Examining ASCI Computing Models

by

Karl-Heinz A. Winkler

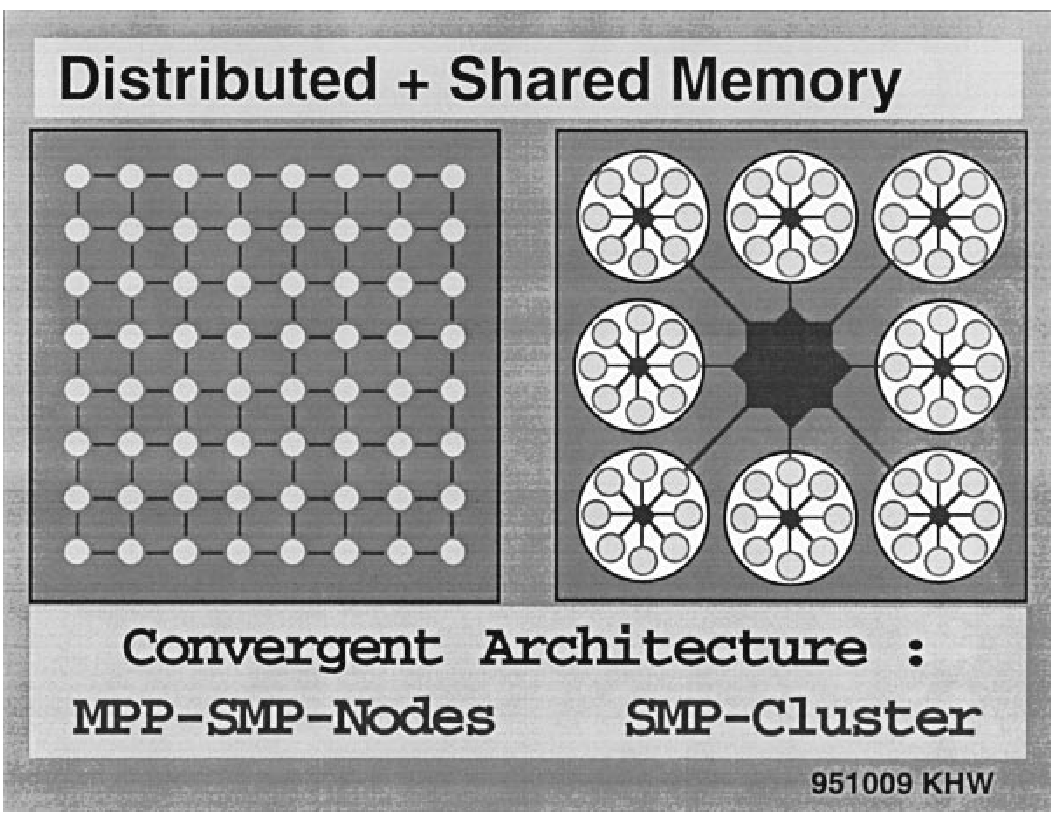
LANL

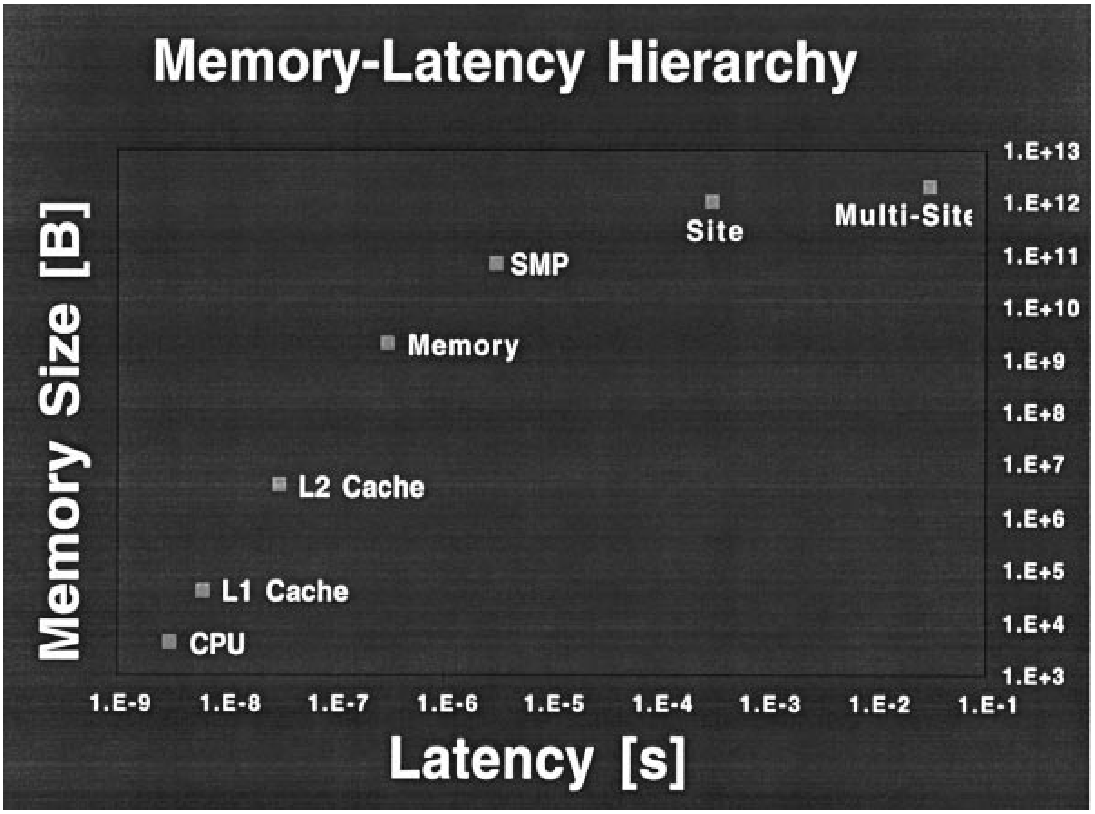
Present Situation

- Experienced Radical Changes
- No Nuclear Tests, compute-based approach
- Last Decade: Great Variety of Architectures
- Realigned CRI, Convex Phased out Intel
- RIP CCC, KSR, TMC, ...
- Mass market FLOP/s less demanding
- DOE ASCI 10x every 4 years
- Moore's law 4x every 3 years, last 25 years
- Application development on time critical path

Can we establish a period of stability of several (many) years for the ASCI programming models?

