Designing a Notebook PC

Emerging Trends in Electrical and Computer Engineering
Carnegie Mellon University

November 16, 2006

New World. New Thinking.™

lenovo™

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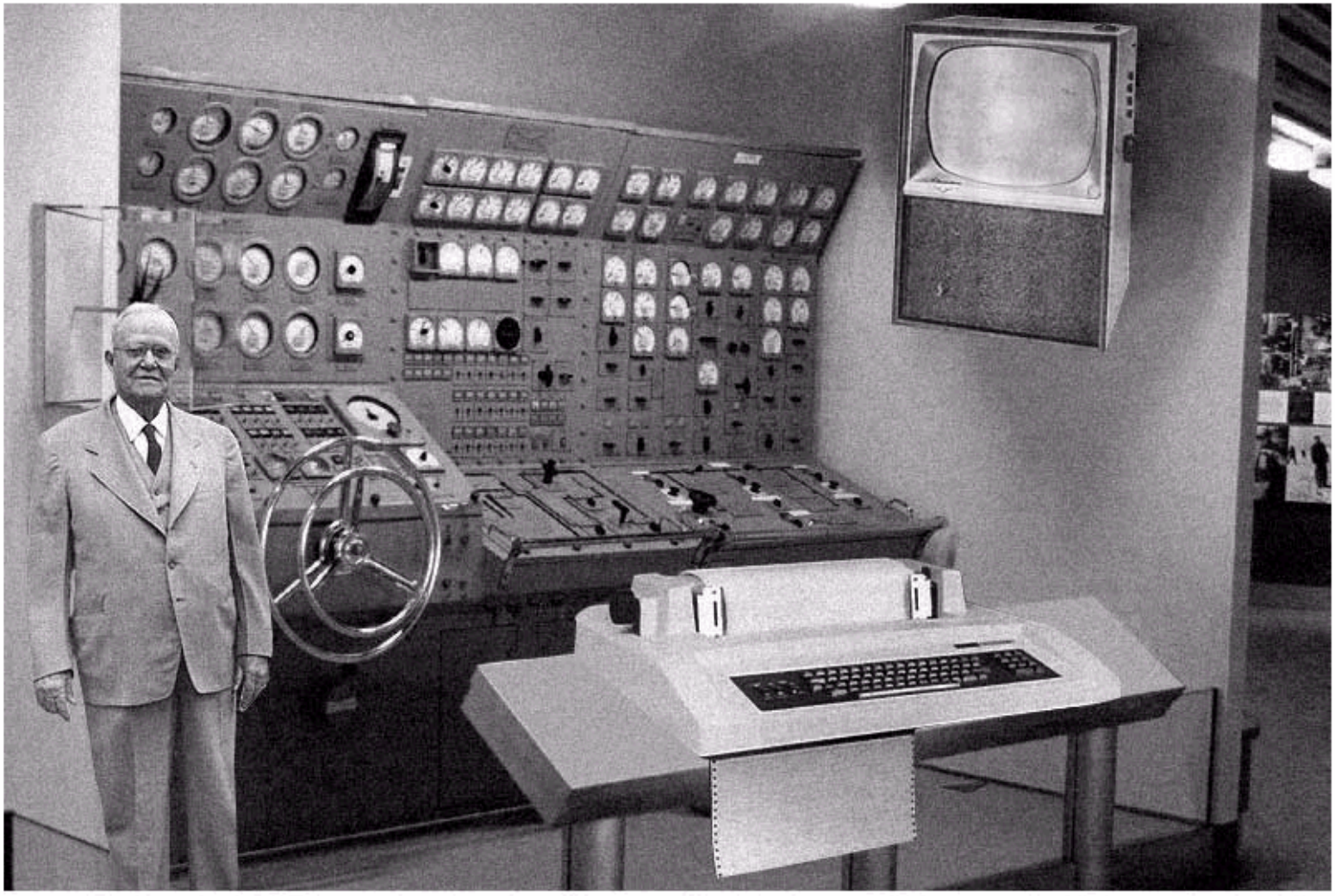
It’s hard to predict the future!



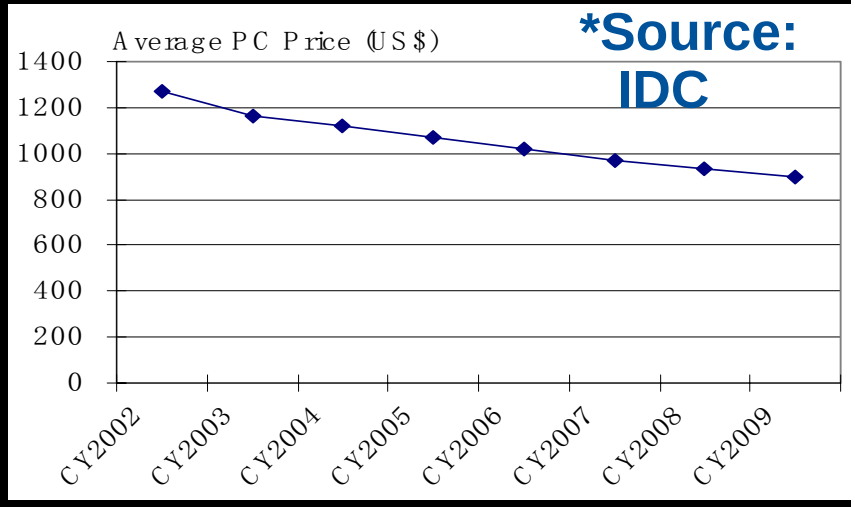
Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use and only

Personal Computer Average Price Is Going Down

Facts & Trends

- PC cost reduction is always a market requirement, especially for emerging countries
- Technology improvements and standardization lowering PC's cost - continuing commoditization of PC including laptops
- Profit from PC sale becomes marginal
- IC - PC industry core technology cost down
  - Chip technology process will use 0.13um-0.09um in 3-5 years, and many foundries have the production line
  - The mask fee continues to decline

www.walmart.com, Nov. 30 2005

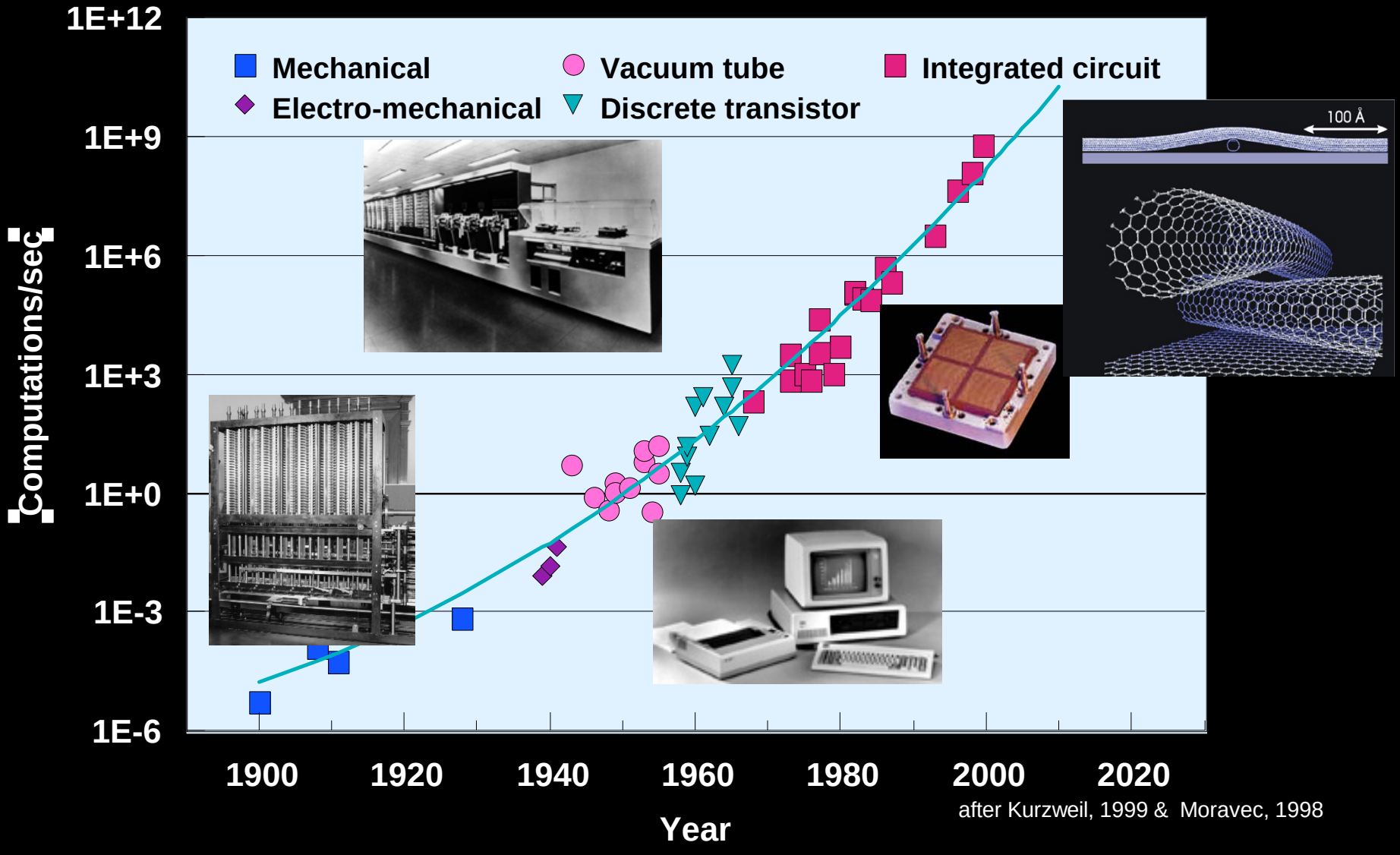


***Source: IDC**

Observations & Implications

- Personal computer price and cost continues downward ➔ harder to make profit consistently

$1000 Buys...



after Kurzweil, 1999 & Moravec, 1998

GTC 2003

The ThinkPad X60 – Design Areas of Focus

Battery Life

- Up to 8.0 hours with one battery
- Support for 2nd battery

Communications

2.69 lbs.
1.0" thick

Performance

Thermals

Expansion

Safety

Ergonomics

Security

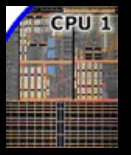
Component Protection

Processors

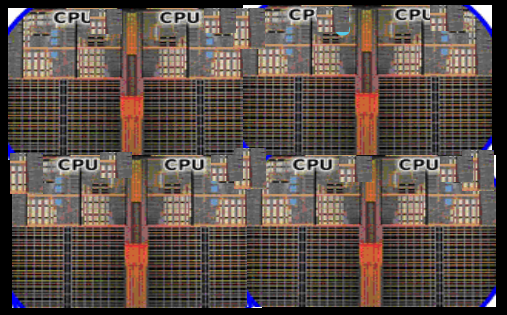
Facts & Trends

- **Frequency differentiation is no longer of value to most users**
  - **Only a few small percent of users will pay for highest frequency parts**
- **Users require relevant additional function to justify higher price processors (ROI)**
  - **Hardware security, Virtualization, Manageability**
- **Processor vendors need ability to scale die size to reflect new market demands**
  - **Multi-core critical as die size can scale from entry (one core, one thread) to high end (8 cores, 8 threads) allowing processor vendors to price based on cost**

