Title
ESnet: The Energy Sciences Network

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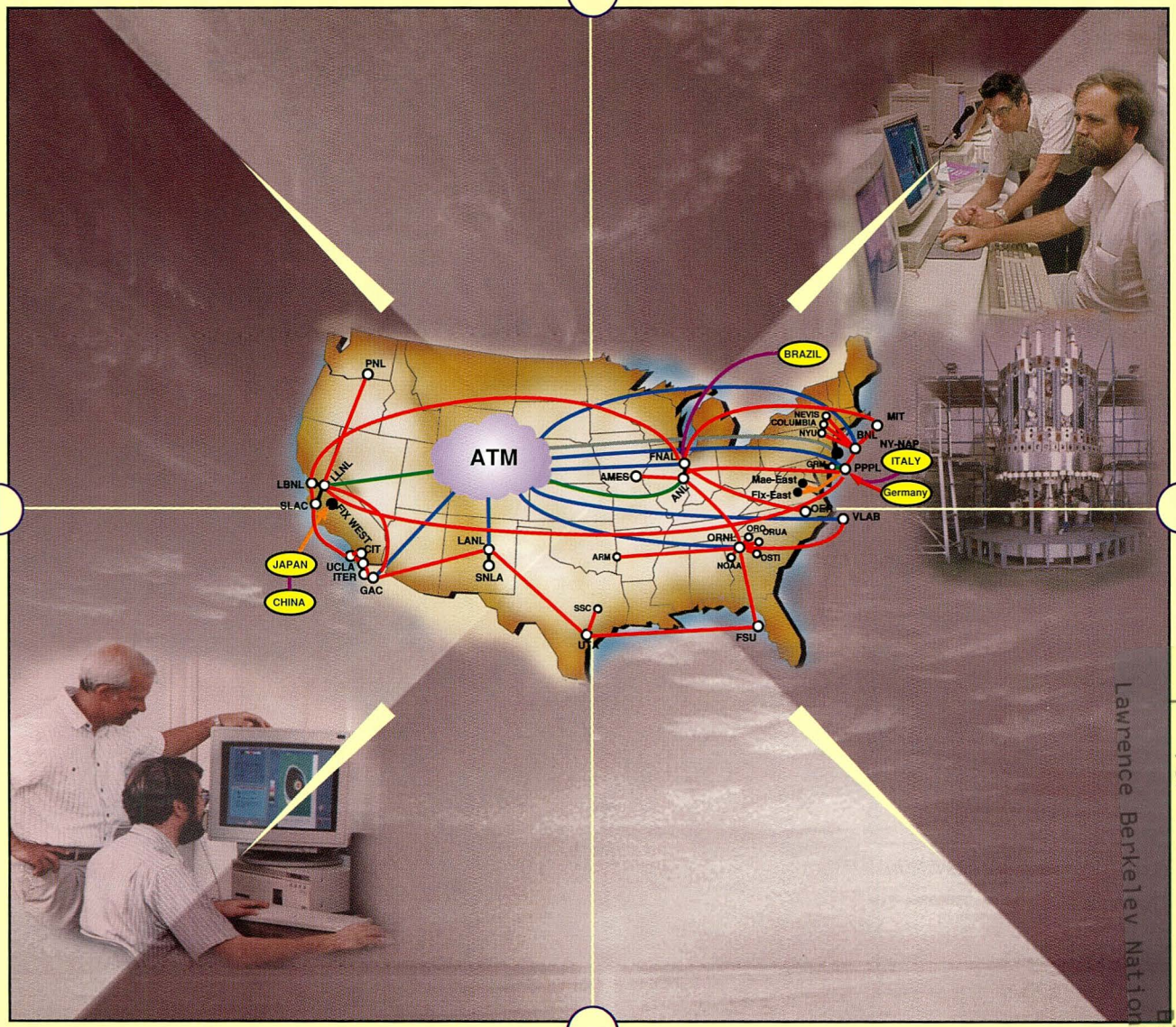
THE ENERGY SCIENCES NETWORK



For 4 weeks

Lawrence Berkeley National

Front cover:

While remote control of instrumentation is not new, remote operation of a complex magnetic fusion experiment from the other side of the country is a different matter.

The Alcator C-Mod tokamak (a device for confining high-temperature plasmas) at the Massachusetts Institute of Technology (MIT) Plasma Fusion Center in Cambridge, Massachusetts, was designed with network-based control and data acquisition systems. In March 1995, a team of scientists from MIT and Lawrence Livermore National Laboratory in California used ESnet to conduct fusion experiments on the Alcator C-Mod in the first transcontinental operation of a tokamak.

