The Engines that Drive Collaboration

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Abstract

The emergence of virtual reality technology has introduced an exciting new approach to scientific research and development. Virtual reality environments such as the CAVE (Cave Automatic Virtual Environment) are allowing researchers to conduct three-dimensional simulations---to go "inside" experimental data and interact with results computed on high-performance supercomputers. Current applications include drug design, simulation of the casting process for car and aircr˝aft parts, and modeling of combustion within commercial boilers. In the future, collaborative virtual laboratories may enable distributed scientific research groups to share unique large-scale experimental facilities such as accelerators, electron microscopes, and light sources. Using emerging high-speed networks like those being developed as part of the I-WAY (International Wide Area Network) proje˝ct, researchers in different locations will be able to collaborate naturally and effectively over rich virtual environments tha˝t support audio, video, and gesture capabilities. Through telescience technology, researchers also may remotely control operations in deep-sea exploratory submarines, space sh˝uttles, and nuclear reactors. Virtual environments present significant technological challenges, but t˝he rewards are clear: new insight; faster understanding of complex, multidimensional phenomena; and increased scientific productivity. Noteworthy examples are the I-WAY project, which focuses on mechanisms t˝o link supercomputers and advanced visualization environments via asynchronous transfer mode; and the LabSpace project, exploring electronic virtual laboratories to support remote operation an˝d control of scientific experiments.

(The author did not provide a formal written version of his paper but instead made available the transparencies from his talk.)

The Engines that Drive Collaboration

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What is the talk about..

- Long term vision for collaborative environments
- Computing and networking technology
- Research projects and directions
- Connections to the I-WAY project
- Open problems and Invitations for collaboration

Roadmap for Research Programs to Support the Global Information Infrastructure

Collaborative Modeling

today's Grand Challenges

Algorithms

- physical models
- matrix methods
- spectral methods
- reactive flows
- molecular models
- electronic structure
- structural mechanics
- n-body methods
- optimization

Architectures

- workstations
- clusters
- single MPP
- vector computers
- simple distributed sys
- largely single domain
- strong on Flops
- weak on I/O
- small data systems

Tools

- compilers
- debuggers
- auto parallel pre-X
- event tracing
- visualization
- algorithm prototyping
- libraries (MPI, p4)
- "tool kits"
- templates

Networks

- ethernet (LANs)
- FDDI (LANs)
- HIPPI (sub-LANS)
- FCS (not yet)
- ATM (not yet)
- fiber infrastructure
- long haul T1/T3
- experimental OC-48
- workstation peers

Languages

- Fortran 77
- C
- C++
- HPF (not yet)
- Fortran 90 (not yet)
- Fortran M (not yet)
- PCN
- Linda
- extensions vs new

Applications

- extensions of vector codes
- physical models
- few non-science
- few engineering
- mostly modeling not design
- little linkage to exp
- batch still prime mode

Collaborative Analysis and Design

distributed shared resources

Algorithms

- caching, browsing
- MDA, MDO
- statistics
- comparative analysis
- interactions
- CAD linkage to models
- database linkage
- compression
- automatic filters
- neural networks

Architectures

- workstation aggregates
- MPP aggregates
- heterogeneous nodes
- cooperative systems
- mobile nodes
- database linkages
- multimedia support
- archival storage
- data systems
- I/O intensive

Tools

- multi-user AVS
- multi-user MMA
- hetero MATLAB
- linkage CAD/MMA
- linkage CAD/MPP
- linkage CAD/DB
- linkage CAD/MDA
- multisite above
- penbased interfaces

Networks

- gigabits to the desk
- national filesystem
- ATM combo
- nonmetered
- bandwidth on demand
- high peak / low mean
- aggregate for blasting
- standard HW/SW
- blasting protocol

Languages

- integrated analysis and CAD languages
- MDO extensions
- hetero parallel
- fast MATLAB
- AVS like extensions
- OBJECT support
- implicit I/O support
- DB integration
- analysis objects

Applications

- manufacturing of complex systems
- analysis of 3ary science problems
- rigorous analysis of computational exp
- simulation intensive engineering

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Virtual Reality and Multimedia

multiviewer interactive
distributed deployment

Algorithms

- projective geometry
- rendering
- kinematics
- linkage to physics
- new paradigms for visualization of data
- interactions
- compression
- indexing
- data movement

Architectures

- CAVE^n
- CAVE++
- HD-CAVE
- HD-Goggles
- body suit I/O
- retinal imagers
- 3-D projection
- holographic display
- holographic input
- mobile links

