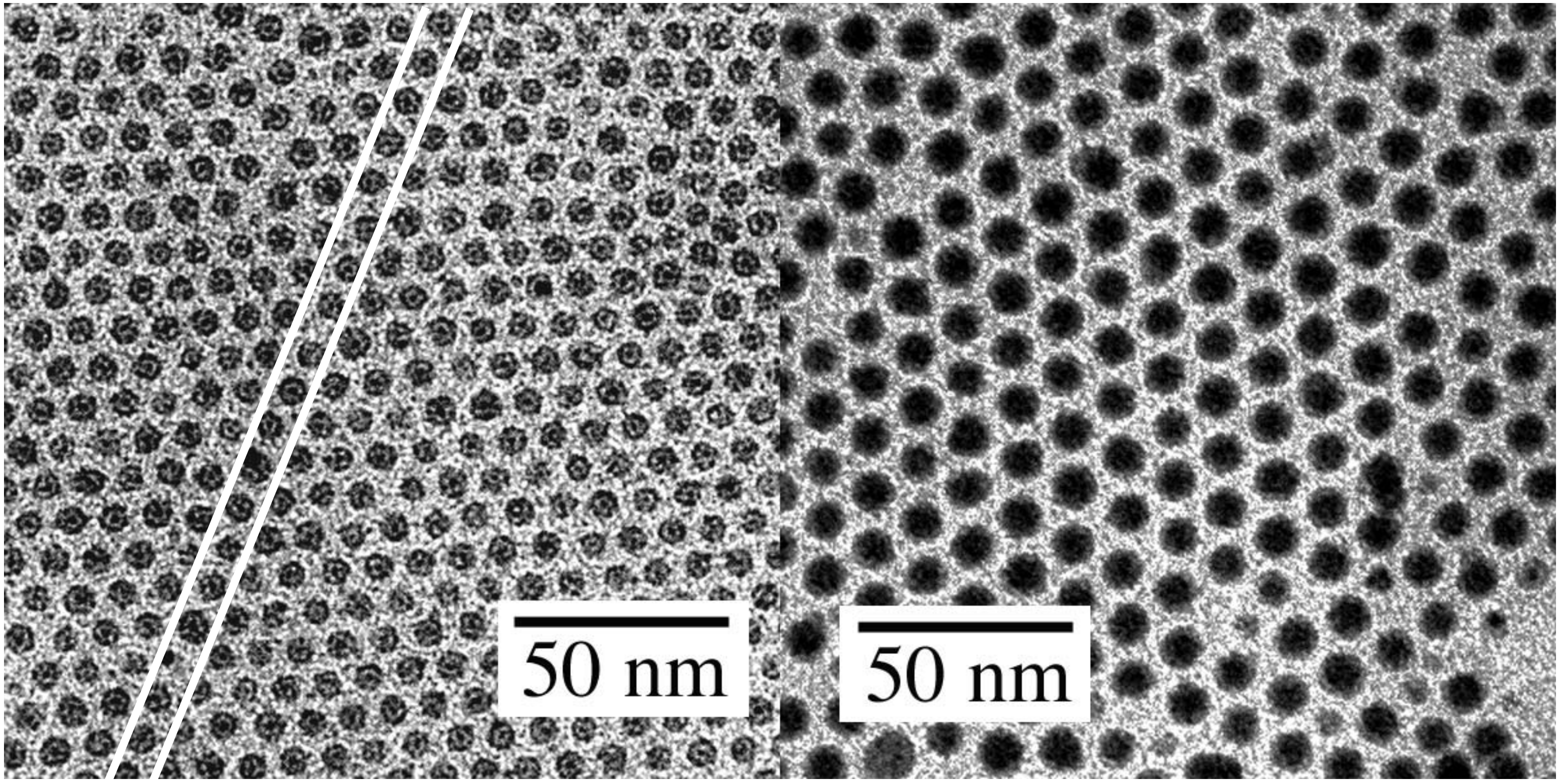


Areal density

71 Tbits/inch^2

Nanoparticle Arrays (Size)

S. Majetich

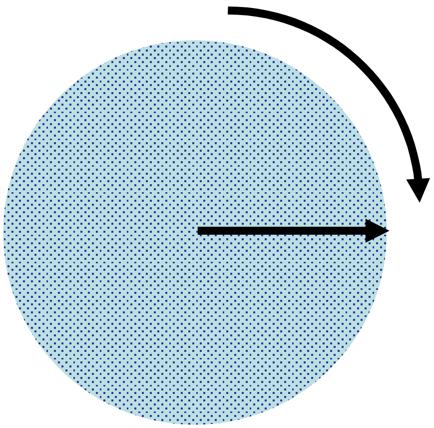


7.0 ± 0.8 nm *9.2 ±0.7 nm*

“Preparation and Characterization of Monodispersed Fe Nanoparticles”, D. Farrell, S.A. Majetich, J.P. Wilcoxon, *J. Phys. Chem*. **107**, 11022(2003).

