Next Generation Internet: Realizing the Future

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Where is the Internet Today?

- Faster household penetration than telephone or television: reached 50 million Americans in five years
- 27% of American families use Internet more than 3 times/month
- Over 200 million people connected to Internet world-wide

Where is the Internet Today?

- Internet Protocol (IP) has won, killing off IPX, SNA, DecNet, etc.
- UUNet reports its network traffic has grown 10X each year for 8 years.
- Business Week reports Internet traffic is doubling every 3 months.
- Optical equipment continues to double the capacity it delivers at a given price every nine months - twice as fast as Moore’s Law on computer power.
- Single fiber capacity has grown from 45 megabit/sec to 10 gigabit/sec for shipping products; lab demonstrations have exceeded 1 terabit/sec

Where is the Internet Today?

- Internet is transforming business, government, education - may be partly responsible for economic productivity growth of last two years
  - e.g. CISCO has over $600K sales per employee - business model is Internet based
  - Dell and Oracle report similar productivity growth with similar business model
- Wireless is the new Internet frontier
  - Cell Phones, Personal Digital Assistents (PDAs), wireless ethernets

So What's Wrong?

- Security
  - System vulnerabilities and hacker attacks
  - Authentication, signatures, privacy
  - Surreptitious cookies, web spies, data gathering
- Manageability
  - Network engineering and traffic planning
  - Network scaling and routing management
  - Peering arrangements
- Reliability
  - Service level agreements: not enough 9's
  - Quality of Service
  - Latency, jitter, packet loss

So What's Wrong?

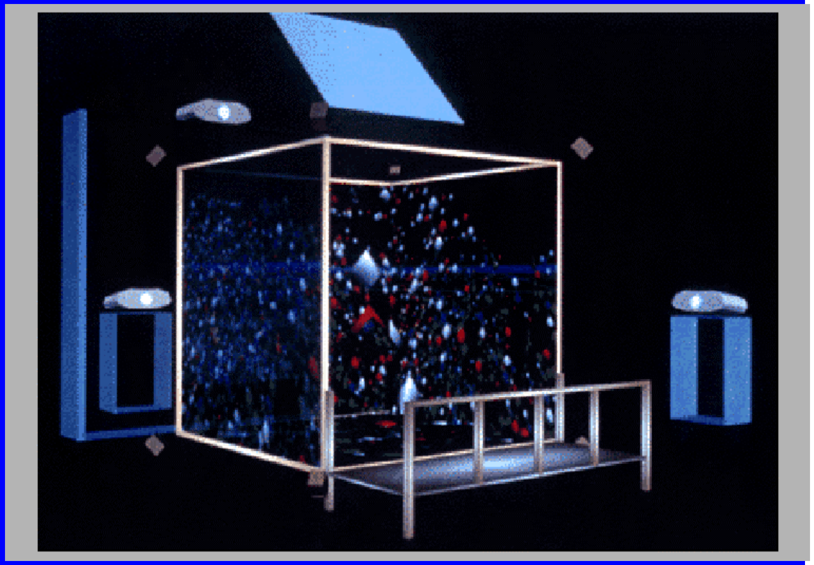
- Interoperability
  - Compatibility among service providers
  - Limited, proprietary services
  - IETF vs. companies
- Ubiquity
  - Integration of wireless
  - Graceful degredation over lower bandwidth channels
  - Accommodating disabilitiew
  - Advanced services such as QoS, multicast, Ipv6
- End-to-end engineering
  - End-to-end bandwidth typically < 10 Mb/sec. even over Gb/sec circuits

Let’s Look into the Future

Predicted Evolution of Internet

TODAY	TOMORROW
• Interact with things	• Comfortably interact with people
• Static 2D images	• 3D real-time audio-video
• Mostly visual, some audio	• Rich environment: sight, sound, touch, smell?
• One-to-one	• Many-to-many, self configuring
• Primitive search and organizing tools	• Automatic agents, distributed file system
• Difficulty matching content to bandwidth	• Application discovers network capabilities

Immersive Environments Pose Demanding Network Requirements

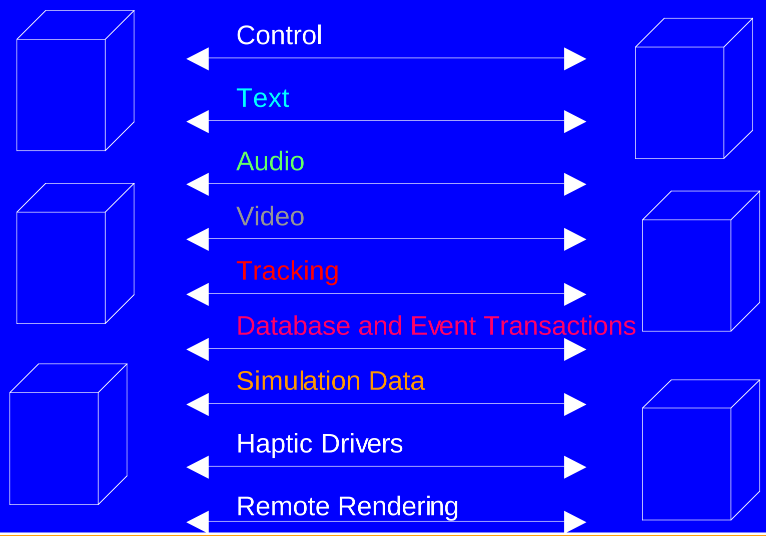


CAVE

Immersa-Desk

See, e.g., www.fakespace.com

Tele-immersion Networking Requirements



- Immersive environment
- Sharing of objects and virtual space
- Coordinated navigation and discovery
- Interactive control and synchronization
- Interactive modification of environment
- Scalable distribution of environment

