Design for the Environment
at Intel

ERC Teleseminar Series
March 25, 2004

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Intel Fellow – Director EHS Technologies

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Agenda

- Brief Overview of Intel
- Moore's Law
- Design for Environment (DfE) in Manufacturing
- Product Ecology – Definition & Focus Areas
  - Lead-free Program
  - Materials Declaration
  - Energy Efficiencies
- Questions

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Brief Overview of Intel

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Intel Snapshot

Intel, the world's largest chip maker, is also a leading manufacturer of computer, networking and communications products.

- Year founded: 1968
- Number of employees: 79,700
  - 49K US, 30K non-US
- Revenues: $30 Billion (2003)
- Over 450 products and services
- 294 offices and facilities in 48 countries

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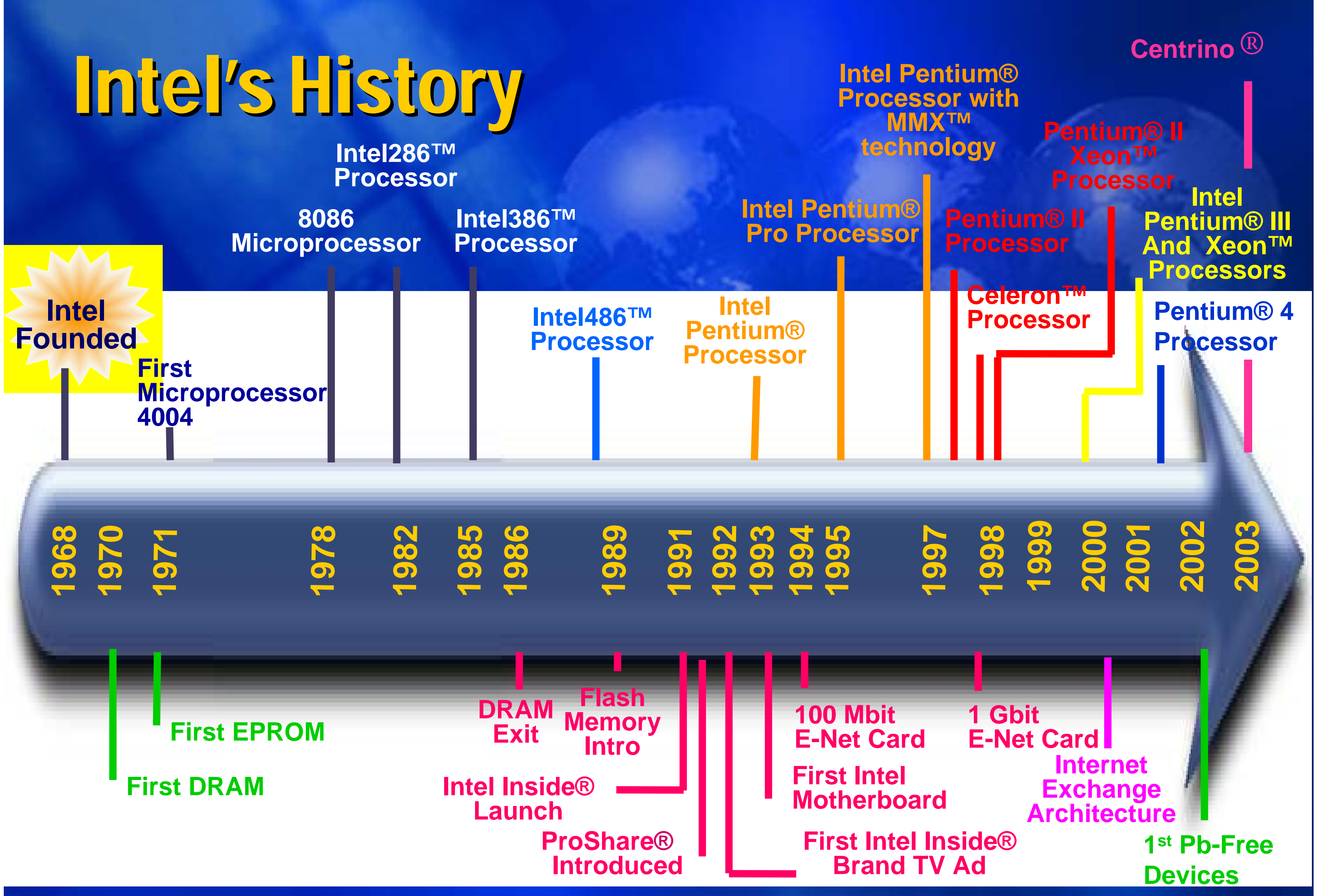

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Intel's Strategic Direction

Convergence of Computing and Communications

CLIENTS | COMMUNICATIONS | SERVERS

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Intel's High Volume Wafer Fabrication, Assembly/Test and Systems Sites

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Intel Environmental Health & Safety

A Commitment to Excellence

"At Intel, we pursue EHS performance the same way we pursue performance in the marketplace. We have worked to become global leaders in EHS. This commitment is integrated throughout the corporation, from our executives to every employee."