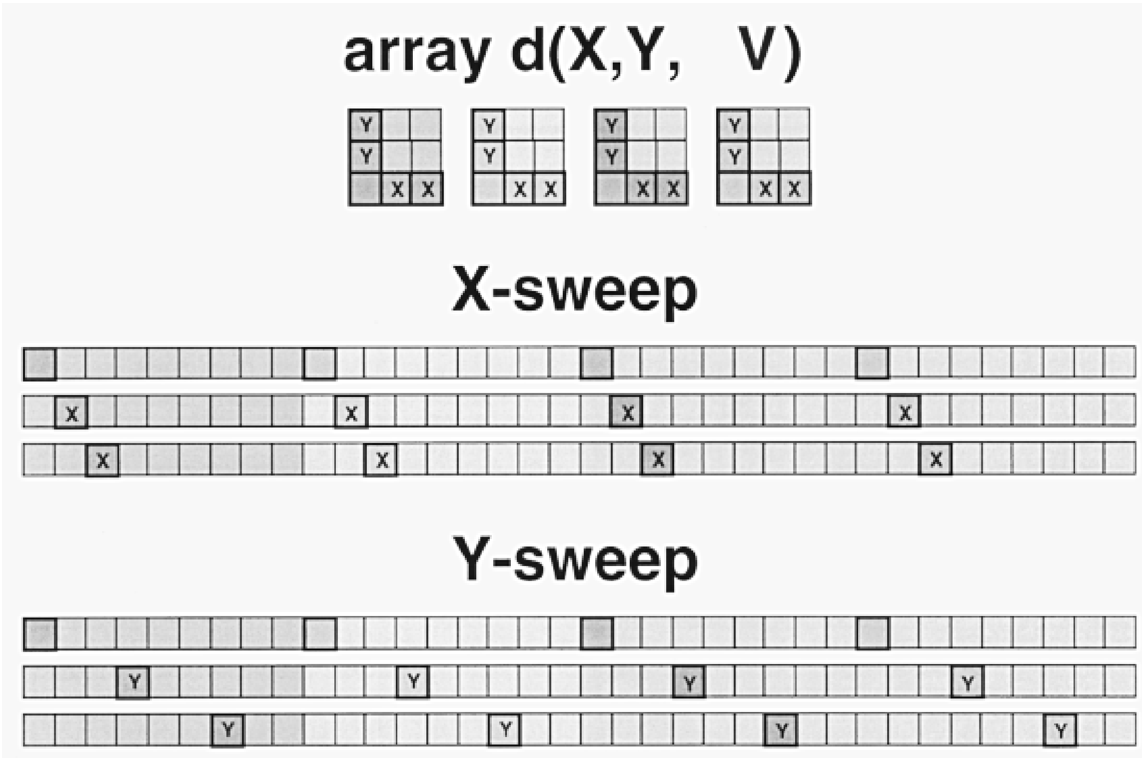
What will be the successful programming models for ASCI class computers?