Tools

- 3-D AVS
- 3-D highend MMA
- multisite CAVE env
- 3-D tcl scripting
- CAVE/ MOSAIC
- Goggleland
- connections
- linkages
- pad based kibitzing
- scalability

Networks

- CAVE-to-CAVE
- low latency sync lines
- scaling up/down
- 10's Gb each site
- fanin/fanout problem
- GB to each user
- mobile head to head
- LAN-MAN-WAN

Languages

- 3-D and VR extension
- VR objects
- parallel objects
- parallel interacting agents
- coupling to world DBs
- visual programming
- visual tuning
- pen based sketches
- 3-D story boards/lang

Applications

- medical imaging
- remote exploration
- database mining
- education
- telecollaborations
- 3-D data immersion
- micro manufacturing
- entertainment
- travel reduction

Telepresence

remote manipulation
and monitoring
remote "participation"

Algorithms

- autonomous systems
- solids models
- planning, interactions
- navigation
- multimedia fusion
- sensor fusion
- human/computer int
- compression
- geometry reasoning
- vision and mages

Architectures

- gigabits network
- hetero drivers
- MPP
- workstation
- realtime links
- multi-sensor
- robotic support
- manipulators
- nanobots
- mobile support

Tools

- protocols
- sockets for multisense
- SVP simple video pro
- roboKIT interfaces
- stationary video interf
- voice/vid/window
- manipulator KIT
- multiview protocol
- DB interfaces
- agent interfaces

Networks

- gigabits/human-rin
- short range radio
- transparent LB/radio
- digital video
- low latency ATM
- radio ATM interfaces
- multimedia mix
- multisense mix
- network compressior

Languages

- scripting for RINs
- manipulationscripts
- programming by example
- multisense objects
- multisense extensions
- linkage to multisense
- databases
- autologing of events
- autolog I/O library

Applications

- monitoring r activities
- r manufacturing
- r assembly
- r exploration
- r experiment manip
- r inspections
- semi auto develop
- r piloting
- toys

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Workthink Trends

- Virtualization of organizations
- Merging of work/life/play/home/school
- Work as conversation/communication
- Dominance of new/multidisciplinary problems
- Dominance of consumer products/tech drivers
- Self-assembly (business, research, education, recreation)

What is the right infrastructure to support future work?

How would life be different if travel was free and instantaneous ?

Hmmm ?

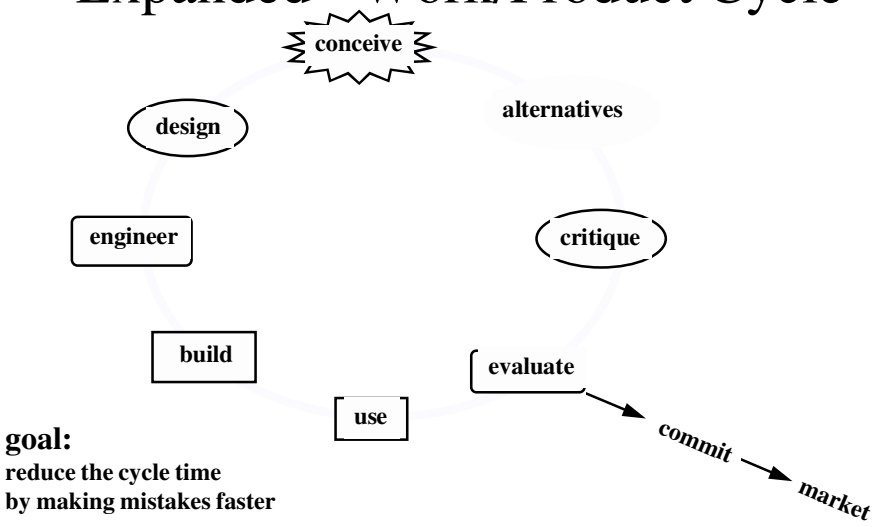
- You would live **where you want to.**
- You and your colleagues would meet in **interesting places**.
- You would **leave your things** where you need or use them.
- You would need to **"arrange"** to meet people in certain places at certain times.
- You would need mechanisms to **"locate"** people and things.
- **Security** would be problematic. (see Tales of Known Space)
- You would develop **habitual hangout places**, most likely to find friends and family.
- You would adjust. (with apologies to **John Gorka**)

The Need for Persistent Electronic Spaces

Adding the concept of **Persistent Electronic Spaces** to the current suite of computer supported collaborative work tools can provide the virtual equivalent of instant and (almost) free travel.

