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# **US Federal Agency Advanced Network Research Programs**

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# US Federal Agency

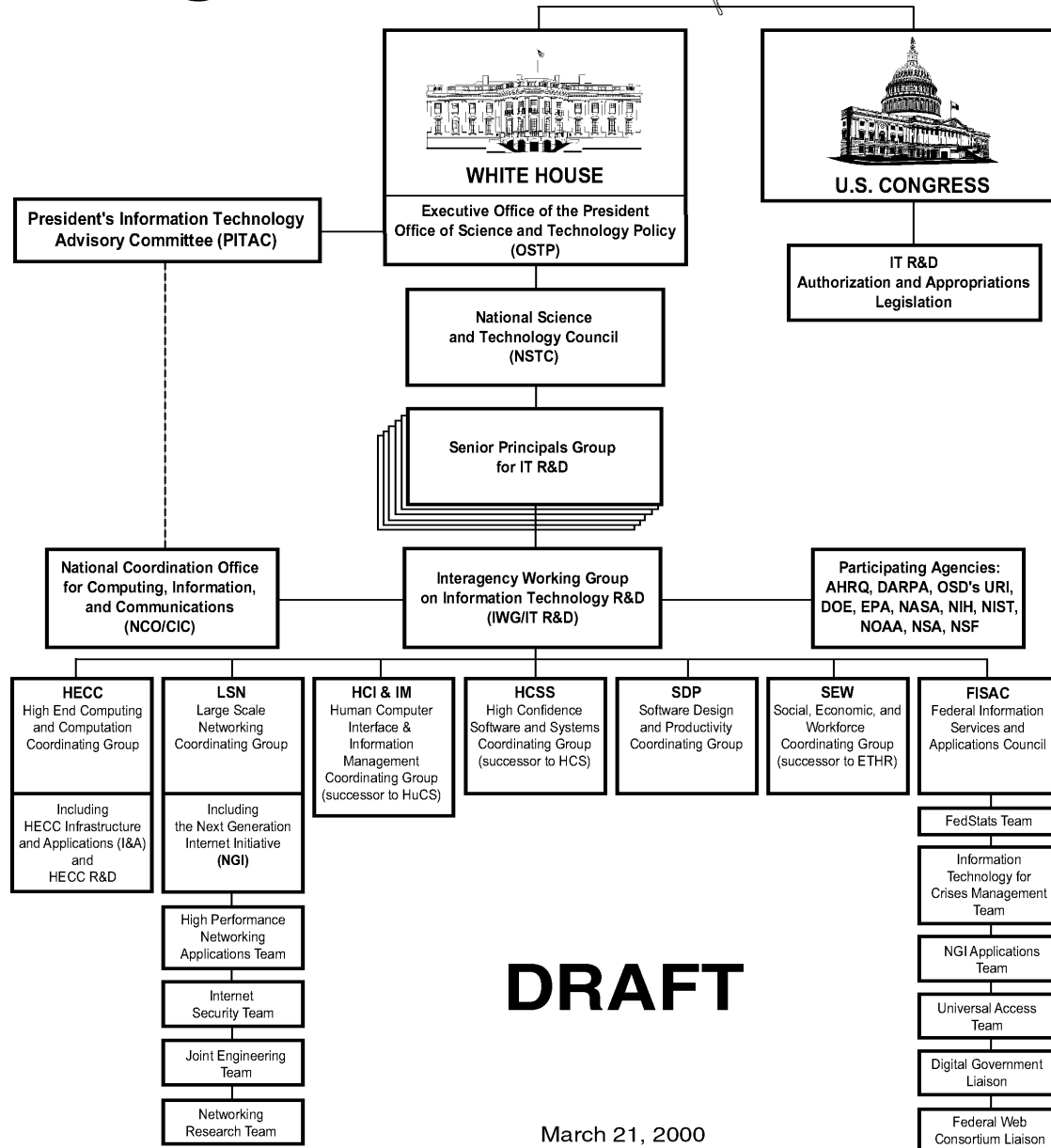
## Network Research Program Components

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- Large Scale Networking (LSN) coordinates Federal activities and R&D efforts to maintain and extend U.S. technological leadership in high performance networking through research that advances leading edge networking technologies, services, and performance.
- Next Generation Internet (NGI), A Component of the LSN: Networking research, Advanced Testbeds, Revolutionary Applications
- Scalable Information Infrastructure (SII), A Component of the LSN: Networking Extensibility, Ubiquity, Management



