Industry's evolutionary path
Moore's Law: ¿*Que sera sera*

Goodness

Grand Chalengeland
New systems, classes, & apps

Base Case

Evolution in performance, cost

2000   Time   2012
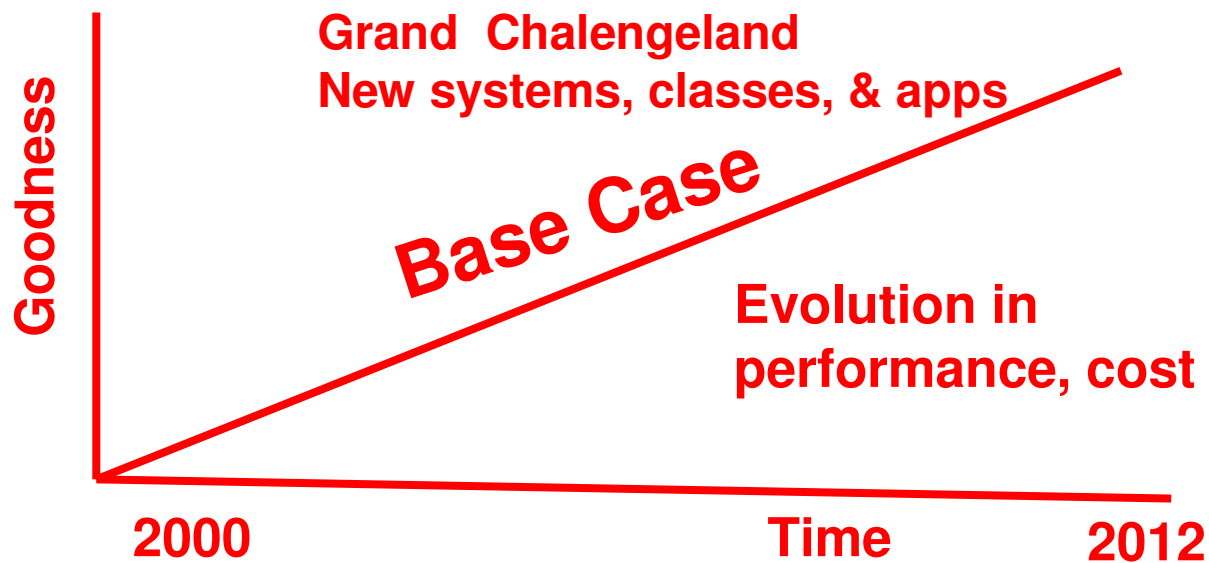
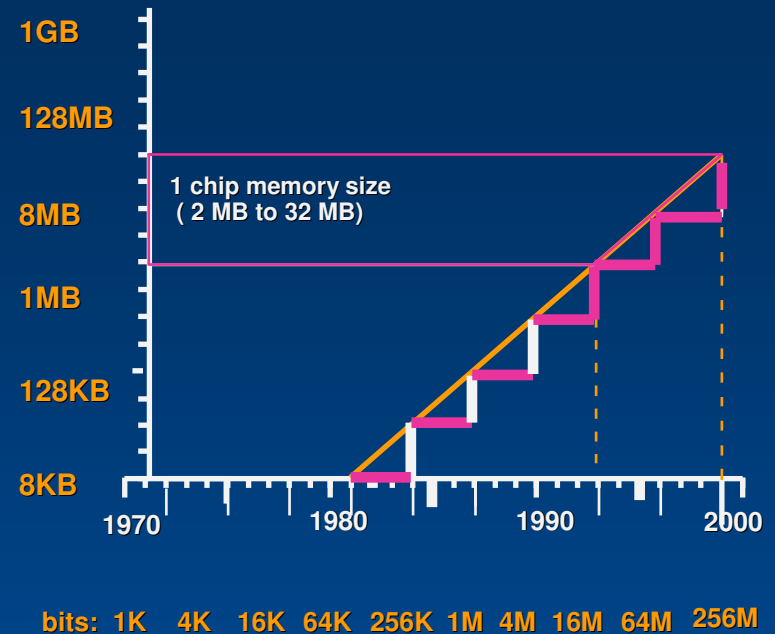## Gordon Bell
Microsoft Research

Outline

- Theory of Computer Industry formation
- Interesting new & converging classes
  - Large stores: PC rebirth; capture all corp. data
  - Small form factor everything; phone, PC, camera...
  - Wireless sensor nets
  - Convergence: Computers & Consumer Electronics
- Game changers
  - GPU
  - Speech – the technology of the future
  - New user interfaces & apps… life beyond WIMP?

Moore's First Law

- **Transistor density doubles every 18 months 60% increase per year**
  - Chip density transistors/die
  - Micro processor speeds
- **Exponential growth:**
  - The past does not matter
  - 10x here, 10x there … means REAL change
- **PC costs decline faster than any other platform**
  - Volume and learning curves
 - PCs are the building bricks of all future systems

1GB

128MB

8MB

1MB

128KB

8KB

1 chip memory size
(2 MB to 32 MB)

1970   1980   1990   2000

bits: 1K   4K   16K 64K 256K 1M 4M 16M 64M 256M
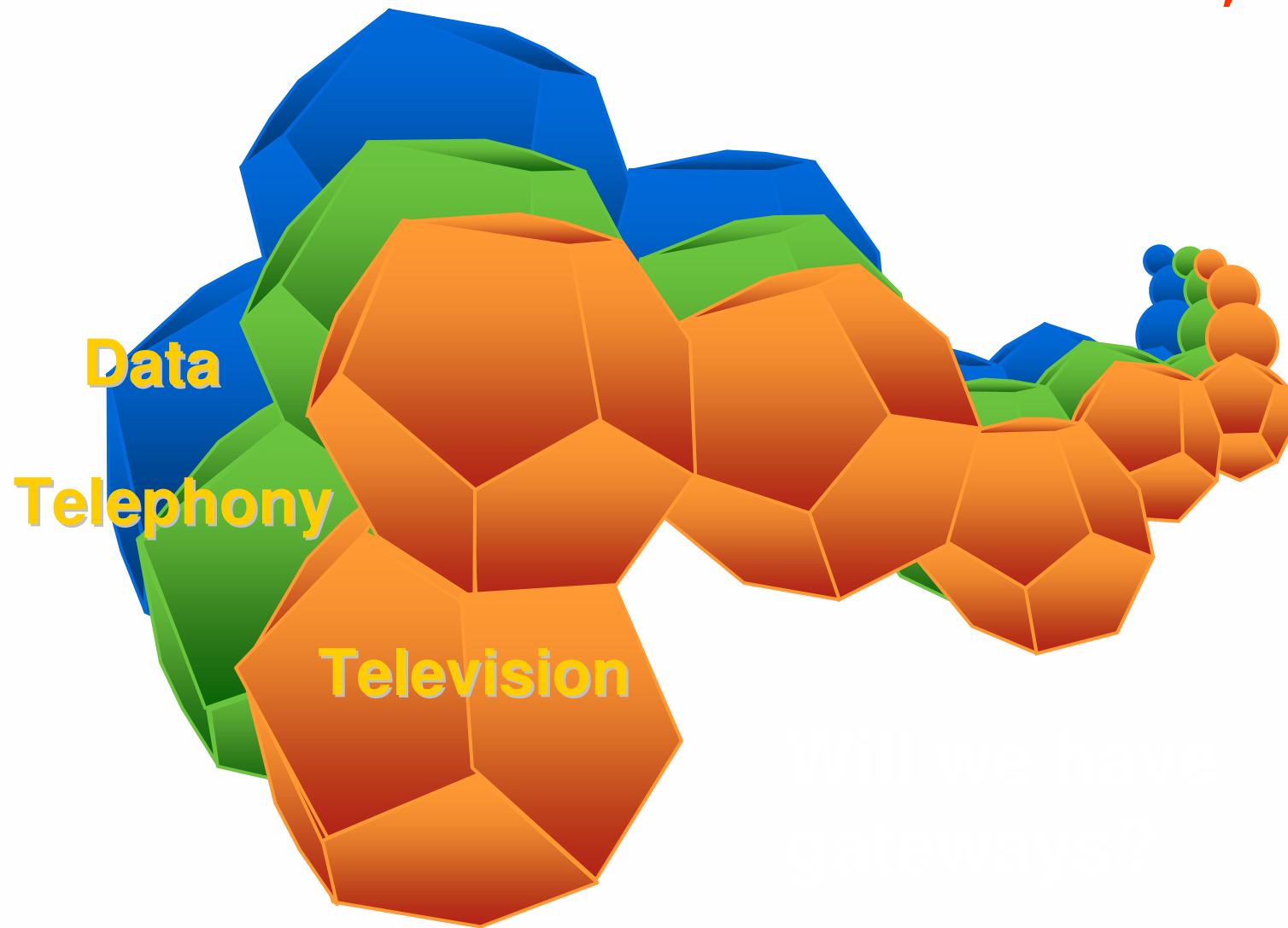
Computing Laws

Computer components must all evolve at the same rate

- **Amdahl's law: one instruction per second requires one byte of memory and one bit per second of I/O**

- **Storage evolved at 60%; after 1995: 100%**

- **Processor performance evolved at 60%.**
  - **Performance flat >1995.**
  - **Multi processors.**
  - **GPU**

- **Wide Area Network speed evolved at >60%**

- **Local Area Network speed evolved 26-60%**

- **Grove's Law: Plain Old Telephone Service (POTS) thwarts speed, evolving at 14%!**

Everything cyberizable will be in Cyberspace! Goal? Quest? or Fate?