Craig R. Barrett
Chief Executive Officer

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Intel's EHS Guiding Principles:

- Prevent all injuries in the workplace
- Be an EHS leader in our communities and our industry
- Reduce the environmental footprint of our products, processes and operations

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Moore's Law
and
Design for Environment (DfE) in Manufacturing

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Moore's Law
The engine of innovation

- Moore's Law, first formulated by Gordon Moore in the mid-60's, has remained valid for 4 decades
  - Article in the 35th Anniversary of *Electronics* magazine (April 1965)
- Initially, Gordon saw a doubling of transistors each year
- Established the vision, driving force and roadmap for the trillion dollar semiconductor and electronics industry

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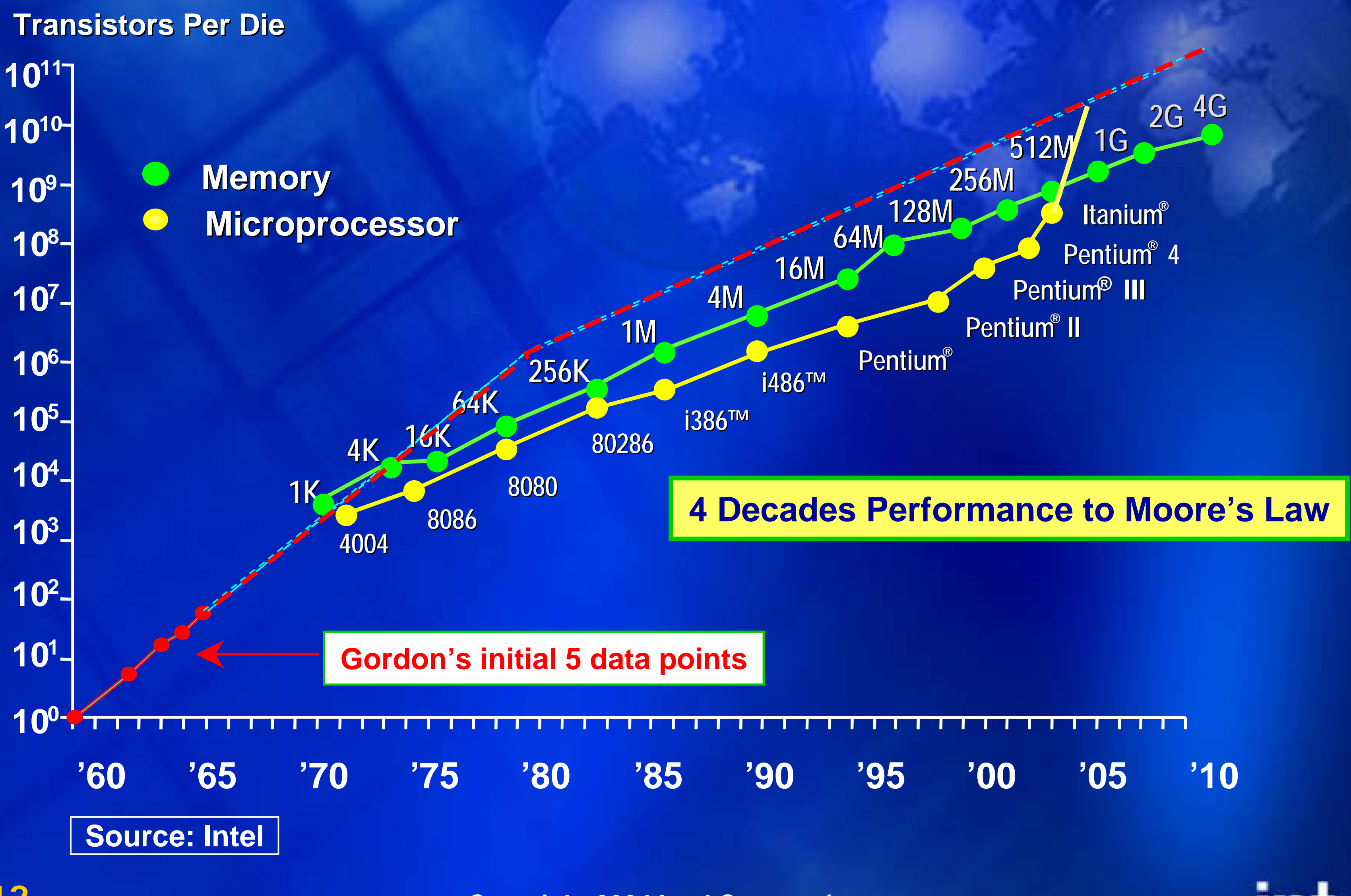
Integrated Circuit Complexity Grows



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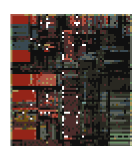
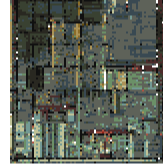
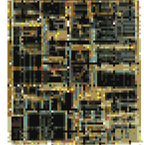
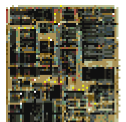
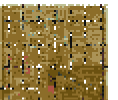
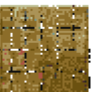
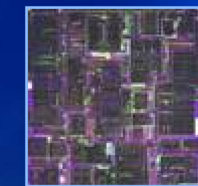
Intel's Process Technology

Source: Intel

Basic Feature Size in microns

	0.8µ	0.6µ	0.35µ	0.25µ	0.18µ	0.13µ	# Transistors In Millions
Pentium® Processor							3.3
Pentium® Pro Processor							5.5
Pentium® II Processor							7.5
Pentium® III Processor							9.5-25
Pentium® 4 Processor							42+
Itanium® 2 Processor							480

In 26 years, the number of transistors on a chip has increased more than 18,000 times, from 2,300 on the 4004 in 1971 to 42 million on the Pentium® 4 processor.

