

Architecture at HP: Two Decades of Innovation

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Computer Architecture at HP

- **A summary of motivations, innovations and implementations in the period 1981 to the present**
- **Some observations about emerging systems requirements for the next decade and ongoing research to address them**

A Capsule History

The 80s:

- RISC consolidation and evolution
- Spectrum, HP Precision Architecture, and PA-RISC
- Migration from HP 3000, 1000, M68000 architectures

The Early 90s:

- Beyond RISC: The quest for concurrency
- Superscalar, VLIW, Wide Word
- Compatibility with PA-RISC

1994 - Present:

- The Intel alliance
- Next generation technology and IA-64

WHAT'S NEXT?...

Precision Architecture Principles

- **Compiler does what it does best**
- **Hardware does what it does best**
- **As simple as possible, but not simpler**
- **Measure / justify everything**
 - **Optimize for application throughput**
 - **Most work in least time**
- **Architecture scales across family of implementations**
- **Seamless migration essential**

Technology Enablers of RISC Architecture

- **Progress in VLSI: Fast registers, cache**
- **Globally optimizing compilers**
- **Performance measurement and analysis tools**

Challenges of RISC Architecture

- **Compiler accuracy and reliability**
- **Migration of legacy code**

Major PA-RISC Innovations

- **Compound instructions based on usage statistics**
- **Instruction nullification**
- **Legacy software migration**
 - **Binary code translation**
 - **Millicode**
 - **Migration centers**
- **64-bit addresses**
 - **32-bit segments**
- **Graphics and multimedia extensions**

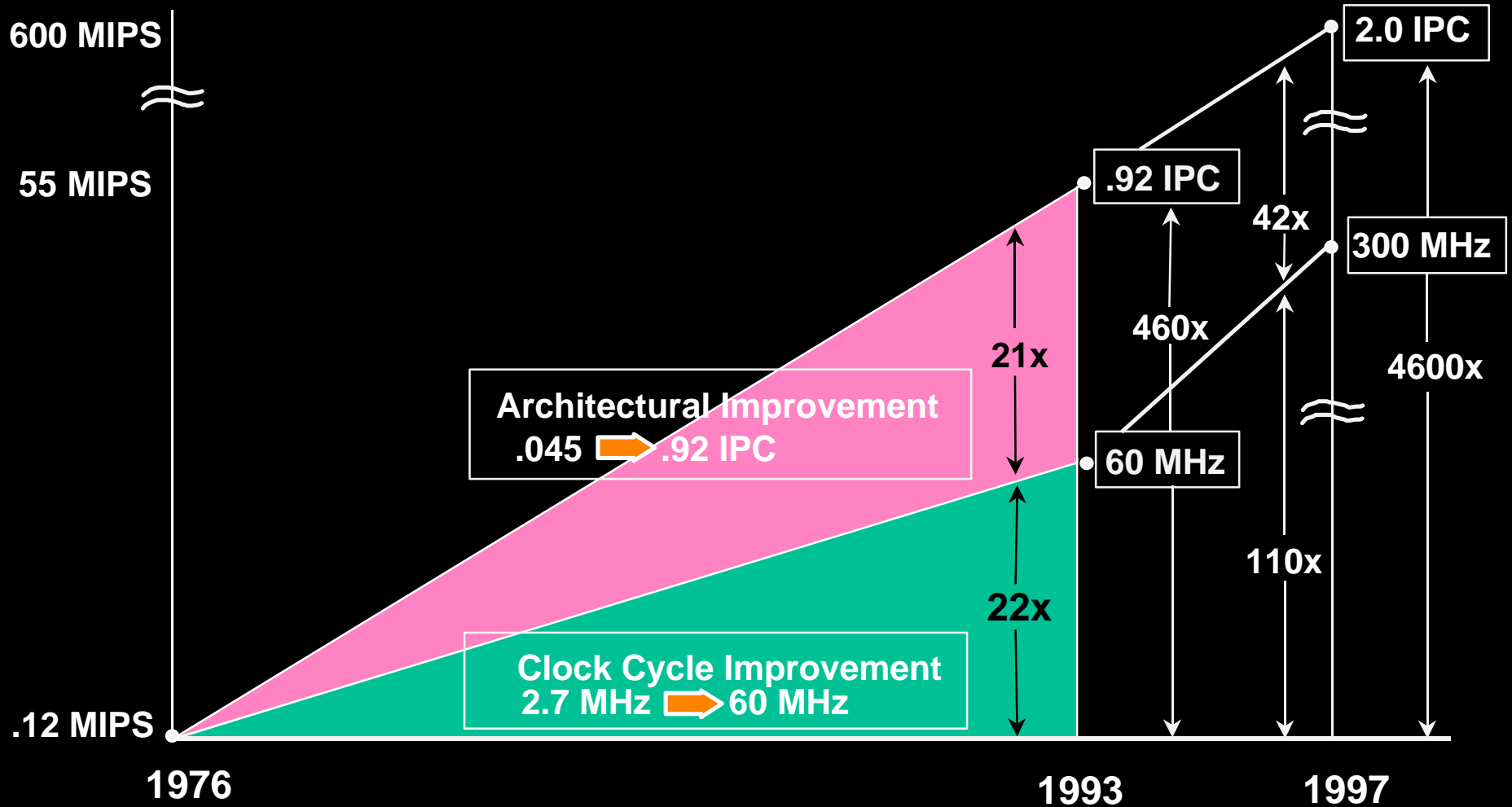
Why a New Architecture?