Continent

World

Region/Intranet

Campus,
including SANs

In Body
On Body

Car

Home
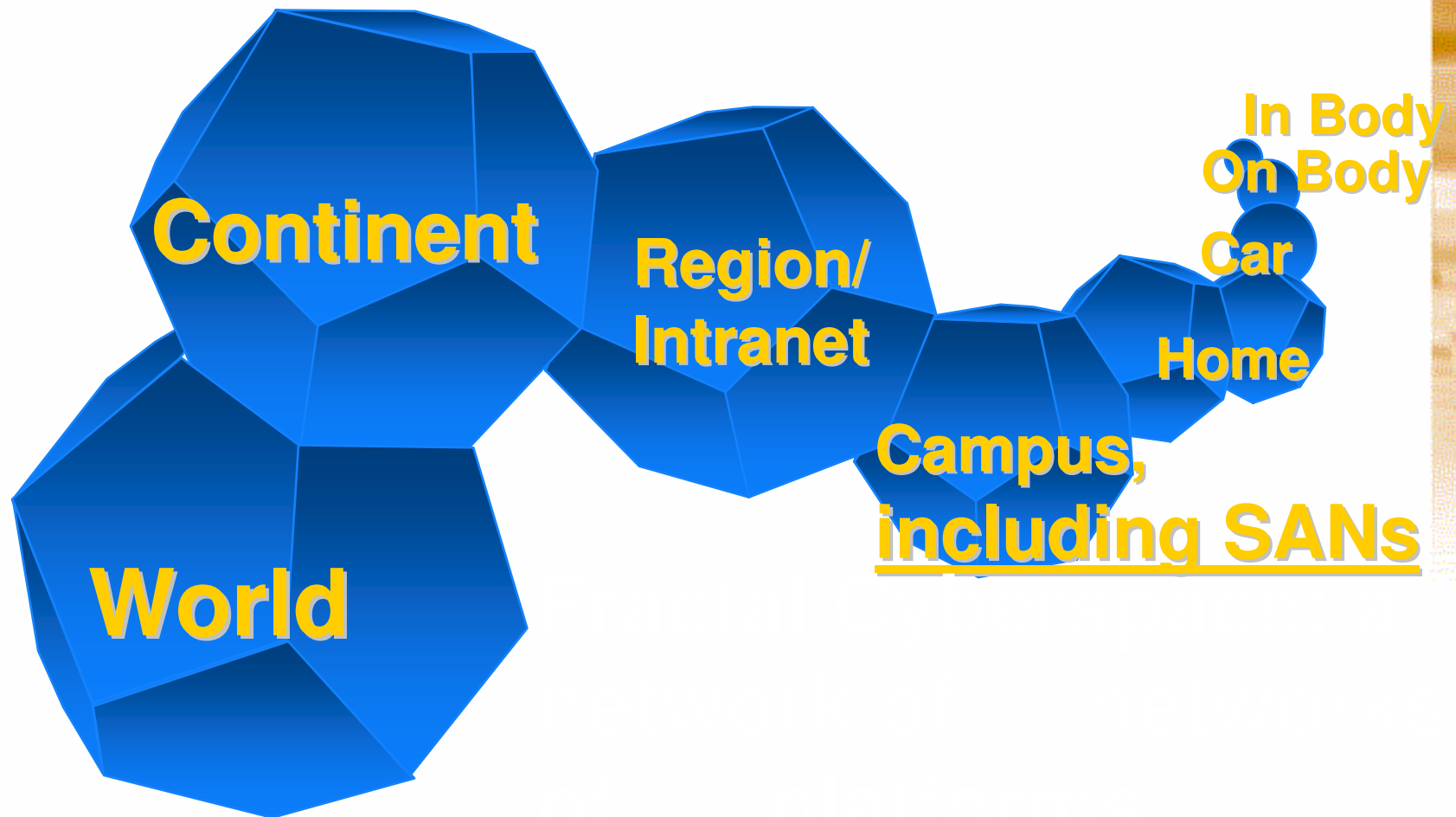
Cyberspace: one, two or three networks? in 2005, 2010, 2020

Data

Telephony

Television
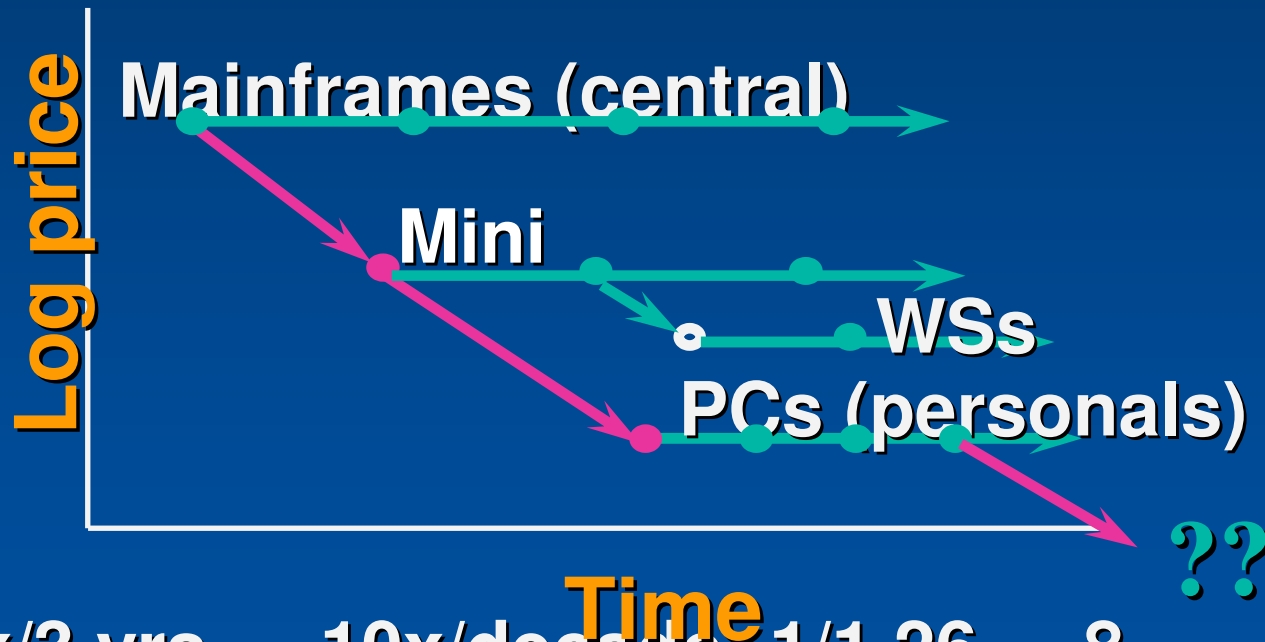
Computer Classes…
Every Decade a new one emerges to cover Cyberspace

- Every decade a new, lower cost class of computers emerge defined by
  - Computing platform
  - Interface to humans or other parts of world
  - New networking and/or interconnect structure
- The classes… a decade in price every decade

60s	$millions	mainframes
70s	$10K-100K	minis
80s	$10K	workstations and PCs
90s	$1K	PCs
00s	$100s	PDAs & cellphones
10s	$10	wireless sensor nets, motes, etc.

Bell's Evolution Of Computer Classes

Technology enables two evolutionary paths:
1. **constant performance, decreasing cost**
2. **constant price, increasing performance**

Log price

Mainframes (central)

Mini

WSs

PCs (personals)

??

Time

1.26 = 2x/3 yrs -- 10x/decade; 1/1.26 = .8

1.6 = 4x/3 yrs --100x/decade; 1/1.6 = .62

Platform, Interface, & Network Computer Class Enablers

	"The Computer" Mainframe	Mini & Timesharing	PC/WS	Web browser, telecomputer, tv computer
Platform	tube, core, drum, tape, batch O/S	SSI-MSI, disk, timeshare O/S	micro, floppy, disk, bit-map display, mouse, dist'd O/S	PC, scalable servers,
Interface	direct > batch	terminals via commands	WIMP	Web, HTML
Network		POTS	LAN	Internet

Computing Laws

Bell's Nine Computer Price Tiers

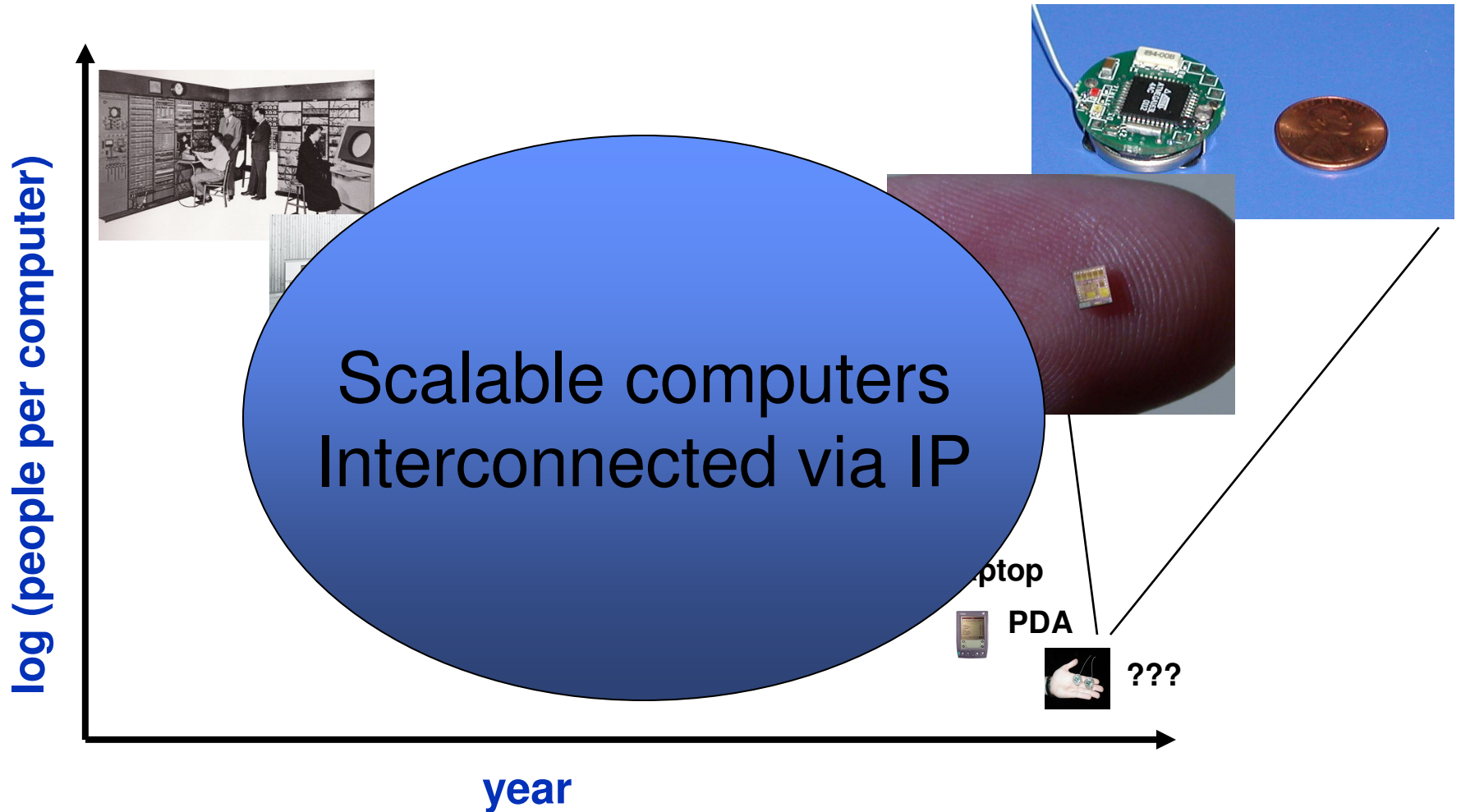|	
1$:	embeddables e.g. greeting card
10$:	wrist watch & wallet computers
100$:	pocket/ palm computers
1,000$:	portable computers
10,000$:	personal computers (desktop)
100,000$:	departmental computers (closet)
1,000,000$:	site computers (glass house)
10,000,000$:	regional computers (glass castle)
100,000,000$:	national centers