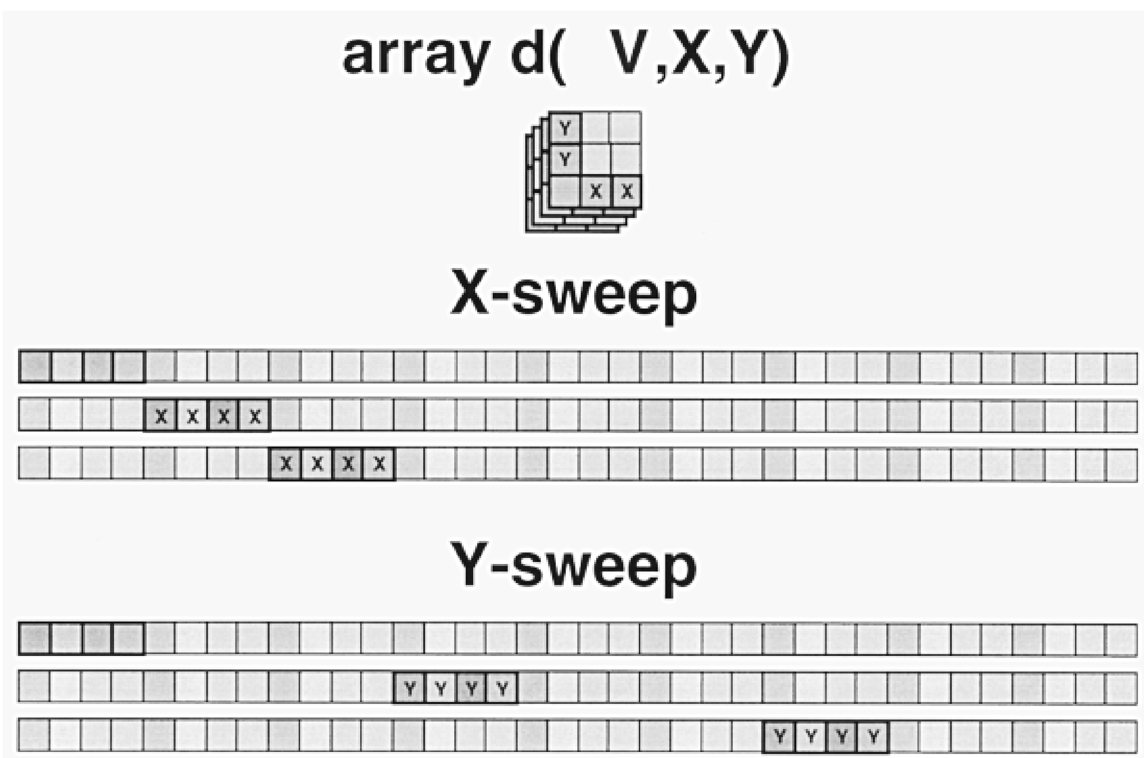


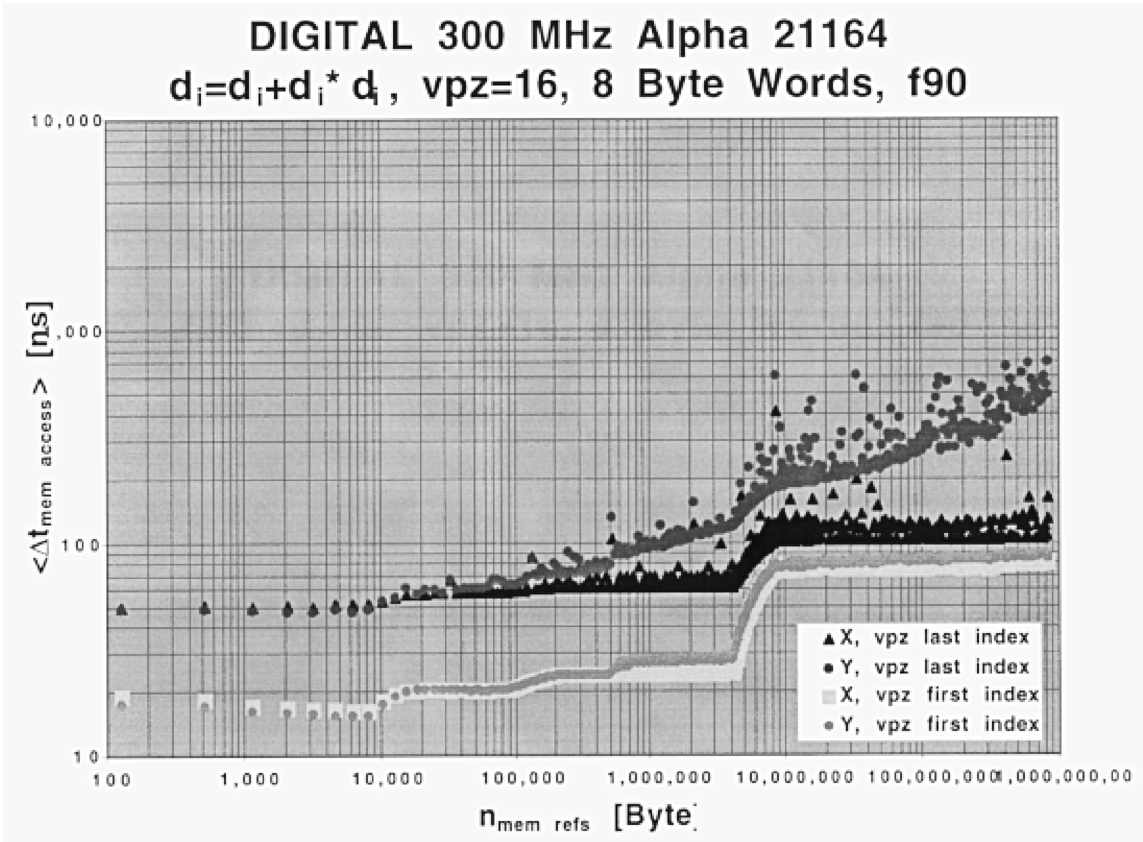


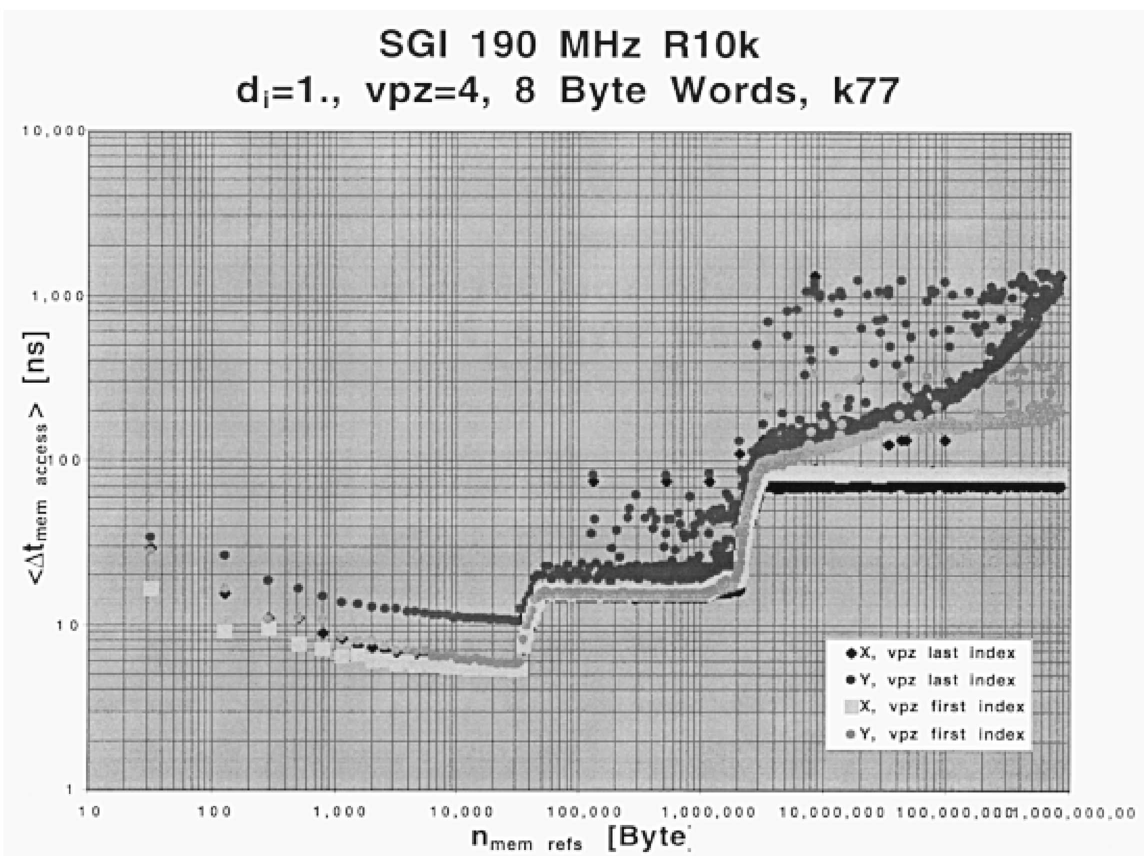
Hierarchical Distributed Shared Memory Programming Model

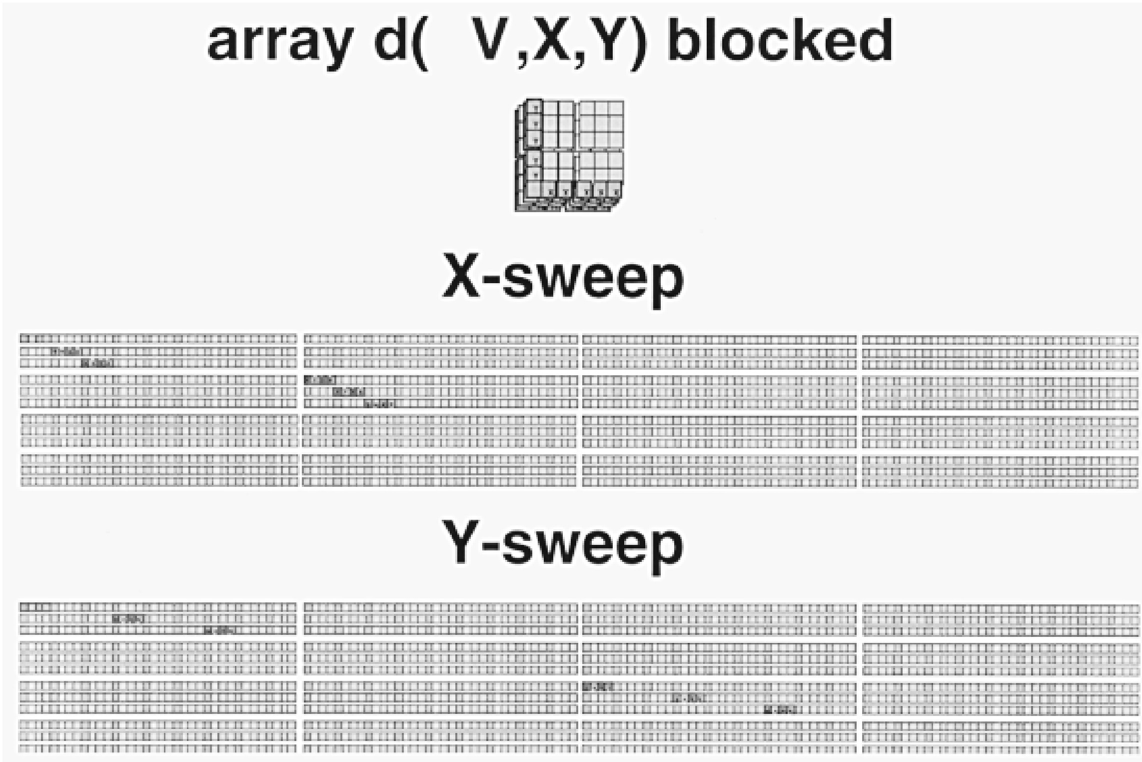
- **Hierarchical**
  - Take Advantage of Memory-Latency Hierarchy
  - Utilize Memory (Contiguous Data Layout), Cache of SMPs
  - Complete Algorithm Update on Small Subset of Zones
  - No Partial Algorithm Update on all Zones (traditional)
- **Distributed**
  - Explicit Message Passing between SMPs, MPI
  - Logical Shared Memory across Cluster, DSM
  - Exploit Surface to Volume Effect of SMP Boundary Zones
  - Overlap Computation and Communication
- **Shared Memory**
  - Multi-Tasking, POSIX Threads, Java
  - Make Single SMP behave like one Unit in Cluster Context