# LSN Organization



## DRAFT

March 21, 2000

9/2000



# LSN Funding Table

\$ Millions

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<b>Agency</b>	<b>FY 2000</b>
DARPA	\$69.9
NSF	81.2
DOE	24.8
NASA	20.1
NIH/NLM	63.0
NIST	5.2
Other Agencies	12.1
<b>Total</b>	<b>\$276.3</b>

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# NGI Funding Table

## \$ Millions

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<b>Agency</b>	<b>FY 1998</b>	<b>FY 1999</b>	<b>FY 2000</b>
DARPA	\$42	\$50	\$37
NSF	23	25	25
DOE		15	0
NASA	10	10	10
NIH/NLM	5	5	5
NIST	5	5	5
<b>Total</b>	<b>\$85</b>	<b>\$110</b>	<b>\$82</b>

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# NGI Thrusts

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- Thrust 1: Develop High Performance Networking Technologies with the support of a 1000 X network testbed (Supernet)
- Thrust 2: Develop High Performance Network Applications with the support of a 100 X network testbed (vBNS, DREN, NREN, ESnet)



# NGI Thrust 1: Networking Research

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- Conduct R&D in advanced end-to-end networking technologies for reliability, robustness, security
  - Multicast
  - Quality of service/differentiation of service
  - Network Security
  - Network Performance Measurement
  - Network management (including allocation and sharing of bandwidth)



## NGI 1,000 X Testbed (Supernet)

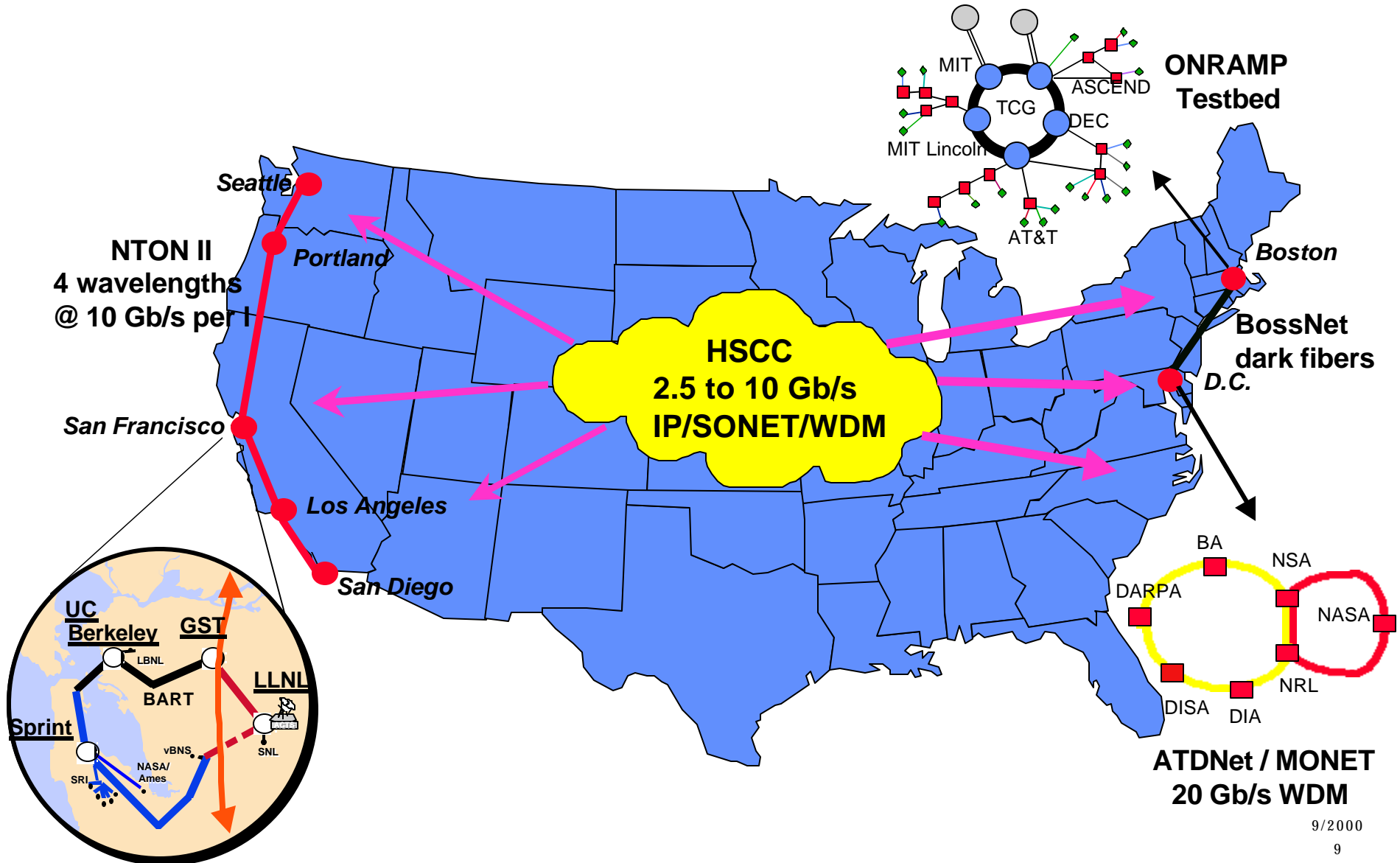
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- SuperNet goal:
  - Connect about 10 sites with end-to-end performance at least 1,000 times faster than the Internet of 1997 (~ 1 Gbps)
- Built on Federal networks: IP over Sonet and WDM
  - East Coast: ATDnet (Multiagency), BossNET, Dark Fiber
  - West Coast network (Nortel network, includes NTON)
  - Qwest fabric between West and East coasts (OC48)
- System-scale testing of advanced technologies and services and developing and testing of advanced applications
- 15 sites will be connected in FY 2000: multiple users at each site