Entry



High End

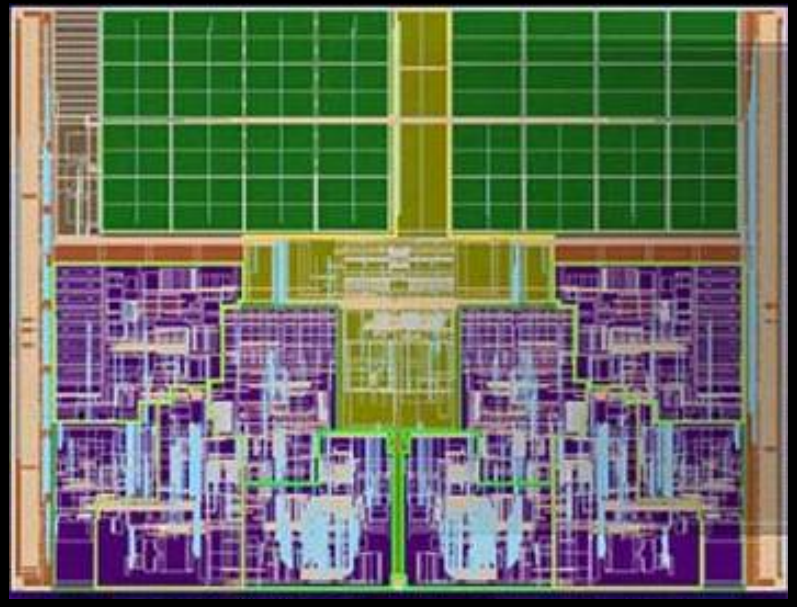


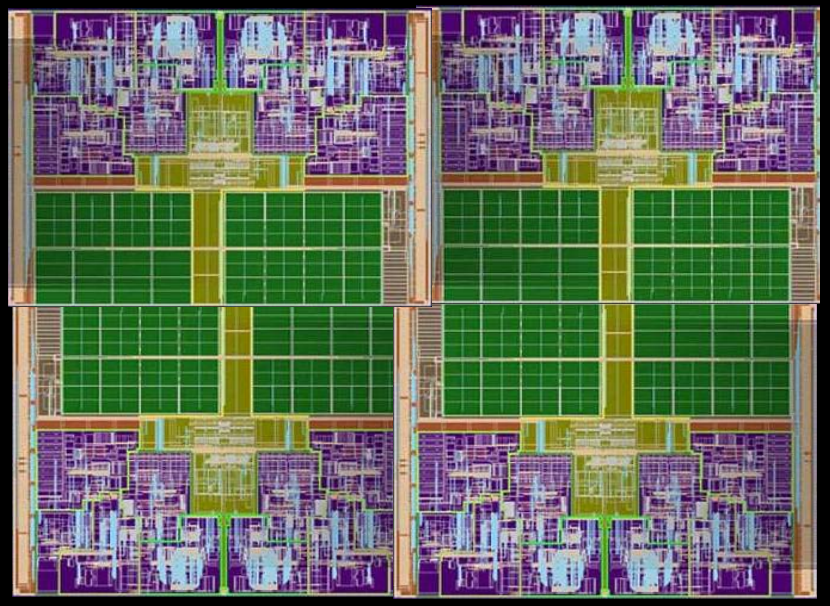
Observations & Implications

- Intel/AMD can offer extremely low cost processors for emerging entry price cells
- Common architecture can scale to high end (gamers, etc.)
- Addition of hardware security and virtualization enables PC OEM's to offer differentiated offerings

Processors – Many Cores on one die

- Today – 2 Cores (mainstream)
- Just announced – 4 cores
- Tomorrow – 8 Cores





By approximately 2010 you will have a 16-way server on your lap

Processors

Facts & Trends

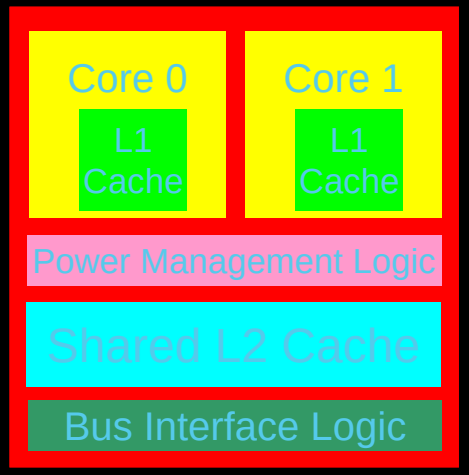
Thermals are a problem for both notebooks and desktops

Past: Higher Performance = Higher Clock Frequency

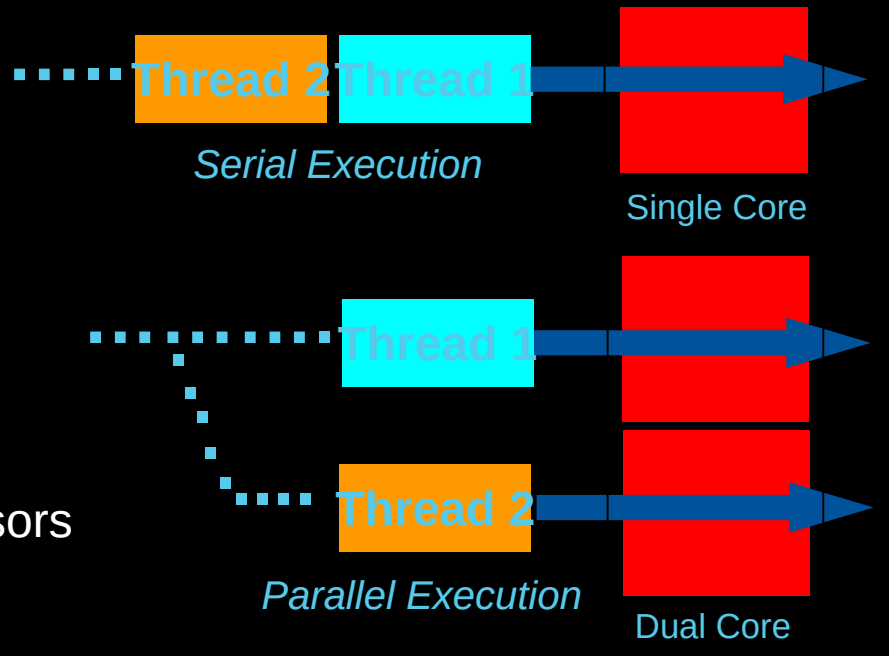
→ Higher Power Consumption **Thermal Issue**

Multi-Core processor can achieve better performance and power saving for Multi-Thread applications

Better Power Efficiency *Performance WATT*



Dual-core CPU structure



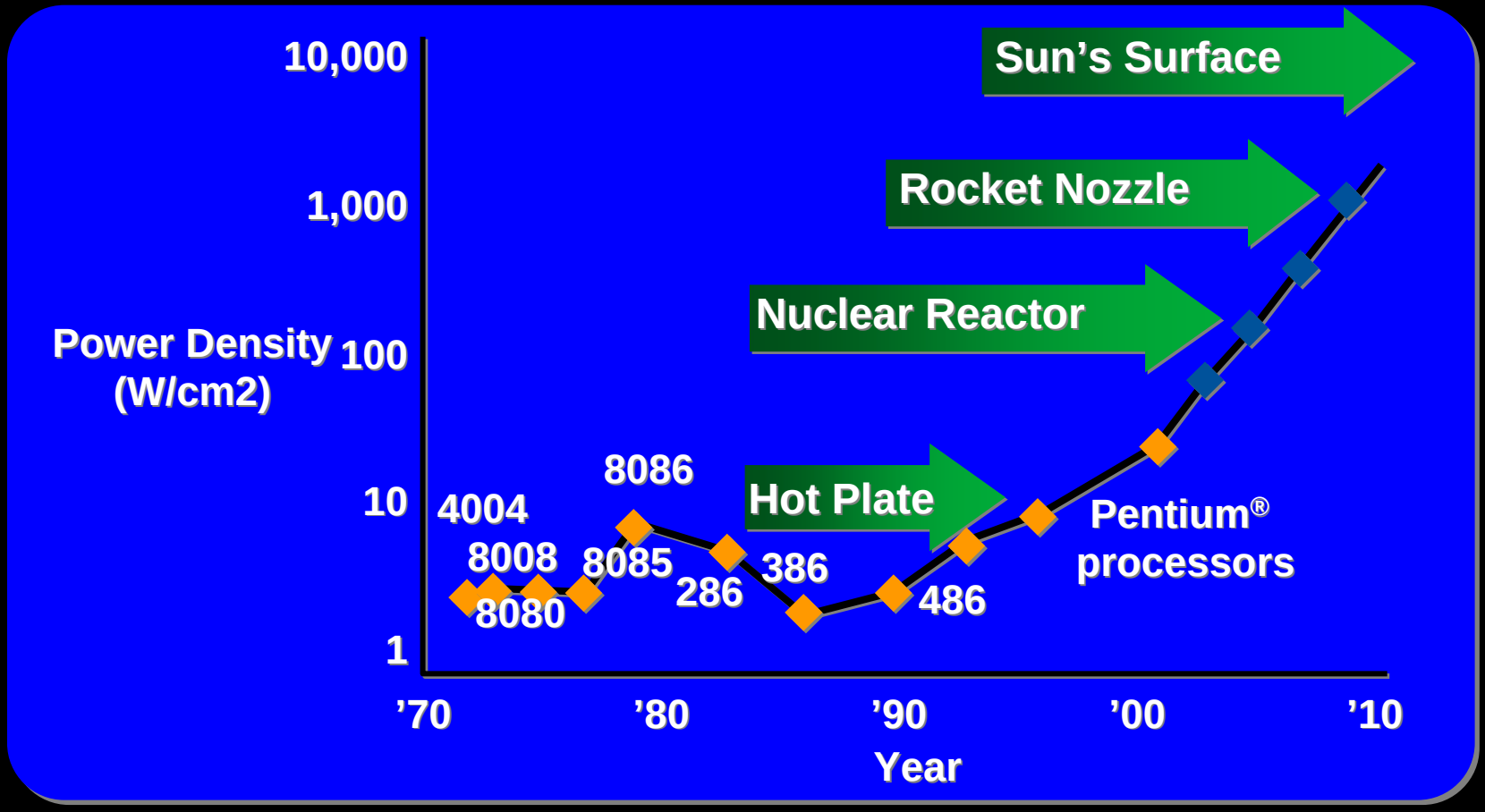
Multi-thread execution

- Intel convergences mobile and desktops dual core processor architecture in 2006

Observations & Implications

- Thermal strategy will continue with multi-core processors
  - (4 cores – 8 cores – 16 cores) over time

Power Density: The Fundamental Problem



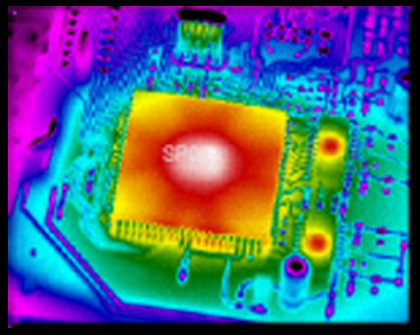
Need to Keep the Junctions Cool

- Performance (Higher Freq.)
- Lower leakage (Exponential)
- Better reliability (Exponential)

Liquid Cooled ThinkPads

Super Efficient Heat Exchange

- ✓Moderates Temp.
- ✓Increases Battery Life
- ✓Full Speed Processors



Thermal - Facts and Trends

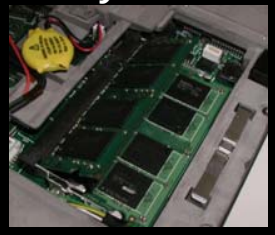
- Heat Source
  - Processor (Power & Density growing)

  - DC/DC and Voltage Regulator

  - Communication Card (WWAN, WLAN)

  - Graphic (Integrate and Discrete Model)

  - Memory

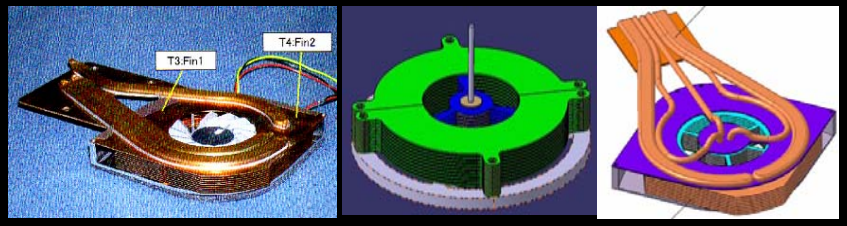


  - High Speed HDD / Optical Drives

- Other requirements for better thermal design
  - Windows Vista's new GUI (Aero Glass)
  - Reduction in system size
  - Customer's Request for lower temperature skin