Converting to 0.09µ = 90 nanometers

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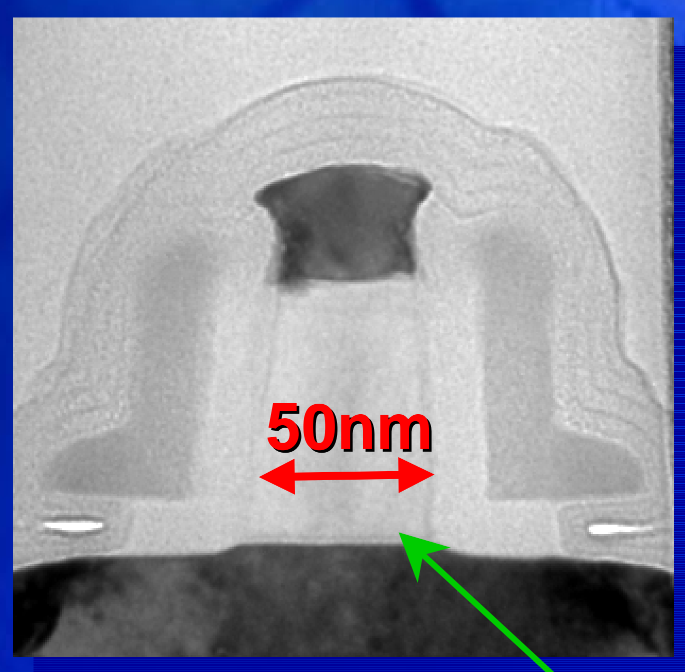
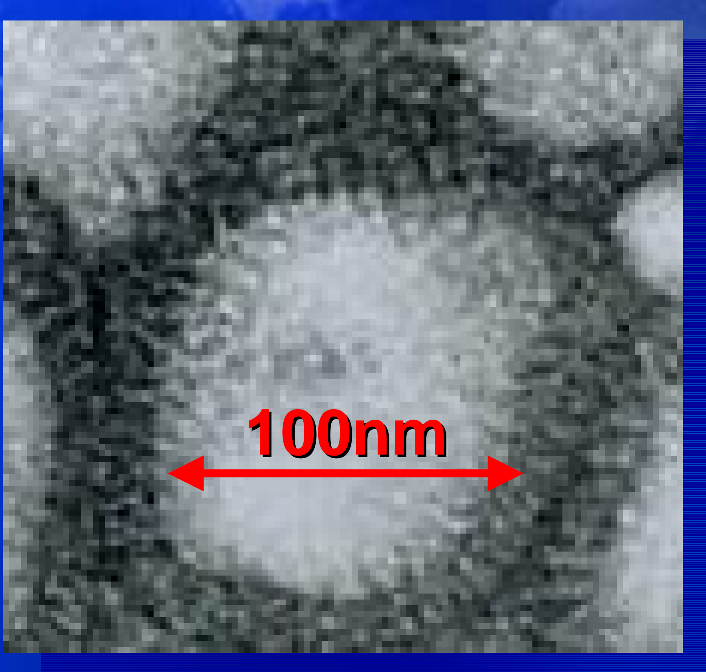
Current Status of Silicon Technology

50 nm transistor is ~2000x smaller than diameter of human hair



Transistor for 90nm Process

Source: Intel



Influenza virus

Source: CDC

Gate dielectric thickness = 1. 2nm

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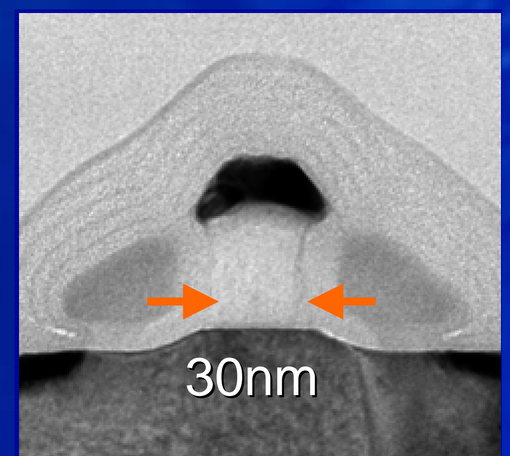
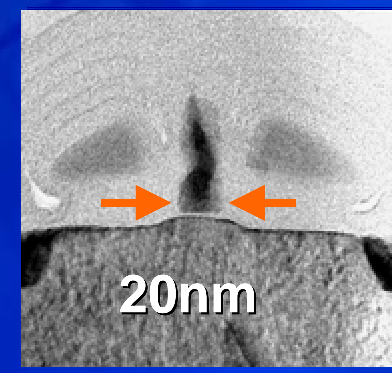
Intel's Transistor Research to 10nm