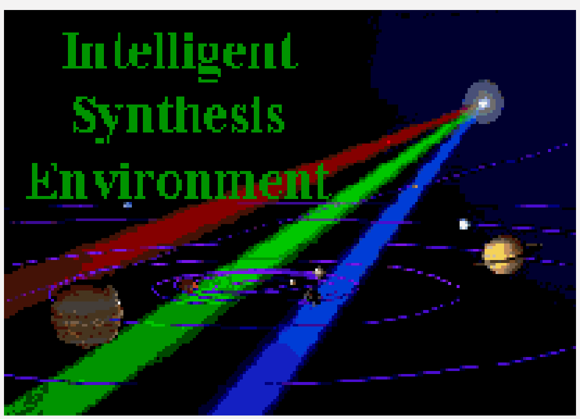
Type	Latency	Bandwidth	Reliable	Multicast	Security	Streaming	DynQos
Control	< 30 ms	64Kb/s	Yes	No	High	No	Low
Text	< 100 ms	64Kb/s	Yes	No	Medium	No	Low
Audio	< 30 ms	Nx128Kb/s	No	Yes	Medium	Yes	Medium
Video	< 100 ms	Nx5Mb/s	No	Yes	Low	Yes	Medium
Tracking	< 10 ms	Nx128Kb/s	No	Yes	Low	Yes	Medium
Database	< 100 ms	> 1GB/s	Yes	Maybe	Medium	No	High
Simulation	< 30 ms	> 1GB/s	Mixed	Maybe	Medium	Maybe	High
Haptic	< 10 ms	> 1 Mb/s	Mixed	Maybe	High	Maybe	High
Rendering	< 30 ms	>1GB/s	No	Maybe	Low	Maybe	Medium

Reference: Rick Stevens, ANL, Tom Defanti, U. Ill.

Intelligent Synthesis Environment (ISE)

The Vision

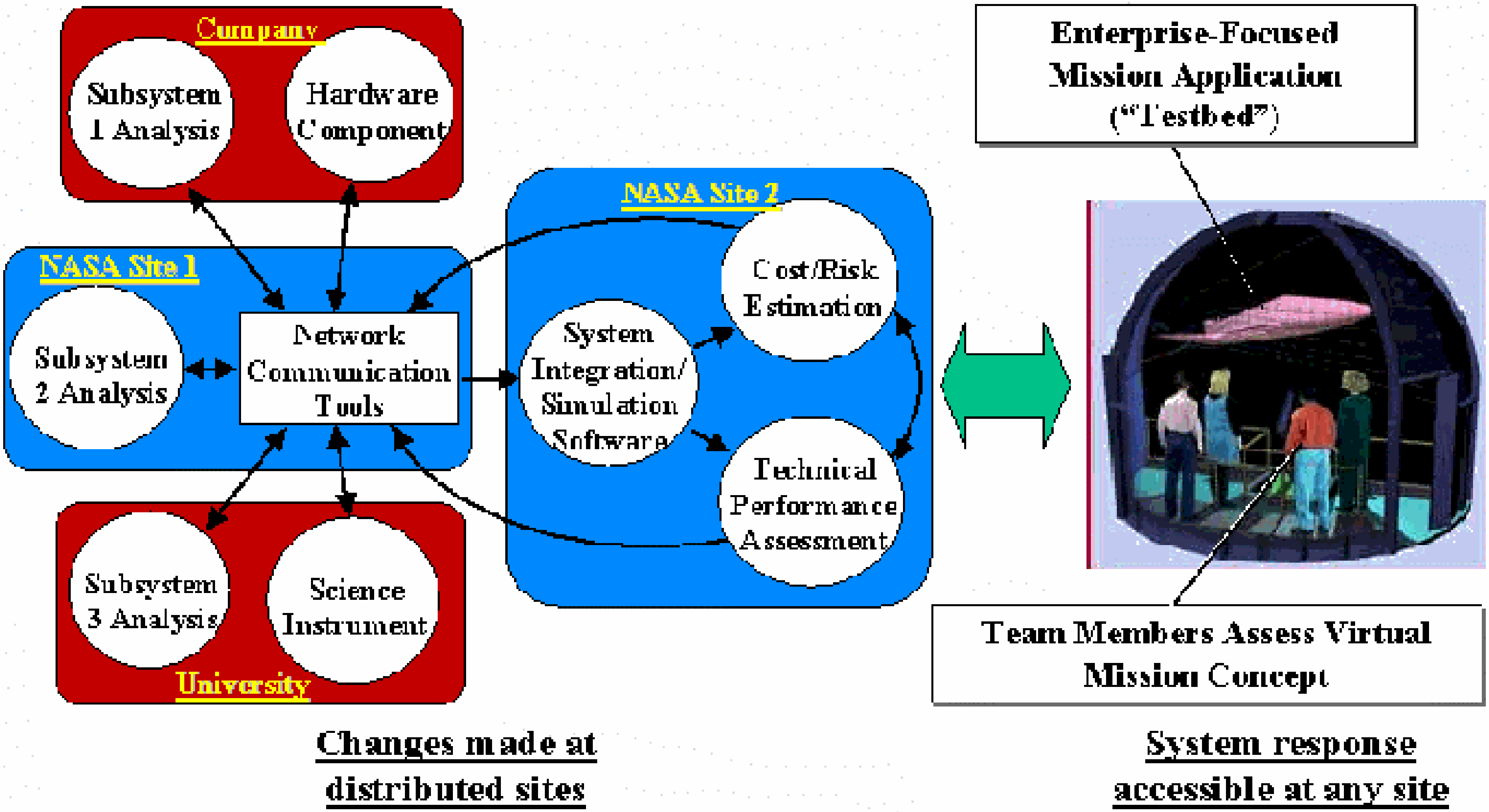
To effect a cultural change that integrates into practice widely-distributed science, technology and engineering teams to rapidly create innovative, affordable products