The plasma shape, hydrogen fueling source, radio frequency heating, and a reciprocating probe were all controlled in real time from Livermore over ESnet. Scientists also exchanged a variety of data between Cambridge and Livermore: video images, experimental data from diagnostic equipment inside the tokamak, and video and audio communications between researchers at each end. Multiple video cameras captured images of the control room in Cambridge, of the exterior and interior of the tokamak, and of researchers in Livermore.

This demonstration was the definitive test for controlling a large, complex physics experiment from a remote location. Researchers found that success requires not only real-time access to controls and diagnostic equipment but also direct access through sound and visuals to scientists and technicians on location at the experiment. The real-time visuals of the people and equipment in Cambridge helped bring the experiment to life for the scientists in Livermore.

DISCLAIMER

ESnet

THE ENERGY SCIENCES NETWORK

What is ESnet?

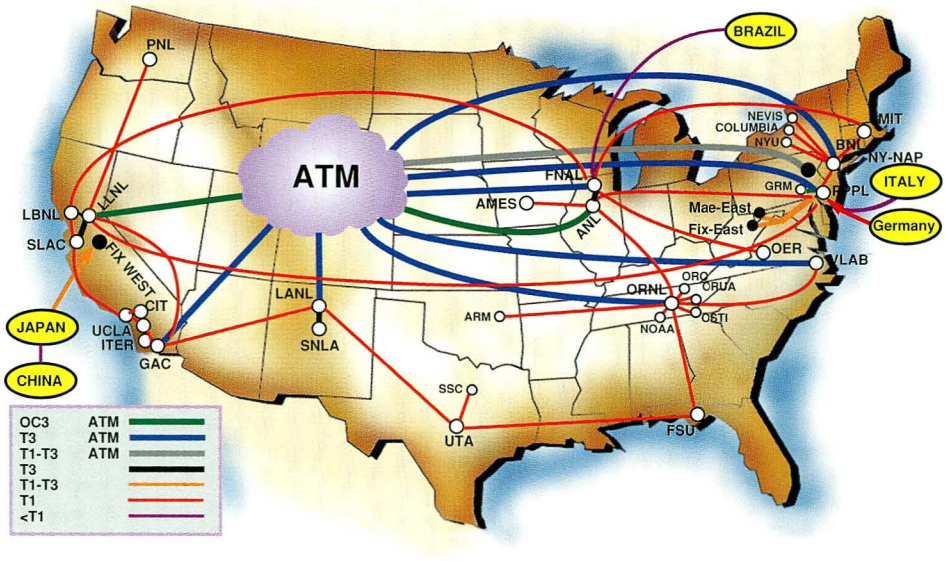
The Energy Sciences Network (ESnet) is a nationwide data communications network managed and funded by the U.S. Department of Energy Office of Energy Research (DOE/OER) for the purpose of supporting multiple-program, open scientific research. ESnet is intended to facilitate on-line remote access to major DOE scientific facilities, such as the National Energy Research Scientific Computing Center (NERSC), and to support needed information access and dissemination among scientific collaborators by providing

a) widespread network access to research facilities,
b) state-of-the-art, high-performance communications for collaborators, and
c) on-line information and related services.

ESnet is a "backbone" network, that is, a network to interconnect other networks, in particular the local area networks (LANs) of the directly connected sites (Figure 1). However, connectivity to numerous other scientific and educational locations is provided through extensive interconnections with other networks, making ESnet a member of the global Internet.

ESnet began initial deployment of its T1 circuit-based backbone in late 1989, with transmission speeds from 1.3 to 1.5 million bits per second (Mbps). It became fully operational with the initial configuration in early 1990, including 19 major OER-supported sites directly connected to the backbone. Today over 30 sites are directly connected at speeds as high as 155 Mbps. Growth in network traffic since January 1990 is shown in Figure 2.

Figure 1: ESnet backbone, mid-1996

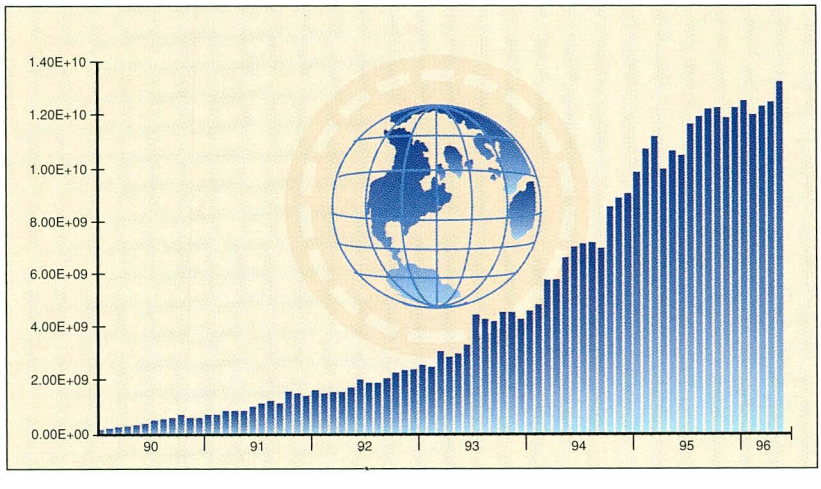


How is it managed?