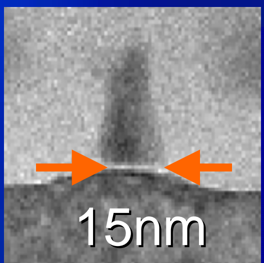
DNA is 15 nm wide



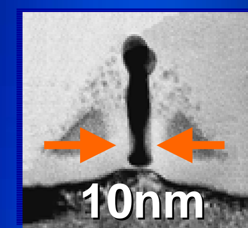
65nm process
2005 production



45nm process
2007 production



32nm process
2009 production



22nm process
2011 production

Source: Intel

nm = nanometer (1 billionth of a meter)

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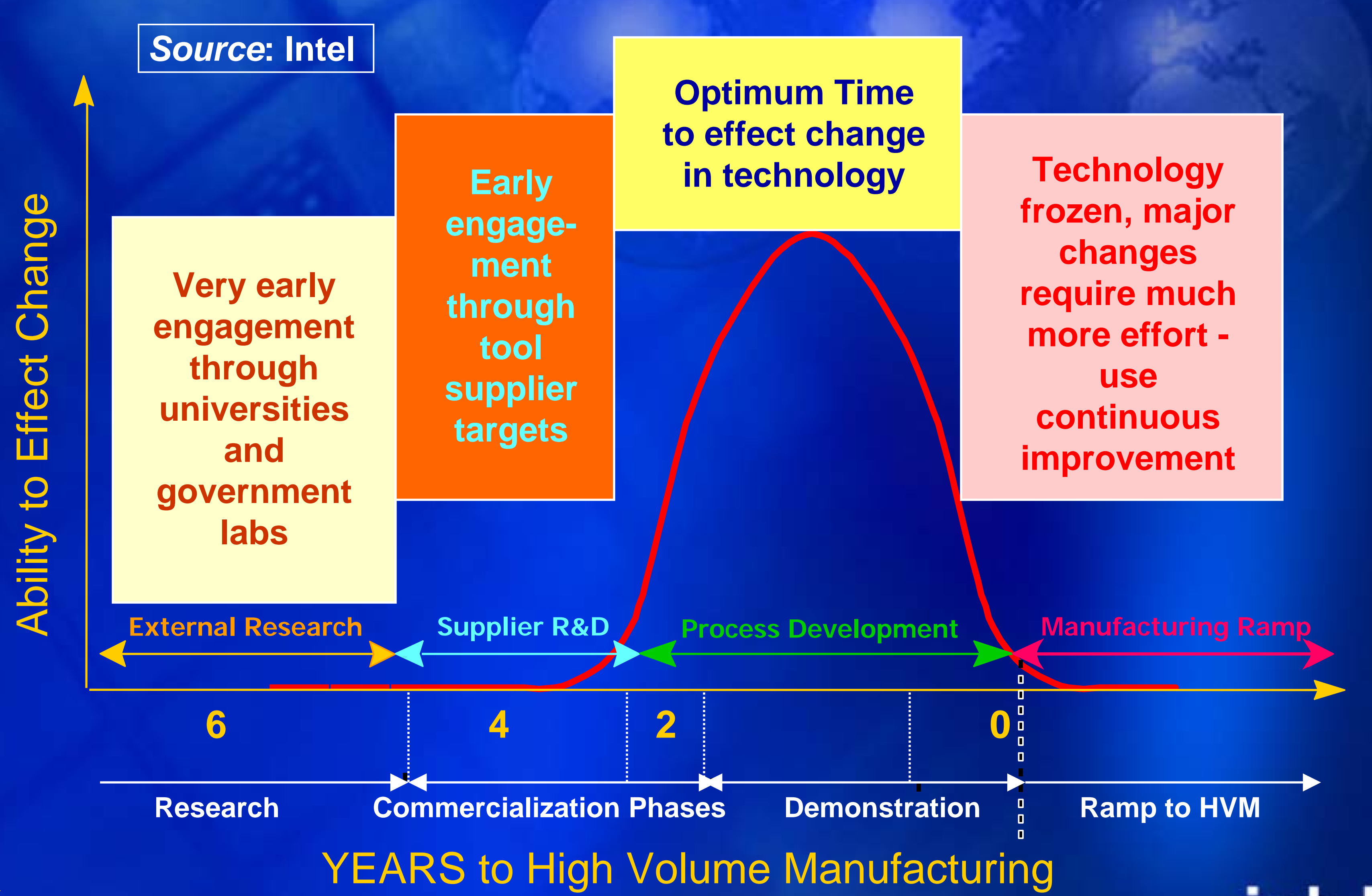
EHS Technology Engagement Model



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Microprocessor Ramp Trends

Source: Intel

Wafer Starts / Week
(200mm Equiv.)