- Persistence is needed to build electronic communities
- Persistence is needed to map the real world to virtual environments
- Persistence is needed to lead us away from the phone call model for collaborations towards the "**Cafe**" model
- Persistence is needed to improve navigation and discovery processes for the GII

Expanded - Work/Product Cycle



goal:
reduce the cycle time
by making mistakes faster

Virtual Organizations:

instant teams
spontaneous workgroups

- Have no particular physical location
- Can have mission oriented lifetimes
- Can have non-hiearchical structure
- Require awareness and loyalty of members
- Require a variety of communications support
- Require sharable resources (data, machines, etc.)
- Require mechanisms for organizational navigation and discovery
- Require resource allocation mechanisms
- Require ability to determine membership status

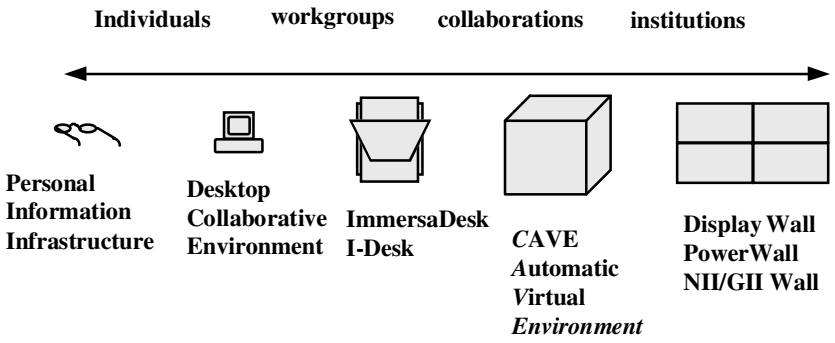
What do we Mean when we say Virtual Environments?

- 3D real time Graphics
- Point of view rendering
- Wide field of view (immersive)
- High resolution
- Audio and other sense modalities (touch, temp, smell, etc.)
- Responsive model interactions (low lag)
- Collaborative (i.e. ability to interact with other people & VR at the same time)

Collaborative Environment Scale Metaphors

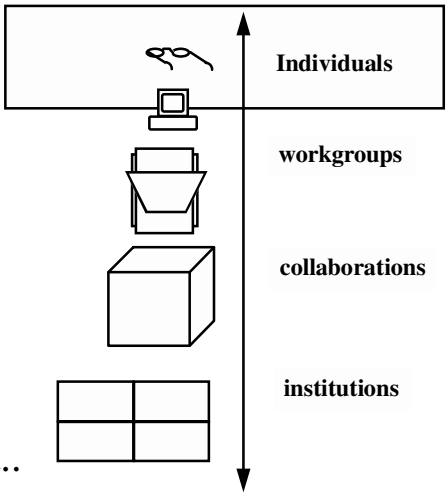
Personal	**Desktop**	**Desk**	**Room**	**Theater**
wrist watch	tv	drafting table	library	movie house
earrings	stereo	sewing mach	dark room	church
pocket books	cd-rom	piano	kitchen	store
pens	sketch pad	table saw	wood shop	mall
eyeglasses	PC	cook top	art studio	sports arena
clothing	keyboard	sink	garage	concert hall
cell phone	mouse			
headsets	telephone			
PDA	**MediaStation**	**ImmersaDesk**	**CAVE**	**DisplayWall**

Continuum of Collaborative Environment Display Technologies



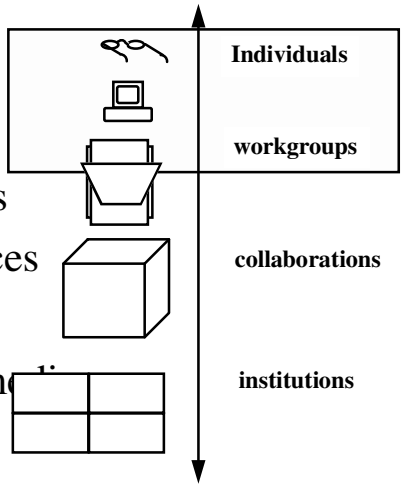
Personal

- Lightweight
- Wireless
- Wearable
- Always available
- Audio dominate
- Keyboardless
- $80-$800 price point..