# 1,000x SuperNet Testbed





# Recent Supernet Experiments and Demonstrations

- 5x270 Mbps HDTV/POS transmission over 300 Km
- 1.2 Gbps TCP/IP between desktops: POS, 300 Km
- 1.5 Gbps HDTV/ATM Transmission over 300 KM
- 600 Km GbE over MONET/ATDNET
- 10 Gbps dynamic path setup over MONET/ATDNET



# DARPA Networking Program

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- 2-3 Years:
  - 1-10 Gbps
    - End host architecture
    - Local/metro/regional network architecture (ONRAMP)
    - Protocol Research, e.g. flow switch to bypass routers
  - Optical Access Technology
  - Network Monitoring, Analysis, Visualization, e.g. Coral Tool (OC3mon)
- 5 Years: Optical Burst Switch
  - Optical burst switch: End-to-End Optical Flow Switching



# DARPA Networking Program Continued

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- 10+ Years: Ultra-Fast all Optical Logic
  - All-Optical Logic Gates
  - All-Optical Switch Implementation
  - Networking Architecture and Protocol
- 40+ Years: Interplanetary Internet



# NGI Thrust 2: Advanced Networking Applications

## *NGI Applications*

- Hundreds of applications across DARPA, NASA, NIH/NLM, NIST, NSF
- Supported by the 100x testbed built on LSN R&D networks that emphasizes end-to-end performance
- Supernet applications by DARPA supported by the 1,000x testbed
- End-to-end performance measurement to support upgrading end user capabilities



# NGI Example Applications

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- **Examples:**

- Illinois-Chicago (Grossman): data mining
- Oklahoma (Droegemeier): weather research
- North Carolina (Smith, Jeffay): nano-manipulators
- UC San Diego (Ellisman): international microscopy
- Un of Washington (Richardson): Internet HDTV: Up to 2.4 Gbps
- West Va. Un (Van Scoy): International collaboratory for virtual reality and telepresent

- **Messages:**

- This initiative is about more than bandwidth
- Researchers are attempting things on this network that they might not have attempted on the Internet