- **Insatiable demand for more performance**
- **Processor/memory speed gap implications**
 - **Higher bandwidth**
 - **More registers**
 - **Overlapped memory latencies**
- **Need for greater number of instructions per cycle**
- **Diminishing gains from growing microprocessor design complexity**

Industry Solutions

- **Superscalar RISC**
 - **Improved ILP, but:**
 - **Significant hardware complexity**
 - **Not transparent to compiler**
 - **Asymptotic IPC of 1.5 - 3**
- **VLIW, Vector Architectures**
 - **Even higher ILP**
 - **Explicit parallelism**
 - **Parallelizing compilers**
 - **But limited applicability, scalability, and compatibility**
- **Drives the need for a new architecture**

Microprocessor Performance Growth

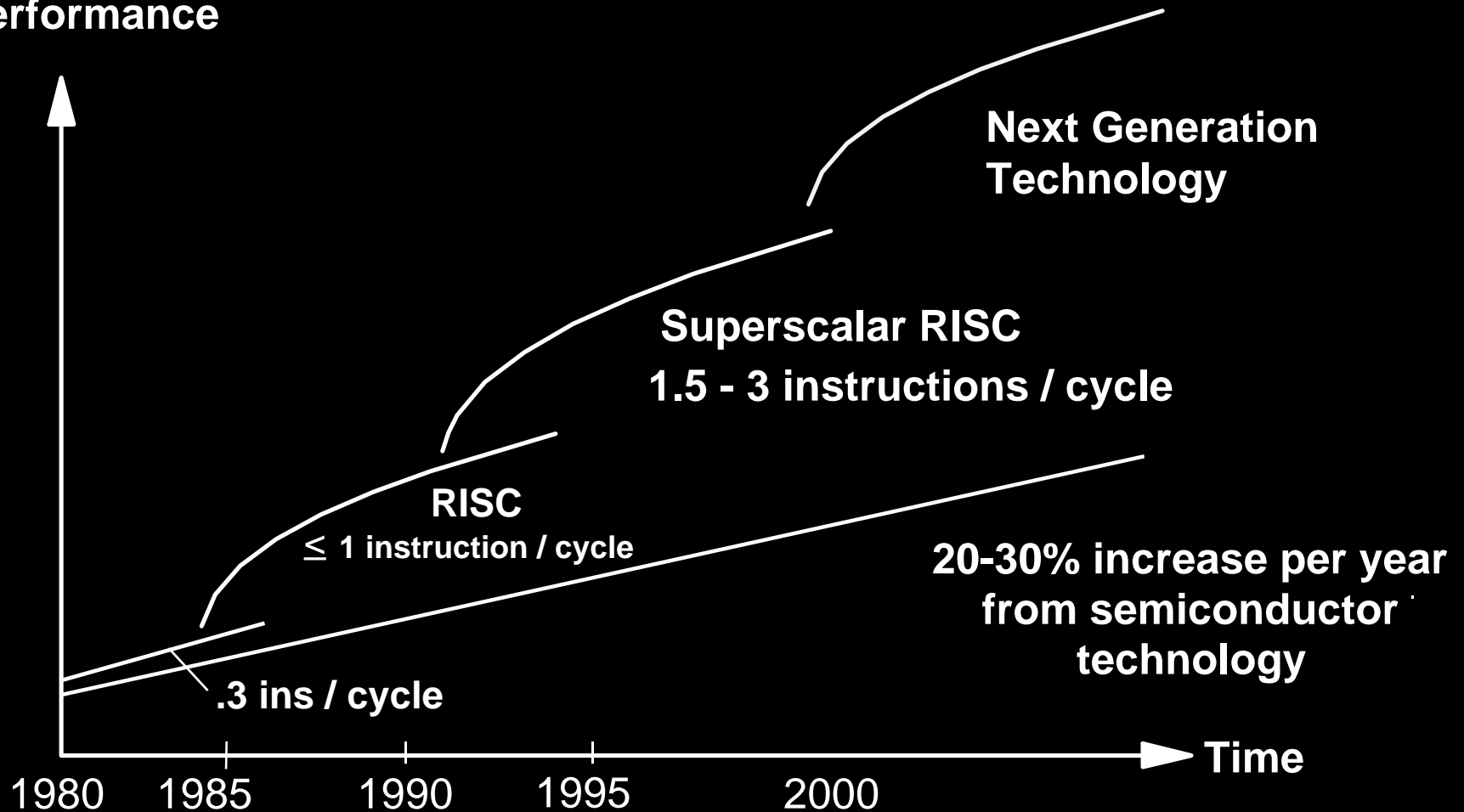


Major Conclusion: High ILP Needs a New Architectural Approach

- **High ILP requires explicitly scheduled code**
 - **Scheduling by compiler**
- **Architecture must expose parallelism**
- **Scalability across implementations and applications required**