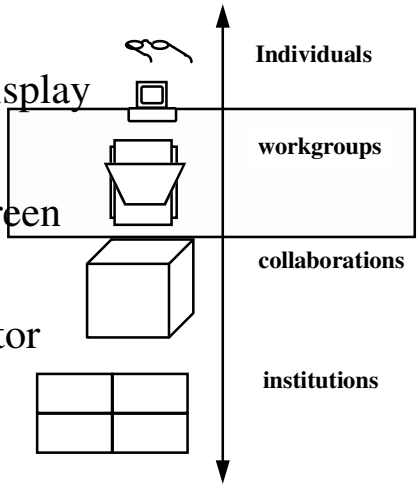
Desktop

- Interactive video
- Multichannel audio
- Text, 2 and 3D graphics
- Flexible drawing surfaces
- Keyboards/mouse
- Ambient and focused m
- Multiscreen
- $8K price point



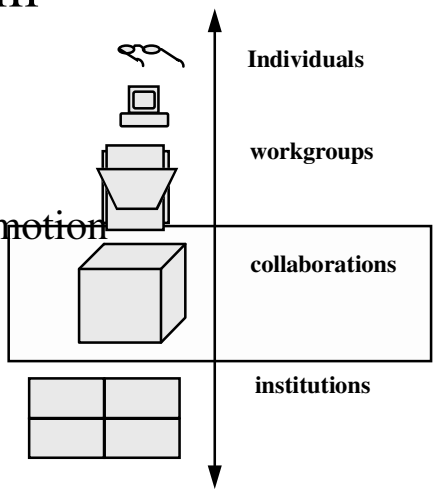
Desk

- 3D immersion/stereo display
- User tracking
- One high-resolution screen
- Seated or standing
- Drafting table form factor
- Stereo Audio
- 1-3 people
- $80K price point



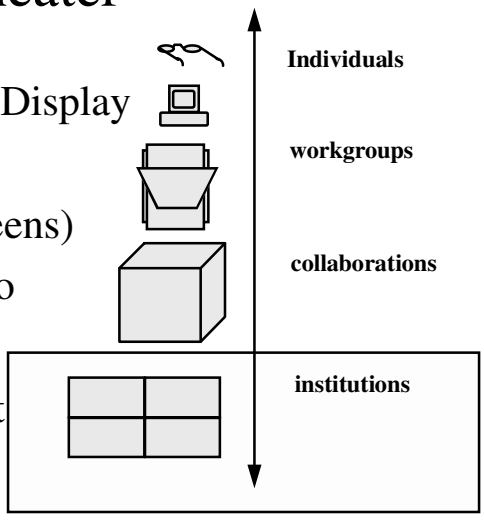
Room

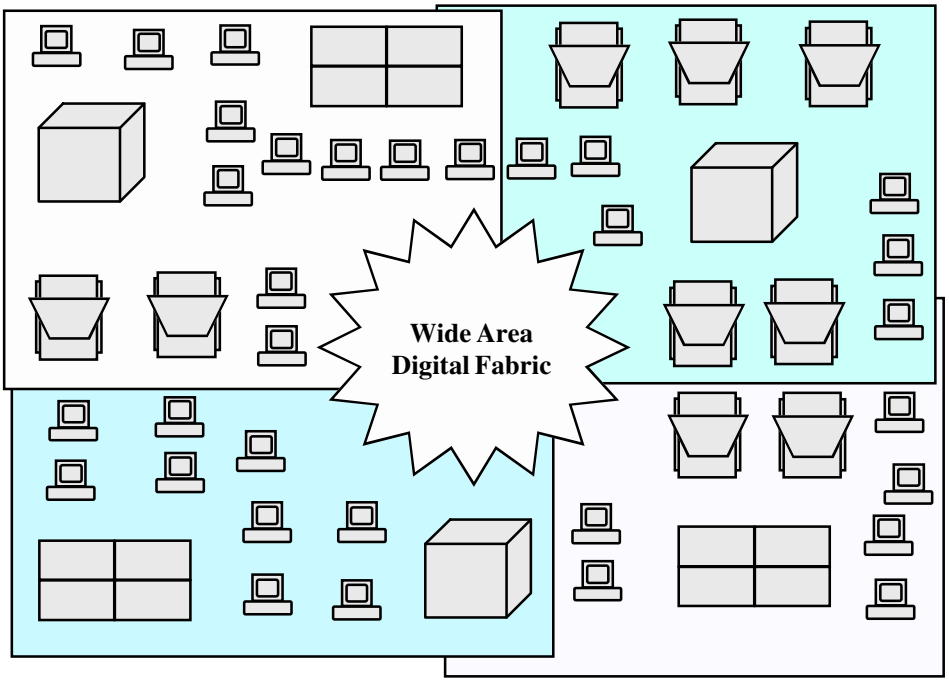
- 3D immersion
- 1 user tracking
- Standing with limited motion
- 4 high-resolution walls
- 1-8 people
- Quadraphonic Audio
- $800K price point