Super server: costs more than $100,000
"Mainframe": costs more than $1 million
an array of processors, disks, tapes, comm ports

Computing Laws

A New Computer Class Emerging

log (people per computer)

Scalable computers
Interconnected via IP

ptop

PDA

???

year

David Culler UC/Berkeley

Software Economics: Bill's Law

$$\text{Price} = \frac{\text{Fixed\_cost}}{\text{Units}} + \text{Marginal \_cost}$$

- **Bill Joy's law (Sun):
don't write software for <100,000 platforms
@$10 million engineering expense, $1,000 price**

- **Bill Gate's law:
don't write software for <1,000,000 platforms
@$10M engineering expense, $100 price**

- **Examples:**
  - **UNIX versus Windows NT: $3,500 versus $500**
  - **Oracle versus SQL-Server: $100,000 versus $6,000**
  - **No spreadsheet or presentation pack on UNIX/VMS/...**

- **Commoditization of base software and hardware**

The Virtuous Economic Cycle that drives the PC industry

Competition
Innovation
Utility/value
Volume
Standards

The Hz, Bits, Bytes, Pixels

CACM 1997 Predictions

Average Price of Storage
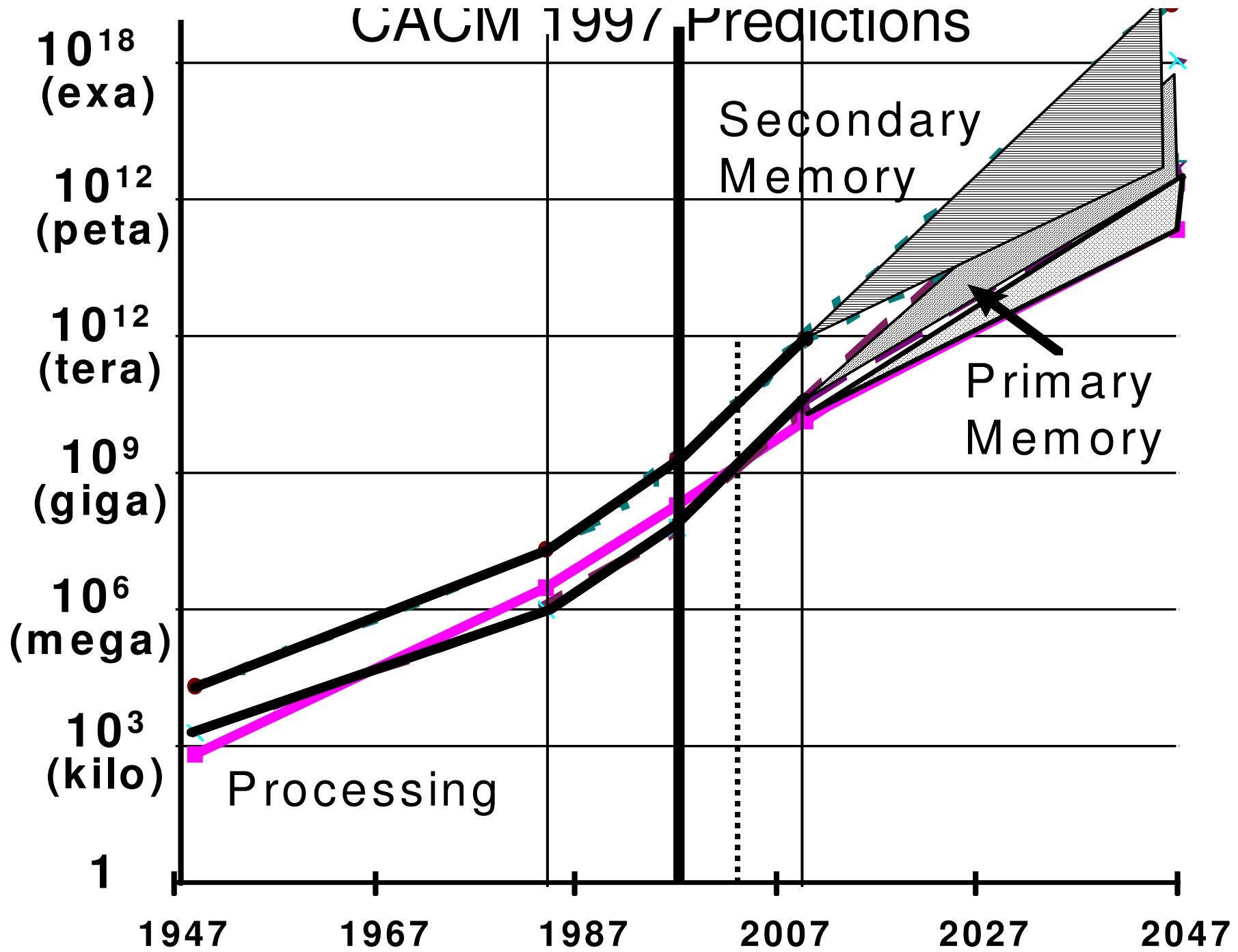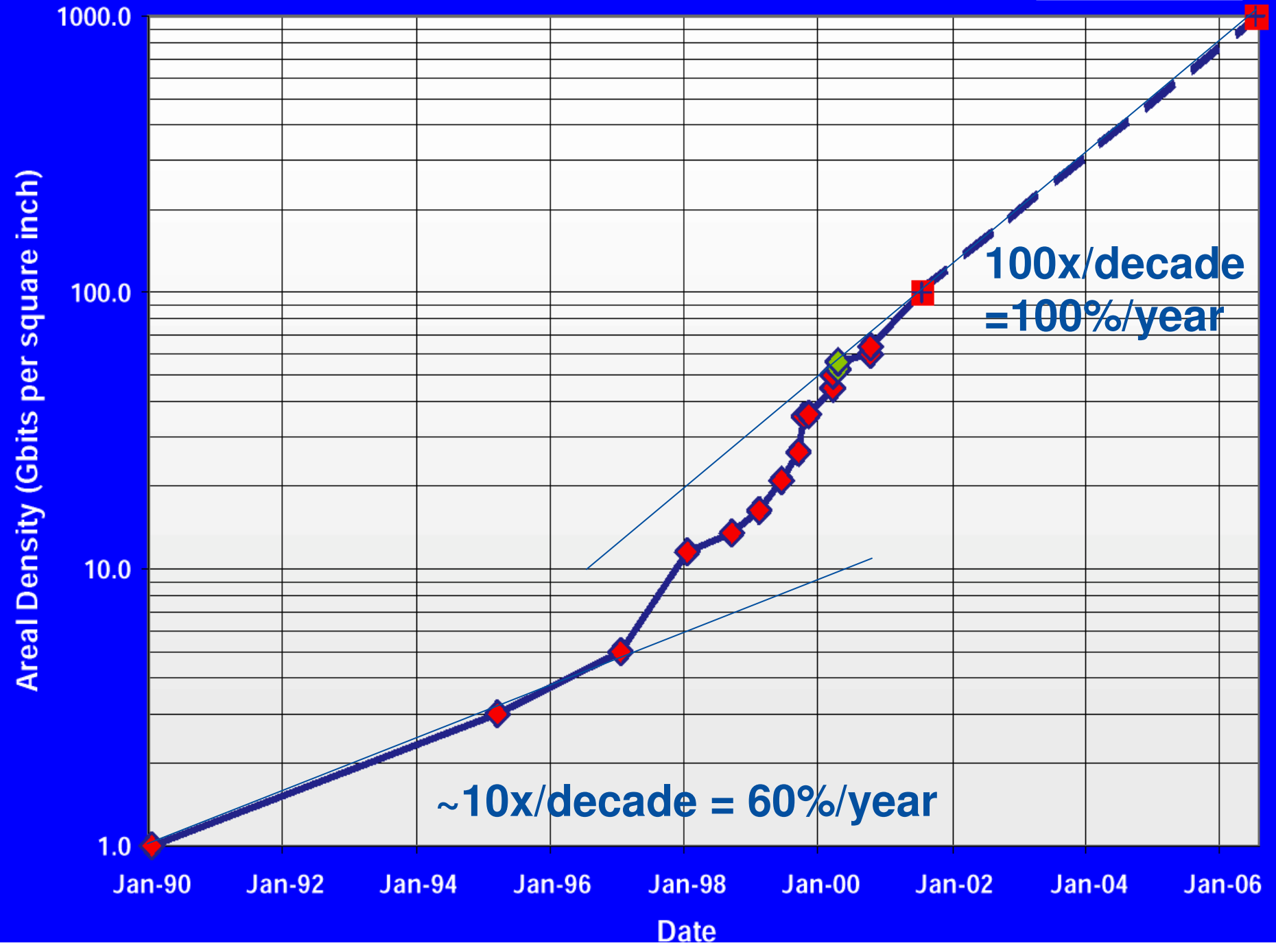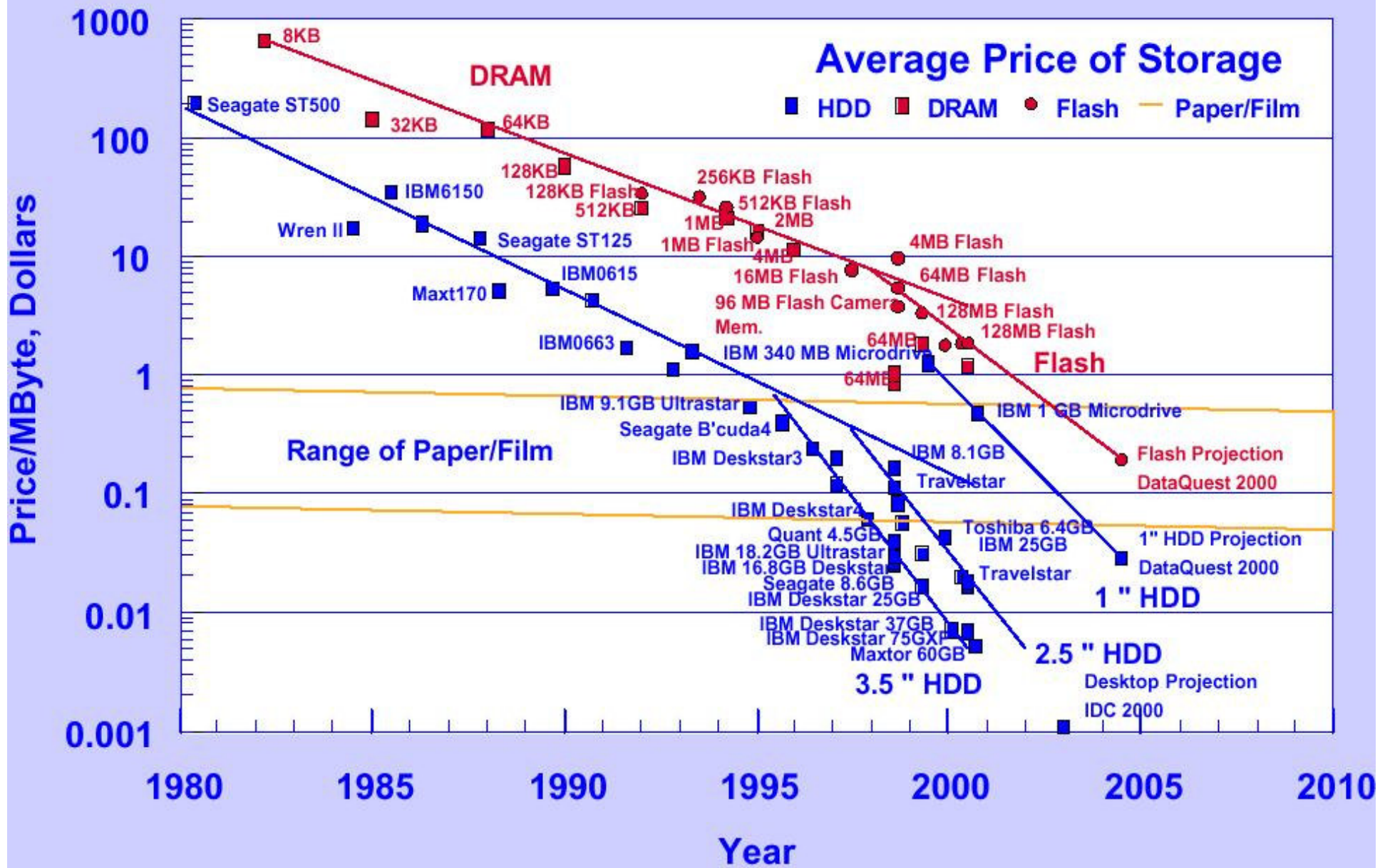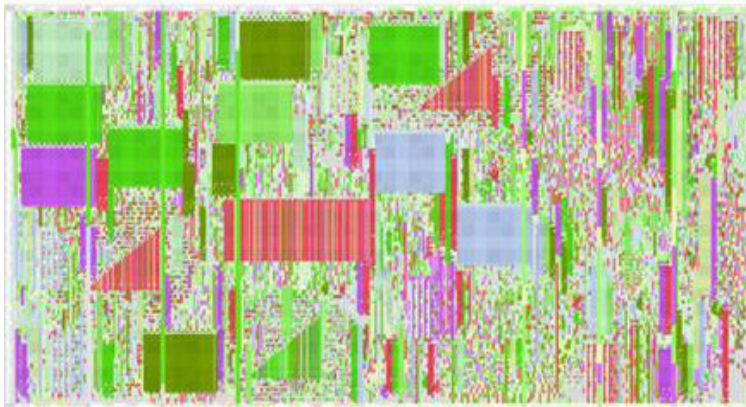
Source: Ed Grochowski, IBM Research Almaden