IPC Evolution from Architecture and Microarchitecture

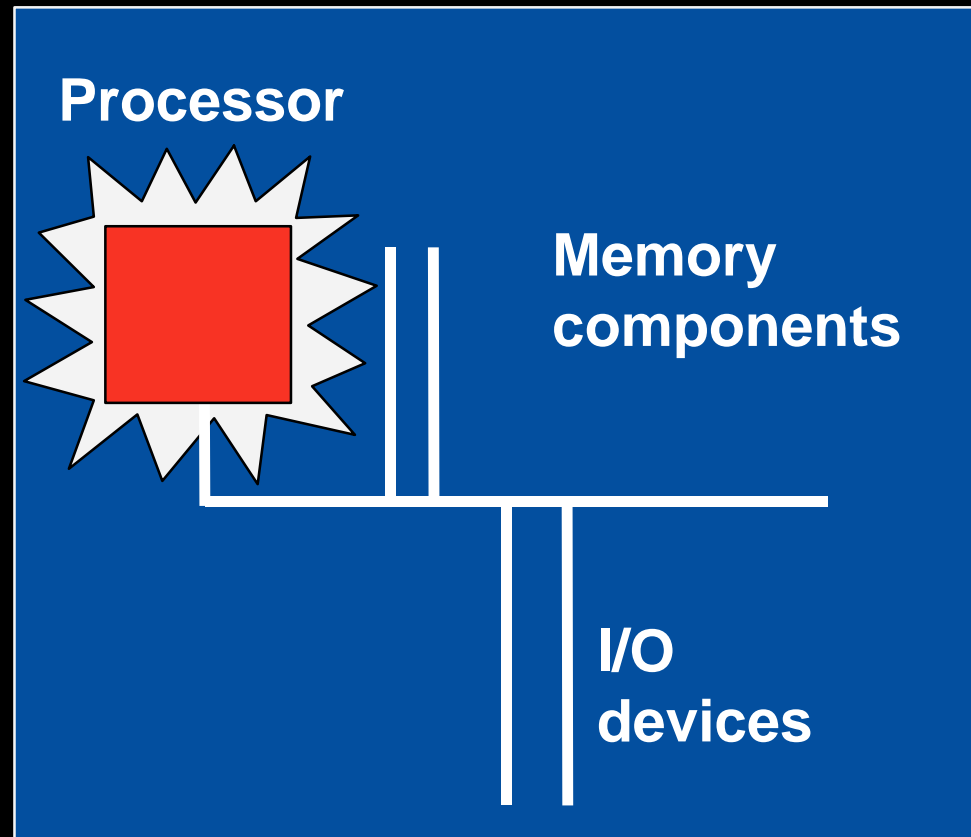
Performance



Need for a New Industry-Standard Architecture

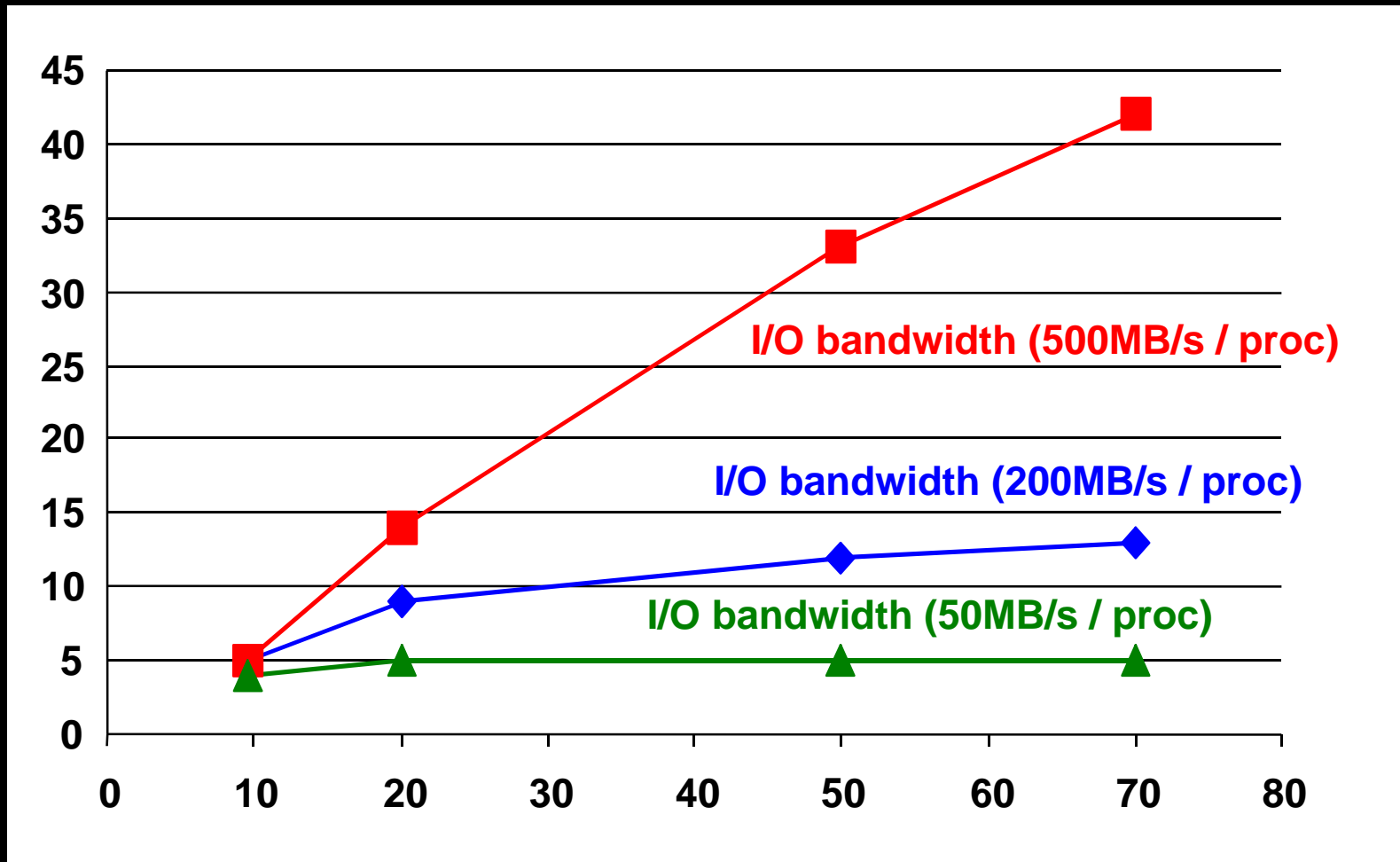
- **HP alone would not succeed with a new proprietary architecture: economics, acceptance by ISVs**
- **Technology alliance melds architecture/design / fabrication excellence of Intel with architecture and systems excellence of HP**
- **Opportunity for scalable common hardware platforms across operating systems**