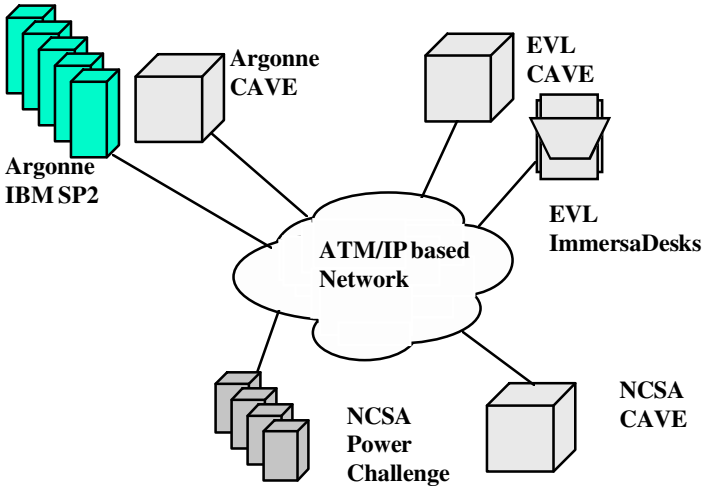
Theater

- Limited 3D Stereo Display
- Large format
- (NxM high-res screens)
- Multichannel Audio
- 10-100's people
- $800K+ price point



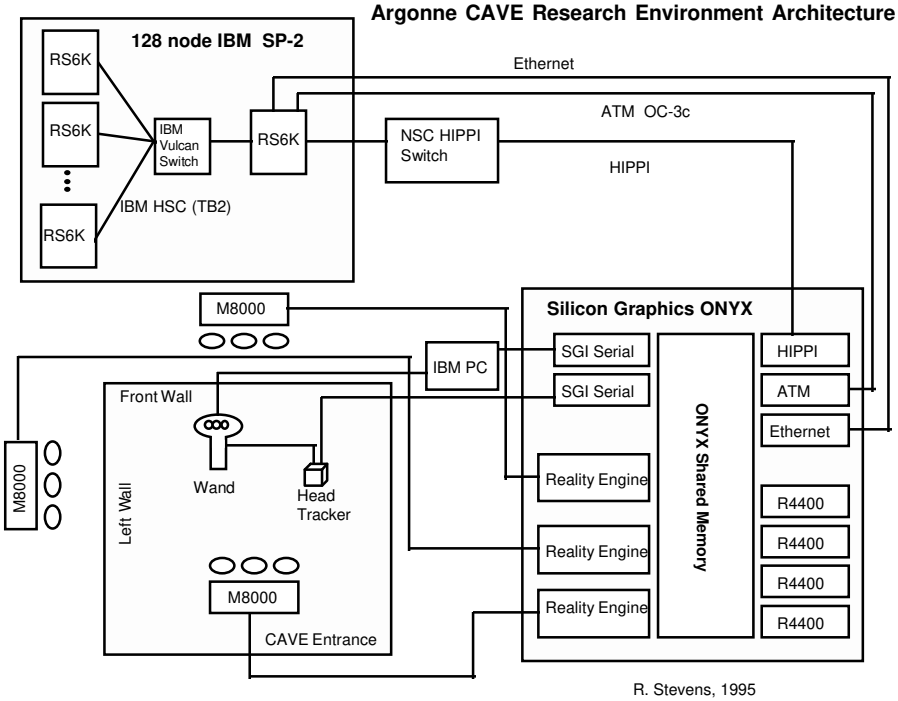


I-WAY Testbed Alpha'



Integrating Virtual Environments and Massively Parallel Computing

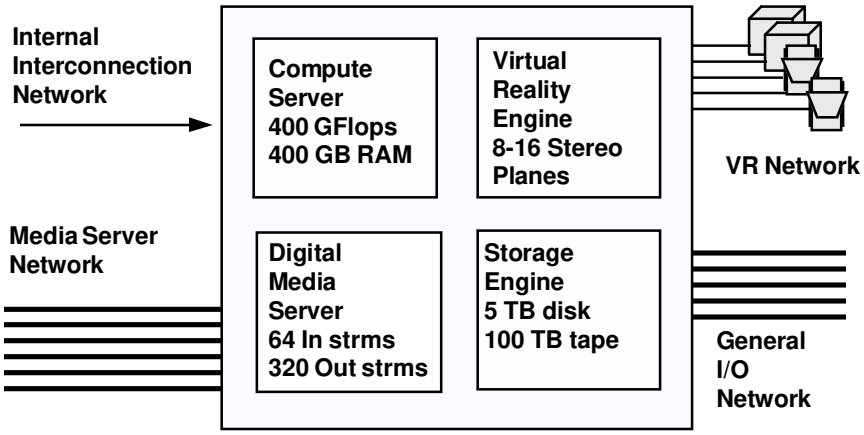
- Scalable interconnect of “rendering engines” to simulations
- Low latency network interface, WAN latency management
- Mechanisms for sharing models (simulation vs. rendering)
- Support for recording/playback
- Support of video data types
- New programming environments (open inventor++)