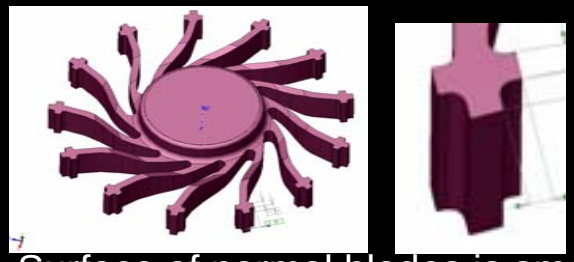
Thermal - Recommended Future Thermal Solutions 1/2

1. Omni Direction Fan / Laminar Flow Fan



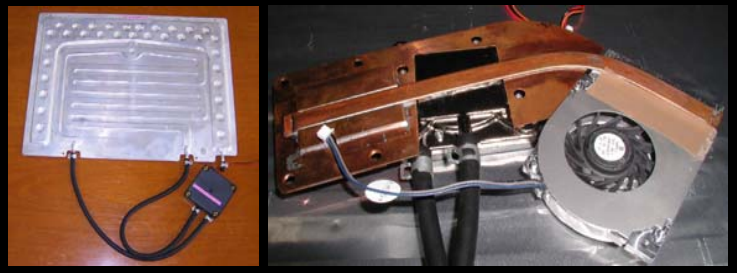
Horizontally installed fins are connected together with columns. It can provide a lot of air. Need to decrease cost

2. Silent Owl Blade



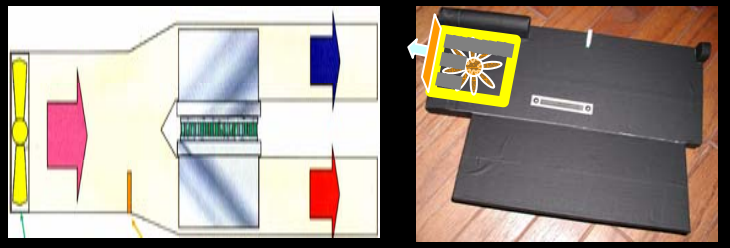
Surface of normal blades is smooth. Owl fan has a small bump on each blade. It is more silent than normal fan. It can supply a lot of air. Need to decrease cost

3. Liquid Cooling System



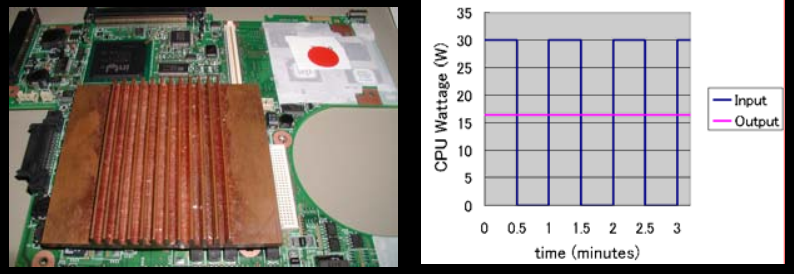
It can convey heat from system side to top side. Need to decrease cost

4. Cooling Dock



System is additionally cooled when docked.

5. Thermal Capacitor



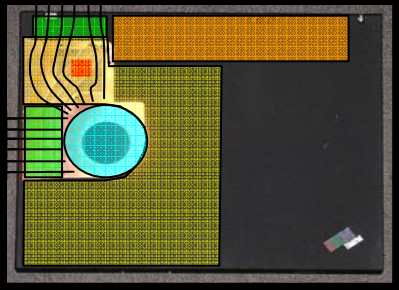
Thermal Capacitor can temporally store heat

Thermal - Recommended Future Thermal Solutions 2/2

6. Thermal Insulation Sheet (Vacuum Pack)

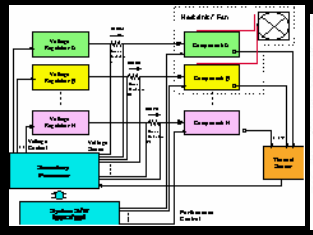
Vacuum pack is less conductive of heat than air. Need to decrease cost

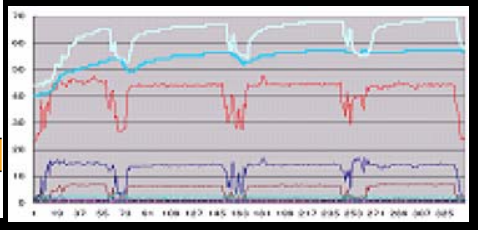
7. Effective System Design



It is effective to have a lot of inlet/outlet louvers, to have low air flow resistance, to have a fan at the back corner with two exhausts and so on.

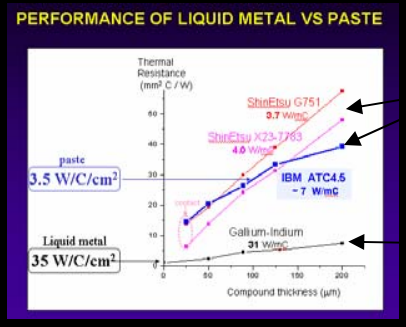
8. Thermal Management Function





- Adaptive Performance Control
- Intelligent control with temp. and power data
- Next generation Thermal / Power Management

9. Liquid Metal TIM



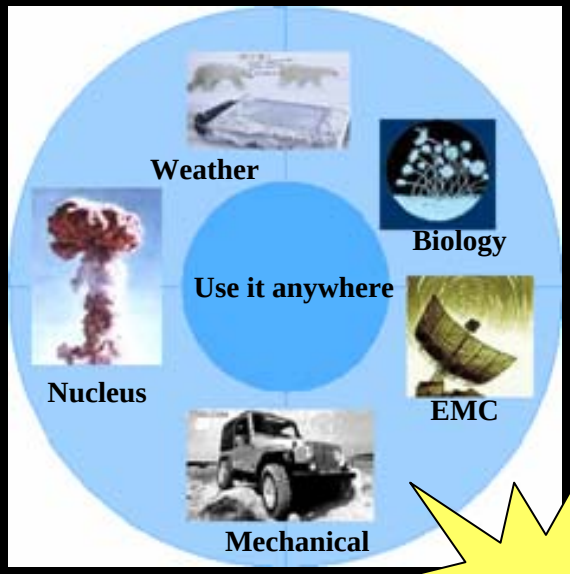
Normal TIM

Gallium Indium

Metal is 10 times more conductive of heat than current silicon type grease

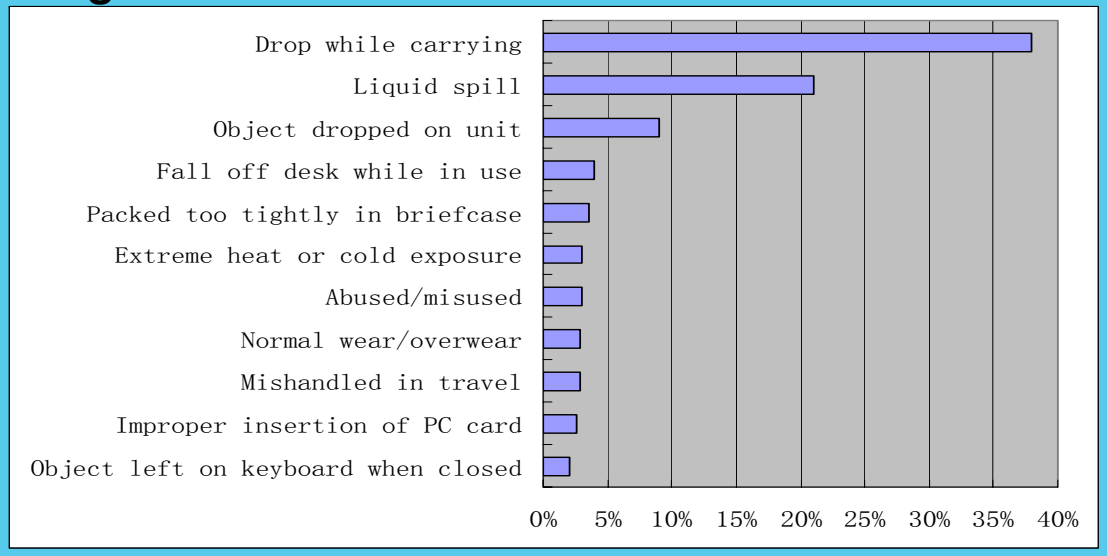
Facts

- Use environment: more extensive and use mode: more diversely

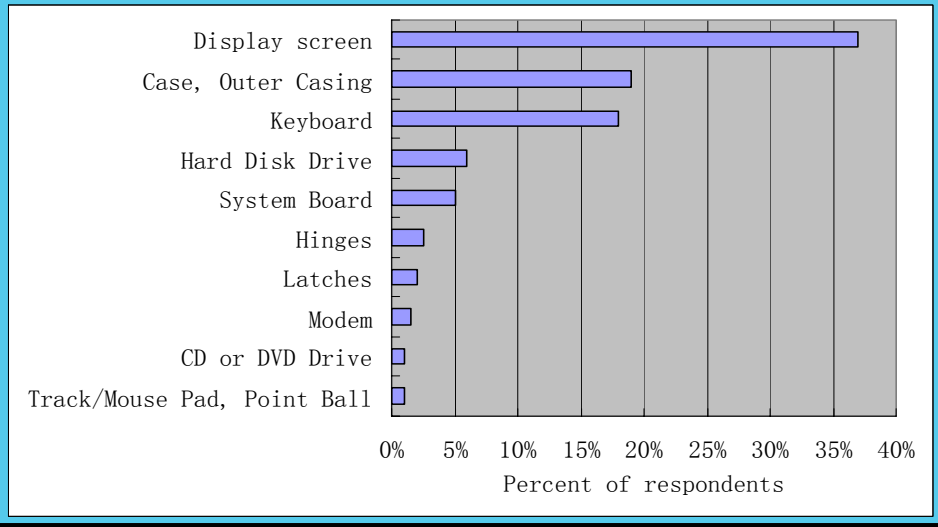


Damage

Damage reasons



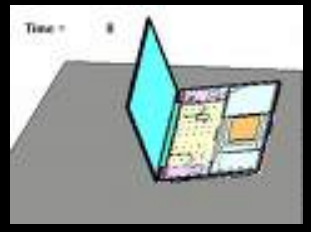
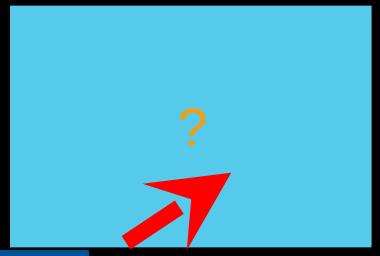
Damaged parts



Implications: Drop and Spill are the main reasons!