Approach to Achieve ISE Vision

To develop the capability for personnel at dispersed geographic locations to work together in a virtual environment, using computer simulations to model the complete life-cycle of a product/mission before commitments are made to produce physical products

An ISE Team at Work



Automated intelligence aids design and decision processes

Related Government and Industry Programs

- DOD/DARPA - Large-scale simulation, simulation-based design
- NIST - Automated manufacturing, standards
- DOE - Immersive environments, risk analysis, simulation
- Lockheed-Martin - integrated design and development
- Boeing - consolidation of engineering processes
- Commercial developers of engineering tools (McNeal Schwindler, Dassault, UAI, Parametric Technologies, SDRC, Muse, Intergraph, Analytic Graphics, etc.)
- Graphical interface and database development activities for entertainment,business, and commerce
- Non-aerospace industry design and development programs (Automotive, electronics, etc.)

Productive leveraging is crucial

Where is the Internet going in the next 2-3 years?

- Higher Bandwidth
  - End-to-End bandwidth is the important metric
    - 10Gb/s WANs
    - 100 Mb/s and 1 Gb/s LANs
    - xDSL, Cable Modems to home, small office
  - Interactive video (conferencing, broadcasting)
  - Telecommuting
  - Distance learning
  - Telemedicine

Where is the Internet going in the next 2-3 years?

- Wireless systems and services
  - metropolitan, based on “cell phone” technology
  - local, based on 802.11, Bluetooth, etc.
  - But low bandwidth and mostly small screens
- Computer-computer communication
  - Network attached storage, agents, distributed data bases, distributed computing
- Practical voice command
- Network convergence? E.g. voice-over-IP, ATM
- But service won’t be cheap

Where should the Internet be going in the next 2-3 years (but probably won't)

- Inter-carrier Quality of Service addressable at application or service level
- System Reliability at level of phone system: 99.999…%
- Enforced service level agreements based on objective measurements
- Integrated security services (e.g. IPSec)
- New Protocols implemented to reduce hacker attacks

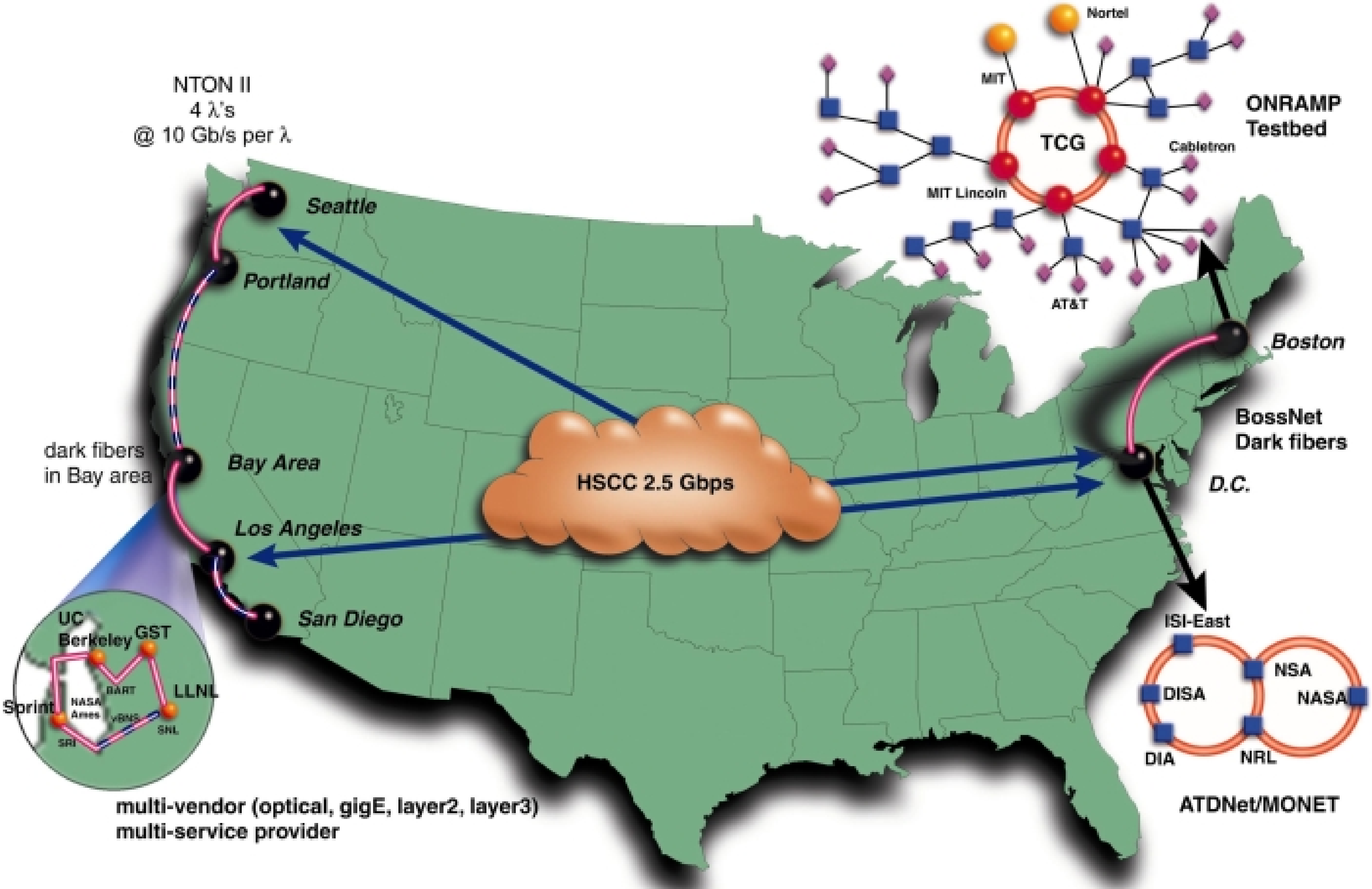
Next Generation Internet Initiative Explores Tomorrow's Networks and Applications