Current and Future Application Bandwidth Requirements

- Remote CAD prototyping (50 Mb/s)
- Typical 8-way LabSpace session w/archive (100 Mb/s)
- Cave to Cave applications (200 Mb/s)
- Nanotech design transmission (500 Mb/s)
- 8-way shared space CAVE session (1 Gb/s)
- APS detector data rate (1 Gb/s)
- Raw CAVE I/O (8 Gb/s)
- DOE Metalab backbone (500*100 Mb/s) ==> 5x10^4 Mb/s ==> 50 Gb/s
- Realtime earth system simulation (1 Tb/s)
- Distributed teraFLOP supercomputing (2 TF ==> 2 Tb/s)

Campus Digital Resource Engine



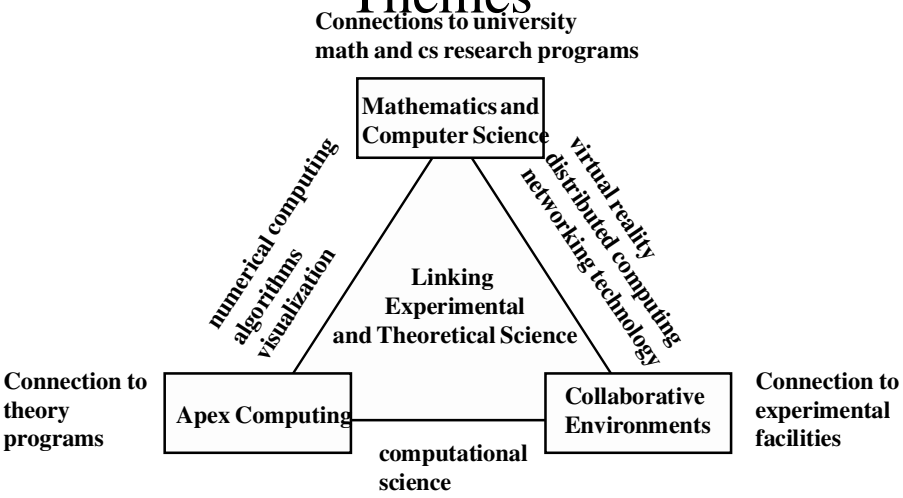
Core Digital Resource Engines

- Cycle Server
- I/O - mass store-- persistence for the environment
- Stream media -- page servers -- video/audio/web++/events
- Graphics -- geometry-rendering servers -- engines for visual immersion
- Networks -
  - internal component interconnects --> 1 GB/s/link
  - local fabric -- shallow networks --> 1 Gb/s/link
  - wide area -- deep networks --> 1 Gb/s/link

Software Environment

- object oriented --> multithreaded --> language independent mechanisms
- integration with communications and security
- integration with media stream support (multicast, real-time etc.)
- building blocks for collaborations
- brokering/proxy capable
- multi-paradigm
- storage integrated-- performance centric-- persistent
- dynamically downloadable
- peerable server/client/models

"Integrating Research Themes"



Philosophical Goals Behind Voyager and Avalon

- **Techno-Empowerment**: recognizes the great disparity in productivity and cognitive skills present in groups and organizations. The key point is to amplify the **best and brightest**, the **problem solvers** and the **primary integrating thinkers**. In addition through technology, uplift the middle and margins and empower everyone to contribute to organizational goals.
- **Key problems**: scalable interactions and coordination.

