PRELIMINARY

PITAC FY00 Report to Congress on the Next Generation Internet (NGI) Initiative

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PITAC NGI Subcommittee

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Slides based on presentation by George Strawn, LSN co-chair

Congressional Charge to the PITAC

- The Next Generation Internet Research Act (10/98), requires PITAC to review the implementation of the Next Generation Internet (NGI) initiative and report annually on:
  - **Advanced Networking Research:** Progress in NGI-funded advanced networking research
  - **NGI Testbeds:** Progress in implementing high-performance network testbeds,
  - **NGI Applications:** Progress in developing high-performance network applications
  - **Geographic Reach:** Addressing geographic penalties faced by rural institutions
  - **Minority- and Small- College Reach:** Addressing access by historically black and Hispanic-serving institutions and colleges and universities with fewer than 5,000 students
  - **Technology Transfer:** Flow of NGI ideas to industry
  - **Agency Coordination:** Effectiveness of coordination among the NGI agencies
  - **IT Leadership:** The extent to which Federal research support will maintain U.S. IT leadership

Next Generation Internet (**NGI**) Initiative http://www.ngi.gov/ 10/24/98 act

- Amended High Performance Computing Act (1991)
  - Do high performance computing, human-centered computing, dependable systems, training, education,

  + research
    + focused on network infrastructure
    + interoperation among Federal computer nets
    + reduce geographic penalty
    + develop network management tools.
    + promote network standards
- Directs NSF, DOE, NIH, NASA, NIST,
  - Increase Internet capabilities
  - Deploy next generation test beds connecting research sites
  - Develop next generation applications that meet national goals and agency mission needs

NGI Program

- NGI was a three year FY98-FY00 program funded at $100 million per year with optional continuation for two more years
- Administration proposes continuation in FY01-02 part of $594M ITR&D plus-up.
- The FY98-FY00 NGI program has three goals:
  - Advanced networking research — the three major areas are:
    - Network growth engineering
    - End-to-end quality of service
    - Security
  - Two testbeds:
    - The 100x testbed would include 100 sites and have end-to-end performance 100 times faster than the Internet of 1997
    - The 1,000x testbed would include 10 sites and have end-to-end performance 1,000 times faster than the Internet of 1997
  - 100 “revolutionary” applications that require NGI technologies

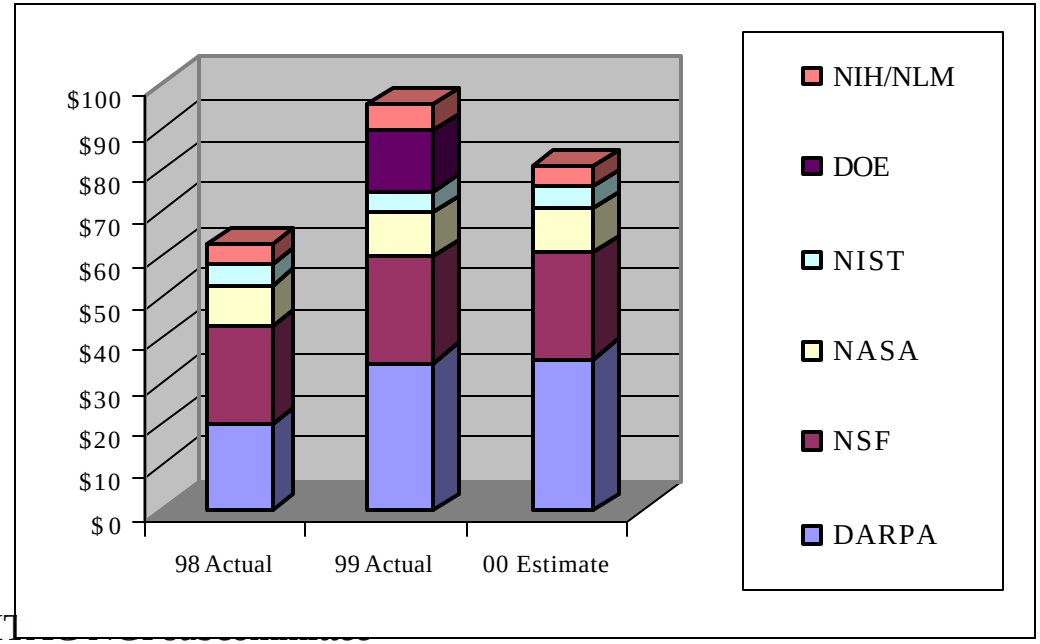
NGI Budget Profiles (Dollars in Millions)

