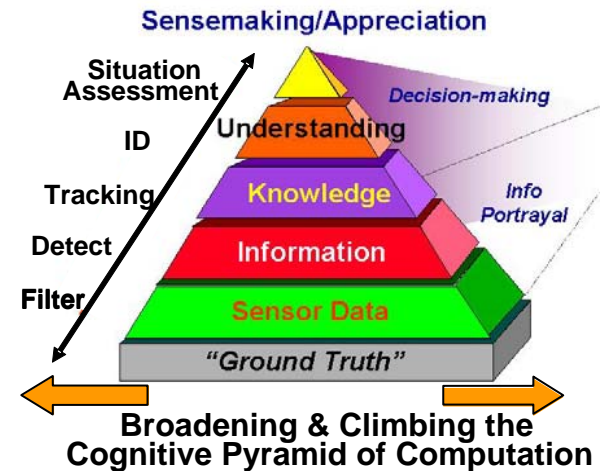


Amending Moore's Law for Embedded Applications

29 Sep 2004



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Senior Scientist, Advanced
Computing Architectures
AFRL Information Directorate



Contribution of Moore's Law to Improvements of Embedded Systems



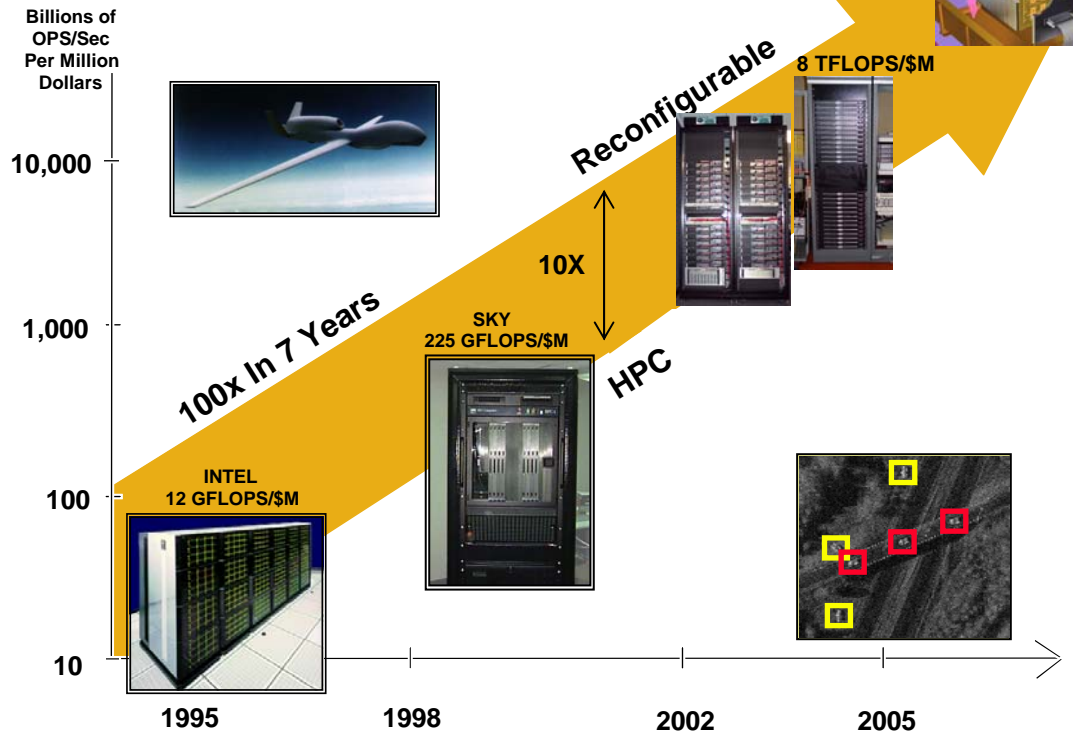
- **Price/Performance:** Gigafllops/\$M affordability
- **Memory Capacity:** programming simplifications
- **Steep memory hierarchy:** programming inefficiencies and complexities
- **New flexibilities:** e.g. reconfigurable hardware
- **New complexities:** software and parallelism
- **Dramatic new system capabilities**



Extending the Affordability Trend



Exponentially Improving HPC Affordability Transitioned to AF Users



CHALLENGE:

Develop and Incorporate the Most Affordable Embedded Information Technology Available

APPROACH:

- Leverage Commercial Investments In Computer Architectures
- Develop Portable Embedded DoD Applications using middleware standards
- Leverage DARPA, and Other DoD Efforts In Emerging Architectures

Projection:

2007: 60 trillion flops/\$M

2010: 360 trillion flops/\$M



Contribution of Moore's Law to Improvements of Embedded Systems



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Airborne COTS HPC

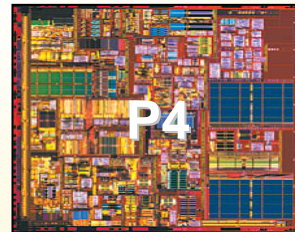


25 Dual-Xeon Compute Nodes

- **Dual GbE Network (80 MB/s per link)**
- **1U Rack-mounted**
- **\$87K approximate cost - 3.1 DP TFLOPS/\$1M**

Commodity Compute Node:

- **Dual 2.66 GHz Intel Pentium 4 Xeon CPU**
 - 512KB L2 Cache
 - 21.3 SP GFLOPS peak per node
- **Dual GbE network interfaces**
- **6 GB DDR SDRAM**



Peak Performance:

- **532.5 GFLOPS (IEEE 32 bit)**



Swathbuckler Cluster
(Coyote)



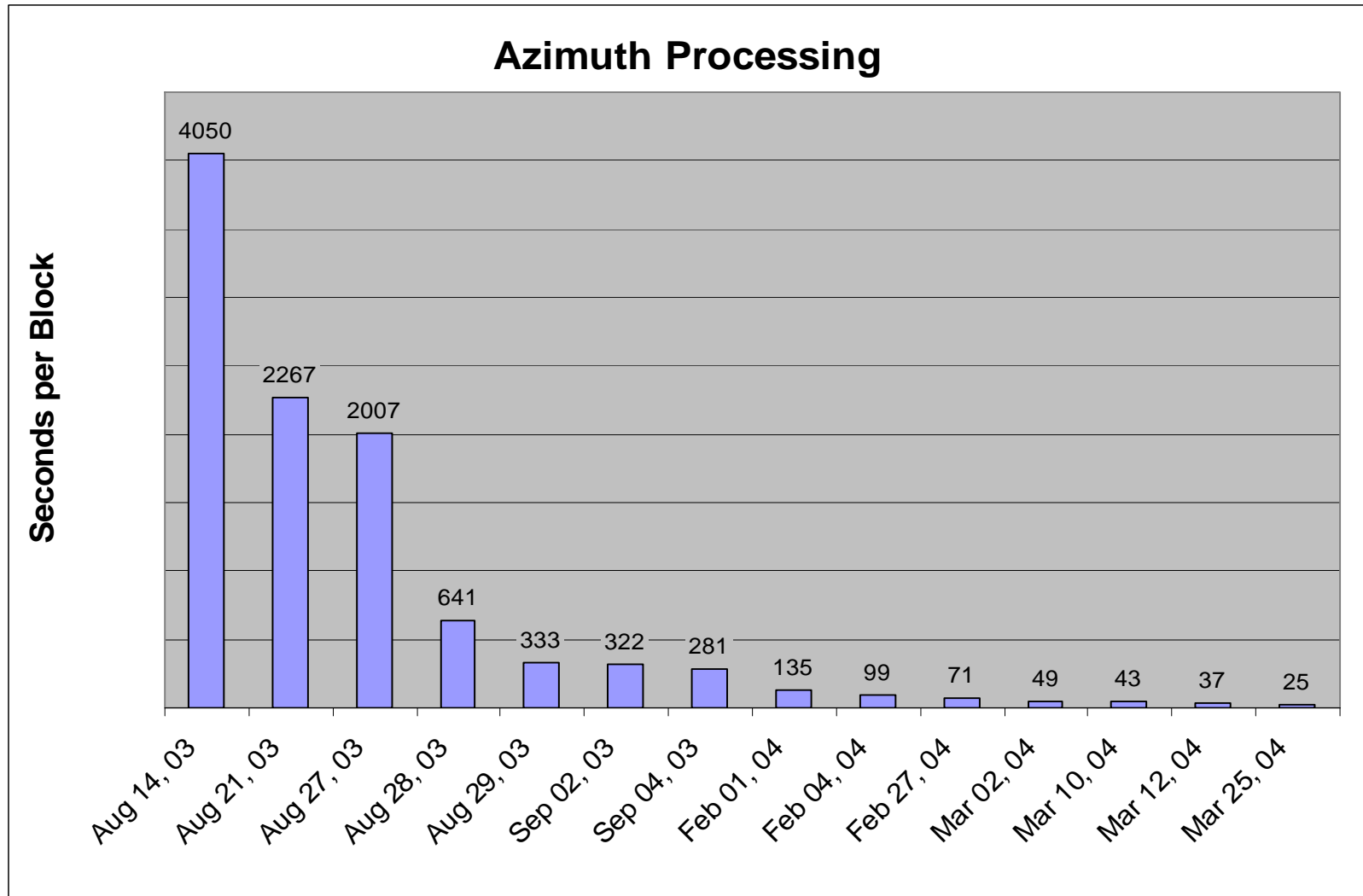
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Can we preserve historical improvement rates?