- Presidential Initiative begun 1998
- Approximately $100M per year
- Five agencies funded directly
  - DARPA, NSF, DOE, NASA, NIH, NIST
- Several other agencies collaborating
- Cooperating with university-based Internet 2 program
- See www.ccic.gov and www.ngi.gov

Goals of Next Generation Internet Initiative

1. Conduct **research** in next generation networking technologies to add functionality and improve performance.
2. Develop a Next Generation Internet **testbed**,emphasizing end-to-end performance, to support networking research and demonstrate new networking technologies
   - 2.1. at least 100 NGI sites -- universities, Federal research institutions, and other research partners -- at speeds 100 times faster than today's Internet (**100X**)
   - 2.2. at least10 sites at speeds 1,000 times faster than the current Internet (**1000X**)
3. Develop and demonstrate **revolutionary applications** that meet important national goals and missions and that rely on the advances made in goals 1 and 2

Goal 2.2: DARPA Supernet



NGI Goal 2.1 Testbed

- A "leading edge but stable" infrastructure for providing end-to-end high performance and advanced services (referred to as NGI/I2 class) for the purpose of Goal 3 applications development
- Wide area backbone networks (referred to as "JETnets") involved in this infrastructure:

vBNS from MCI and NSF

University Corporation for Advanced Internet Development

ESnet

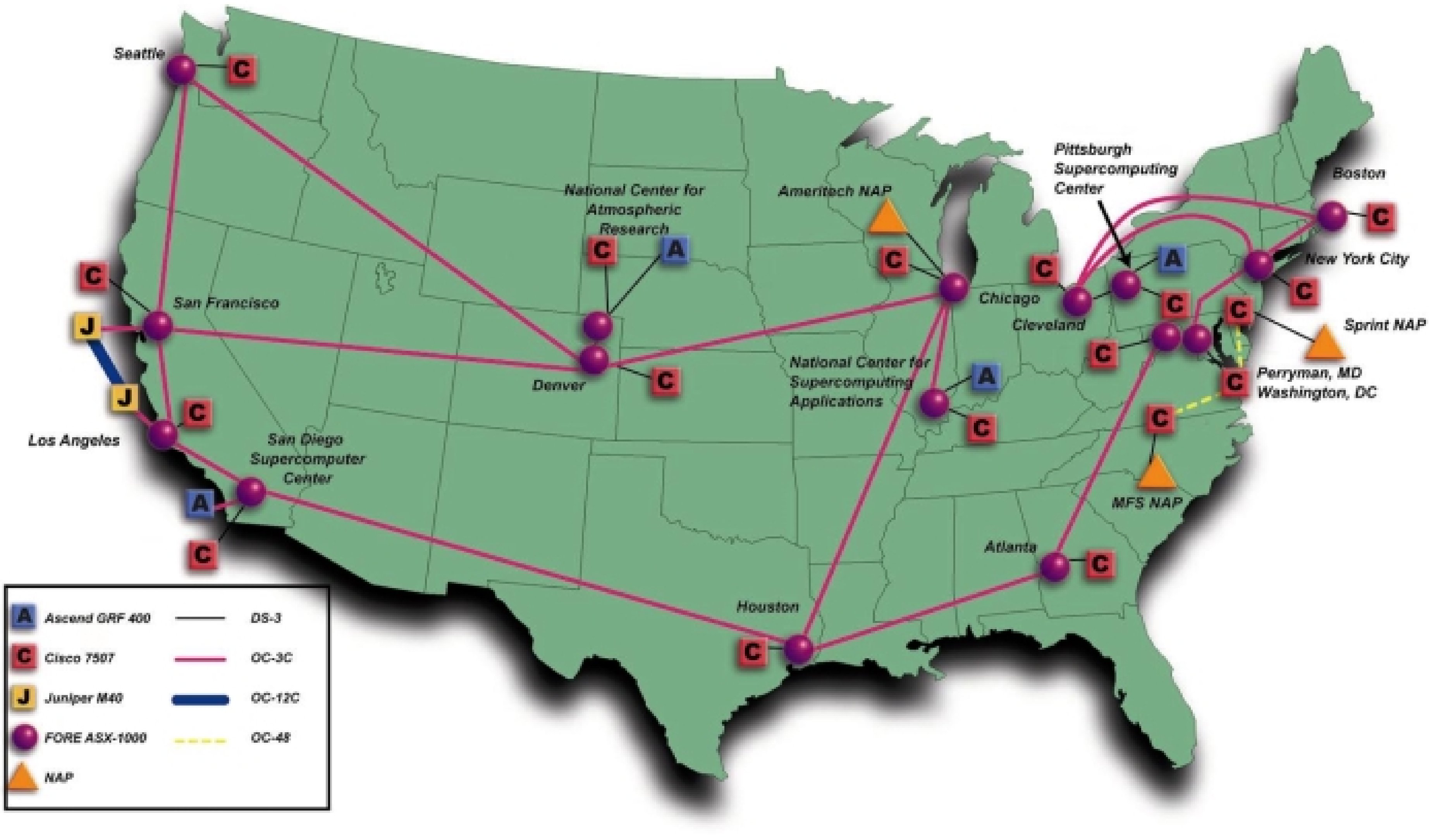
NREN

HPCMP

(DREN)