	FY98		FY99		FY00	
Agency	**Requested**	**Actual**	**Requested**	**Actual**	**Requested**	**Estimate**
DARPA	$40	$42	$40	$45	$40	$36
NSF	10	23	25	25	25	25
DOE	35	0	25	15	15	0
NASA	10	10	10	10	10	15
NIH/NLM	0	5	5	5	8	5
NIST	5	5	5	5	5	5
TOTAL	**$100**	**$85**	**$110**	**$105**	**$103**	**$86**

NGI Budget Profiles (Dollars in Millions)

- 80% funding (actual/promised)
- Funding was random
  NSF domain name money
  DOE surprises
- Some funding was "reprogrammed" money
- Agencies & Scientists need long-term stability

Agency	98 Actual	99 Actual	00 Estimate	sum
DARPA	$20	$35	$36	$91
NSF	23	25	25	$73
NASA	10	10	10	$30
NIST	5	5	5	$15
DOE	0	15	0	$15
NIH/NLM	5	5	5	$15
TOTAL	**$63**	**$95**	**$81**	**$239**



PITAC's Assessment of the NGI (1)

- The NGI program
  has achieved many of its FY98-FY00 goals and
  is likely to achieve most of those goals in FY02
- NGI funding shortfalls delayed or eliminated some activities
  - FY98 NSF funding delayed till early FY99
    - Testbed deployment and applications development effectively delayed one full year
  - DOE received no NGI funds in FY98 or FY00
    - There has been less NGI R&D in network engineering, measurement, performance, and middleware
  - There has been less R&D in NGI applications technologies:
    - Collaboratories
    - Remote operation of advanced scientific instruments

NGI Networking Applications (1)

- The NGI agencies have developed and documented more than 90 NGI applications

- More NGI applications are being developed without explicit NGI funding
  - At universities — through their access to NGI testbeds
  - Jointly by universities and industry

NGI Networking Applications (2)

The 90+ documented NGI applications organized according to the categories in the NGI Implementation Plan (many applications belong to more than one category):

Applications Technologies	
Collaboration Technologies	32
Digital Libraries	6
Distributed Computing	6
Remote Operations	17
Security and Privacy	4

Disciplinary Applications	
Basic Science	37
Crisis Management	1
Education	13
Environment	15
Federal Information Services	4
Health Care	28
Manufacturing	9

NGI's Advanced Networking Research (1)

- NGI agencies have a strong, balanced collection of networking research projects that address most key topics:
  - Network growth engineering
    - Network modeling
    - Monitoring, control, analysis, and display
      - Adaptive network management
      - Bandwidth and traffic management
      - Middleware for visualization applications
      - Monitoring and analysis of IP packet flow and performance
      - Resource management
      - Scheduling
      - Test and measurement tools
      - Web performance
    - Integration
      - Application to network interfaces
      - Protocols and standards
    - Data delivery
      - Group communications
      - Hybrid land-based, wireless, and satellite networks
      - Multicast
      - Multimedia networking

NGI's Advanced Networking Research (2)

- Network growth engineering (continued)
  - Managing lead user infrastructure
    - Networks for data intensive applications
    - Optimizing distributed application performance
    - Smart environments
- End-to-end quality of service
    - High performance routing and switching
    - Managing denial of service
    - Managing quality of service in hybrid land-based, wireless, and satellite networks
    - Multi-protocol label switching
    - Performance trade-offs
    - Reservation of service
    - Testbeds (in cooperation with Internet2 and industry)
- Network security
  - Standards such as PKI
  - Testbeds
- New technologies
  - Hybrid land-based, wireless, and satellite networks
  - Optical networking technologies
  - Ultra high bandwidth on demand