Contribution of Moore's Law to Improvements of Embedded Systems



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Heterogeneous HPC Hardware



- 48 Nodes in 2 cabinets
- Server product leverage
- Each node with: Dual 2.2 GHz+ Processors
 - 4 Gbyte SDRAM
 - Myrinet 320 MB/sec Interconnect
 - 80 GB disk
 - 12 M gate Adaptive Computing Board
- 34 TOPs demonstrated
- Online FEB 2003 supporting HIE, TTCP and SBR projects



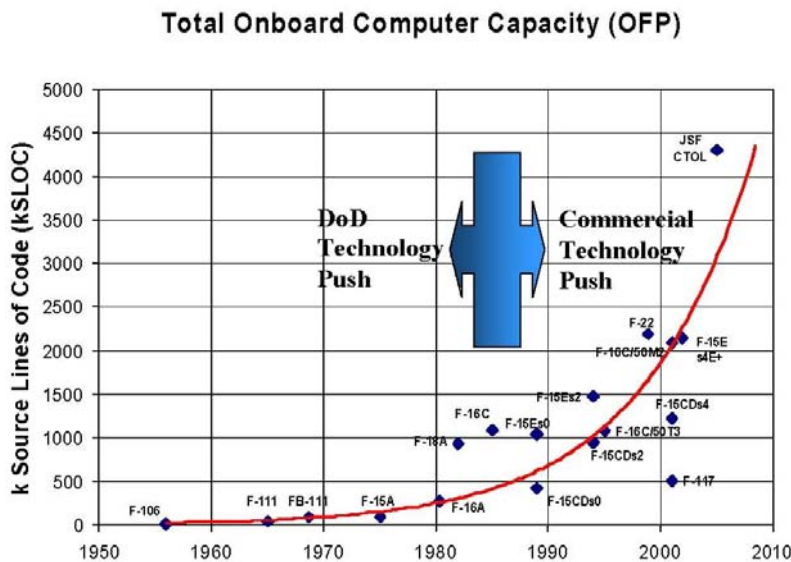
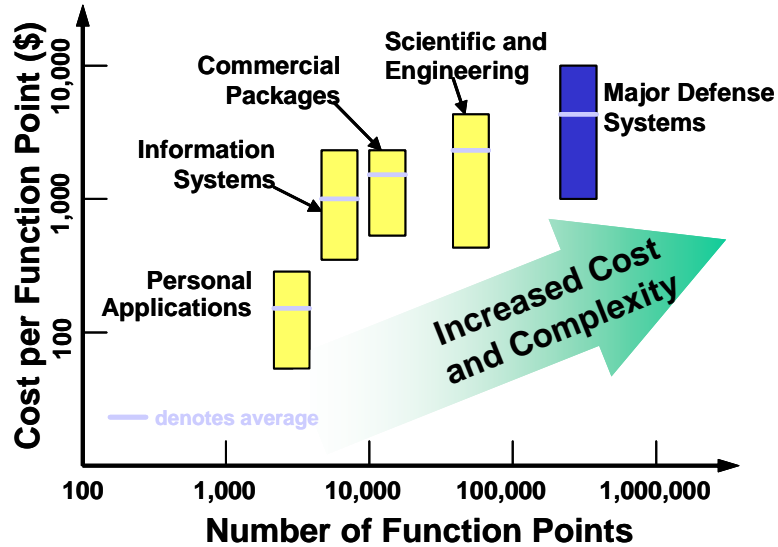
**Heterogeneous High
Performance Computer**



Contribution of Moore's Law to Improvements of Embedded Systems



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- **Traditional Embedded SW Development**
 - **Low Level Programming**
 - **Ad Hoc Approaches**
 - **Stand-alone, Static Implementations**
 - **Custom Systems**
 - **Little Code Re-use**
 - **V & V is labor intensive** (e.g. F/A-22)
- **Result is**
 - **Prolonged Design Schedules**
 - **Excessive Cost**
 - **Difficulty in Maintenance/ Upgrade/ Retrofit**
 - **Limits on Functionality**
- **Looking Ahead**
 - **Increased Functionality => Complexity**
 - **Move Towards Networking, Interconnecting Systems**
 - **Distributed Computation Models**
 - **Reconfigurability, Dynamic Modifications**
 - **Code Correctness/ Safety Concerns**
 - **Security**
 - **Shortage of Skilled Programmers**

11



Can we preserve historical improvement rates?



Of necessity, innovate in the broader architecture design space

slowing VLSI motivates more architectural exploration

Invest hardware to simplify software

Encapsulate sophisticated software to achieve performance with portability