Molecular mechanics accelerator
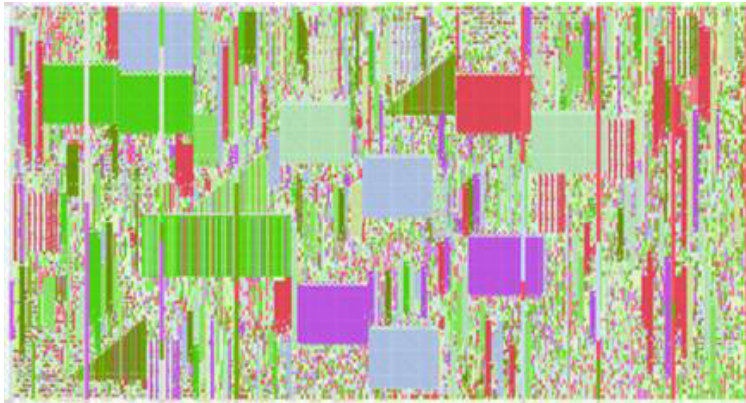
Hardware accelerator logic (1 of 14)

Hardware accelerator logic (7 of 14)

» Pharmix has developed the first system to implement an entire molecular mechanics calculation on a single chip

» **1000x speedup** (vs. 1GHz PIII) **supercomputer → one chip year 2020 → year 2002**

» Enables complex simulations of drug-receptor interactions **for unprecedented accuracy**

PROPRIETARY AND CONFIDENTIAL

PHARMIX

Product and Industry Implications

Prediction, c 1995

- —in a 1995 *Computerworld* article headlined "The View from Here: Gordon Bell Previews a Future in Which Plugging in to a Worldwide Network Is as Easy as Getting a Dial Tone"

- **Mainframes, Minicomputers, Servers, and Workstations**
  Individual low-cost, high-powered PCs, such as Compaq Computer Corp.'s ProLiant, combined with Windows NT, SQL-based databases and a single communications network will form the heart of the scalable computer. Youcan say good-bye to mainframes, proprietary minicomputers, servers and workstations.

Very large disks … are the driver
Old world vs. New World

- Mainframe: a few TB
- Cents/transaction
- Cost: $85/GB
- Sparse transactions

- Scaled out PCs
- Zero cost/transaction
- Cost: $1M/year/petabyte
- Capture Everything!!!
  - Track every item e.g. sheet rock…serial no.
  - Phone call
  - Track every person x ad

Debit/Credit Benchmark – Jim Gray

Figure 1: A $10M Tandem 208 tps system (1, 2) and a 2M$ IBM 70 tps system (3) circa 1988. A $0.002M Toshiba 8,350 tps system circa 2005 (4); the desktop equivalent of this machine costs ~$400 in 2005 (5).

1988: Tandem 10M   208 tps

IBM   2M   70 tps

2005: Toshiba PC   8350 tps

14M BofA accounts = 4 GBytes

Archive.org

- Founded in 1996 to archive the internet

- Includes books, movies, music, and programs

- Copies: San Francisco, Alexandria, and Amsterdam

Brewster Kahle
Archive.org
1 petabyte store

$2K/terabyte/year

$0.0004/page/year

Ad Execs Want to Track Every Move By Joanna Glasner

**Story location:** http://www.wired.com/news/ebiz/0,1272,67390,00.html

02:00 AM May. 02, 2005 PT

SAN FRANCISCO -- Marketers are testing new techniques to measure whether advertisers' messages are getting across, and they are prepared to spend vast sums and deploy astonishingly complex technologies to do so.

At the Ad:Tech conference in San Francisco last week, advertising experts contemplated a variety of approaches, ranging from round-the-clock automated ad tracking to simply reducing the number of ads per show, that could make it easier for advertisers to reach an increasingly fragmented viewing public.

To measure the impact of ad campaigns, VNU, the parent company of television-audience measurement firm Nielsen Media Research, and Arbitron, the media research firm, are developing an experimental program called Project Apollo that takes the concept of viewer tracking to a level of unprecedented detail.

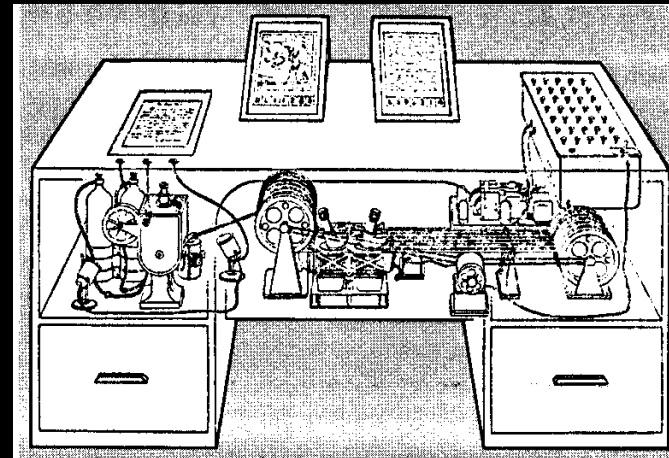
RECYCLE-A-BIKE
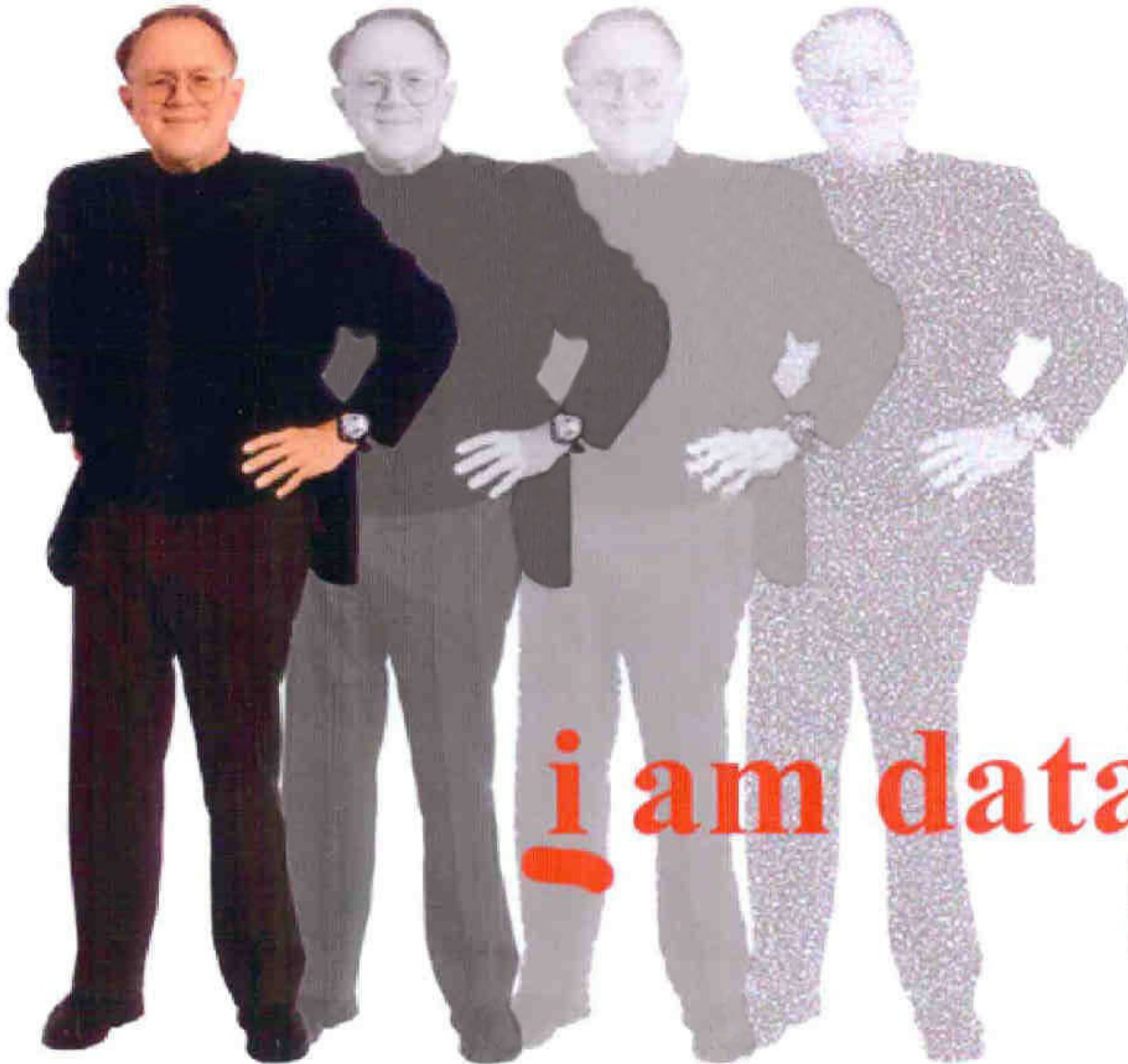
i am data.