NGI Testbeds

- The NGI program has established two testbeds :
  - The 100x NGI testbed connects more than 150 sites (goal was 100)
  - The 1,000x Supernet testbed will connect 15 sites (goal was 10)
- The 100x testbed includes:
  - Federal NGI networks
    - NSF's vBNS
    - DOE's ESnet
    - NASA's NREN
    - DoD's DREN
  - The academic sector's (Internet2) Abilene (Qwest, Nortel, Cisco, and the University of Indiana) network

Additional NGI Testbeds (1)

- NASA
  - NGIX-West — OC-3/OC-12 ATM and planned OC-48 packet over SONET connectivity point with performance measurement capabilities
  - Multicast Internet eXchange (MIX) — Test and deploy protocols that scale
  - NREN Multicast — Native multicast data distribution over wide area networks
  - NREN OC-48 — 2+ Gbps aggregate flow among three endpoints
  - CEOS/GOIN Earth Science International Demonstrations

Additional NGI Testbeds (2)

- DOE
  - EMERGE — ESnet/MREN Regional Grid Experimental testbed
    - Authentication, collaboratories, e-commerce, Globus, health sciences, multicast, QoS, remote instruments, scheduling, security, standardized tool sets, visualization, weather
    - 100 Mbps end-to-end connectivity to five universities, four DOE laboratories, and STAR TAP
- Multi-agency Qbone
  - DOE — QUALIT architecture for IP differentiated services
  - NASA
    - QoS mechanisms, interoperability, testing, and applications prototyping
    - NGIX-West connects multiple university networks nationwide
  - NSF's vBNS backbone

Outstanding Concerns

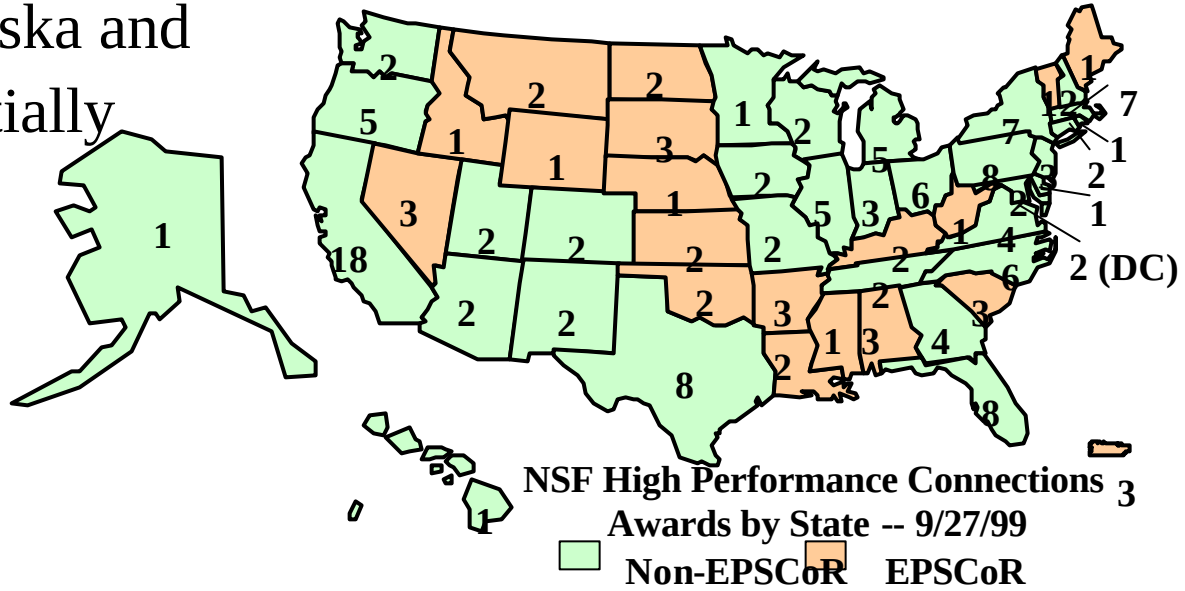
- NGI applications that exploit NGI services emerging.
  - LSN census shows 96
  - Registers app bandwidth, latency, QOS needs
  - “Bridging the gap” http://www.nren.nasa.gov/workshop4
  - Internet2 is sponsoring a Gbps app contest.
- End-to-end is the problem:
  campus is now the bottleneck,
  backbone is Gbps, LAN is often 10Mbps (!)
  Firewalls, proxy,… add bottlenecks and delays
  they also add security!
  - Web100 http://www.scd.ucar.edu/nets/projects/web100
  - Census of NGI test bed partners by mid march.