The Rest of the System?



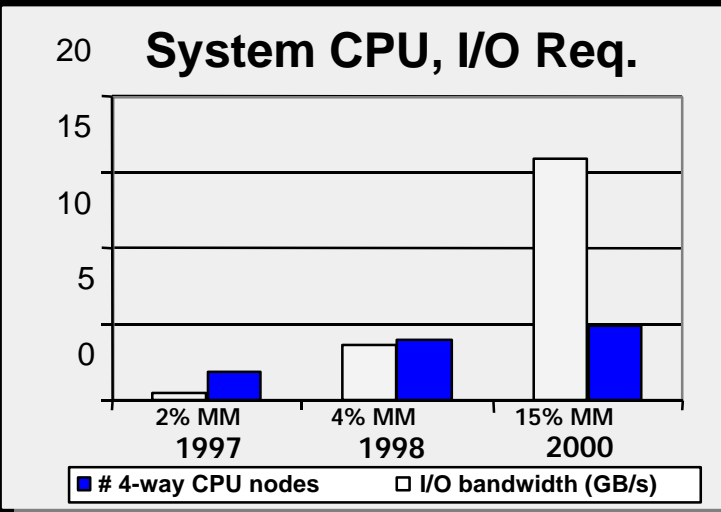
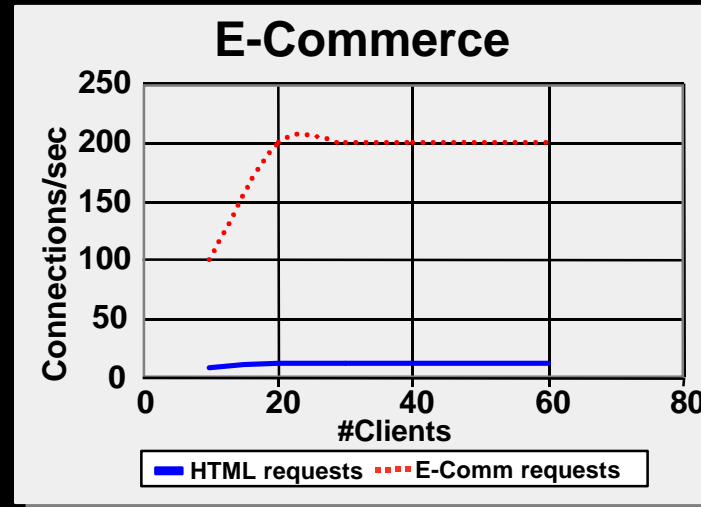
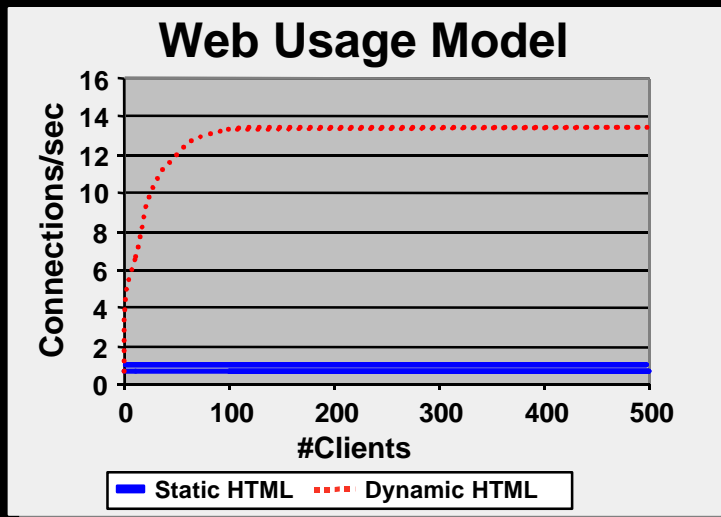
The Rest of the System