Trends – Drop and Vibration



Drop Protect Technology

Key Parts

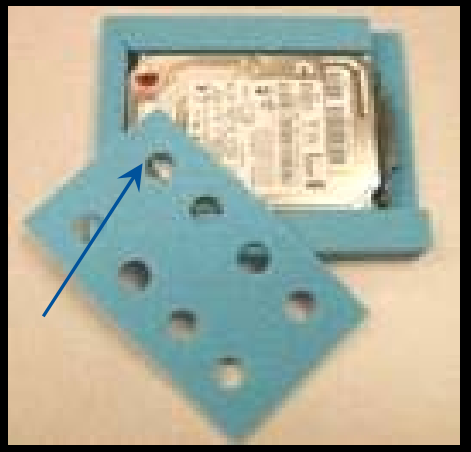
APS
Cusionless (Outer)

Rubber Cushion


2000 2005 2010 2015

Drop Protection Technology

- **Key parts and system passive protection**
  - Technology
    - Rubber and foam internal protection
    - Rubber and plastic external protection
  - Application
    - HDD and Display outer impact protection
      - Low hardness rubber or foam material with good damp feature
      - Enough rubber or foam size for deformation while impact
    - Outer case impact protection
      - High hardness rubber or plastic material
      - Little deformation while impact
  - Advantage
    - Cost-effective
    - Acceptable protection performance
  - Disadvantage
    - Large space needed
    - Increased the system depth
    - Worse temperature performance caused by material



Drop Protection Technology

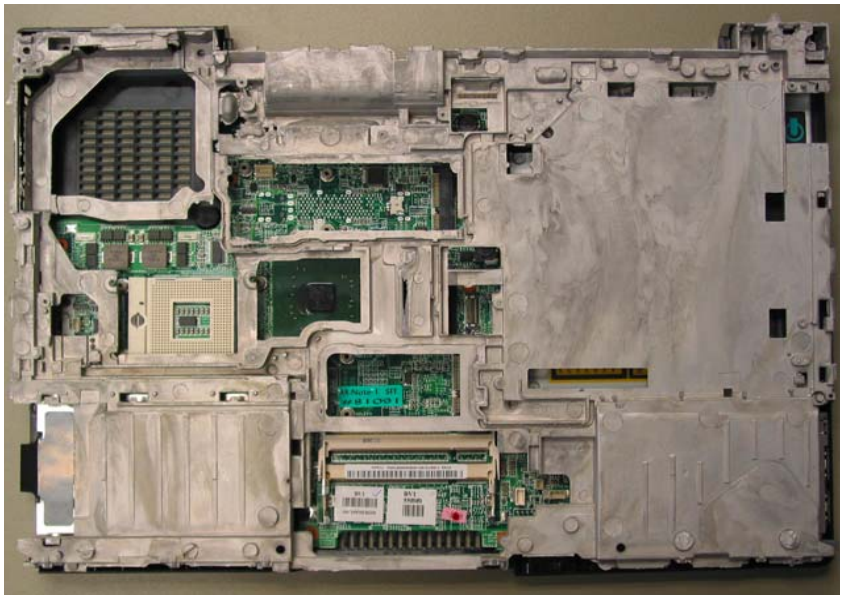
- **Key parts Active Protection System (APS)**
  - Technology
    - Accelerometer technology
  - Advantage
    - Reduce the change of disk head crash the disk
  - Disadvantage
    - Still need protection for disk and spindle
    - Can not improve non-operation performance

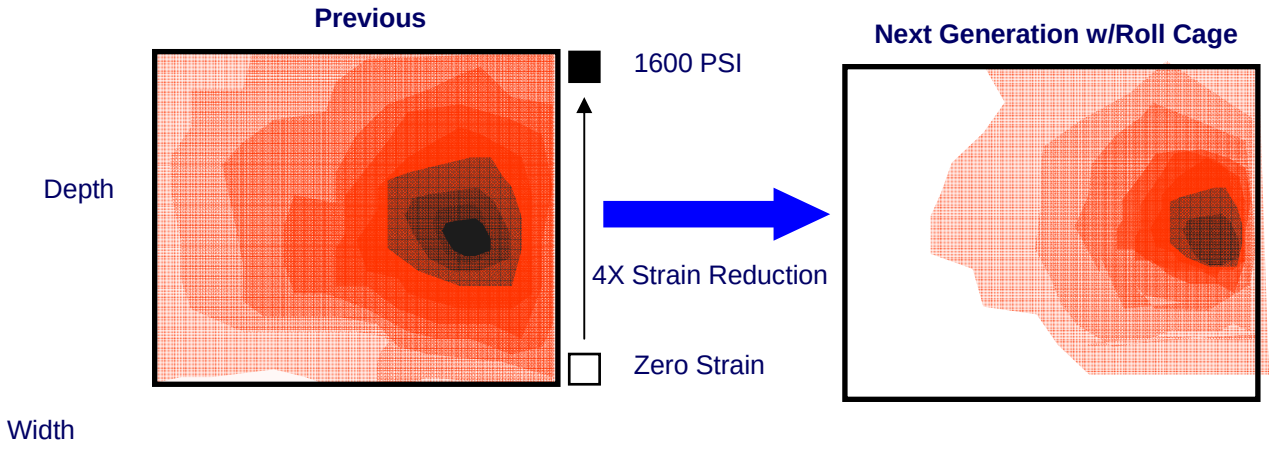
TUX Racer Game

What Do NASCAR and ThinkPads have in common?

Roll Cage

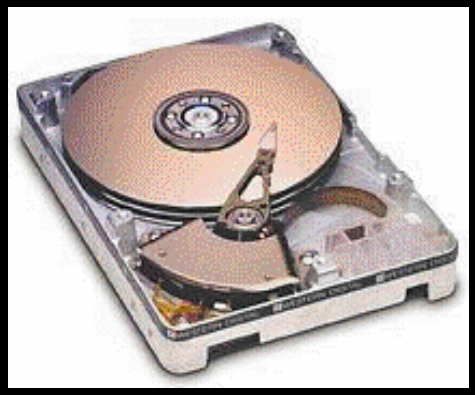
- Magnesium alloy frame around critical ThinkPad parts
- Absorbs shock on drop similar to Formula 1 Racing cars





Layers of Protection – Hard Disk Drive

Design Philosophy – More Protection is Better



Shock-absorbing feet

+

Metal Protection Plate

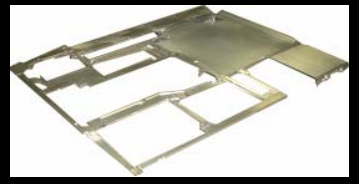
HDD Protection Pack

+

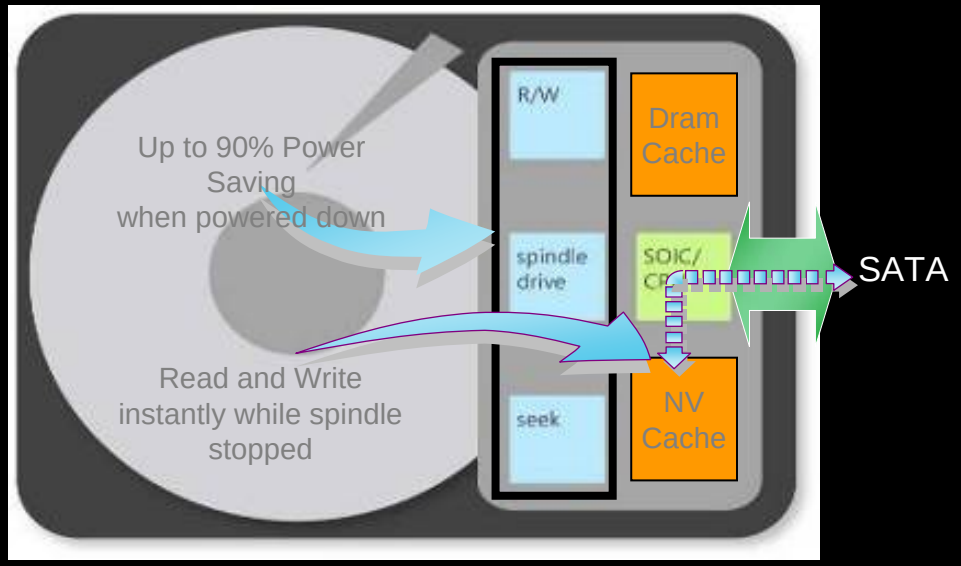
Active Protection System

+

Roll Cage

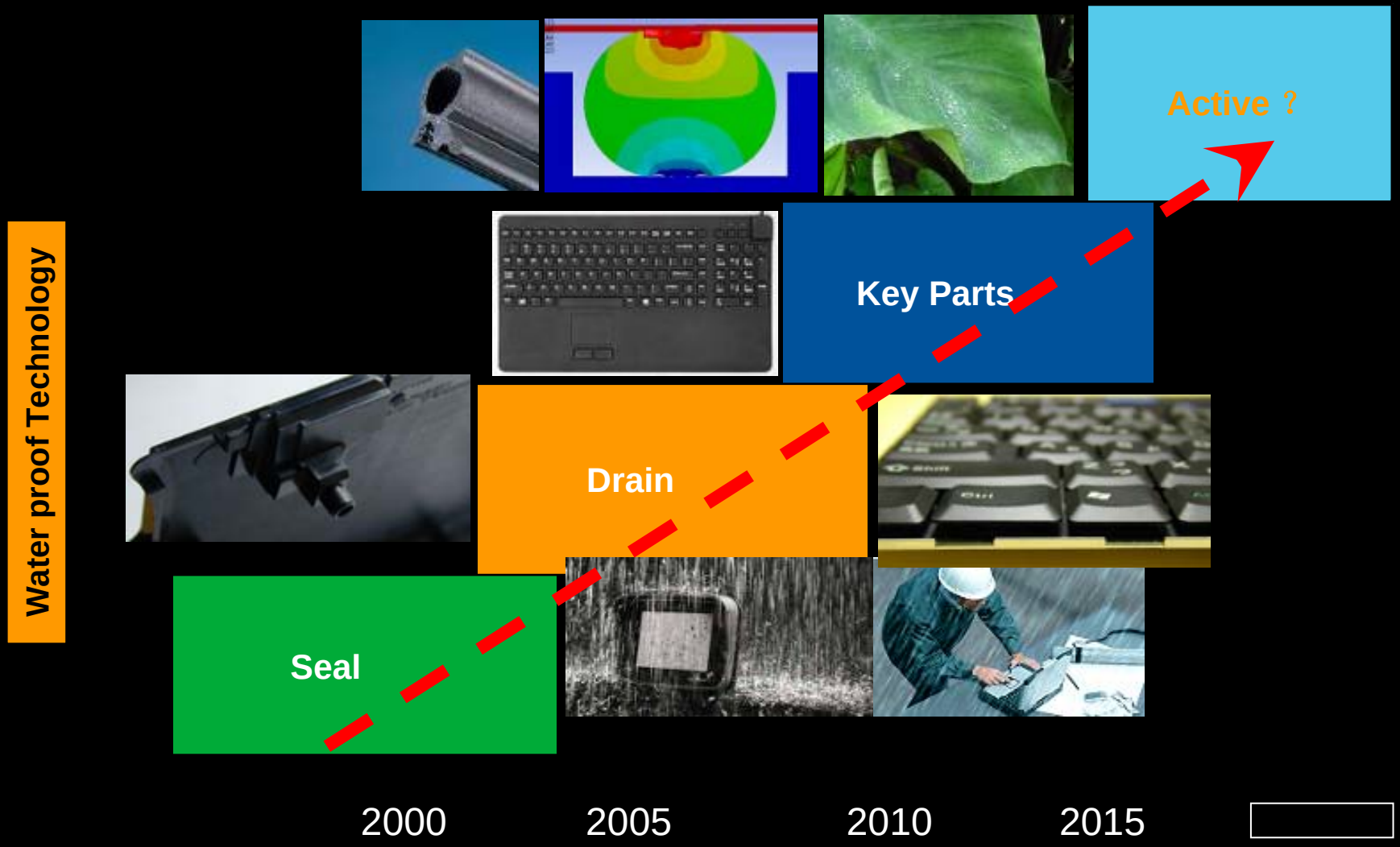


The Future – Hybrid and Solid State Hard Disk Drives



- **Hybrid Hard Disk**
  - **A Nonvolatile cache (NV Cache) is added to the hard disk drive**
  - **Allows data to be read and written while platter is spun down**
  - **Data in cache can be persisted in case of power loss**
- **SuperFetch proactively places the right content into memory**
  - **Pre-populates memory based on current and historical use patterns**
  - **Page priority not based on simple Least Recently Used**
  - **Adapts to memory usage patterns, including complex usage scenarios**
- **Application Boxing**
  - **Set I/O priorities and limit memory working set**
- **New concept in adding memory to a system:**
  - **USB Flash Drives can be used as a cache**
  - **Random reads can be serviced more than 10X faster on average through the USB 2.0 bus than from HDD**