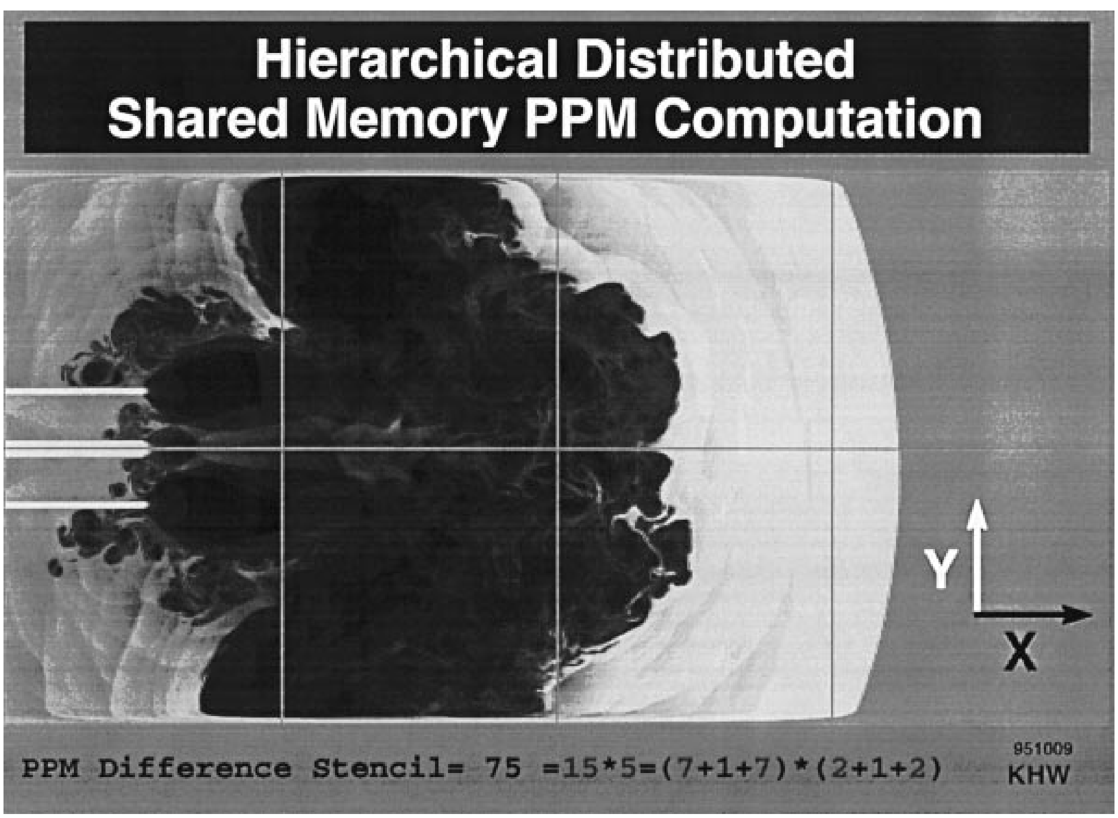

array d(X,Y, V)
X-sweep
Y-sweep

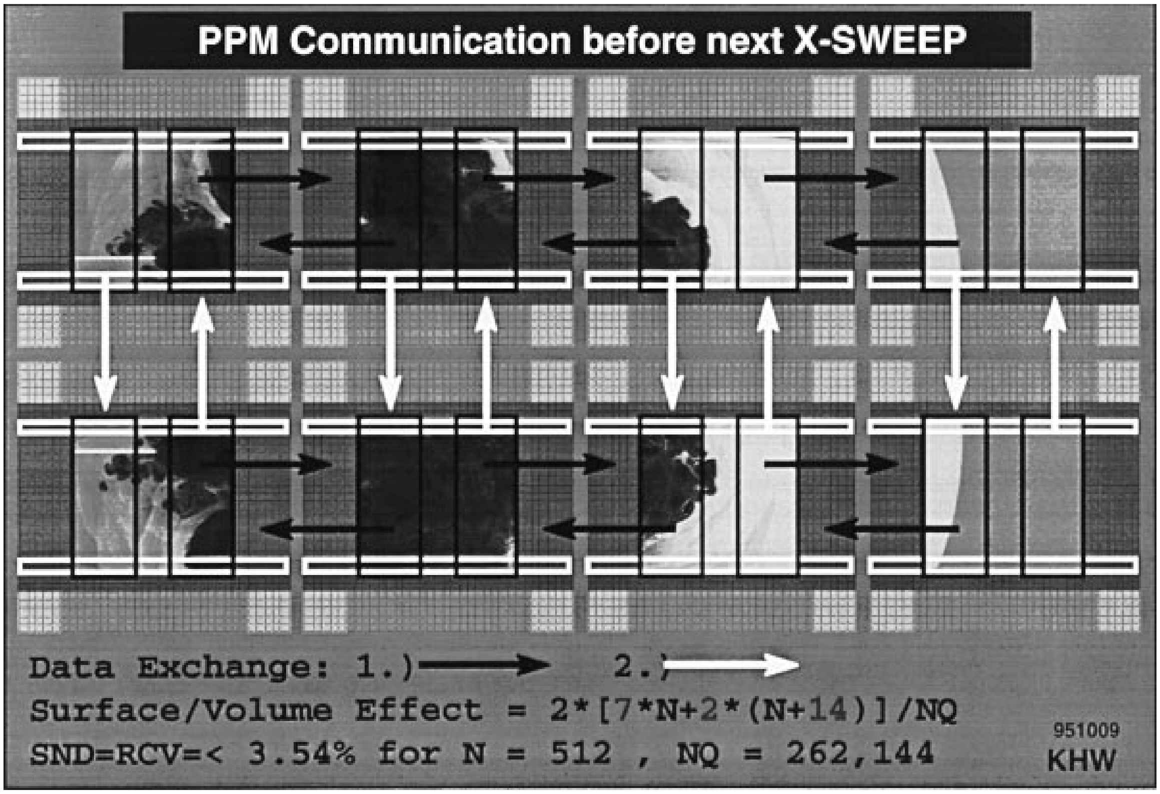

array d(V,X,Y)
X-sweep
Y-sweep

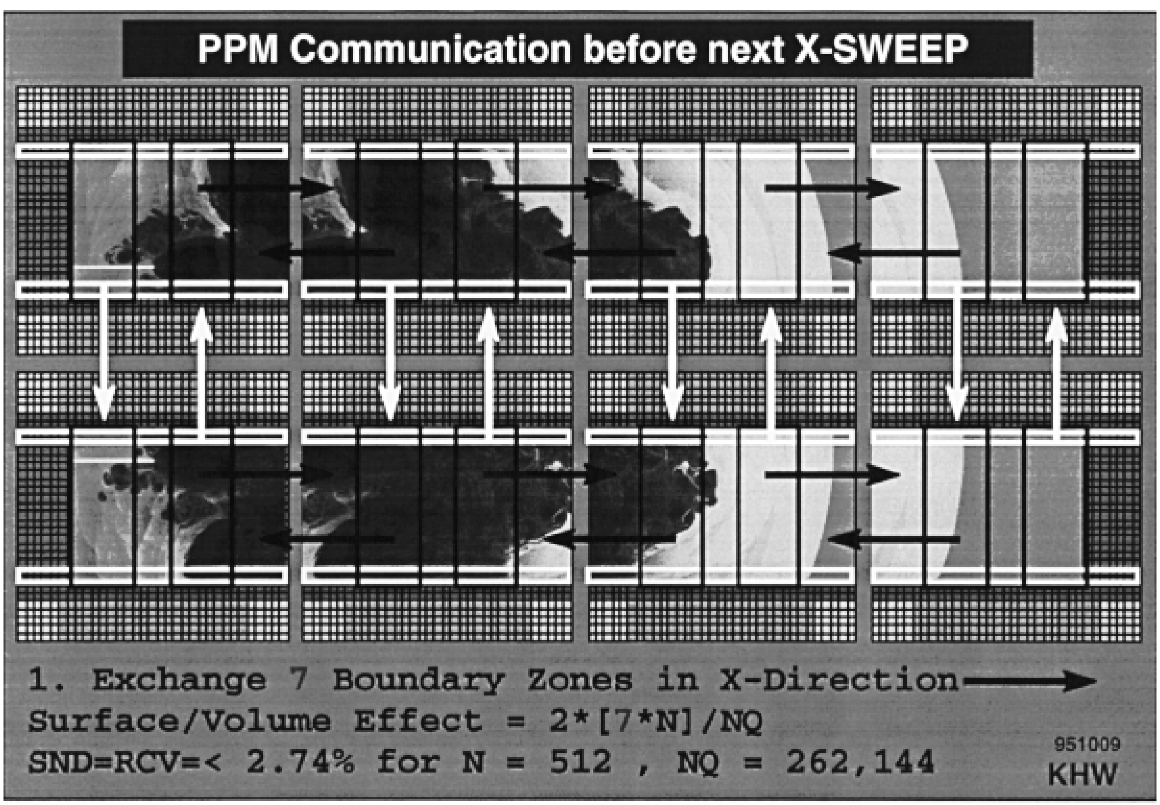

DIGITAL 300 MHz Alpha 21164
$d_i=d_i+d_i^* d_i$, vpz=16, 8 Byte Words, f90
10,000
100
10
<Δt_mem access> [ns]
100
1,000
10,000
100,000
1,000,000
10,000,000
100,000,000
$n_{mem\ refs}$ [Byte]
X, vpz last index
Y, vpz last index
X, vpz first index
Y, vpz first index