Capacity

- ***Limit capacity to 1 Terabyte (8 Terabits)***
  - *Implies an area of 0.16 inch^2 (1 cm^2 media)*
- ***For 1 msec rotational latency***
  - *1 kHz vibration or 60,000 rpm*



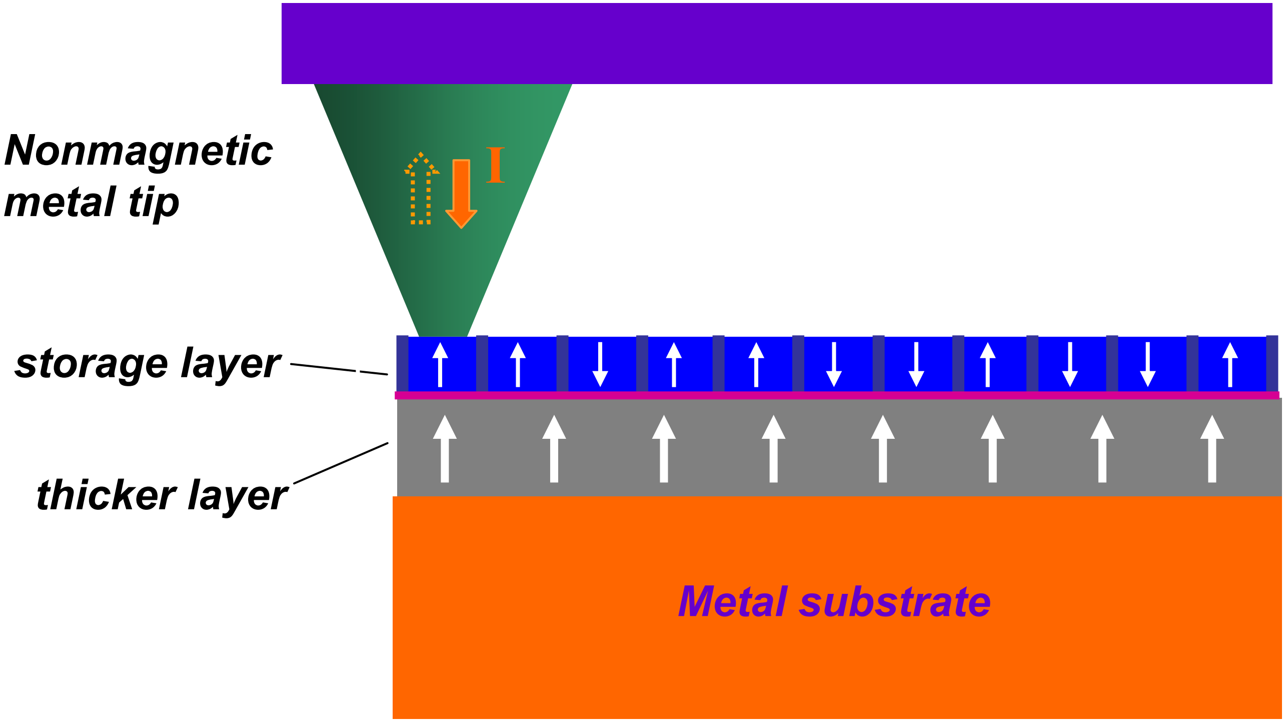
r = 0.564 cm

v = ωr = 2πx1000x0.564

= 35 m/sec

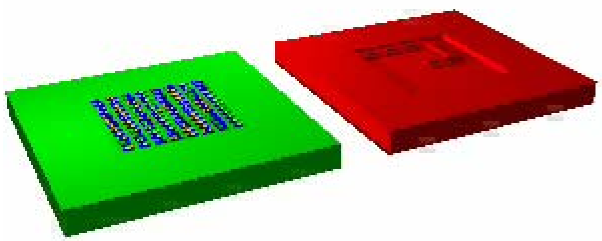
Data rate: 10 Gbits/sec

Writing by Spin Injection (Spintronics)



Courtesy J. Zhu

Memory Intensive Self-Configuring ICs (MISC IC)



Two chips; green represents a CMOS IC that includes a nanofabric or reconfiguration layer, red is a probe layer also fabricated through a CMOS process. These are bonded together.

Applied Physics Course Tree