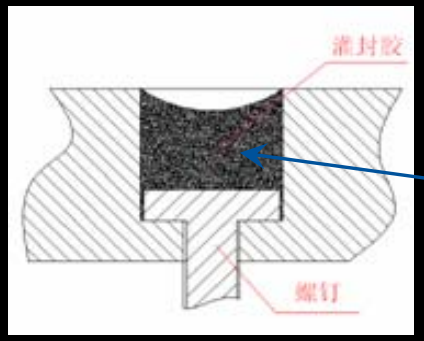
Trends: water-proof

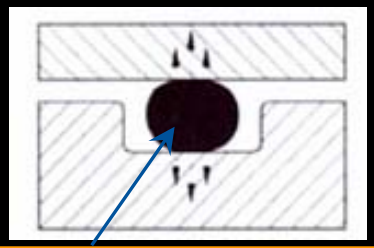


- Implication
  - Water-proof tech. trend:
    Seal → drain → key part

Seal Protection Technology

- Immovable seal
  - Technology
    - Compress rubber
    - Embedding sealant
  - Application
    - B face, C/D face, Touchpad, Fingerprint……
    - Keyboard, Switches
    - Screws
  - Advantage
    - Low cost
    - Simple process and acceptable effect
  - Disadvantage
    - Seal material fatigued, for long term compressed
    - Traditional rubber material with worse temperature feature



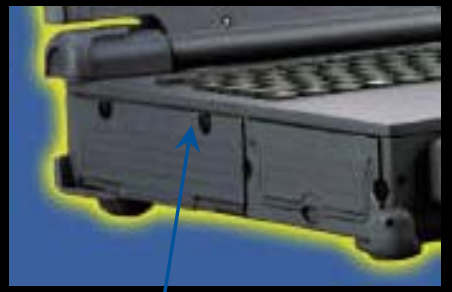


Embedded sealant

Seal Protection Technology

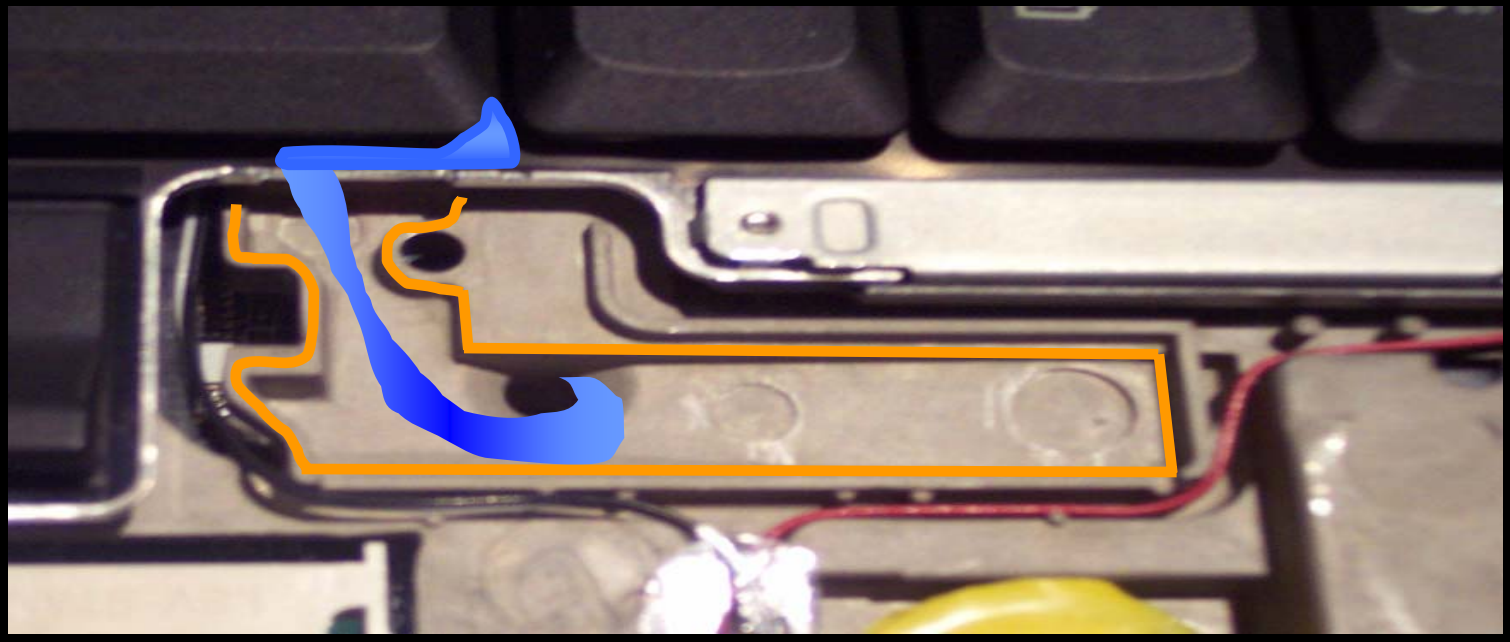
- Movable seal
  - Technology
    - Button design
    - Door design
    - Cabling design
  - Application
    - All kinds of outer Ports
  - Advantage
    - Convenient operation
  - Disadvantage
    - Seal effect control difficult
    - Seal material fatigued cause by frequent open & close
    - Heat retention

Button design



Screw design

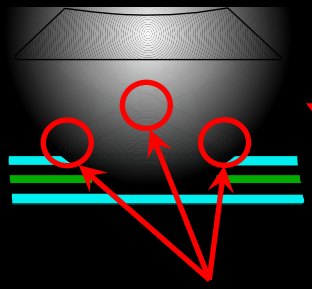
Spill Resistant Keyboards



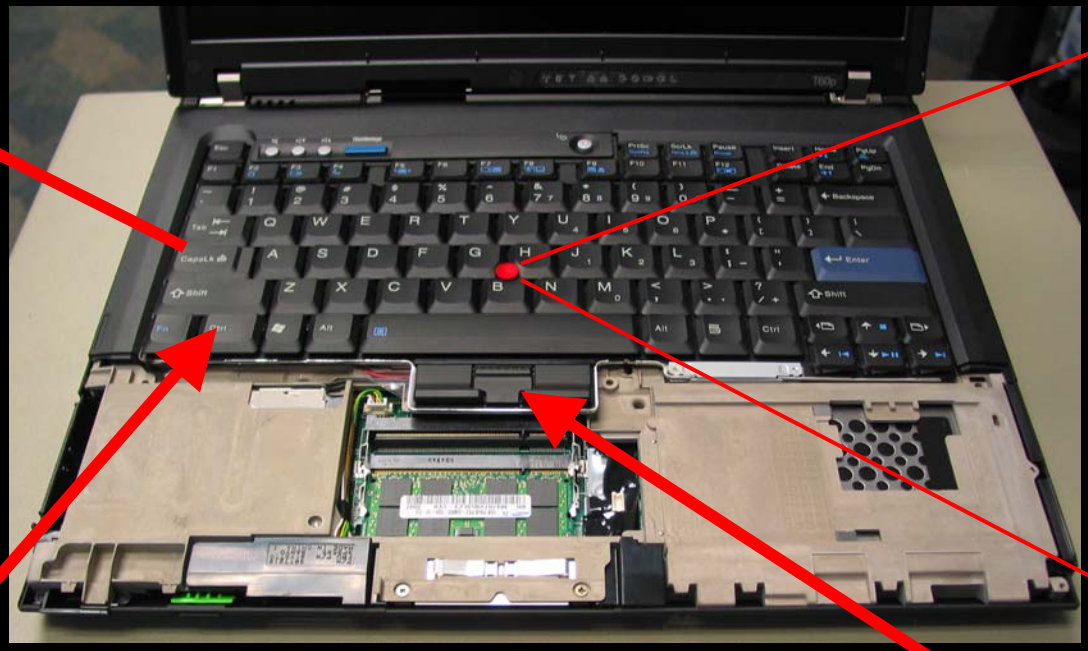
Dual Drainage Holes

Ergonomics

If you are going to sit in front of it for 8+ hours per day, it should be comfortable



Superior key attachment



Seven row, ISO compliant seven row keyboard on all models

Choice of TrackPoint caps

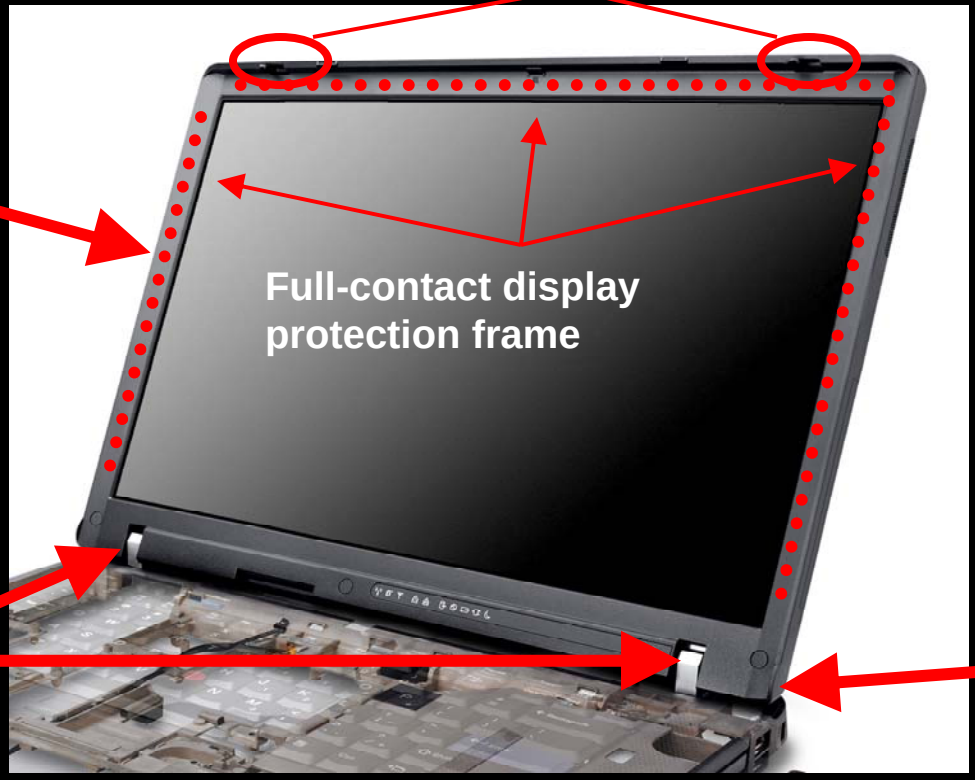
Center scroll button

Layers of Protection – Display Screen

Goals: Protect against breakage, reduce wobble and long-term wear

Dual Latches

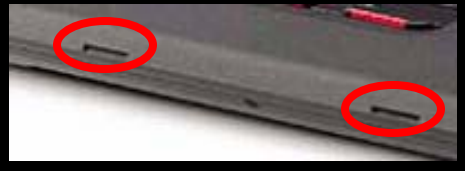
Cover material chosen for stiff, yet lightweight properties