Application performance
(K Conn./sec)



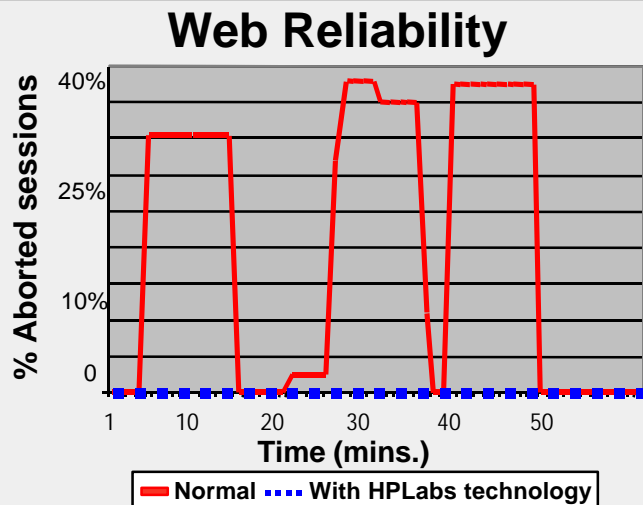
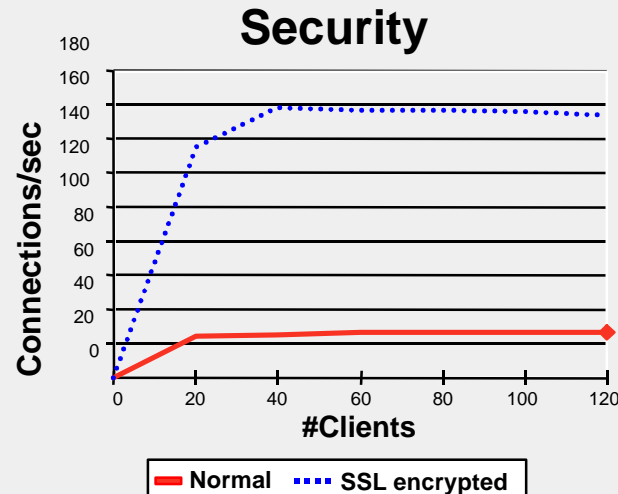
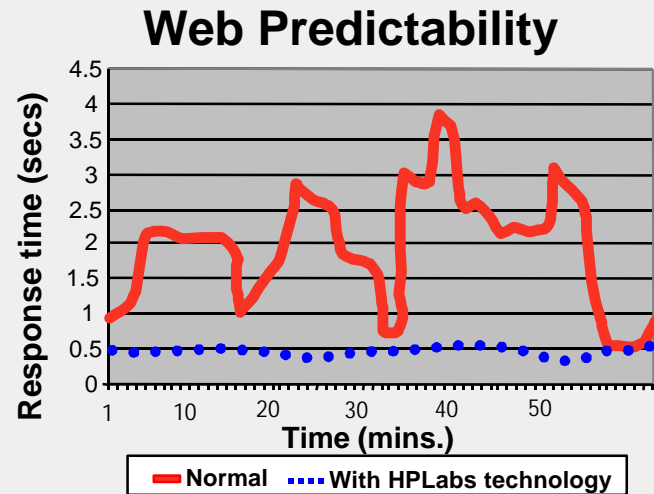
CPU Performance (SpecInt95)