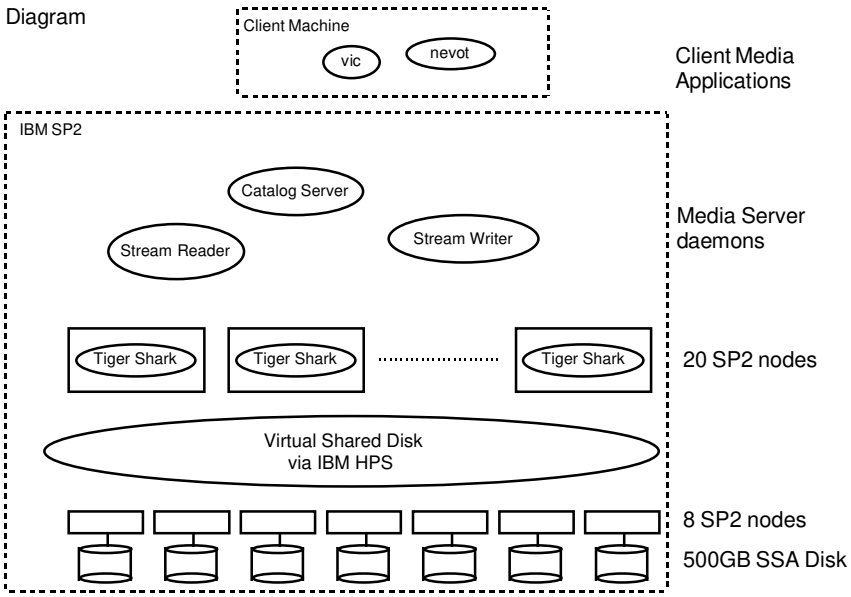
Classical Modes of Working

- Seminars (peers)
- Classes (students, teacher)
- Workshops (long duration)
- Meetings (short duration)
- Conferences (multisession)
- Panels/Roundtables
- Presentations
- Retreats
- Hotel Rooms
- Breakfast
- Collaborative Hacking
- Solo
- One-on-One
- Hallways-coffee breaks
- Help Desk
- Sales calls
- Walks
- Lectures
- Airplanes
- Lunch

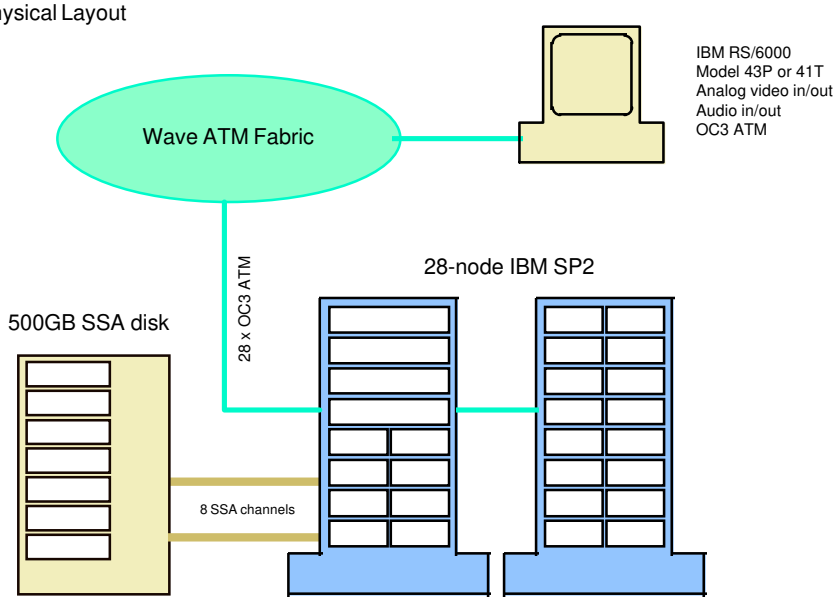
Argonne Voyager

- A project to develop servers to support the communications needs of virtual organizations.
- First effort is a video server (fully symmetric record, playback engine).
- Video server will be demonstrated at SC95 as part of the I-WAY activities.
- After SC95 we will be exploring support for a wide variety of data types and media streams.
- Scalability is a major goal.

SC95 ANL/IBM VideoServer
Logical Diagram



SC95 ANL/IBM Video Server
Physical Layout



Avalon: A One Thousand User Collaborative Environment

- Future research project at Argonne to put a thousand people on-line in a shared virtual environment.
- Prototype of an **Integrated National Collaboratory**.
- Scientific, support and administrative users.
- Based on **Voyager**, **LabSpace**, **Zipper** and **I-WAY** inspired technologies.
- Technology Goal: an ATM based 1000 desktop environment with interactive video, audio, text, web, computation, robotics and database resources.