Thick Stainless Steel Hinges

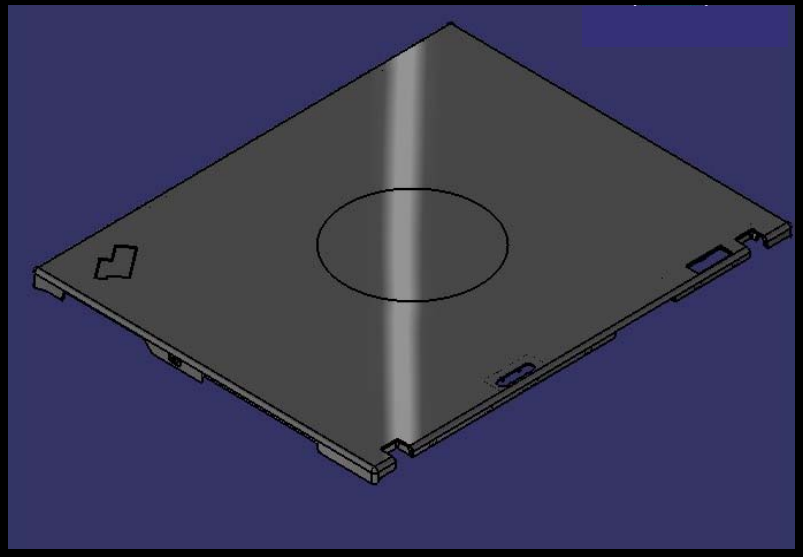
Structural Display Arch

Interlocking Tabs

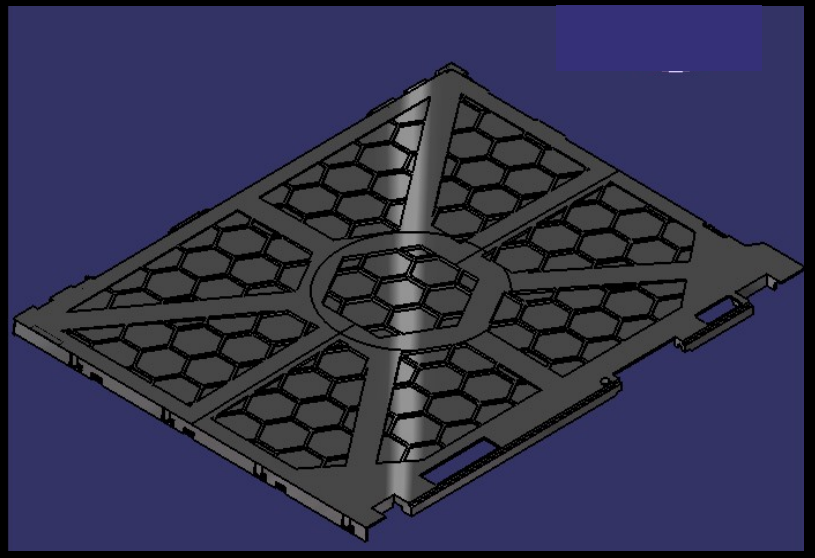


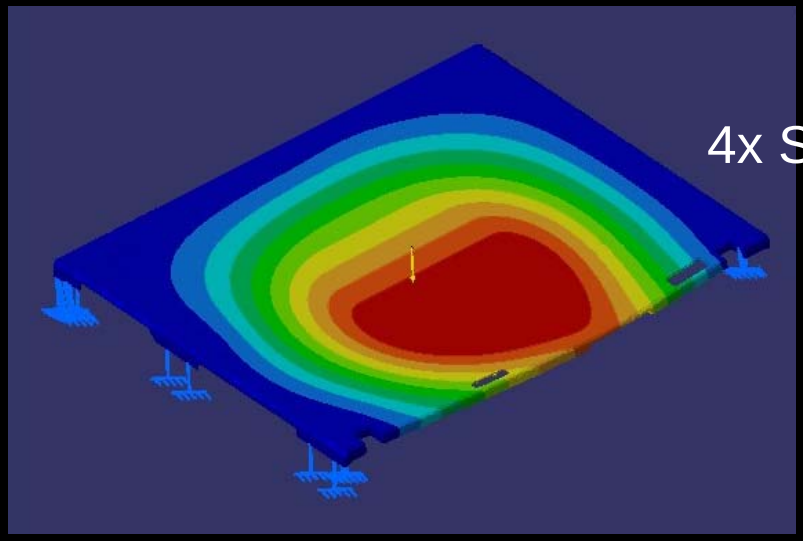
What's Next: LCD Roll Cage

Today

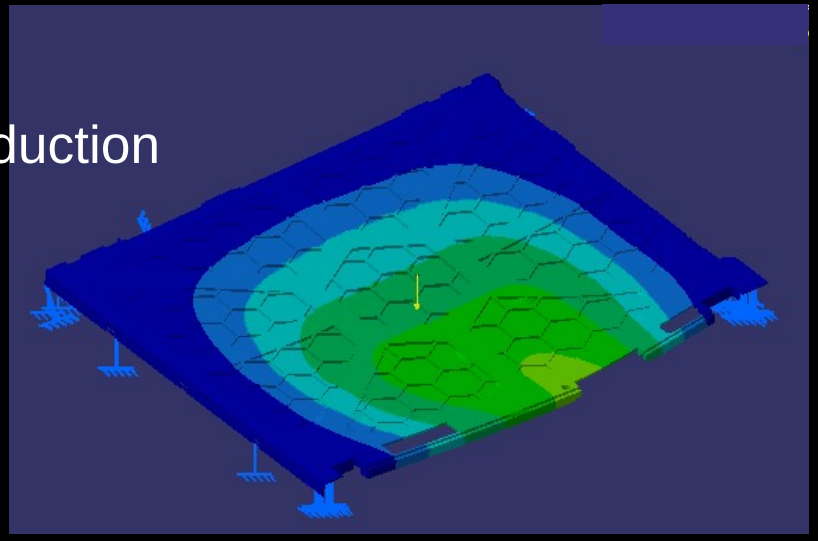


Next Generation





4x Stress Reduction



Heat negatively affects battery life

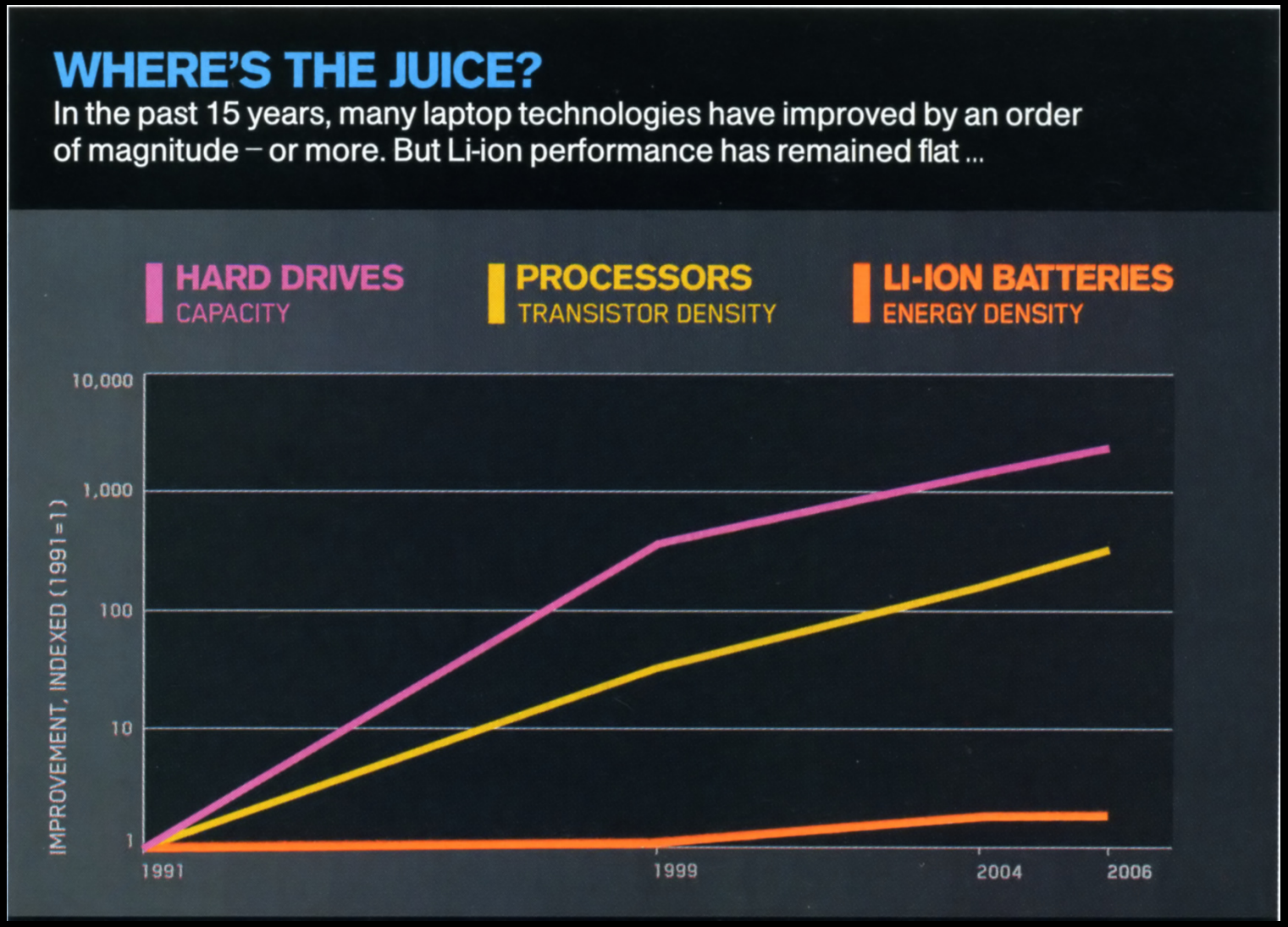
The Challenge

Trend = Increase in performance/function of laptops - hotter processors, more system power, more function

Action = Innovate on power management to improve battery life, size and weight

- Enhanced power management by monitoring usage behavior
- Performance optimization within a specified battery life budget
  - Trade-off performance vs. battery life (smart throttling)
  - Trade-off thermal and acoustics
  - LCD Slow Refresh
    - Refresh rate control (60Hz -> 50Hz) without any usability impact (flicker)
- Lower power consumption CPU / chip set

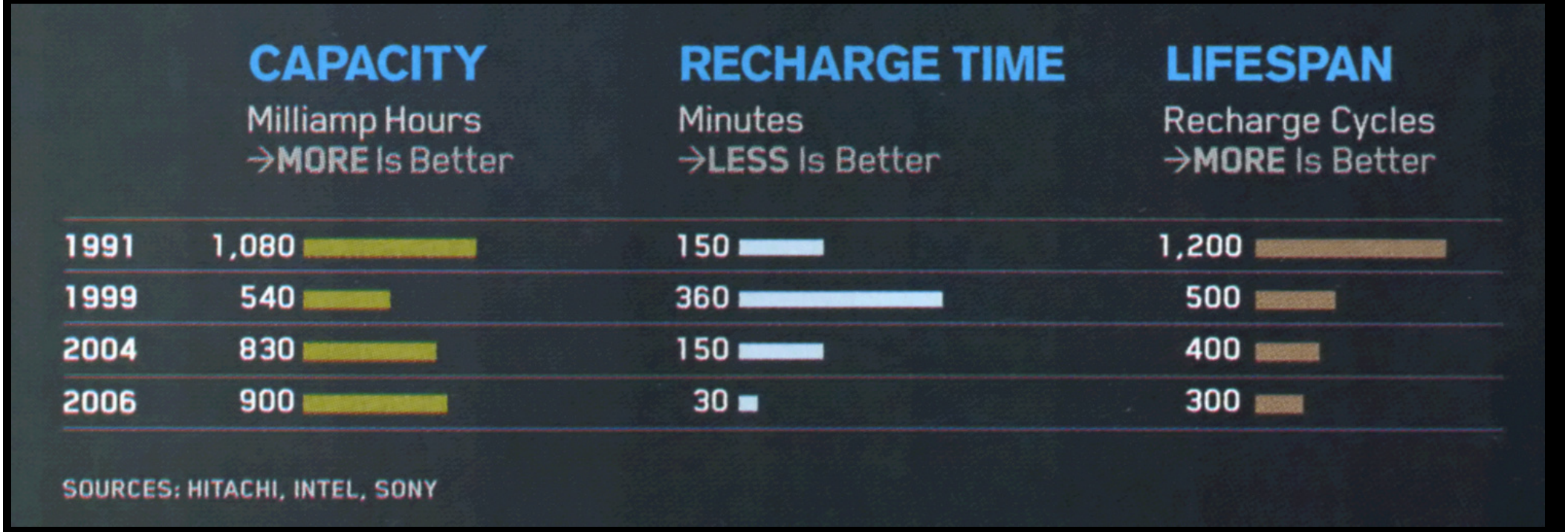
Battery Technology Has Not Caught Up…



Source: Wired November 2006

Battery technology is the single greatest inhibitor to a lighter laptop

Battery Technology Has Not Caught Up… (cont.)