Changing Workloads



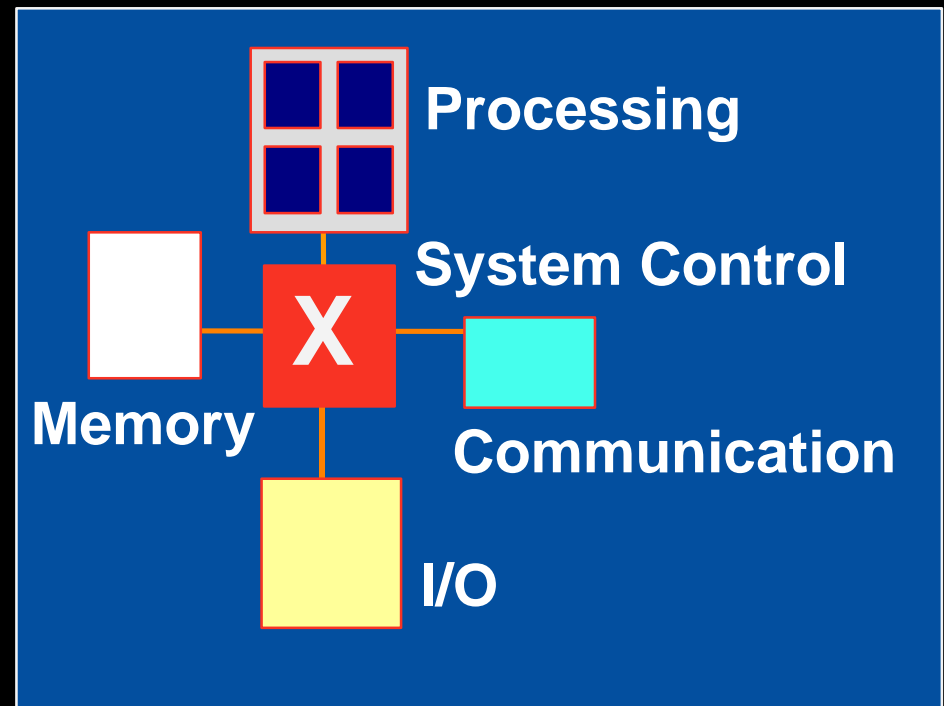
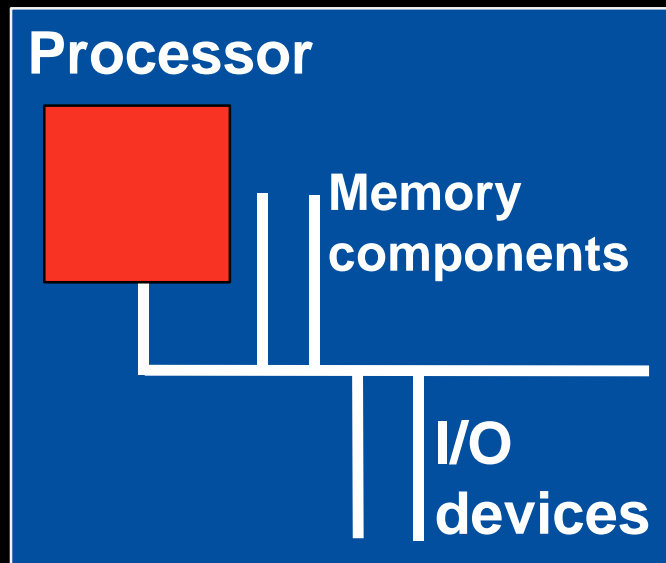
- *Increasing system loads*
- *Increasing system bandwidth requirements*