NISN

NSF vBNS



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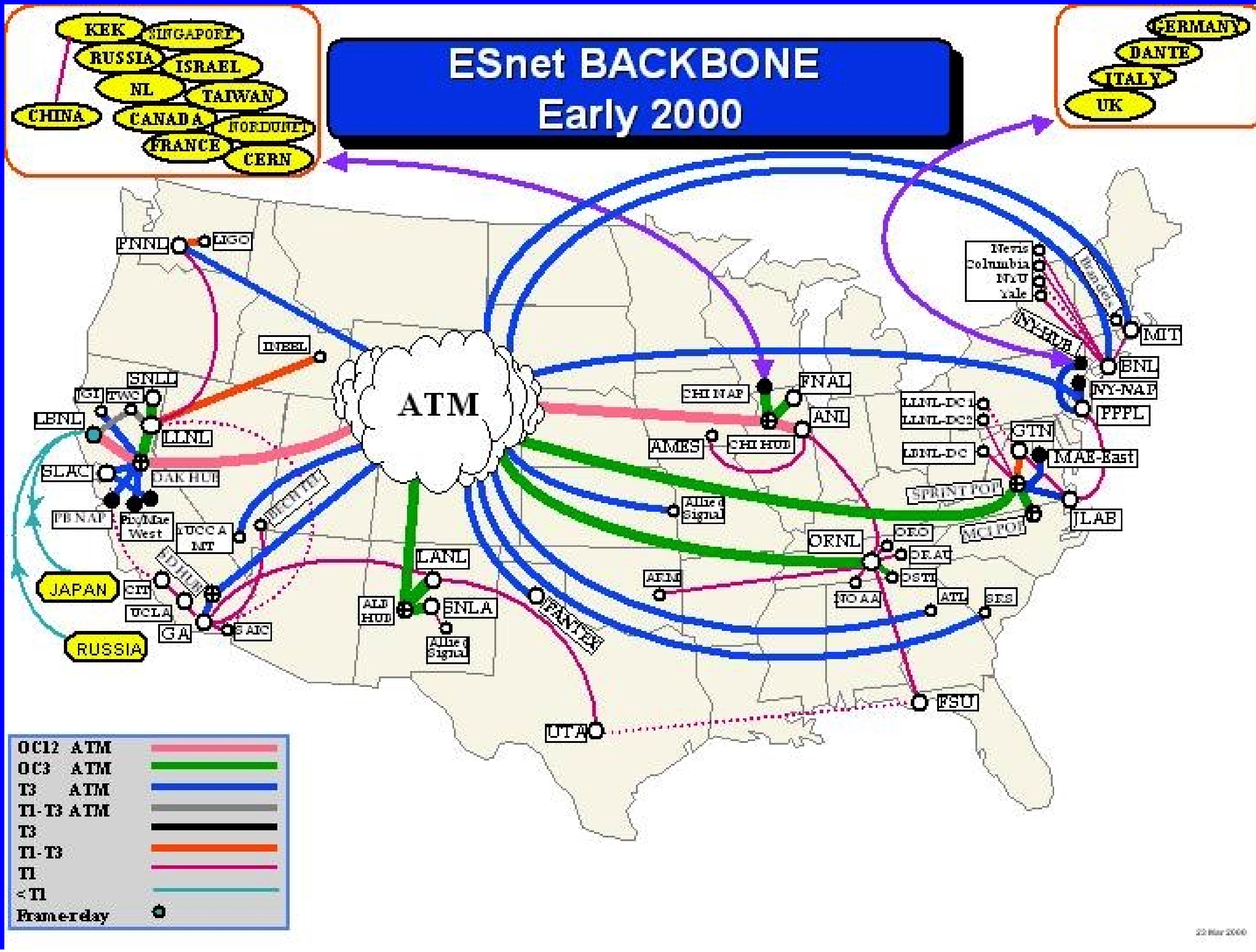
OC-48