Source: Wired November 2006

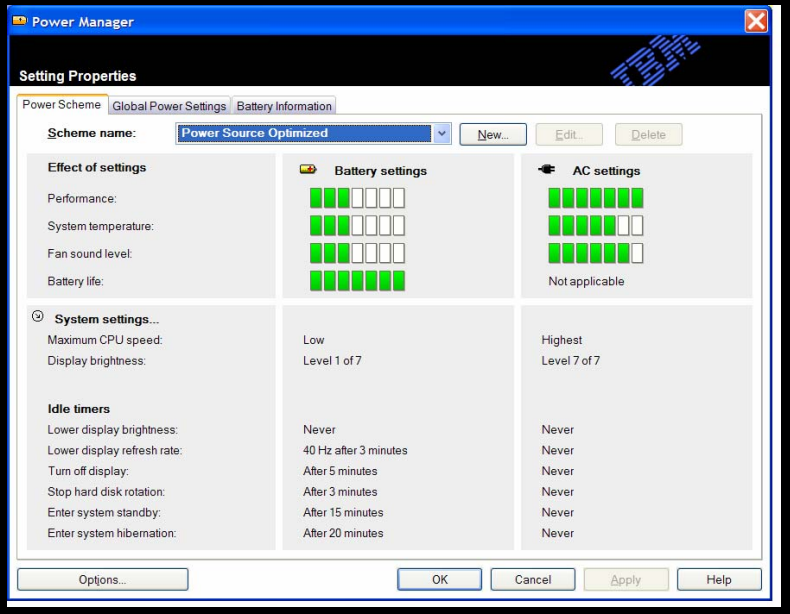
Rapid charging technology is not the answer as it has its own perils

How To Increase Battery Life

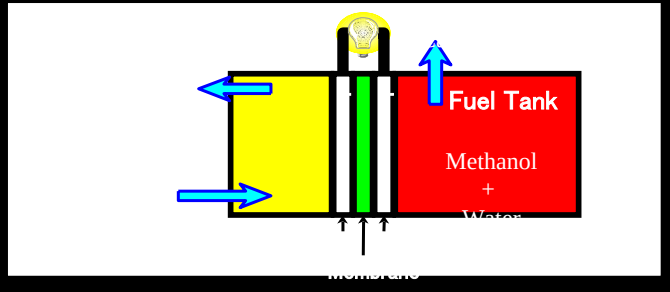
Battery Life:

- Advanced Power Mgmt
- Improvements to Lithium Ion
- New Technology

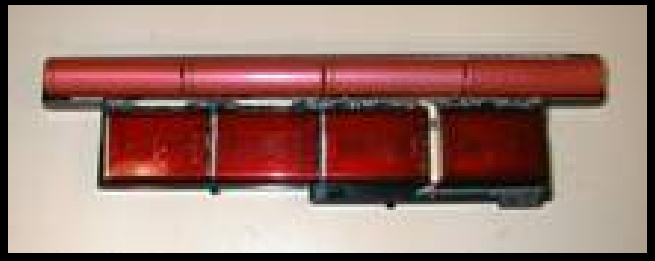
ThinkPad Power Manager



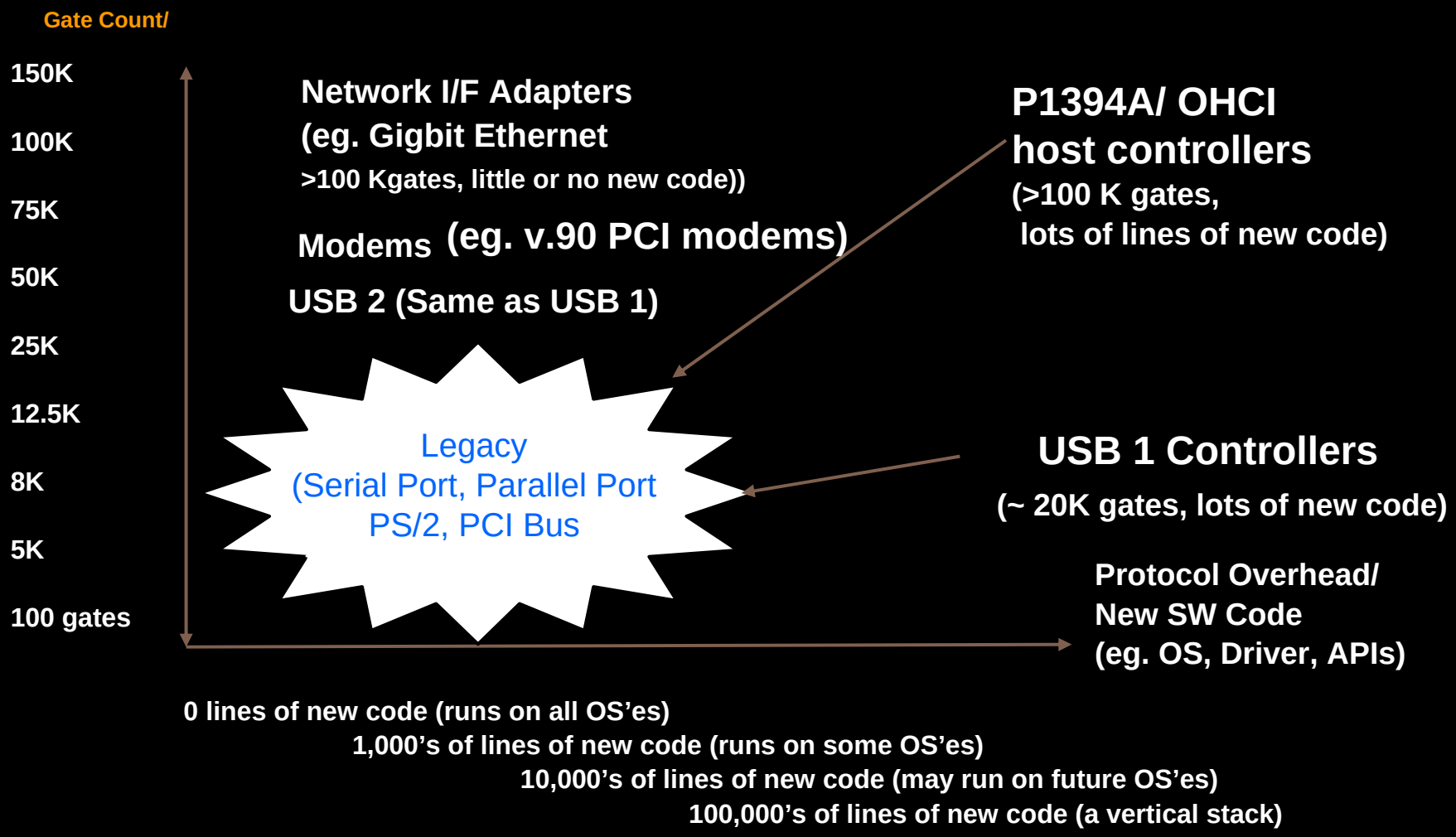
Fuel Cells



Hybrid Battery Technology



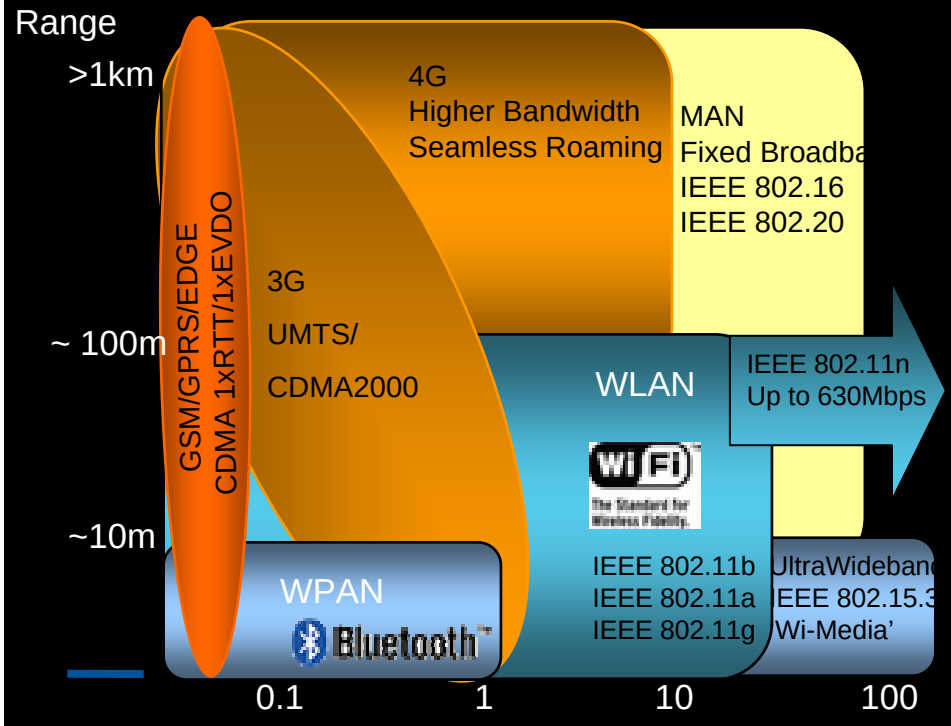
Challenges of adding new standards



Standards that require new software stacks take much longer if ever to become industry pervasive