New Cost-Value Measures



- *Need mechanisms for predictability, security, reliability*

New Control Points



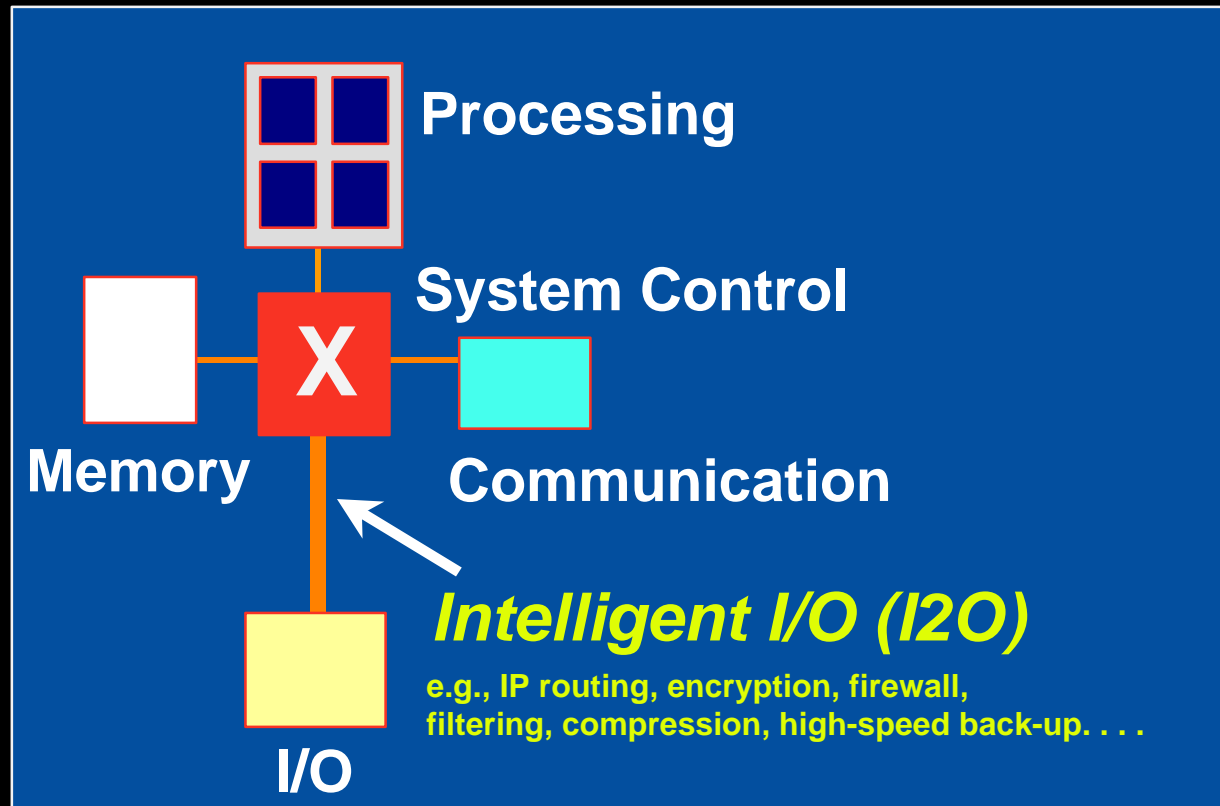
Processor-centric



Semi-autonomous
Subsystems

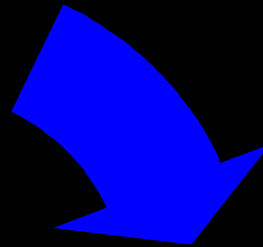
New Control Points

... in an open industry standard framework that permits system value adds



The New Challenges

Computing Components



- Semi-autonomous subsystems
- Integrated communication, memory, and computation

Computing Systems



- Distributed, heterogeneous systems of systems

Computing Services

(Information and Computation "Utilities")

The New Challenges

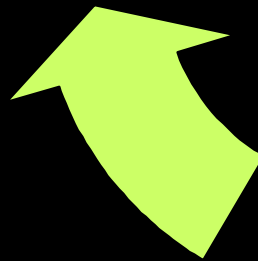
Computing Components

- Custom (embedded) processors
- New control points



Computing Systems

- Information appliances
- Utility servers



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HP Labs is focused on the new challenges of tomorrow