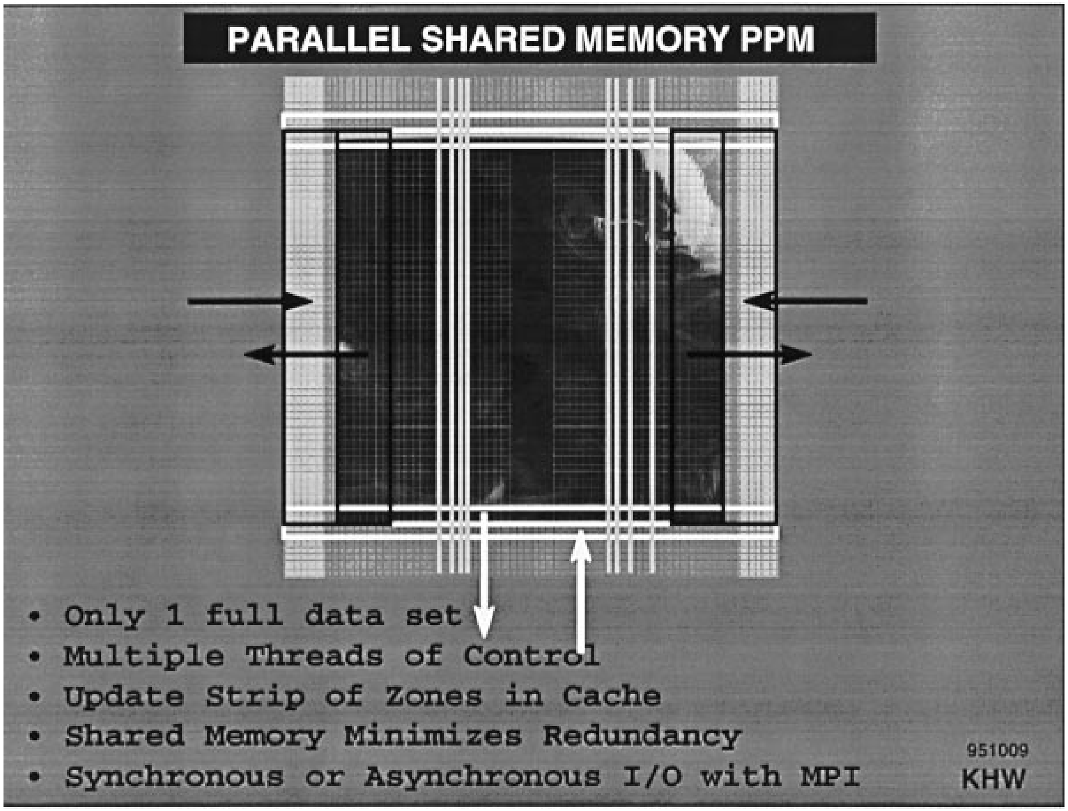

SGI 190 MHz R10k
d_i=1., vpz=4, 8 Byte Words, k77
10,000
1,000
100
10
1
<Δt_mem access> [ns]
10
100
1,000
10,000
100,000
1,000,000
10,000,000
100,000,000
$n_{mem\ refs}$ [Byte]
X, vpz last index
Y, vpz last index
X, vpz first index
Y, vpz first index


array d(V,X,Y) blocked
X-sweep
Y-sweep


Hierarchical Distributed
Shared Memory PPM Computation
Y
X
PPM Difference Stencil= 75 =15*5=(7+1+7)*(2+1+2)
951009
KHW

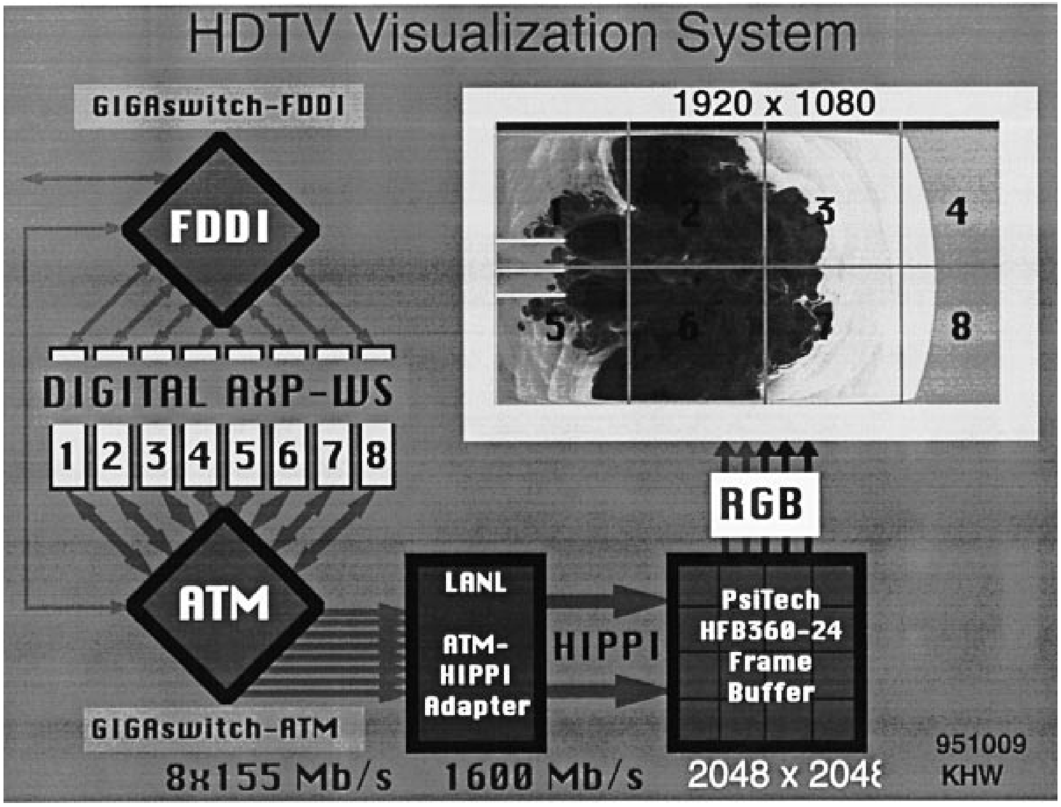

PPM Communication before next X-SWEEP
Data Exchange: 1.) 2.)
Surface/Volume Effect = 2*[7*N+2*(N+14)]/NQ
SND=RCV=< 3.54% for N = 512 , NQ = 262,144
951009
KHW