Minority and Small College Reach

- The NGI was not funded to address Internet access for historically black, Hispanic-serving, Native American, or small colleges and universities.
- However, as part of its standard peer review process, NSF has awarded High Performance Connection grants to two historically black and five Hispanic-serving institutions. This is one more than last year.
- NSF made a four-year $6 million award to EDUCAUSE to help minority-serving institutions develop campus infrastructure and national connections.
  - Award addresses Hispanic, Native American, and Historically Black Colleges and Universities
  - Scope includes: Executive awareness, vision, and planning, Remote technical support centers, Local network planning, Local consulting and training, Satellite/wireless pilot projects, New network technologies: Prototype installations, Grid applications

Geographic Reach (1)

- There are more than 200 NGI sites
  - Every state in the U.S. has at least one NGI site (as shown in the map on the next slide)
  - These include 40 sites in the 19 states in the Experimental Program to Stimulate Competitive Research (EPSCoR)
  - Connectivity to Alaska and Hawaii has substantially improved



Technology Transfer (1)

- NGI technology transfer to U.S. industry is substantial — immediate & direct flow of NGI ideas to industry
- U.S. industry participates in NGI programs and projects
  - The NGI testbeds are managed through cooperative agreements between NGI agencies and telecommunications companies
    - MCI WorldCom deploys NSF's vBNS
    - Sprint deploys research components of NASA's NREN and DOE's ESnet
    - AT&T deploys DoD's DREN
    - Qwest will provide DOE's ESnet
    - The university/industry Abilene network in which Cisco, Nortel, Qwest, and the University of Indiana participate, is part of the NGI testbeds
  - These companies are free to commercialize NGI technologies that they develop
- Many startups are springing from NGI programs.
  - Network Elements, EOSpace, Optical Micro-Machines (OMM), Photonex, Sycamore, Corvis

Technology Transfer (2)

- U.S. industry participates in NGI applications testbeds for the development of standards
  - For example, the joint NGI/Internet2/industry national and international scale Qbone differentiated services testbed
- U.S. industry participates in NGI meetings and workshops
  - Bridging the Gap Workshop
  - DARPA/NSF/NIST Networking Research Principal Investigator (PI) Meeting
  - DOE PI Meeting
  - Public Key Infrastructure for Advanced Networking Technologies Workshop
  - End-to-End Gigabit Networking Workshop (future)

Technology Transfer (3)

- Continued NGI technology transfer is enabled by having 150 universities, where new generations of industry workers are educated, also participate directly in NGI programs, projects, and workshops
  - More than 100 universities are connected to the NGI testbeds
  - Researchers, students, and employees at these universities collaborate with industry and Government personnel in:
    - Deploying, operating, measuring, and improving the performance of the NGI testbeds
    - Developing advanced applications that are run over the NGI testbeds

Technology Transfer (4)

- Start-up companies are formed as NGI PIs and researchers join new companies as chief technologists
- This has some negative consequences:
  - Fewer university researchers
  - Fewer educators of future generations of networking and applications researchers
  - Fewer Government program managers

Interagency Coordination (1)

- Large Scale Networking Coordinating Group (LSN CG)
  - Coordinates multi-agency NGI R&D
  - Participants include NSF, DARPA, NIH, DOE's Office of Science, NASA, NIST, AHCPQ, NIST, NOAA, EPA
- LSN Teams
  - Joint Engineering Team (JET)
  - High Performance Networking Applications Team (HPNAT)
  - Network Research Team (NRT)
  - Internet Security Team (IST)
  - Participants: LSN agencies Cisco, Gigapop operators, MCI WorldCom, Qwest, UCAID/Abilene, and university networking departments
- National Coordination Office for Computing, Information, and Communications (NCO/CIC)
  - Coordinates LSN and NGI program planning, budgeting, and assessment
  - Supports LSN CG and the LSN Teams
  - Provides single point of contact for information about the NGI program