Re-discovery of Memex
As We May Think, Vannevar Bush, 1945

"A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility"

- Full-text search, text & audio annotations, and hyperlinks

AS WE MAY THINK
A TOP U. S. SCIENTIST FORESEES A POSSIBLE FUTURE WORLD
IN WHICH MAN-MADE MACHINES WILL START TO THINK

The 1 TB Life

- 40 MB/day = 1 TB for 65+ years of:
  - 100 email messages a day (5KB each)
  - 100 web pages day (50KB each)
  - 5 scanned pages a day (100KB each)
  - 1 book every 10 days (1 MB each)
  - 10 photos per day (400 KB JPEG each)
  - 8 hours per day of sound - e.g. telephone, voice annotations, and meeting recordings (8 Kb/s)
  - 1 new music CD every 10 days (45 min each at 128 Kb/s)
- It will take you 5 years to fill up your 80 GB drive
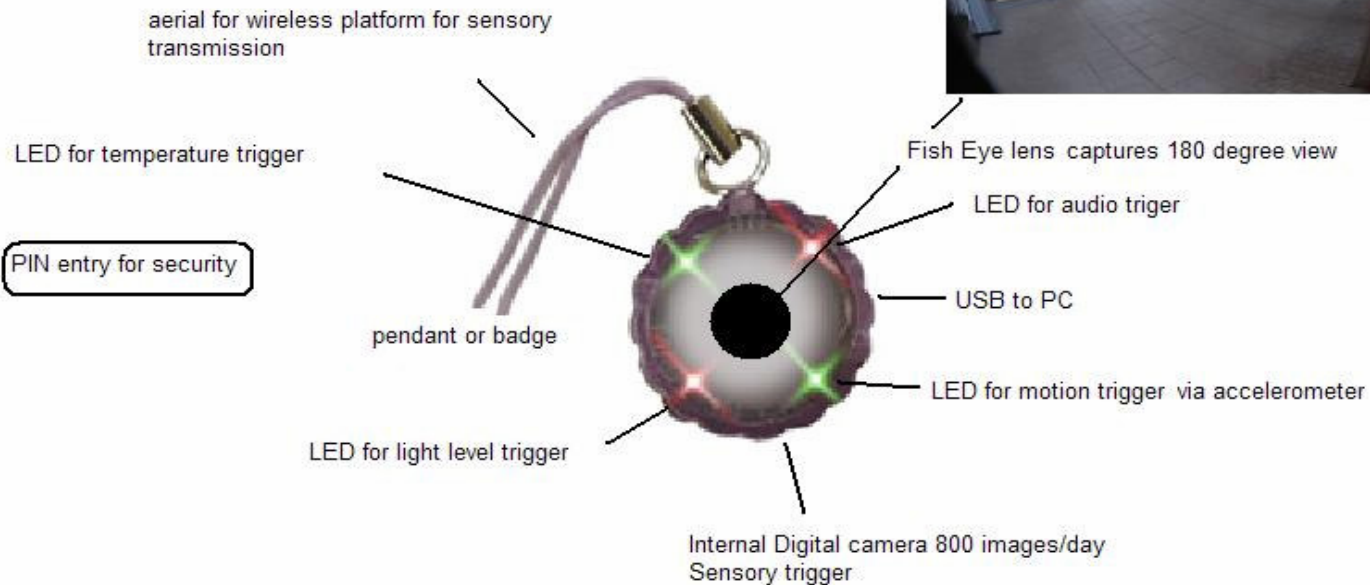- Want video? Buy more cheap drives (1 TB/year lets you record 4 hours/day of 1.5 Mb/s video)

Capturing what you see or hear

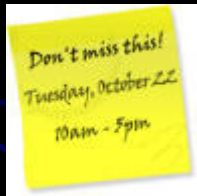# Wearable & interactive jewellery LEDs flash according to sensor type triggered
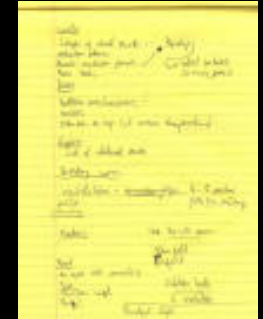

Prototype V1

aerial for wireless platform for sensory transmission

LED for temperature trigger

PIN entry for security

pendant or badge

LED for light level trigger

Fish Eye lens captures 180 degree view

LED for audio triger

USB to PC

LED for motion trigger via accelerometer

Internal Digital camera 800 images/day
Sensory trigger

SenseCam 17 Oct 2003

A device for "personal video recall" of the days, weeks events.
"where did I leave my keys? where have I been? Who have I met?

Lyn
MSR Cambridge

Potentially useful trivia – but not normally photographed

Convergence: Computers & Consumer Electronics

Cassette
Legacy

stereo

CD
Legacy

stereo

VCR
Legacy

stereo
Video*

DVD
Redundant

5.1 digit
comp.