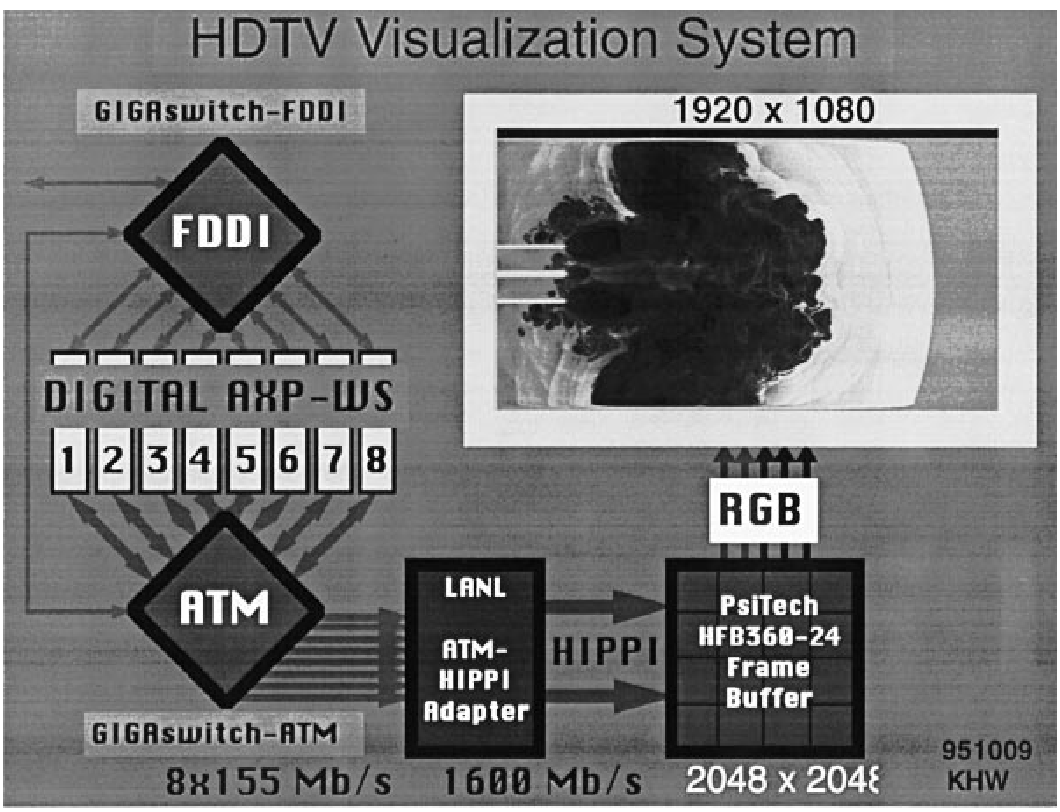

PPM Communication before next X-SWEEP
1. Exchange 7 Boundary Zones in X-Direction
Surface/Volume Effect = 2*[7*N]/NQ
SND=RCV=< 2.74% for N = 512 , NQ = 262,144
951009
KHW



Visualization Done The Same Way

- Up to 8 Distributed Workstations Sustain 1 Gigabit/s Communication Bandwidth and Display a Single High-Resolution Digital Movie at a Rate of up to 60 Frames per second.


HDTV Visualization System
GIGAswitch-FDDI
FDDI
DIGITAL AXP-WS
1 2 3 4 5 6 7 8
ATM
GIGAswitch-ATM
1920 x 1080
1 2 3 4
5 6 7 8
RGB
LANL
ATM-
HIPPI
Adapter
HIPPI
PsiTech
HFB360-24
Frame
Buffer
8x155 Mb/s
1600 Mb/s
2048 x 2048
951009
KHW


HDTV Visualization System
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FDDI
DIGITAL AXP-WS
1 2 3 4 5 6 7 8
ATM
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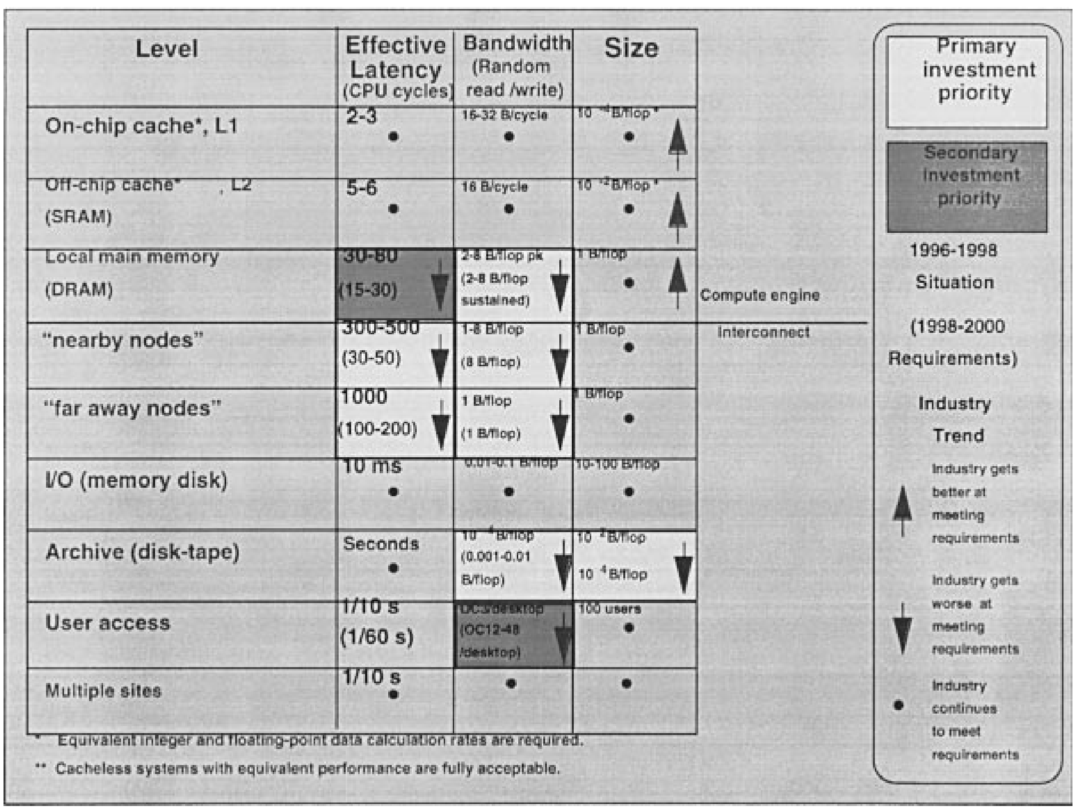
1920 x 1080
RGB
LANL
ATM-
HIPPI
Adapter
HIPPI
PsiTech
HFB360-24
Frame
Buffer
8x155 Mb/s
1600 Mb/s
2048 x 2048
951009
KHW

Does the federal government need to support the development and engineering of ASCI scaling and integrating technologies?

Yes!

If yes, how much money is needed?

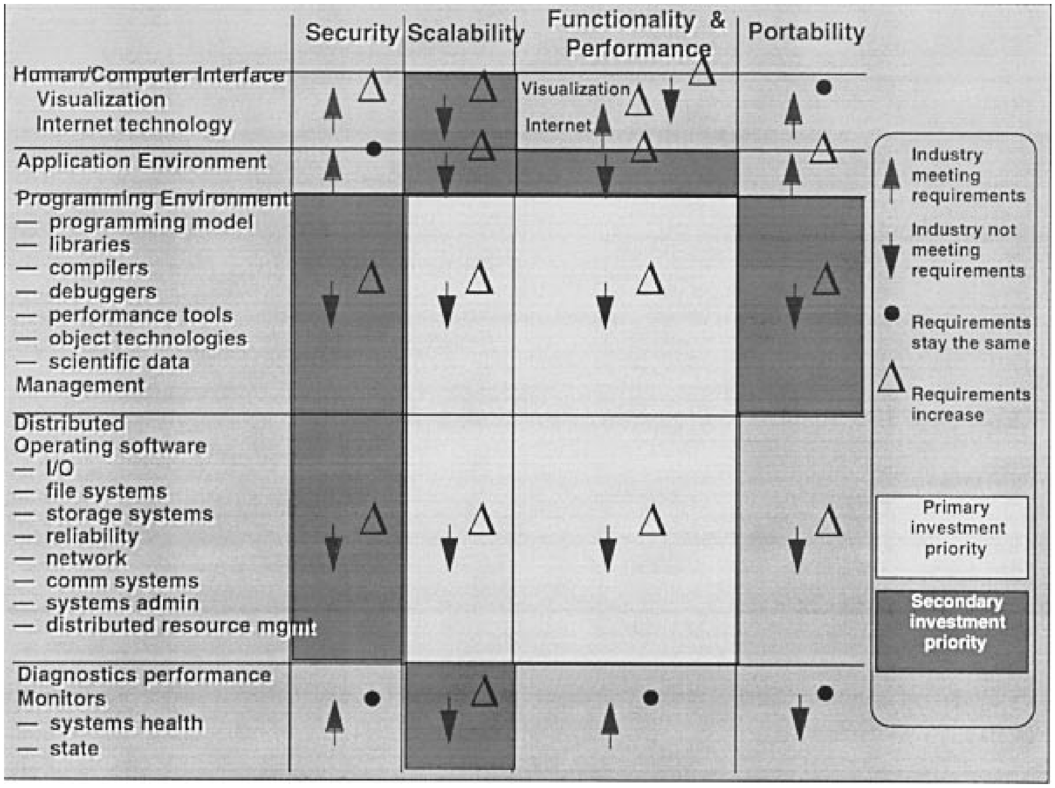
Depends!