Collaborative Environments -- Telepresence

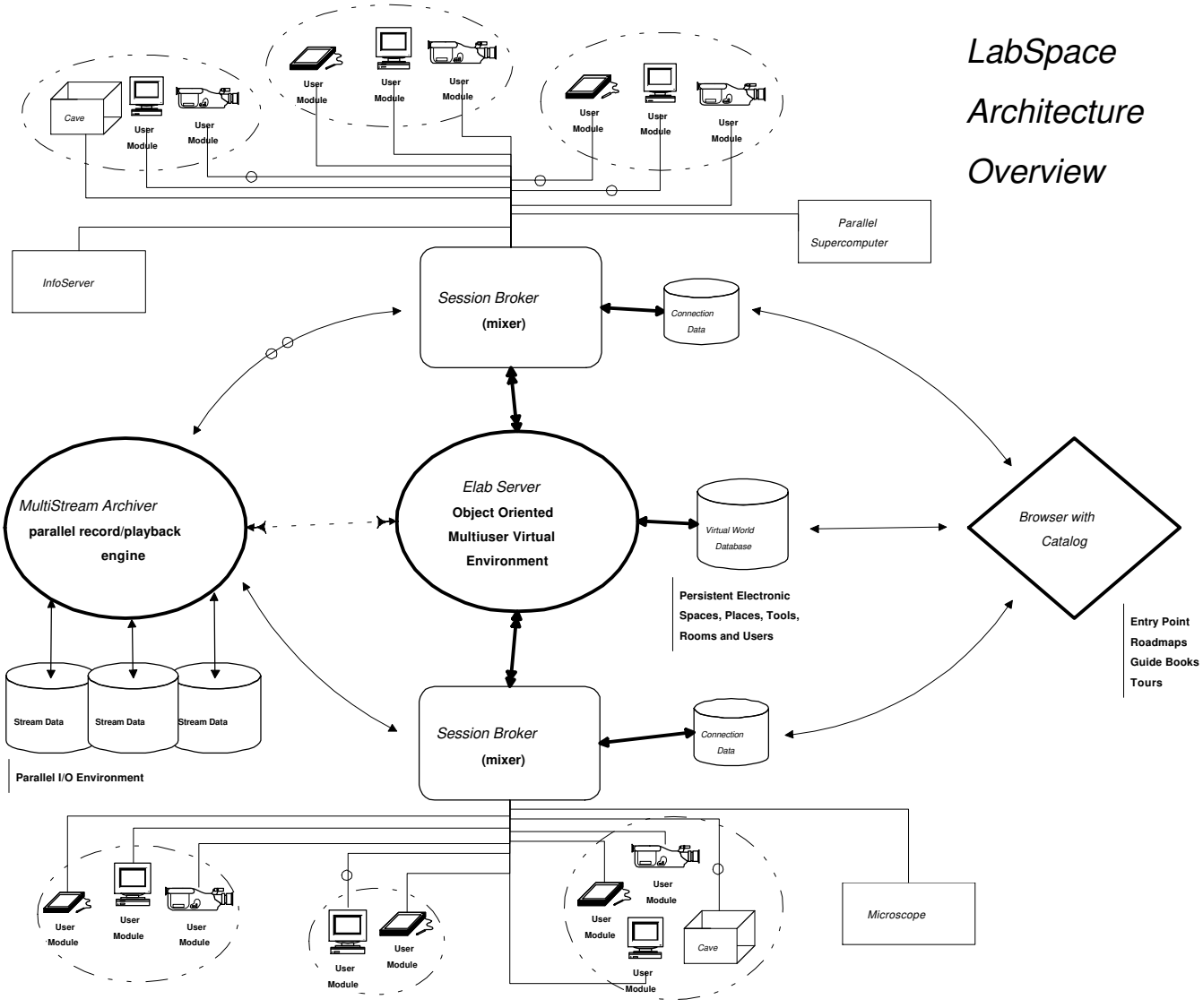
- Provide the user with flexible ways to **"be there"**
- Includes both high-end tools (CAVE-to-CAVE) and desktop collaborative environments (LabSpace)
- I-WAY demonstration of telerobotic **"proxy"**
- Has major potential to change the way people work
  - telecommuting, telescience
  - remote control of experiments
  - distributed collaborative research groups
  - works for administrative as well as technical users
  - can reduce costs and reduce staffing levels

Distributed Collaborative Environments Technology

- Software and systems to support distributed scientific and engineering collaborations
- The "**LabSpace**" system combines audio, video and data streams into a **"telepresence**' environment to support remote operation and control of scientific experiments
- System will be piloted with users in Materials Science and CAT*s of the Advanced Photon Source
- Users will be able to collect and analyze data remotely and interact naturally with colleagues
- This technology can dramatically expand the utilization of DOE's ER facilities (e.g electron microscopes, light source beam lines)

* Collaborative Access Teams

Elab Server

- **Text based- multi-user virtual environment**
- Based on Lambda MOO server technology from Xerox PARC (e.g. BioMOO, AstroVR, InfoPark, WaterfallGlen, JHM, Lambda)
- Provides virtual environment "**context**"
- **Manages Database** of virtual locations, attributes, access mechanisms, users and objects
- Extensible and Object Oriented
- Scalable and portable

LabSpace Architecture Overview