Set top

stereo
Video*

IR

Receiver

Wfr

Spkr

5 speakers

Spkr
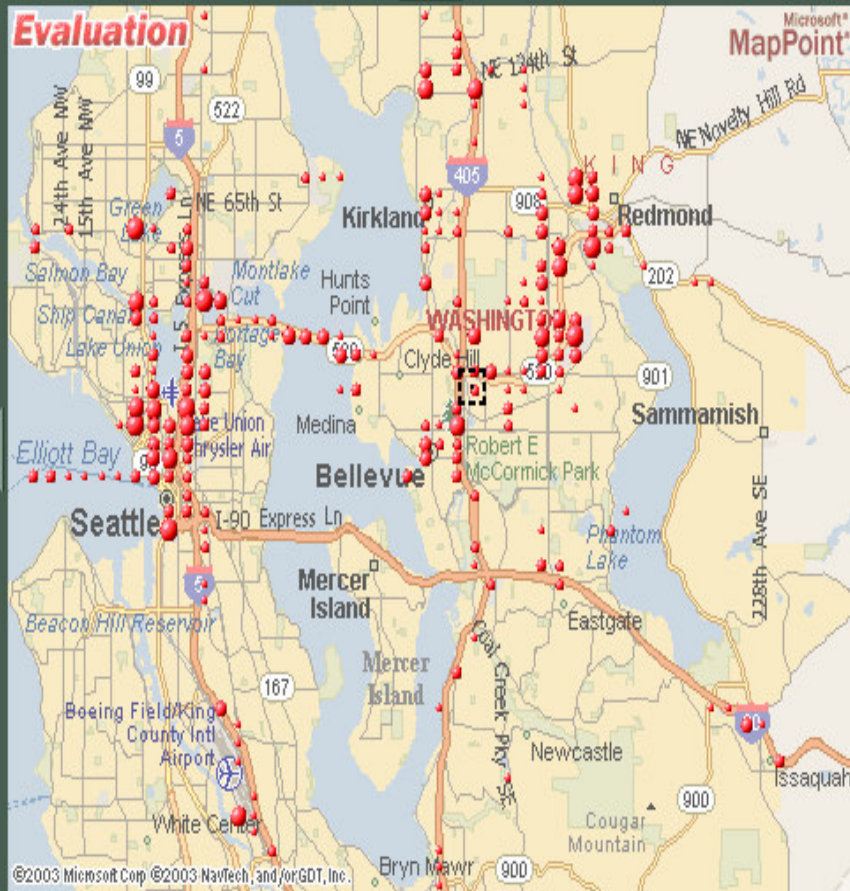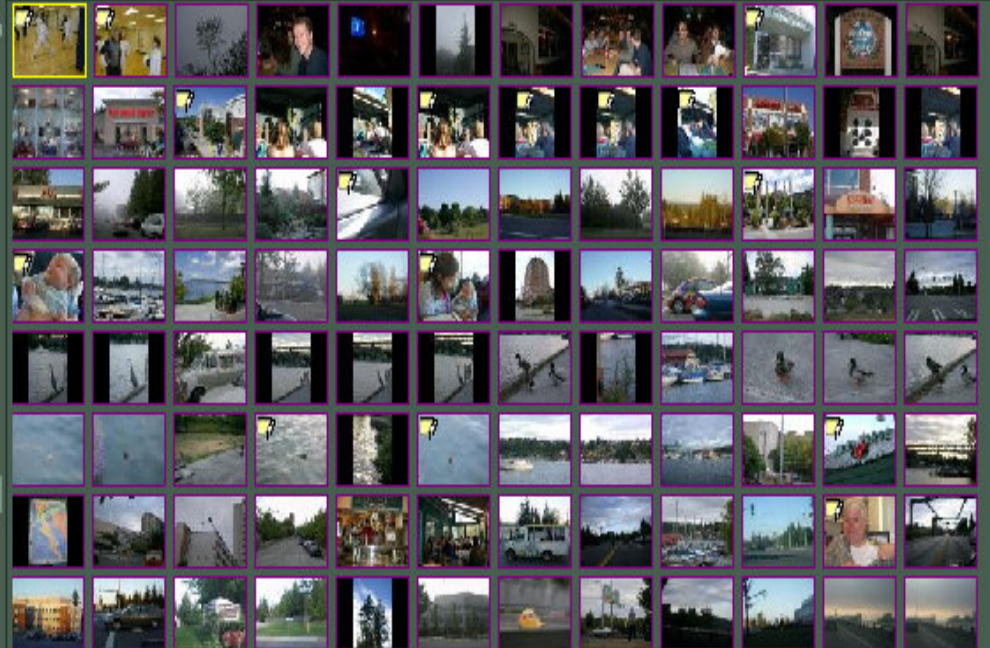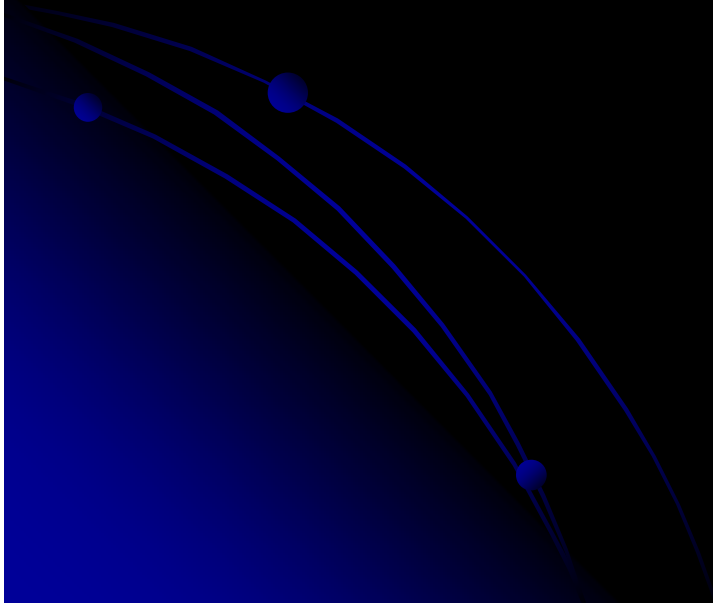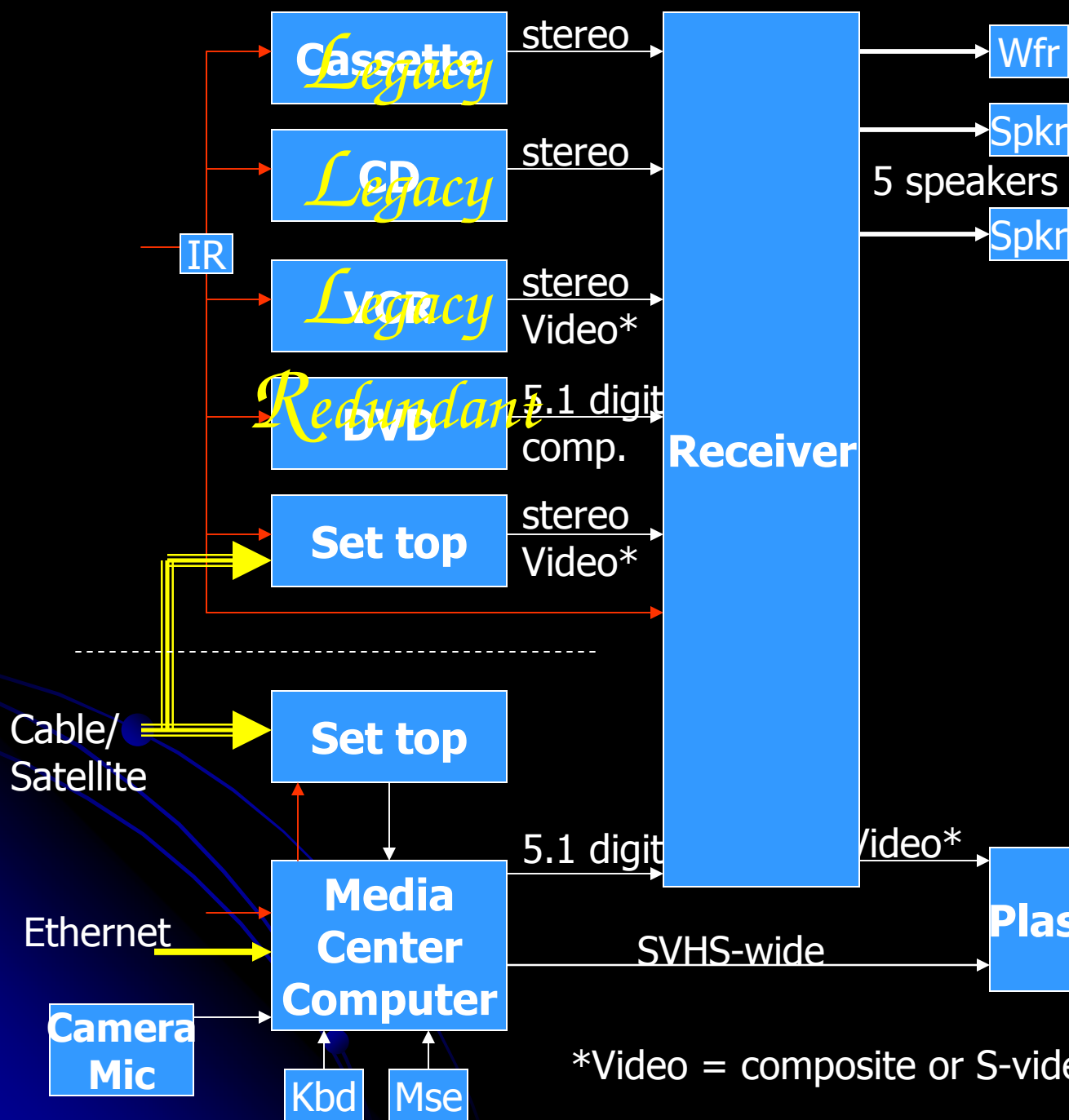
Cables/links
Speaker 5+1
Plasma 2 or 3
Cable/Enet 2
IR 8
Stereo 4
5.1 digital 2
Comp./S-video 3
Plasma panel 1
Power 10
Kbd/mse 2
Monitor II (opt.) 4
Camera 2
Total 42 − 46
Things 18+remote

Cable/
Satellite

Set top

Ethernet

Media
Center
Computer

Camera
Mic

Kbd

Mse

5.1 digit

Video*

SVHS-wide

Plasma Panel

*Video = composite or S-video

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Address http://www.nytimes.com/cnet/CNET_2100-1001-980103.html   Go   Links

The New York Times   **Technology**   January 10, 2003

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Past 30 Days   QUOTES   Welcome, cgordonbell

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ARTICLE TOOLS SPONSORED BY   STARBUCKS.COM

Microsoft Seeks Antitrust Dismissals

Joe Wilcox, Staff Writer, CNET News.com, News.com

CNET News.com

Microsoft on Friday hopes to reverse a series of legal setbacks before a Baltimore judge, whom it will ask to dismiss three private antitrust cases pending against the software giant.

During a hearing before U.S. District Judge J. Frederick Motz, Microsoft will argue that cases brought by Be Inc., Burst.com and Sun Microsystems are without merit. Lawyers for the plaintiffs are expected to explain why the cases should be allowed to continue.

The cases largely draw on Microsoft's lengthy antitrust case, which effectively ended in November, with U.S. District Judge Colleen Kollar-Kotelly approving a settlement agreed to by Microsoft, the Justice Department and nine states. Separately

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Internet

start   Microsoft Seeks Artic...   Media Center

CLEAN WATER ACT TO CHANGE

CNN Headline News
Didn't Get Popular Majority: Jim Douglas passed VT governor by state legislature

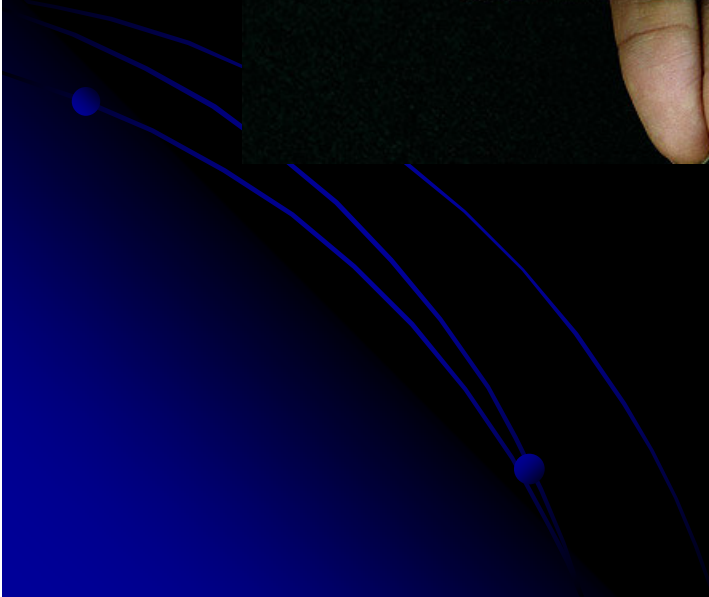# Convergence: Computers, Phones & Consumer Electronics…
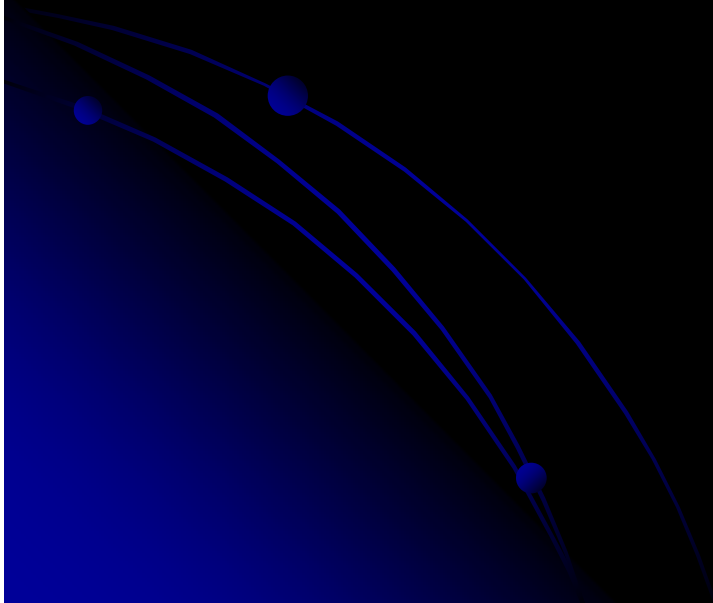
Personal devices