DOE ESnet


ESnet BACKBONE
Early 2000
KEK
SINGAPORE
RUSSIA
ISRAEL
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CHINA
CANADA
NORDUNET
FRANCE
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GERMANY
DANTE
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OC12 ATM
OC3 ATM
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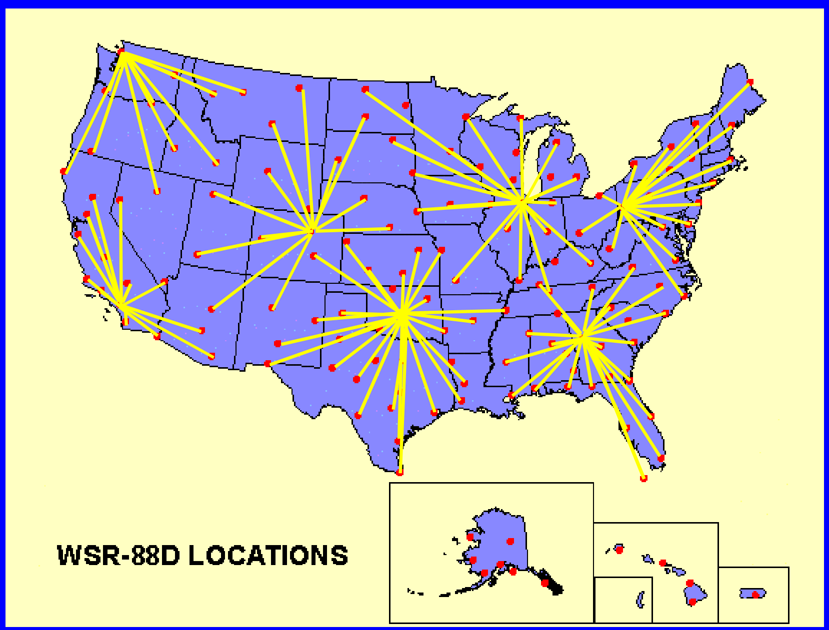
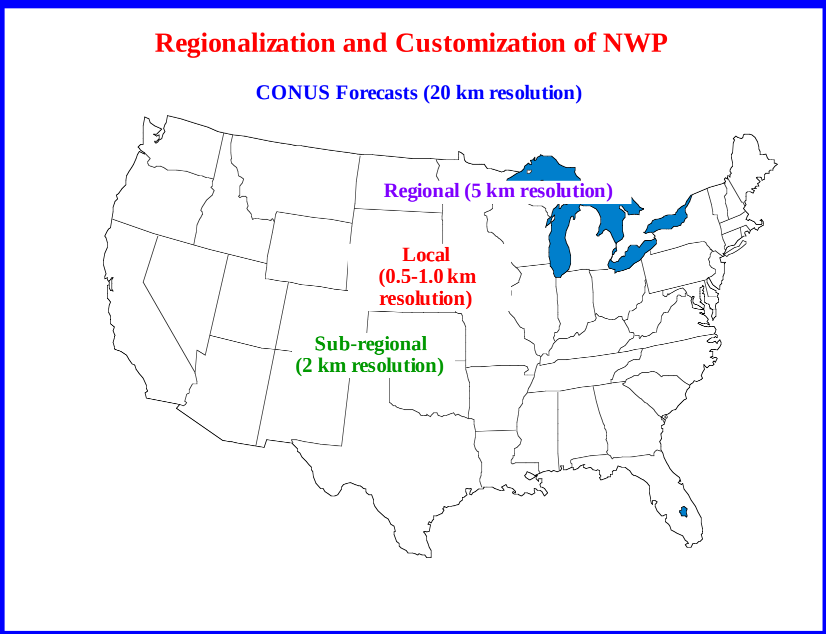
Framerelay

University of Oklahoma

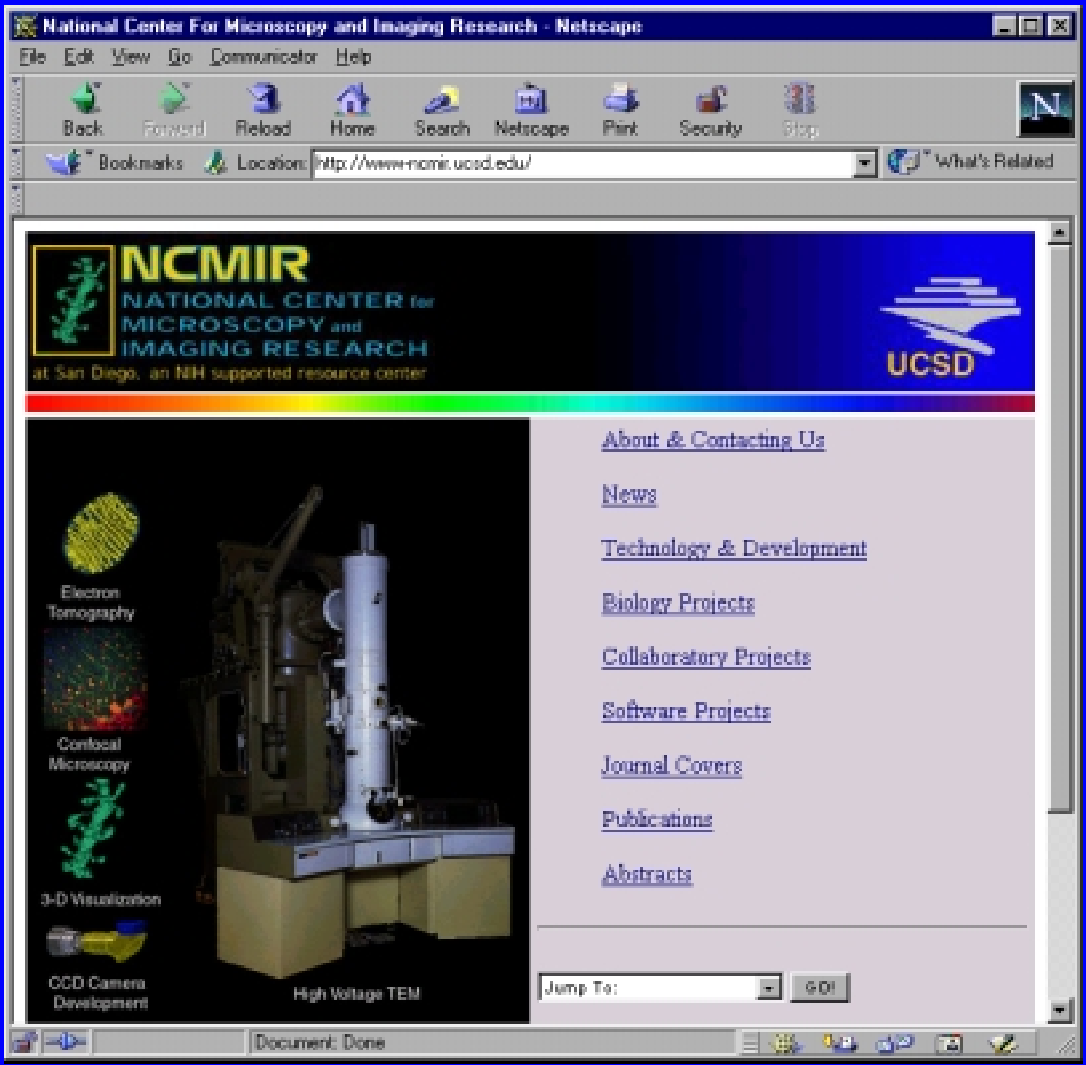
(www.caps.ou.edu)