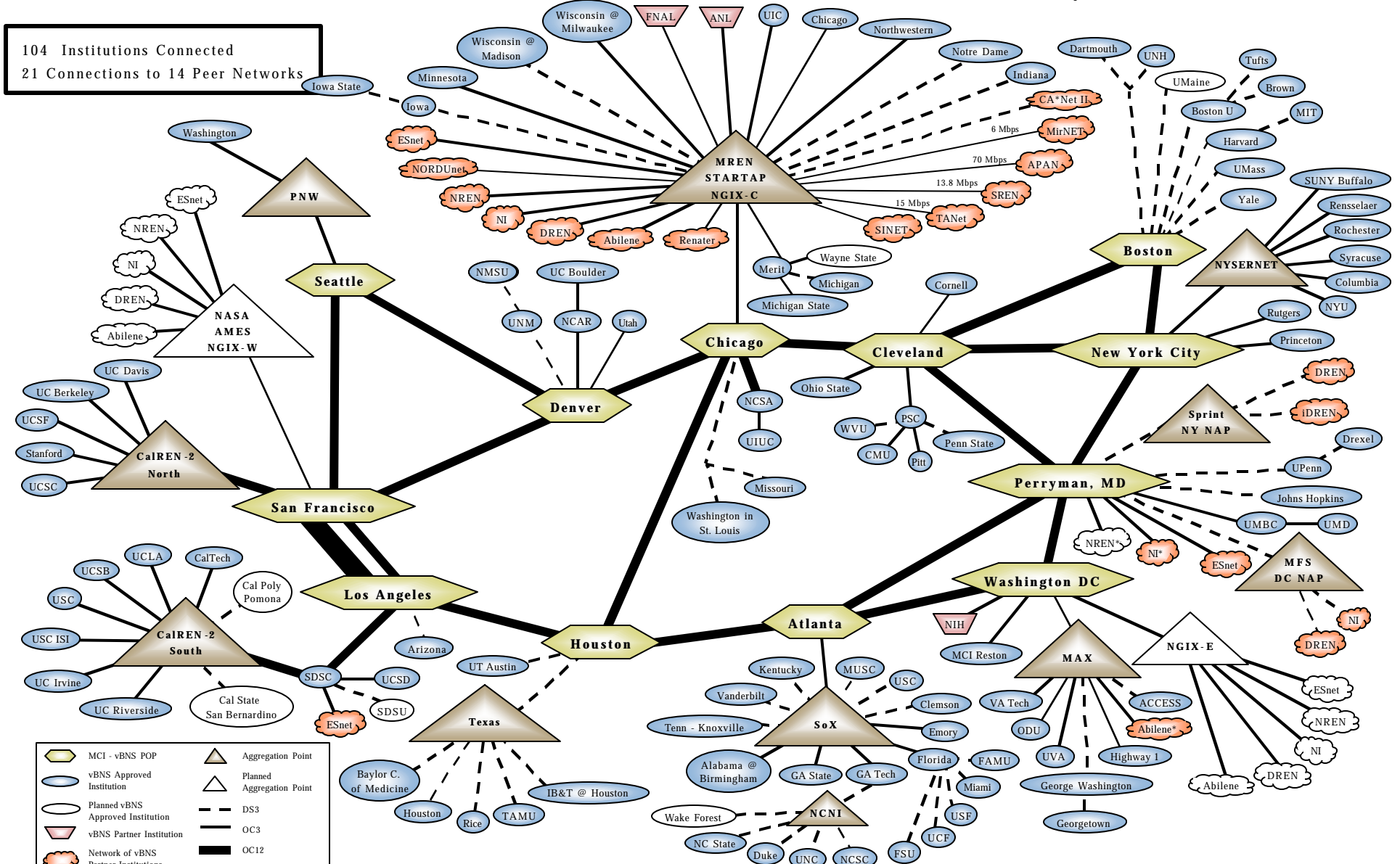
# NGI 100 X Testbed

- The 100 X Testbed supports Thrust 2
  - Built on Federal networks, primarily ATM:
    - NSF's very high performance Backbone Network Service (vBNS): MCI
    - NASA's Research and Education Network (NREN): Sprint
    - Defense Research and Engineering Network (DREN): AT&T
    - DOE's Energy Sciences network (ESnet): Sprint
  - Connect 100 research partners at speeds 100 times faster end-to-end (~100 Mbps) than 1997's Internet
    - Over 180 sites will be connected in FY2000
    - Foster end-to-end performance: Solve last mile, last foot issues

# vBNS Logical Network Map

Last Updated 08/12/99

104 Institutions Connected  
21 Connections to 14 Peer Networks



	MCI - vBNS POP		Aggregation Point
	vBNS Approved Institution		Planned Aggregation Point
	Planned vBNS Approved Institution		DS3
	vBNS Partner Institution		OC3
	Network of vBNS Partner Institutions		OC12
	Planned Network of vBNS Partner Institutions		OC48

NOTES: Lines between institutions and aggregation points or NAs represent the configured bandwidth of their connection to the vBNS. The bandwidth of the actual circuits may be greater than shown.