- Will the notebooks we all know and love to carry, take on a much smaller and or disintegrated form factor?
  - Phone+ camera, GPS, personal store, "PC", body area gateway
- Tablet or book?
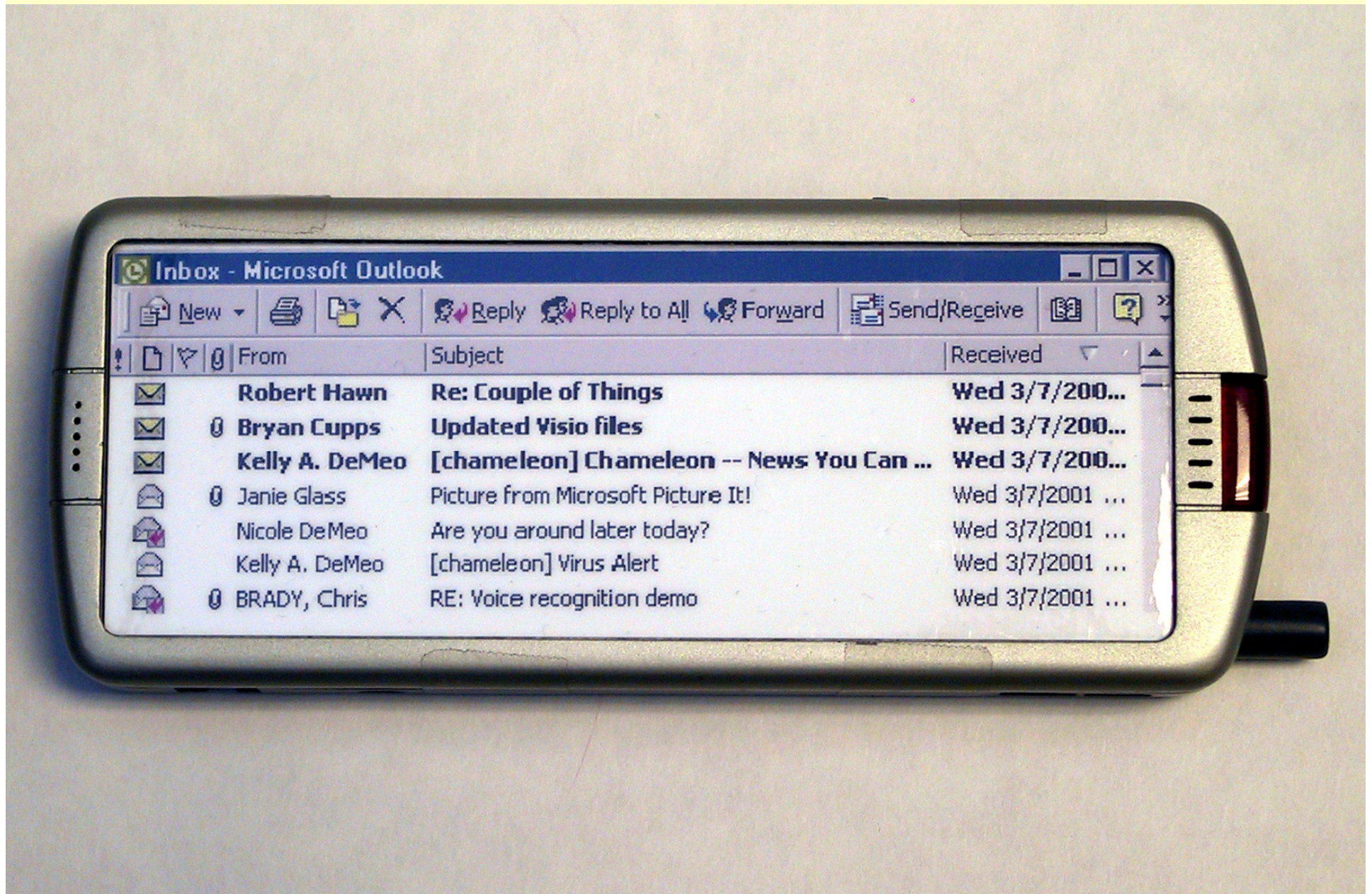- General purpose or n special appliances?

OQO & Tiquit

Chameleon: PC/XP & CE phone c2001
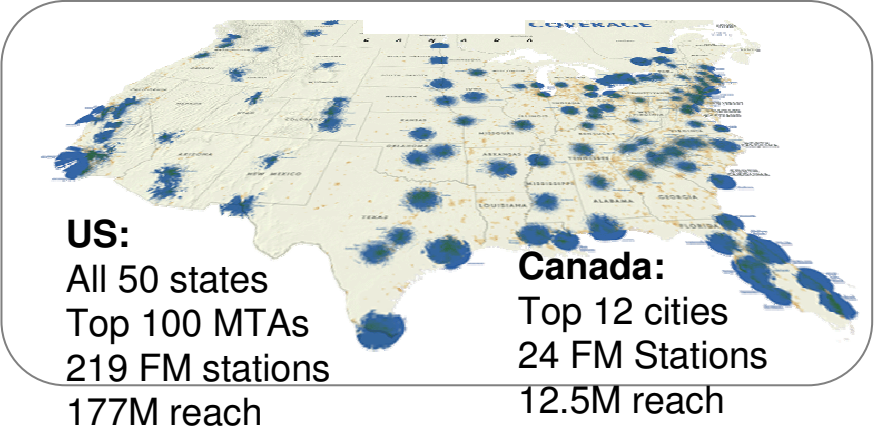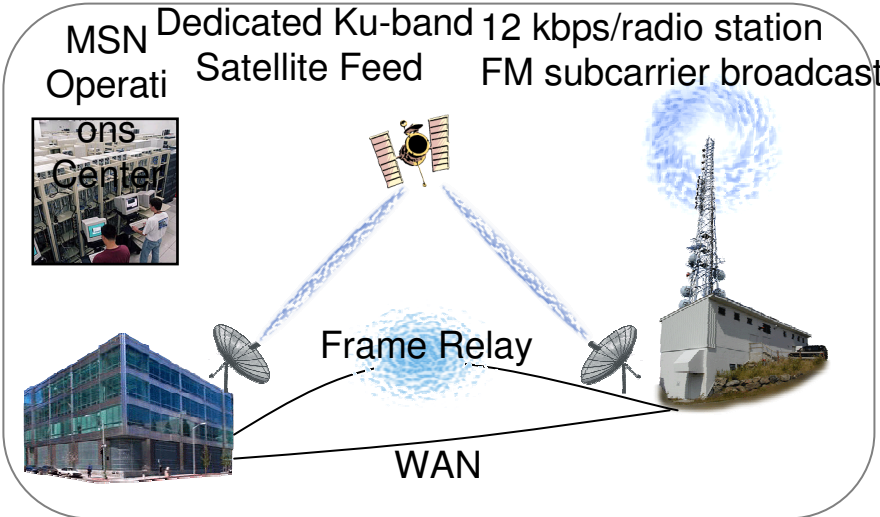## 20-40 MB; 400 x 800 pixels

SPOT Overview

Services

And more...

Network

MSN Operations Center

Dedicated Ku-band Satellite Feed

12 kbps/radio station FM subcarrier broadcast

Frame Relay

WAN

US:
All 50 states
Top 100 MTAs
219 FM stations
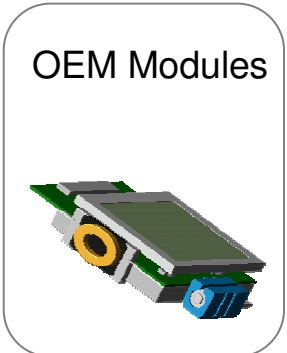177M reach

Canada:
Top 12 cities
24 FM Stations
12.5M reach

Watches

Small Footprint CLR & Applications

OEM Modules

Components:
LCD, Battery, Module, Case & Strap

ARM720
512K ROM
384K SRAM
FM SCA Radio

National Semiconductor

What Are Smart Personal Objects?
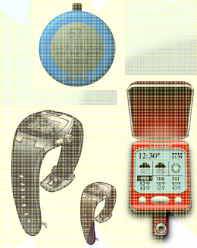
PC Peripherals   **Smart Personal Objects**   **Consumer Appliances**   **PCs and Servers**

Smart Personal Objects

- Everyday devices whose core functionality is amplified and improved with the addition of software

- Devices that provide people the personalized information they want, when they want it

- A new computing space that compliments existing technology and provides a new method for people to remain connected to their world

SPOT
Smart Personal Objects Technology

- Makes Smart Personal Objects smarter, connected and essential information tools for people

- Incubated in Microsoft Research for the past three years

  - Developed a new hardware platform to enable low power, low cost, connected devices

  - Extends the reach of .NET architecture into a smaller and broader class of devices

- Incorporated July 2002
- Goals:
  - Turnkey networks
  - No embedded software development
  - Highest performance
- SmartMesh shipped Aug 2004

DUST™
NETWORKS

Conclusion

- **Wired** sensor networks are everywhere today
  - HVAC, security, power, lighting, process control, …
- Installation is dominated by wiring costs
- Commercial adoption of **wireless** sensor networks is gated by reliability and power consumption, and virtually nothing else

DUST™
NETWORKS

Flashback: 2002, UC/Berkeley
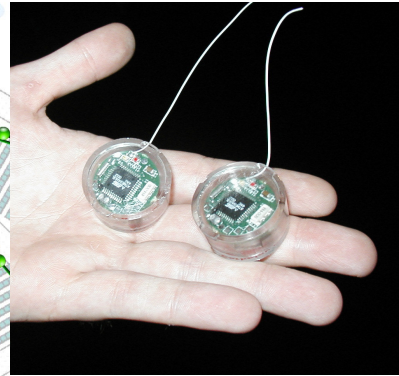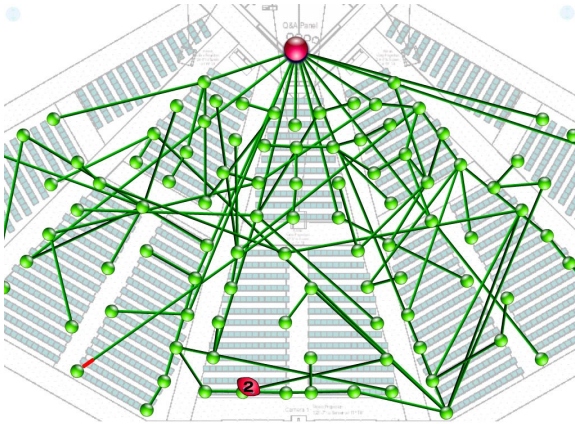
Intel Developers Forum, live demo 800 motes, 8 level dynamic network,

Motes dropped from UAV, detect vehicles, log and report direction and velocity

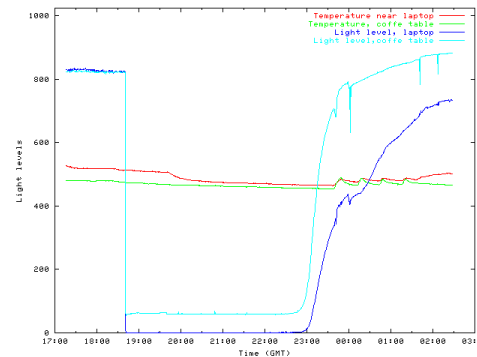**Seismic testing demo: real-time data acquisition, $200 vs. $5,000 per node**

50 temperature sensors for HVAC deployed in 3 hours. $100 vs. $800 per node.

vs.