0.6 µm
0.35 µm
0.25 µm
0.18 µm
0.13 µm

1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005

Forecast

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Rapid Technology Changes

Provides Opportunities and Challenges

- Intel develops and delivers a new chip manufacturing process every 2 years:
  - Each new process is 30 months for Technology Development
- Primary opportunity for EHS improvements is in TD
- Intel has an integrated Design for EHS Program
- EHS is involved throughout the TD process for:
  - Manufacturing Process development
  - Chemical selection and Waste Management
  - Facility design
  - Ergonomics and Equipment Safety
  - Manufacturing equipment selection
- Manufacturing process is *"Copy Exactly"*

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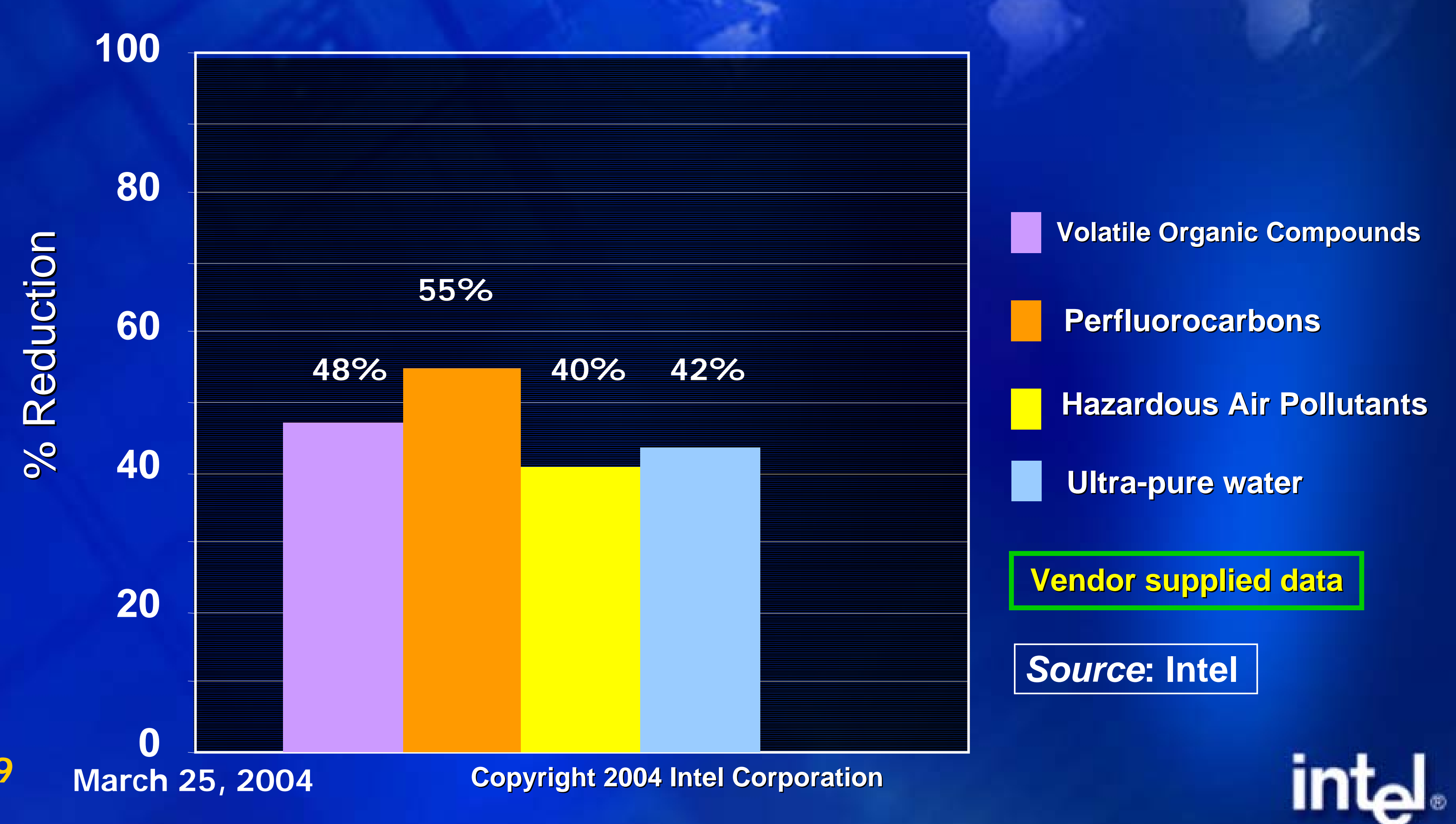
Estimated 300mm emissions & water use Relative to 200mm in chip manufacturing

300mm is more Environmentally Friendly



Source: Intel

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Environmental Performance 2003

- >61% of Chemical Waste recycled worldwide
- >74% of Solid Waste recycled worldwide
- Fresh water usage 16.5 million gallons/day worldwide
- 30% reduction in VOC emissions since '99 (205 tons worldwide in 2003)
- Global warming emissions 1.0 MMTCE (includes electricity usage)
- ISO 14001 Certified for all manufacturing
- >35,000 PCs refurbished and delivered to schools and non-profit organizations

Intel's EHS Report: www.intel.com/go/ehs

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Product Ecology

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Product Ecology – Definition & Focus

- Product Ecology – Designing environmentally compatible products and manufacturing processes while maintaining product price/performance and quality characteristics.
- Intel's Focus Areas for "*Green Products*" are:
  - Material Composition (e.g. Pb-free)*
  - Manufacturing Design for Environment (DfE)*
  - Design for Disassembly (DfD)
  - Energy Usage (Products & Manufacturing)*
  - End-of-Life Management
  - Product Packaging

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Lead in PCs – Where is it used?