Interagency Coordination (2)

- Coordinated projects
  - Coordination is accomplished through informal mechanism
    - Joint agency funding of projects has proved to have high administrative barriers
    - Agencies jointly developed the NGI Implementation Plan
    - Agencies serve on other agencies' peer review panels and participate in joint PI reviews, thereby assuring that program implementations remain coordinated — examples are:
      - DOE PI Meeting
      - DARPA/NSF/NIST Networking Research Principal Investigator Meeting
      - Agencies coordinate assessment and planning at joint workshops
      - Bridging the Gap Workshop
      - Public Key Infrastructure for Advanced Networking Technologies Workshop (future)
      - End-to-End Gigabit Networking Workshop (future)
    - Individual agency NGI testbed networks interoperate and peer at NGI-West, NGI-Midwest, and will do so at the future NGI-East

NGI Leadership

- NGI program helps maintain U.S. leadership in advanced networking capabilities by funding R&D in leading-edge technologies and applications
- University researchers train the next generation of scientists and researchers.
- Academic ideas will be cornerstones of future industries.

Most Significant Agency Accomplishments

- DARPA
  - Optical networking
  - Applications on the 1,000x Supernet testbed
- NSF
  - 100x testbed
  - Broad spectrum of applications under development
- DOE — Collaboratory technologies and tools
  - Examples are China Clipper tools and Combustion Corridors
- NASA — NGIX-West
- NIST — Collaboration with manufacturers for standards
- NIH/NLM
  - Health care applications
  - Community awareness of NGI's potential usefulness

PITAC Assessment of the NGI (1)

- NGI agencies responded to FY99 PITAC recommendations:
  - Measure network performance at NGI sites
    - —NLANR is implementing standardized measurement platforms for throughput, latency, and jitter at 97 NGI sites
    - —Measuring throughput on the NGI backbone
    - —Developing automated standard formats for reporting performance data
    - —Web100 work
  - Increase emphasis on end-to-end applications
    - —*Bridging the Gap* workshop focused networking research on app needs
  - Demonstrate Gbps (Gigabits or 1,000 bits per second) applications
    - —SC99 HDTV demonstration of 2.4 Gbps throughput, 54.7 TB (Terabytes or trillions of 8-bit bytes) of data transferred

PITAC Assessment of the NGI (2)

- The NGI program is also responding to the recommendations for R&D in Scalable Information Infrastructure that were made in the PITAC February 1999 report “Information Technology Research: Investing in Our Future”
  - Collect and analyze performance data
    - —NGI performance measurement program
  - Model and simulate network behavior
    - —DARPA and NSF research programs
  - Conduct R&D in optical, wireless, and wired technologies
    - —DARPA Supernet program
  - Conduct R&D on scaling the Internet
    - —DARPA and NSF research programs

PITAC's NGI Recommendations to Congress (1)

- Fund the NGI agencies at their full Presidential requests in FY01 and FY02
  - The research community needs stable multi-year funding in order to fully realize their potential contributions to advanced networking
- Complete the NGI program according to the plans set forth in the FY98 NGI Implementation Plan as updated in:
  - NGI planning documents
  - Agency NGI solicitations
  - HPCC/CIC/IT R&D Supplements to the President's Budget (Blue Books)
  - HPCC/CIC/IT R&D Implementation Plans

PITAC's NGI Recommendations to Congress (2)

- As stated in our 1999 NGI review,
  PITAC recommends that Congress consider funding a new program in which
  NGI research institutions act as aggregators and mentors for nearby smaller or disadvantaged institutions.

- Since this would be primarily infrastructure, not networking research, it should not be part of the NGI or IT R&D programs.

PITAC's NGI Recommendations to NGI Agencies

- It's the apps!!!
  Encourage, cajole, force,… focus on apps.
  That use high-bandwidth,
  low-latency,
  QoS,
  security,…
- Apps need end-to-end and ubiquitous NGI
  - Measure end-to-end
  - Fix end-to-end problems
- Continue great progress on networking research

Internet Security/Dependability

- DOS attacks on commercial sites recently.
- What can USG do to improve the situation?
- Is enough research underway to improve the situation?
- Does PITAC have any recommendations in this area?