- Distributed data acquisition (NEXRAD radars)
- Distributed dynamic computing
- Distributed decision making and data dissemination
- Intelligent networking and data routing



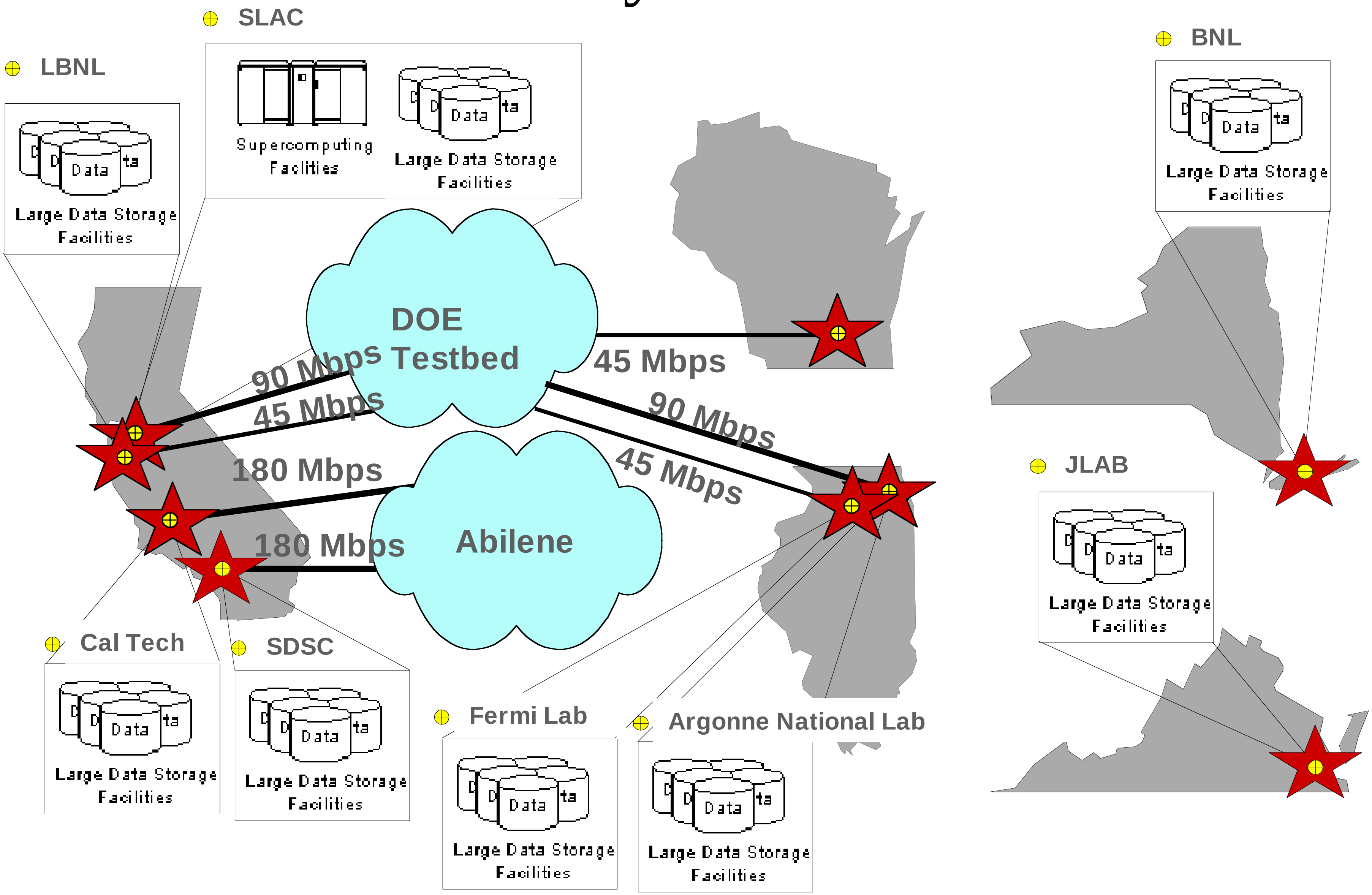


UC San Diego (www-ncmir.ucsd.edu)



- International work
- High throughput (35Mbps)
- Remote instrument control
- Multiple "channels" for controls and images