Exempt from RoHS Directive

Monitor ~900 g (2 lbs)

Printed Circuit Board 5-10 g
Microprocessor ~0.2 g

Peripherals 2-3 grams

For comparison:

- House key = ~0.1-0.3 g
- Car battery = 9000 g (20 lbs)

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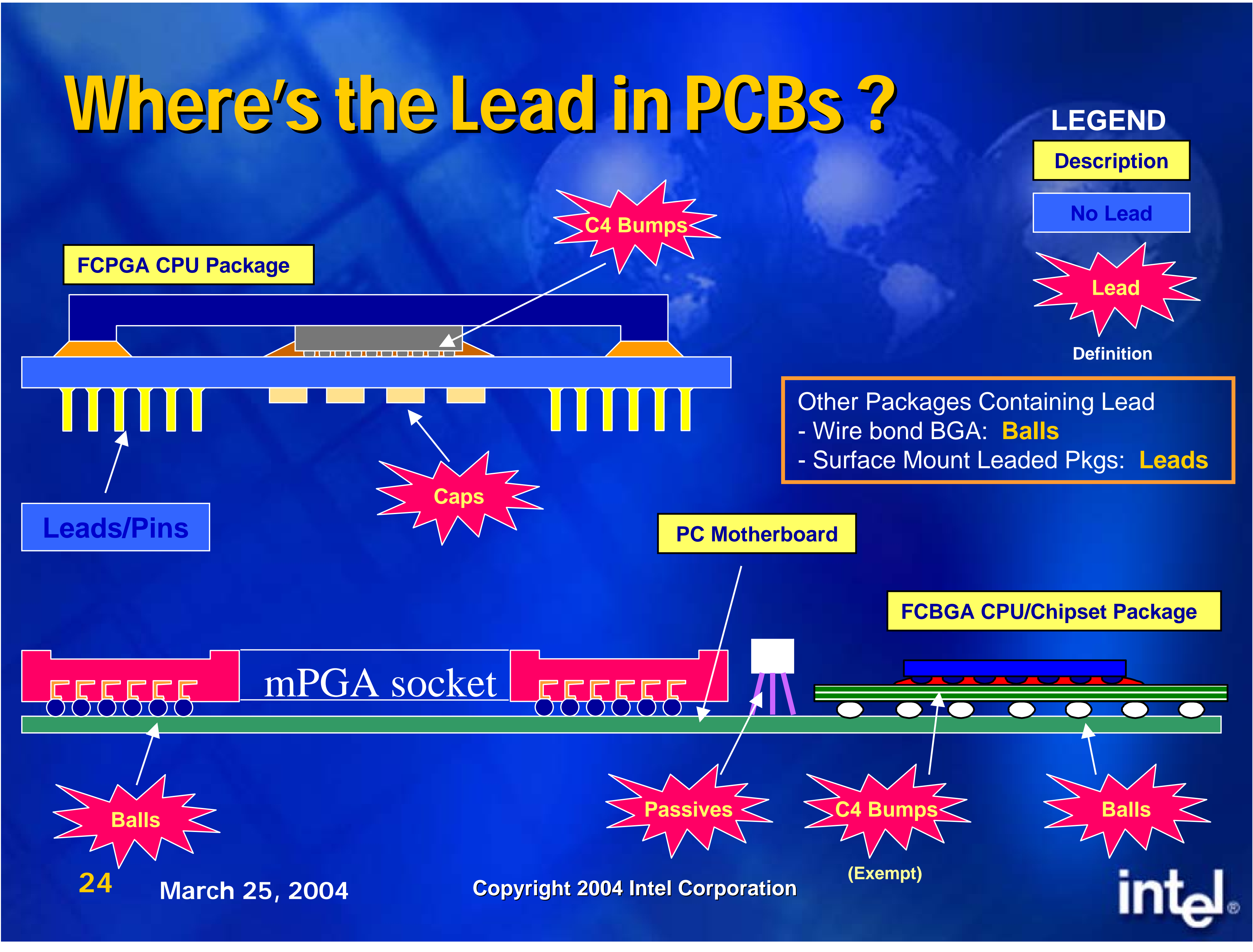
Where's the Lead in PCBs ?
LEGEND
Description
No Lead
Lead
Definition
FCPGA CPU Package
C4 Bumps
Leads/Pins
Caps
Other Packages Containing Lead
- Wire bond BGA: Balls
- Surface Mount Leaded Pkgs: Leads
PC Motherboard
FCBGA CPU/Chipset Package
mPGA socket
Balls
Passives
C4 Bumps
(Exempt)
Balls
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Lead-free BGA Packaging