Level	Effective Latency (CPU cycles)	Bandwidth (Random read /write)	Size
On-chip cache*, L1	2-3	16-32 B/cycle	10^{-4} B/flop*
Off-chip cache* , L2 (SRAM)	5-6	16 B/cycle	10^{-2} B/flop*
Local main memory (DRAM)	30-80 (15-30)	2-8 B/flop pk (2-8 B/flop sustained)	1 B/flop
"nearby nodes"	300-500 (30-50)	1-8 B/flop (8 B/flop)	1 B/flop
"far away nodes"	1000 (100-200)	1 B/flop (1 B/flop)	1 B/flop
I/O (memory disk)	10 ms	0.01-0.1 B/flop	10-100 B/flop
Archive (disk-tape)	Seconds	10^{-4} B/flop (0.001-0.01 B/flop)	10^{-2} B/flop 10^{-4} B/flop
User access	1/10 s (1/60 s)	OC3/desktop (OC12-48 /desktop)	100 users
Multiple sites	1/10 s		

* Equivalent integer and floating-point data calculation rates are required.

** Cacheless systems with equivalent performance are fully acceptable.



ASCI Coordinated Projects Collaboration

The purpose of this collaboration is to develop and engineer a system area interconnect which will meet the ASCI program's (and other high-end users) needs for computing. The interconnect will have to provide a low-latency and high-performance physical fabric which can be efficiently utilized to interconnect SMP-computers, visualization engines, secondary and tertiary storage devices, and external networks. It is expected that efficient use of the interconnect will require hardware support for global addressability and for cache management. It is not a requirement that the interconnect directly implement a global, cache-coherent, shared memory.

Interoperability:

In order to meet the ASCI program's need for complete, balanced systems it will be critical for the interconnect fabric to provide an open interface to a wide variety of devices and microprocessors. It is desirable that it be possible to directly connect the fabric to both the I/O channels and the memory bus interfaces of most common CMOS microprocessors, such as Intel's Merced, IBM's PowerPC, DEC's Alpha, SGI's Mips, SUN's Sparc, Tera's MTA. Furthermore the fabric should connect to disk and tape controllers, network gateways, and network attached peripherals.

Scalability:

The interconnect will need to support thousands of network interface ports. It must have the link capacity and routing logic to minimize contention and congestion due to a mix of large and small messages being inserted into the network from thousands of nodes at once. A modular design is a must which facilitates the tailoring of the network to traffic requirements and which allows scalable growth. Since the topology of the overall system will probably change over time it is important that the switch fabric support different topologies, such as interconnections of 8way, 16way, 32way switches. It is expected that a modular design will also facilitate the physical distribution of switch resources and the economical production of components.

Performance:

Individual network links should approximate in performance the memory bandwidths of microprocessors of the 1999 - 2001 time frame.

This implies a top performance of between 2 - 10 GBytes/s per link over distances of up to 100 yards. Desired latency through the switch should be of order 100s of nanoseconds, certainly less than 1 microsecond.

Low-level Protocol:

A standardized virtual memory interface, supporting both global push and pull, has to be developed and implemented on the various microprocessor platforms. Virtual memory interface libraries and Hippi6400's scheduled transfer protocol may give an indication of the areas of work where consensus between the collaboration members is needed. It will be critical to support routing, packetization, virtual circuits, health monitoring, performance monitoring, and debugging with a judicious balance of network protocol support (hardware and firmware) and system software support (drivers, OSs, and libraries).

Software:

An efficient system area network requires close collaboration between network resources and system software. It is expected that development will be required in at least the following areas: switch operation, low-level drivers, data movement libraries, distributed resource management, performance monitoring, and debugging.

In the area of switch operation the system software will have to be able to create routes (e.g. by discovering/employing routing tables or by interacting with network self-routing mechanisms), recognize and adjust for failing components and/or replacement components, and perhaps prioritize traffic.

The system software must as always form the bridge between hardware and users. For a system area network this means both providing low-level drivers within all target processor-nodes and peripheral devices and providing standard libraries for message passing and data movement.

The system envisioned will have thousands of network ports and a multiplicity of device types. It will be essential that system software support resource management in a distributed, robust manner. Resource management should include the ability to monitor the health of portions of the network, measure and report the performance of operations throughout the network, and provide debugging information to system designers, system administrators, and application designers/developers.

What are the roles of proprietary and non-proprietary technologies?

Commercial Mass Market: proprietary

Commercial Mass Market x 1000: non-proprietary community effort for development and engineering of base technologies

Licensing:

Development of this fabric most likely necessitates the development of ASICs (Application-Specific Integrated Circuits) for the switch itself, for the symmetric optical interconnect links, and for the adaptation to the specifics of the various memory bus architectures. These base technologies, developed on behalf of and paid for by ASCI, will be licensed or sold as chips to anybody without restrictions in intended use. In this way a larger market for the ASIC chips is created from the start which also supports a competitive business model for derivative products such as the switch itself or memory and I/O interfaces.

ASCI Operating systems of choice: UNIX, Windows NT, others?

- **UNIX:** for now.
- **Windows NT:** many issues like security, performance, scalability, 32 bit, MS-DOS remnants, entirely mass market focused.
- **Java:** virtual machine, threads, interoperable, garbage collection.

What are the business models for a self-sustaining high-end computing industry supporting ASCI capability computing systems?

How would this high-end industry relate to the extremely successful mass market computer industry?

Should ASCI forge relationships with vertically or horizontally integrated virtual companies?

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Applications of High Speed Computing in Manufacturing: Godzilla Meets King Kong

Eugene S. Meieran
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Build a Better Mousetrap and...!

Traditional Belief

- The world will beat a path to your door!

Reality

- We will populate the world with smarter and more aggressive mice
- We will have more mouse trap competitors
- The mice will become resistant to mouse-catching procedures

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The Manufacturer's Dilemma: A New Environment

• More expensive products	• With shorter life cycles
• More complex processes	• With less tolerance for defects
• More customization	• But at no higher cost
• A global economy	• With more cultural barriers
• More stuff to dispose of	• With more responsibility for it
• More information management	• Generating information overload
• More customers	• More competitors
• More talented workforce	• Less stable workforce
• More automation	• Leading to lots of unskilled workers
• More difficult manufacturing	• But at a lower cost
• More new technology	• Haven't mastered the old yet!