Example uses

- **Env. Monitoring, Conservation biology**
  - *Precision agriculture, land conservation, ...*
  - *built environment comfort & efficiency ...*
  - *alarms, security, surveillance, treaty verification ...*

- **Civil Engineering: structures response**
  - *condition-based maintenance*
  - *disaster management*
  - *urban terrain mapping & monitoring*
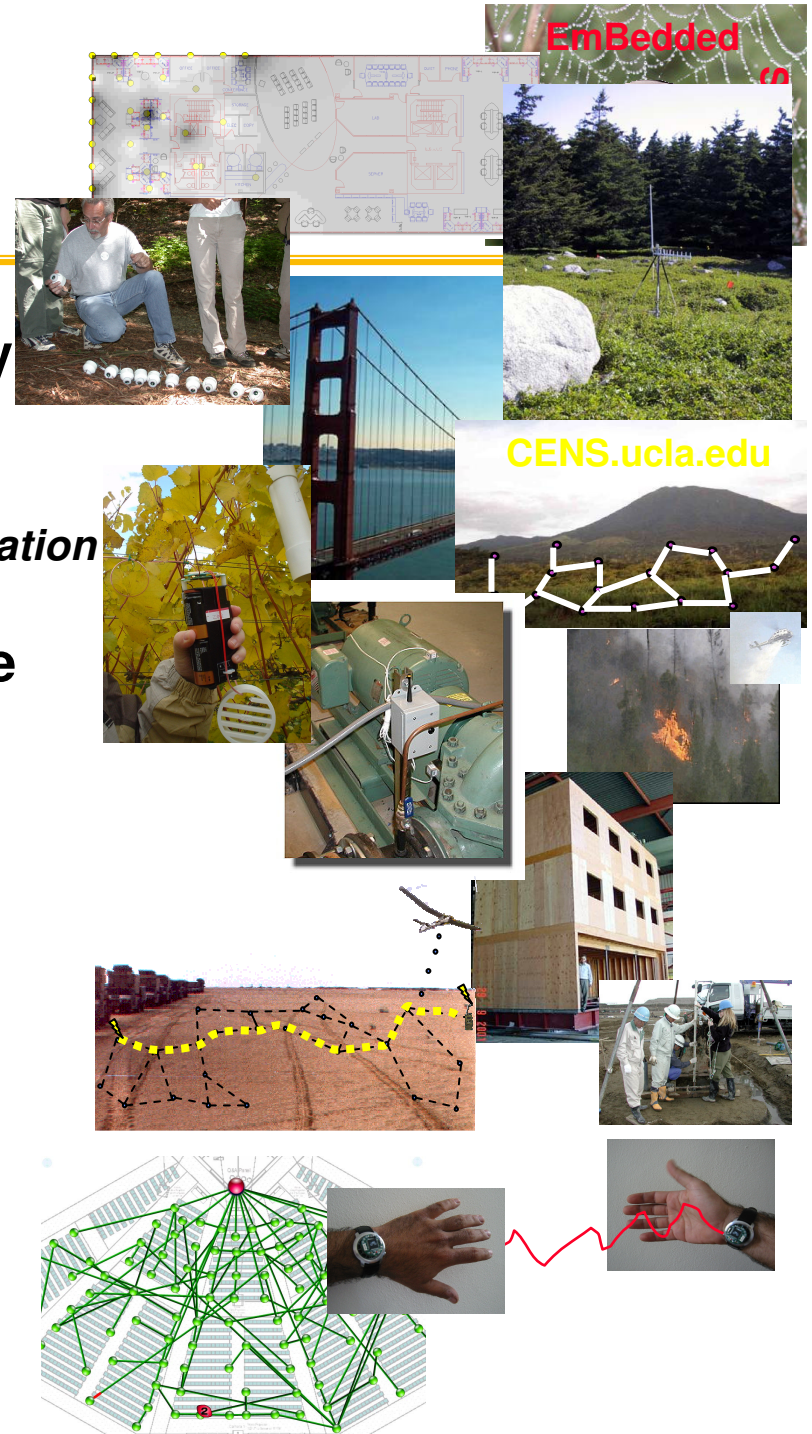
- **Interactive Environments**
  - *context aware computing, non-verbal communication*
  - *handicap assistance*
    - » *home/elder care*
    - » *asset tracking*

- **Integrated robotics**

Lifetime and Scale

Sample Rate & Precision

Mobility & Disconnection

EmBedded

CENS.ucla.edu

Energy Monitoring Pilot

Honeywell

- Honeywell Service: monitor, analyze and reduce power consumption
- Problem: >> $100/sensor wiring cost
- Solution: Dust SmartMesh
  - Entire SmartMesh™ network installed in 3 hours (vs. 3-4 days)
  - 9 min/sensor
  - Software developed in 2 weeks (XML interface)
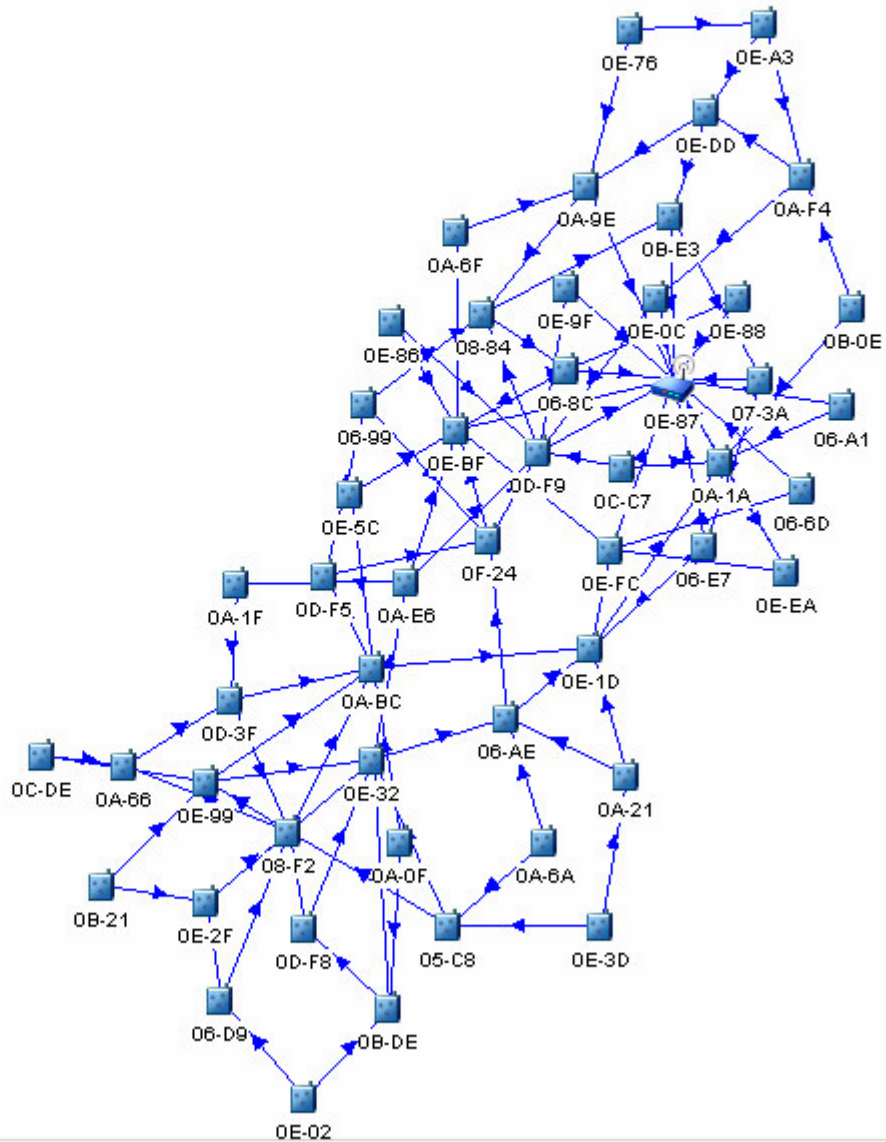 - 5 months, 99.97%

DUST™
NETWORKS

In a decade, the evolution:

We can count on:

- Moore's Law provides ≈50-100x performance, const. $ 20% $ decrease/year => ½ per 5 years
- Paper quality screens on watch, tablets... walls
- Terabyte personal stores => personal db managers
- Murphy's Law continues with larger and more complex systems, requiring better fundamental understanding
- Astronomical sized, by current standards, databases!
- DSL wired, 3-4G/802.11$_j$ nets (>10 Mbps) access
- Personal authentication to access <u>anything of value</u>
- Ubiquity rivaling the telephone.
  - Challenge: An instrument to supplant the phone?
  - Challenge: Affordability for everyone <$1500/year
- Network Services: Finally computers can use|access the web. "It's the Internet, Stupid."
  - Enabler of intra-, extra-, inter-net commerce
  - Finally EDI/Exchanges/Markets

Decade out (cont'd)

We are <u>likely</u> to "get":

- CaA/VS (Computer aided A/V sensing aka surveillance) aided by a new level of radio-linked networks
- Personal location tracking in many environments
- Sensing and non-sensing rooms with "total recall" of everything it saw and heard

Several platform/net classes form:

- Wireless, sensor-effector nets enable a variety of apps
  - On body monitoring/stimulation/x-delivery
  - Building sensing of everything (cf. CaA/VS)
  - Outdoor sensing/surveillance of everything
  - (Sensors/effectors/platforms are the apps!)
  - Serendipity: new platform/net/interface

The End