Today's Lead-Tin Process

New Lead-Free Process

Gold wire bond

Gold wire bond

Silicon Die

Package

Lead-Tin solder ball

Tin-Silver-Copper solder ball

BGA = Ball Grid Array

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Intel's Progress on Lead-free

- Intel has spent 3+ years developing lead-free technologies
- 2001 – Intel's first lead-free product was flash memory with wire bond ball grid array (BGA) package
- 2002 – Lead-free technology developed for select printed circuit board applications (Network Interface Card)
- 2003 – Additional lead-free package types qualified. For example: Stacked Chip Scale Package (SCSP), very fine BGA, easy BGA

Application	Lead-free Solution
Solder Paste	Sn/4.0Ag/0.5Cu
Solder Spheres	Sn/4.0Ag/0.5Cu
Wave Solder	Sn/0.7Cu
Board Surface Finish	Immersion Silver
Lead-Frame Finish	Matte-Sn

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Pb-free Technology Challenges

- High temperature reliability of components and boards
- High end board (i.e. server boards) manufacturing processes and defect rates, etc.
- Matt-Sn acceptance in high end applications (e.g. servers) and highly stressed environments (e.g. telecommunication applications)
- Tin whisker growth using Matt-Sn
- Dual line item manufacturing during transition
- Need for industry standards (e.g. definition of lead-free, temperature reflow profiles, etc.)
- Supply chain conversion and management

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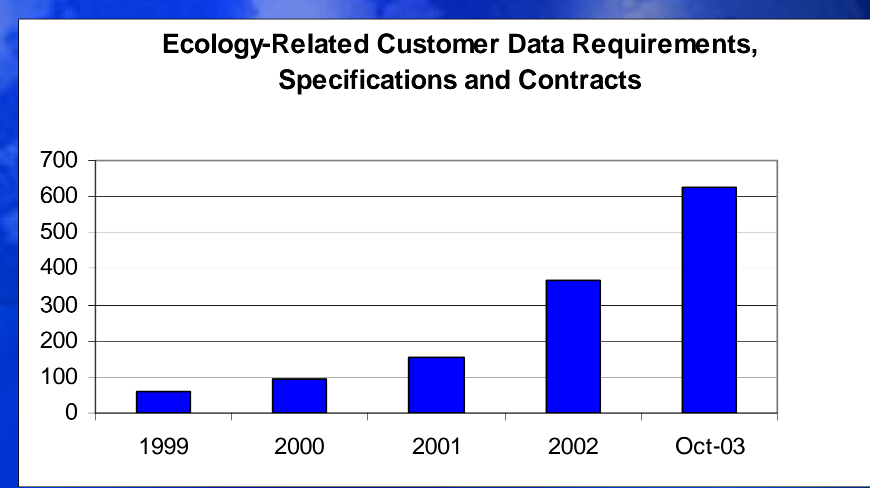
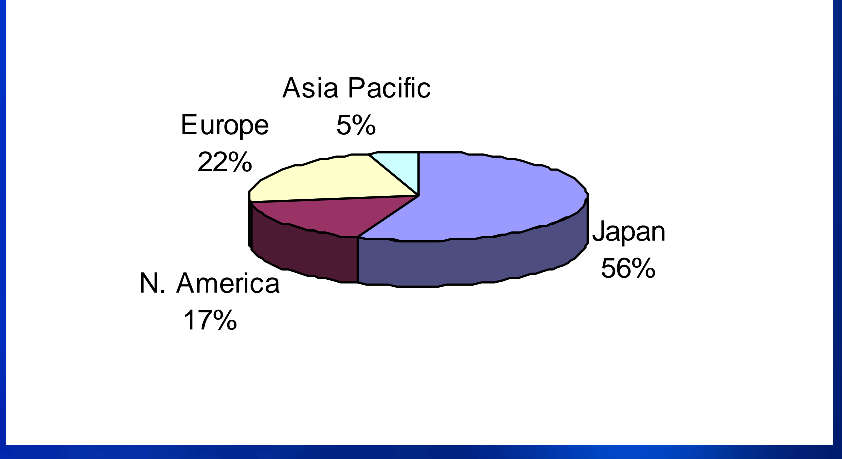
Materials Declaration at Intel

- ISSUE - material composition of electronics is a vital piece of information in the supply chain as OEM's prepare for global initiatives that both restrict the use of certain substances and require recycling
- SOLUTION - Based on the EIA's (Electronic Industry Alliance) Material Declaration Guide, Intel has developed material declaration datasheets (MDDS) to communicate environmentally relevant information to our customers. Transitioning to EIA/EICTA/JGPSSI Guide.