Particle Physics Data Grid



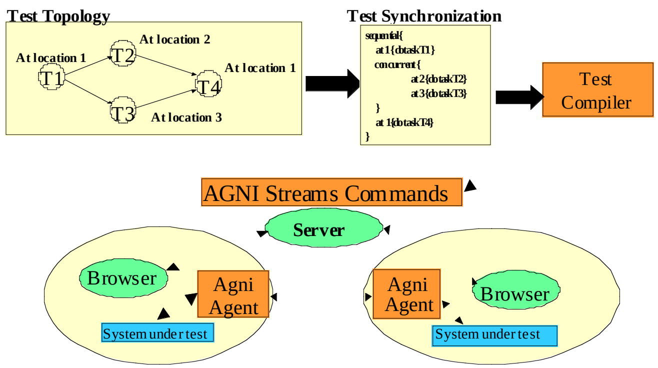
Particle Physics Data Grid Resources

- Network Testbeds:
  - ESNET links at up to 622 Mbits/s (e.g. LBL-ANL)
  - Other testbed links at up to 2.5 Gbits/s (e.g. Caltech-SLAC via NTON)
- Data and Hardware:
  - Tens of terabytes of disk-resident particle physics data (plus hundreds of terabytes of tape-resident data at accelerator labs);
  - Dedicated terabyte university disk cache;
  - Gigabit LANs at most sites.
- Middleware Developed by Collaborators:
  - Many components needed to meet short-term targets (e.g.Globus, SRB, MCAT, Condor,OOFS,Netlogger, Grand-Challenge Cache Manager, Mass Storage Management) already developed by collaborators.
- Existing Achievements of Collaborators:
  - WAN transfer at 57 Mbytes/s;
  - Single site database access at 175 Mbytes/s

Agile Networking Infrastructures

“Reconfigurable Networking on the Fly”

AGNI



Goal

Expedite the development of *agile networking* technologies that enable programmable and reconfigurable communication infrastructures.

Technical Approach

- Research and develop *middleware* technologies for adaptive, reconfigurable distributed systems.
- Evaluate measurement and standardization requirements for networked *pervasive computing* based upon pico-cellular wireless networks and service discovery and composition technologies.
- Develop measurement techniques that enable resource control in *active network* technologies.

Customers

- DARPA, NIST/NAMT
- Middleware & distributed systems R&D community
- CSCW test and evaluation community
- IEEE 802.15, Bluetooth, HomeRF, Sun Java-Jini community

Collaborators

- U. Md, UC Santa Barbra, Old Dominion U.
- NAI Labs, MAYA Design.

Recent Results

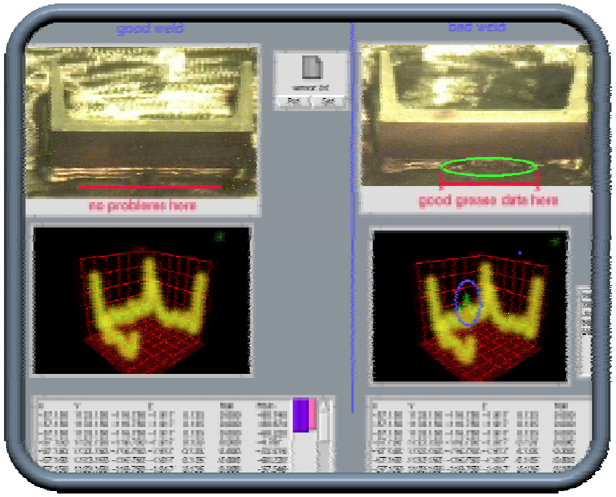
- ***AGNI --*** mobile streams middleware framework and toolkit.
- ***SCAN --*** devised metrics and measurement techniques for Self-Calibrating Active Nodes.

What’s Next?

- Prototype development of AirJava adapter and testbed (FY00)
- Prototype SCAN execution environment for Active Nets (FY00)
- Evaluate alternative approaches to service discovery and composition in pervasive computing networks (FY00-01)
- Characterize the internetworking requirements for pervasive computing networks (FY00-01)
- Research and develop technologies for construction of dynamic virtual overlay networks. (FY00-01)

Manufacturing Collaboratories

“Manufacturing Together on the Net”



Goal

Identify gaps in integration and standards for manufacturing activities stemming from use of collaborative environments

Technical Approach

- Deploy manufacturing collaboratory testbed and evaluate collaboration processes
- Deploy and assess a Robotic Arc Welding collaboratory
- Deploy and assess an industrial pilot collaboratory
- Develop quantitative evaluation methods for collaboration technologies

Customers

- Delphi Chassis
- Borg-Warner
- Caterpillar

Collaborators

- Sun Microsystems
- Teamwave Software
- University of Michigan
- University of Saskatchewan

Recent Results

- Deployed a pilot collaboratory for robotic arc welding and published preliminary results on usage
- Integrated commercial CSCW applications, NIST-developed multi-media playback and annotation tools and "SmartRoom” technologies

What’s Next?

- Continue evaluation of collaboratory technologies for welding research
- Work with University of Michigan to evaluate distributed, collaborative design of clutch system with Borg-Warner Automotive units in U.S. and Germany

Performance Expectation and Issues

- For OC3 or higher connected sites with 100Mbps switched campus nets and fine tuned end systems (and no firewall in the path) you can expect 80 Mbps end-to-end (memory to memory)
- This is not the TYPICAL case
- Most performance bottlenecks are in the end systems: lack of path MTU discovery, TCP implementation, multiple memory copying and buffer management; there are also problems in local networks (under-power routers)
- NGI program first phase mostly focused on wide area nets, now we are focusing on local nets and end systems

Conclusions

- The Internet must become more capable to support tomorrow's applications
- Increased bandwidth will be important, but it must be end-to-end bandwidth
- Management, services and middle-ware must also improve
- The Next Generation Internet Initiative is testing requirements through technology research, advanced applications, and supporting network testbeds
- Substantial investments are planned that assume success of this effort