\*These are temporary peering points. Permanent East Coast peering with these networks will take place at NGIX-E as soon as it is operational.





# International High Performance Networking: STAR TAP Connections

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- Completed:

- vBNS, ESnet, NREN, NISN
- Abilene (UCAID/Internet2)
- CA\*Net (Canada)
- MirNET (Russia)
- SINGAREN (Singapore)
- TransPAC (Japan, Korea, Singapore, Australia)
- TAnet II (Taiwan)

- Completed (Continued)

- NORDUnet (Norway, Sweden, Finland, Denmark)
- SURFnet (Netherlands)

- Pending

- Israel
- Renater (France)



# NGI Accomplishments

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- NGI Testbeds have been implemented with OC12 and above connectivity
  - Bottlenecks are now at campus networks
  - Preliminary testing has identified that backbone network links are not well-maintained, i.e. duplex links are not maintained as duplex, impairing IP performance
- Multicast has been deployed in the NGI backbone. Implementation is now up to the campus networks.
- Implementation of services, such as Quality of Service depends on solving interface, standards, and deployment issues that are difficult



## Federal Agency Network R&D Activities (1)

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- LSN is an Ongoing Program with an Aggressive Agenda and Includes NGI and the Networking Portion of SII

### *Base LSN*

- Coordinated operation and interconnectivity of agency R&D networks
  - DoD's DREN, DOE's ESnet, NASA's NREN, NSF's vBNS 100x testbeds and cooperation with the Abilene network
  - Interconnectivity at NGI-X East, Midwest, and West, and STAR TAP for international connectivity
- NSF — Measurement and network analysis, Wireless
- DARPA — Quorum, Wireless
- DOE — Integrate networking and middleware with applications
- NIST — Wireless
- NSA — Very high speed networking (protocols, optical networking)
- NOAA — Ubiquitous mobile high-bandwidth networking



## Federal Agency Network R&D Activities (2)

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- *Next Generation Internet (NGI)*
- DARPA — SensIT, active networking, innate survivability, simulations and modeling, Supernet 1,000x testbed, optical networking research, network management
- NIST — Advanced encryption standard, PKI, Internet QoS, measurement and standards for network pervasive computing
- NSF — vBNS, networking research, applications, minority-serving-institutions



# Advanced Networking Applications Examples (1)

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- **DARPA:**
  - CSU-CHILL Radar: Data transfers at 240 Mbps to 2.88 Gbps
  - Digital Earth with MIT, CMU, LBL, Berkeley: Virtual Reality transfers at 50 Mbps
- **DOE:**
  - Corridor One: Distance visualization at 50 Mbps
  - Combustion Corridor: Remote visualization at OC12
- **NASA:**
  - Distributed video of launch activities at 10-100 Mbps
  - Tropospheric Radio Scattering Beam Communications to Remote Areas



# Advanced Networking Applications

## Examples (2)

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- NIH:
  - Healthcare Collaboratories: Remote delivery of healthcare, privacy and security
- NSF
  - Internet HDTV: Up to 2.4 Gbps
  - International collaboratory for virtual reality and telepresent environments
  - Data Mining: The CAVE Research environment: Tunable transfer of data sets for data mining



# Scalable Information Infrastructure

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- Deeply networked systems — DARPA and NSF
- “Anytime, anywhere” connectivity — DARPA and NSF
- Network modeling and simulation — NSF and DARPA
- Modeling, simulation, analysis, test methods, and standards for broadband wireless protocols and access technologies — NIST



# Large Scale Networking Future Programs

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- Adaptive Applications
  - Dynamic service discovery
  - Scalable collaborative services
  - Applications tools development
- Multi-Domain Service Management
  - Dynamic traffic engineering
  - Network architecture: Including wireless access, dynamic adaptation to applications/loads
  - Multiparty information distribution
- Scalable Security
  - Scalable PKI
  - Security in self-organizing networks
  - Heterogeneous and adaptive environments