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Product Energy Efficiencies

- Intel has reduced power consumption of our products and also system level products
- Intel has R&D efforts in power management and energy efficiency for the notebook, desktop, and server
- Notebook Energy Efficiencies:
  - **Enhanced SpeedStep™ technology enables the processor to operate at multiple voltages & frequencies based on workload**
  - **Processor includes power-optimized system bus and low-power L2 cache, which turns off parts of the memory**
  - **Micro-operation fusion combines two operations into one enabling faster execution and lower power**
  - **New platform delivers lower power consumption in the LCD panel and Voltage Regulator (consume 40-50% of the power)**

For more information about the CentrinoTM technology, please visit: http://www.intel.com/products/mobiletechnology/index.htm

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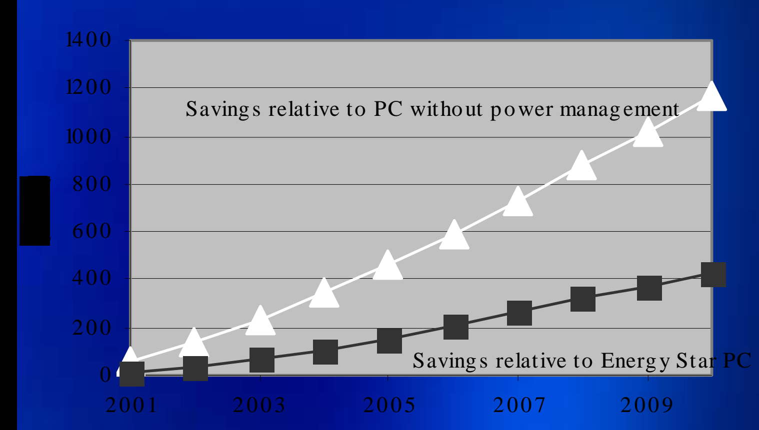
Product Energy Efficiencies (Con't)

Desktop Energy Efficiencies:

- In 1999, Intel released Instantly Available PC (IAPC) power management technology
- Delivers PCs that consume < 5 watts in "Sleep mode" compared to typical power use of 60-70 watts in idle mode
- Provides Quick "wake-up" ~ 5 seconds compared to a typical cold boot up of between 1-3 minutes
- Intel's IAPC Power Management Technology recognized by the U.S. EPA with several awards (2000 Climate Protection Award)
- U.S. EPA estimates for all U.S. PCs with IAPC, the US could save over 16 billion kilowatt hours and 10 M tons CO_2 /year



Source: US EPA

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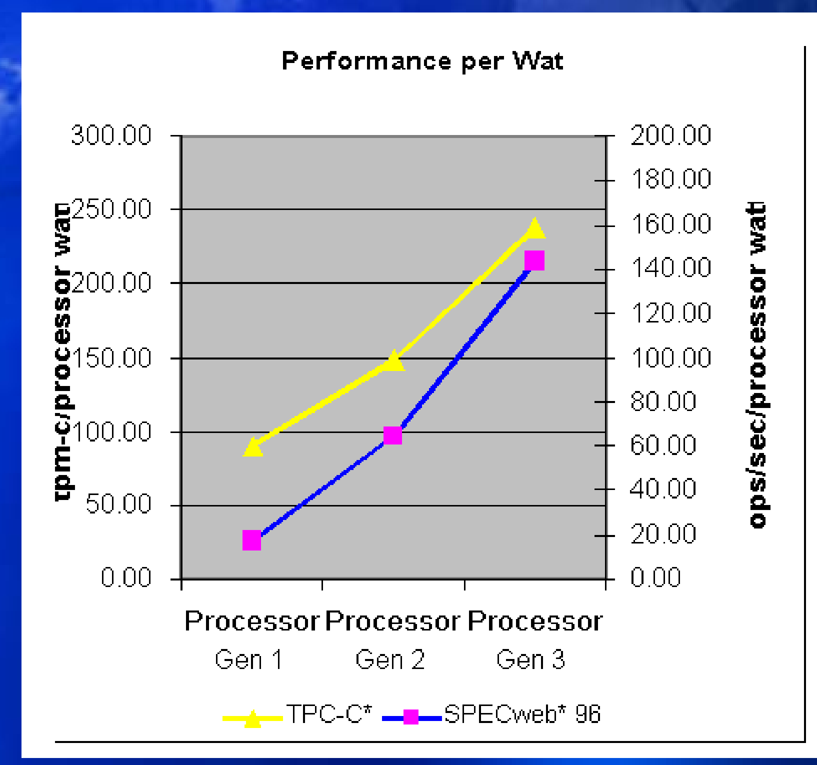
Product Energy Efficiencies (Con't)

Server Energy Efficiencies:

- Since the mid-1990s, the number of servers deployed worldwide has grown by a factor of 150, and the performance level offered by servers has increased more than 10 times
- The power and cooling systems consume about 50 percent of the power and operate less efficiently per unit of performance
- Intel has achieved energy efficiency (performance/power) through the Intel® Server Processors that has more than doubled transaction processing (TPCC) and improved over 600% for web servers



Intel's efforts at developing power efficient servers at:
http://www.intel.com/update/contents/sv09031.htm

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Summary

- Intel has a long history of DfE programs in its manufacturing and product development
- DfE and Product Ecology are built into the way Intel operates.
- Intel continues to develop lead-free products
- One of Intel's major contributions is the development of energy savings technologies including IAPC, SpeedStep^{TM} and Server Processors.

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Questions?

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