Mobile Experience - Wireless

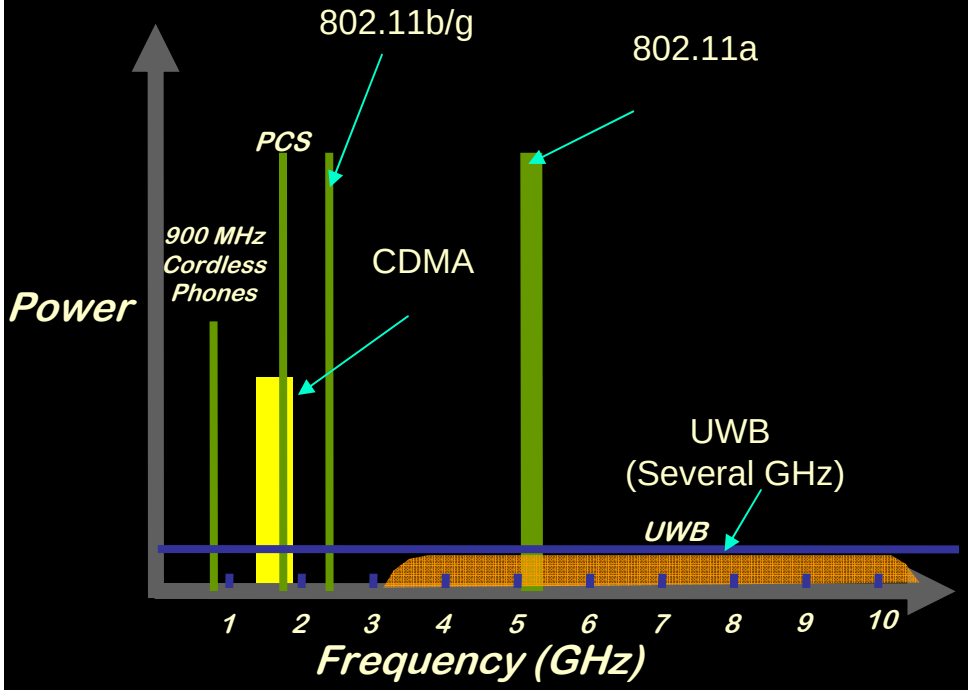
Wireless Technology Landscape

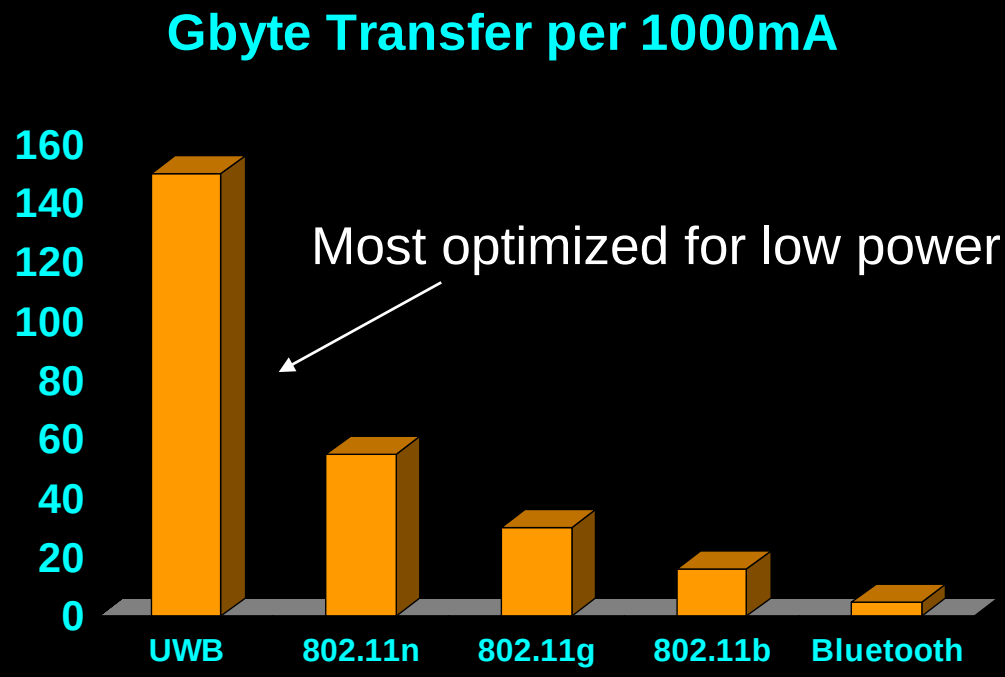


- New Antenna Technology
- Wireless Wide Area Network (WWAN)
  - Choice of Technology CDMA or GSM
  - Working with FCC, Qualcomm and carriers on simplification of certification process
  - Expanding Carriers and Countries support
- Wireless Local Area Network (WLAN)
  - 802.11 n (MIMO) Increase Performance in 1Q07
  - Detail Chart
- Personal Area Network (PAN)
  - Ultra Wide Band (UWB) a better Bluetooth

Wireless UWB

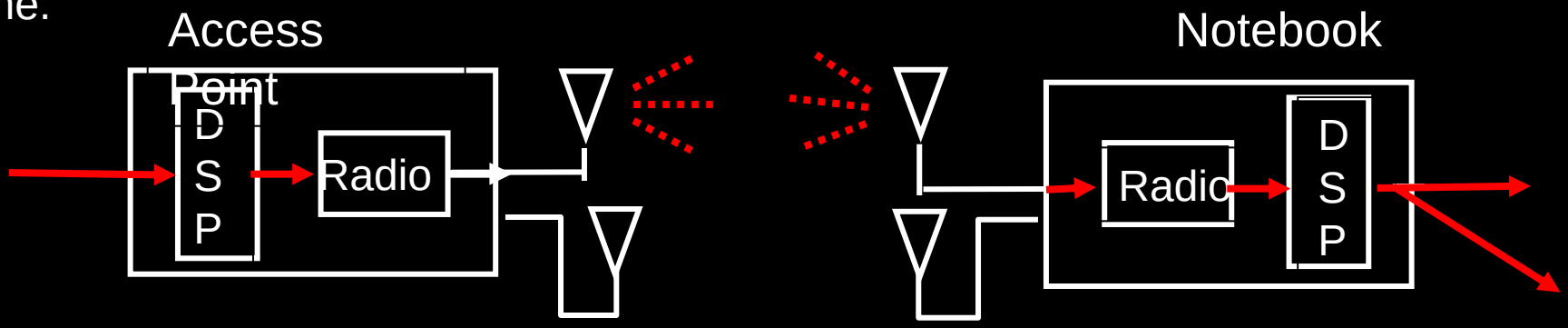
- UWB is a new Short Range / High Throughput Wireless Technology
  - Fits in-between and overlapping with BT and WLAN
  - Up to 480Mbps physical rate now, >1Gbps in the future
  - Uses wide spectrum (3.1-10.6 GHz allocated; initial usage at 3.1 to 4GHz)
  - Very low power for data transfer compared to other wireless solutions
  - Avoids Interference better. Power is so low that other devices don't detect it.
- UWB is not its own protocol. It is a physical interface for multiple protocols.
  - Currently USB ("Wireless USB"). Will expand to TCPIP, Bluetooth,VGA, DVI, etc…



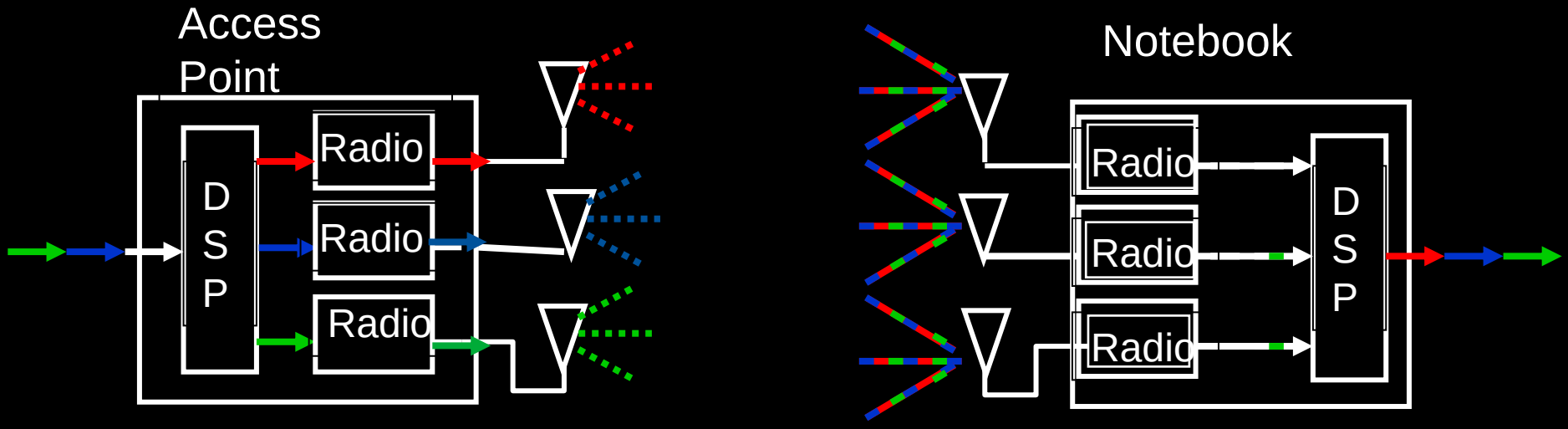


Mobile Experience 802.11n - MIMO

802.11a/g WLAN has one radio and two antenna. Only one antenna is used at a time.



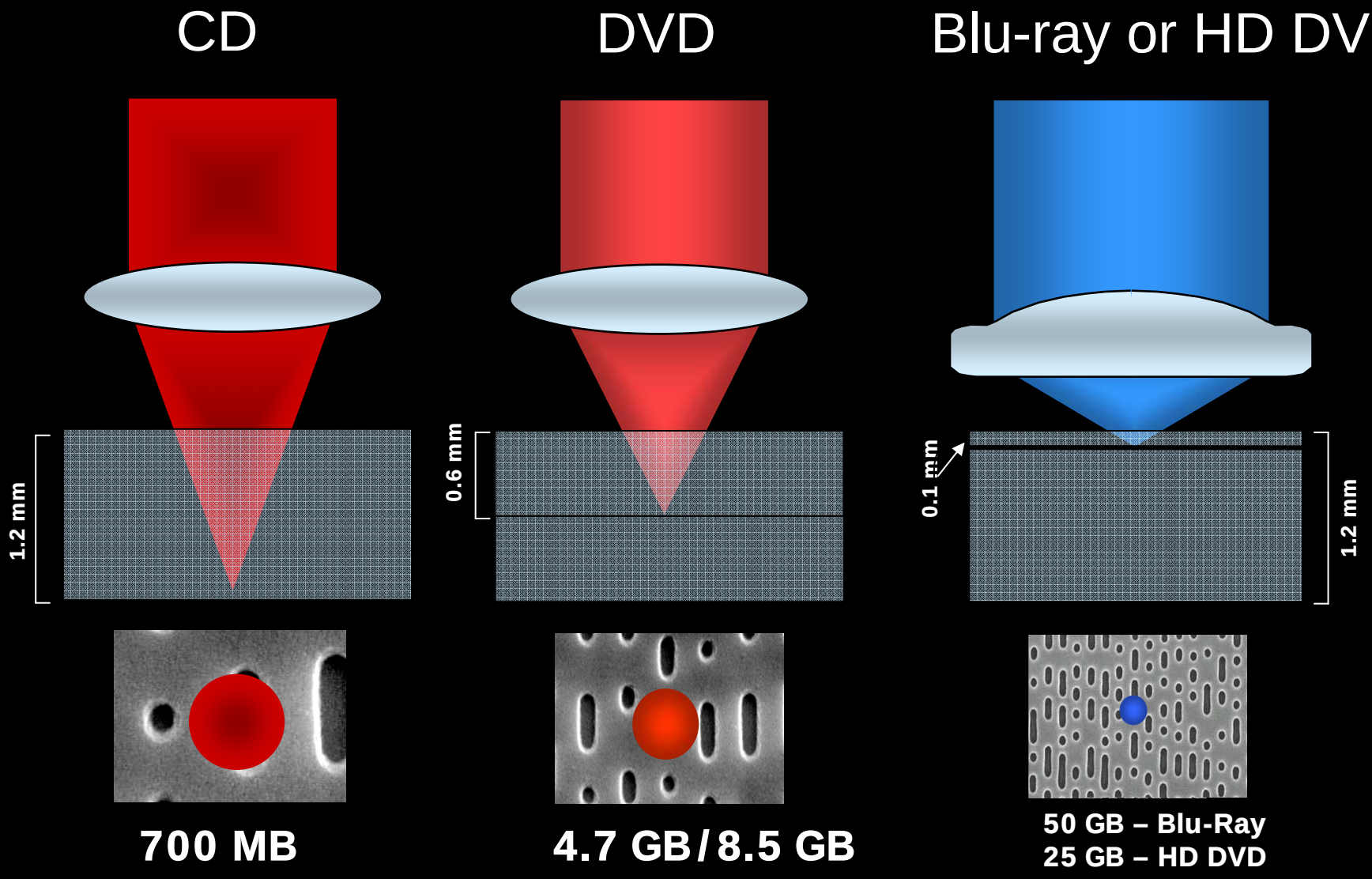
MIMO use multiple radios and multiple antennas at the same time.
MIMO increase communication speed by transmitting multiple streams over the air.



Next Generation Optical

Lenovo is supporting Blu-Ray

- 2x capacity
- All players are read/write (HD DVD has read only) → better cost for write devices



A New Phase: PC Innovation Matters Again

A new phase –
application of technology
- for business advantage
- *as a companion tool*
- *for our digital life style*