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The Manufacturing Environment: Unstoppable Forces

- Ever more complex products and processes
- More physical automation and information automation
- Continuously improving product, process quality
- Globalization of facilities, suppliers, customers
- Increasingly sophisticated competition
- Increasing environmental concerns and regulations
- Better and more expensive facilities
- Faster development time and time-to-market
- Increasing amount of data and information generation
- More electronic commerce; Inter-and Intranet

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Common Issue

All these forces strongly depend on applying more and more sophisticated software and hardware computational and communication tools to improve manufacturing performance.

Godzilla emerges from the depths.

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The Manufacturing Environment: Immovable Objects

- Reluctance to monkey with "family jewels" (source of $)
- Huge obsolete software, hardware, equipment baggage
- "Tower of Babel" heterogeneity of SW, HW platforms
- Fear of further productivity increases (loss of jobs)
- Smart but ignorant work force; fear of new skill needs
- Antiquated management styles; rigid organizational boundaries
- Poor ROI metrics
- Operational inertia
- Hard to choose between too many good alternatives
- Too many bad results; negative press and skepticism

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Common Issue

All these generate strong resistance to the introduction of new technology into the manufacturing arena.

King Kong emerges from the forest

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When Godzilla Meets King Kong

- Long, tedious decision-making process; decision paralysis
- Pocket vetoes and stalemates
- Frustration; loss of motivation, indeed sabotage
- Poorly justified decisions to NOT EVER AGAIN engage in new technology ventures!
- Loss of competitive advantage

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Moral

Creating and introducing more advanced technology does NOT fix the manufacturer's dilemma; plenty already exists.

Indeed, advocating introduction of more new technology may be part of the problem!

The problem is to bring new technology into manufacturing facilities when this is regarded as an avoidable and unnecessary threat.

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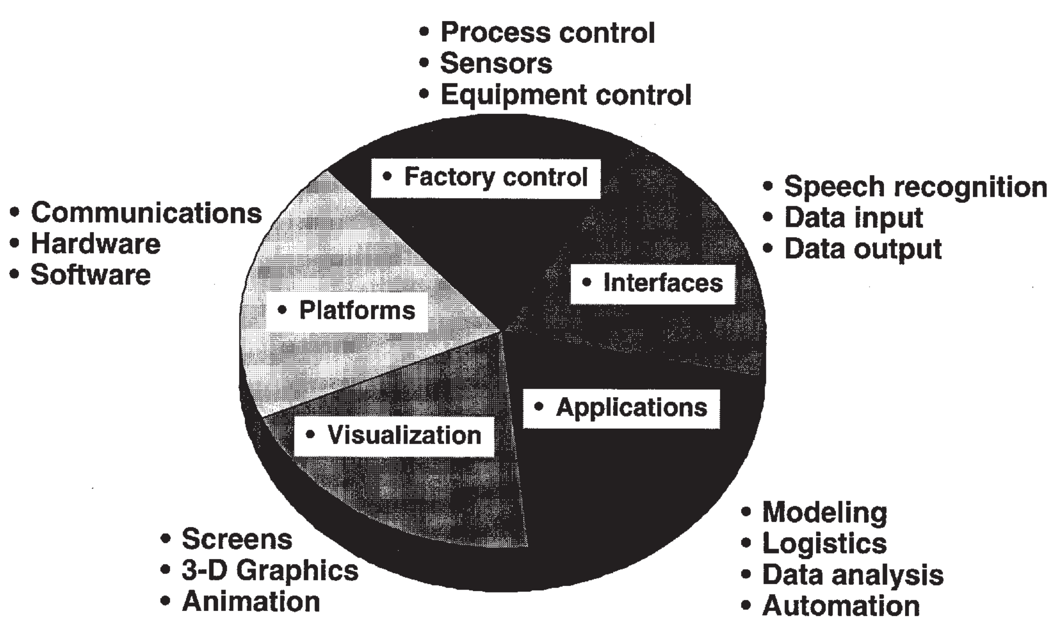
Applications for high speed computing



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High Speed Computing Needs

- Operational modeling and simulation
- Factory, equipment and process control
- Data analyses and decision-assist systems
- Enterprise integration
- User interface improvements

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Operational Modeling and Simulation

- NEEDS:
  – Cheaper decisions (experiments are costly)
  – Faster decisions (experiments are time consuming)
  – Better decisions (wrong decisions are EXPENSIVE!)
- ISSUES:
  – Experts do not have time to create good models
  – Computer whizzes don't understand manufacturing
  – Manufacturing is NOT analytical; cannot simply apply equations
  – Integration of models at different hierarchical levels are very difficult
  – Model validation and testing
  – Discrete event simulation can ALWAYS be faster!

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Factory, Process and Equipment Control

- NEEDS:
  - Need to deliver higher quality products
  - Inter-relationship of very complex, widely separated process steps
  - Faster detection of trends to prevent problems
  - Improved factory environments (waste, resource usage)

- ISSUES:
  - Equipment manufacturers are often small businesses without sufficient expertise to handle topic
  - APC seems antithetical to SPC; "chasing one's tail"
  - Stability of systems

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Decision-Assist Systems

- NEEDS:
  - Faster decisions
    - Avoid reinvention of the wheel
    - Based on past knowledge and experience
  - Better decisions
    - Traceable to source
    - Easy to use
  - Remembered decisions
    - Based on historical record
    - Easy to find and apply
- ISSUES:
  - This is the Holy Grail, so far unsuccessfully pursued
  - These need to be integrated into the factory flow
  - There are too few applicable metrics

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Enterprise Integration

- NEEDS:
  - Faster product and process development
    - 24 hour collaborative development
    - 100% electronic information transfer
  - Faster time to customer
    - Customized products delivered anywhere
    - Electronic data-to-product
  - Better utilization of enterprise resources
    - Minimal number of qualified vendors
    - Dynamic network of suppliers, manufacturers and customers
  - Lower overall cost
    - Customized products at mass produced prices
    - Virtual factories, companies, enterprises,
- ISSUES:
  - Multi-nation, multi-culture, multi-language
  - Long term stability
  - Change control

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User Interface Development

- NEEDS:
  - Fewer errors on the factory floor
  - Lower resistance to using computer tools
  - Ability to handle more data and information
  - Ability to do wireless communication
  - Ability to integrate different applications
  - Space saving
- ISSUES:
  - Too few computer techies KNOW what the factory really looks like or needs
  - Ability to handle non-keyboard, perhaps non-verbal inputs

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Common Needs

• Better hardware platforms	Faster computing Big, reliable servers Parallel processing
• Improved software platforms	Robust code Fast problem resolution Parallel processing
• Expanding application suites	Integration
• Improved user interfaces	Easier, more varied
• Better visualization	Larger, flatter screens Higher resolution screens Personalized screens
• Communications	High speed, high bandwidth Global and wireless Secure

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What Must the Computer Technocrat Do?

- Understand the customer from the CUSTOMER'S perspective!
- Identify and work with key stakeholders
- Benchmark within and outside the industry
- Generate mutually agreeable expectations
- Start small; build incrementally
- Continuously validate benefits and issues
- Remember that most of the costs will be in maintaining the system for a LONG time after the implementation!

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What Must the Computer Technocrat *Not* Do?

- Assume that the best technology automatically SHOULD be adopted (even if you're right!)
- Assume that "proven" significant benefits WILL outweigh even moderate risks in the eyes of the stakeholders
- Assume that the main issue is technology introduction
- Assume the main issue is technology in the first place

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The Bottom Line

- **The issue is NOT technology:**
  Sufficient technology exists to do almost everything a manufacturer wants for the next decade
- **The issue is wisdom;**
  Understand and be responsive to the wishes, desires, fears and needs of the manufacturing customer (who could care less about technology).
- **Prognosis:**
  High speed computing WILL benefit manufacturing IF the technologists (Godzilla) assumes the appearance of the manufacturing executive (King Kong) and thinks, acts and is motivated accordingly
- **Otherwise..... stalemate!**

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