ESnet is an ongoing activity whose success depends heavily on the cooperation and collaboration of the DOE scientific research and networking communities. Although responsibility for the implementation and operation of ESnet resides with the ESnet staff, the guidance and collaboration that make the network a success come from many sources. In terms of the number of sites actively participating, ESnet represents one of the largest and most successful collaborations in DOE.

ESnet is engineered and operated by the ESnet networking staff, co-located with NERSC in the Computing Sciences Directorate at Ernest Orlando Lawrence Berkeley National Laboratory in Berkeley, California. ESnet activity is guided by the ESnet Steering Committee (ESSC), comprising members appointed by the represented programs, currently with one or more representatives from each of five OER programs, and with additional representation from the DOE Defense Programs and Human Resources. The ESnet Coordinating Committee (ESCC) coordinates both the participation of, and information dissemination to, the individual institutions which benefit from the use of ESnet. The current ESnet program plan, prepared by the Steering Committee, is available from the National Technical Information Service as report DOE/ER-0632 (November 1994), and is available online on the ESnet Network Information Center (NIC). A list of current ESSC members is also available via ESnet's World Wide Web server (http://www.es.net).

Figure 2: ESnet packets accepted



Who may use it?

Network activity in support of DOE-sponsored research programs constitutes the principal authorized use of ESnet. The five major OER programs supported are Applied Math Sciences, Basic Energy Sciences, Health and Environmental Research, High-Energy and Nuclear Physics, and Fusion Energy. Several other DOE programs, including Defense Programs and Human Resources, are now participating in ESnet. Support of other activities, such as inter-agency collaboration or foreign country access, may also be considered authorized usage.

What is its impact?

NREN and NII—The High Performance Computing and Communications (HPCC) Program was signed into law in 1991 to bolster the global competitiveness of the U.S. in the areas of computing and communications. HPCC implementation plans included the National Research and Education Network (NREN), a national internetwork capable of gigabit speeds by late 1996. As DOE's contribution to NREN, ESnet has been developed in concert with the provisions of the bill. The program later expanded to include a broader concept called the National Information Infrastructure (NII), or the "Information Superhighway," which emphasizes applications that will make use of the underlying NREN facilities. ESnet will be a major component of DOE's support for NII production-level applications.

Agency effectiveness

For some time, the experimental research community has recognized the importance of the ability to carry out research independent of geography. For example, the extremely high cost of constructing and operating major experiments has made it necessary to centralize major research facilities. However, researchers in widely separated locations need access to these facilities as well as tools for communication among distant, and often international, collaborators. Additionally, DOE is promoting internal, domestic, and international collaborations to accelerate the accomplishment of its missions in national security, science and technology, and the environment.

By providing the infrastructure for this kind of effective and economical remote collaboration, ESnet is playing an essential role in DOE research activities. As the agency endeavors to streamline its operations, even more cooperation and collaboration will be needed to increase efficiency, and ESnet will make vital contributions toward that goal.

What interconnections are provided?

ESnet provides broad interconnectivity to the global research and education community, allowing a researcher at an ESnet site to collaborate effectively with colleagues around the world. This interconnectivity is provided by direct connection of major "backbone sites" to ESnet and by indirect connections though other research, education, and/or commercial networks.

Figure 3 shows the immediate (or directly interconnected) Internet Protocol (IP) networking neighbors of ESnet. Researchers on other networks which are not direct neighbors to ESnet can also be reached by using the direct neighbors as intermediaries.

ESnet backbone sites

By mid-1996, ESnet has over 30 sites directly connected to it at speeds ranging from 56 thousand bits per second (Kbps) to 155 million bits per second (Mbps). A current list of directly connected sites is maintained on the ESnet Web page (www.es.net). These sites can communicate at speeds limited only by the slowest access speed of the collaboration. It is feasible for backbone sites to exchange data at speeds approaching 155 Mbps.

Other federal agencies

ESnet currently maintains access to two Federal Interagency Exchange (FIX) points to allow efficient exchange of data with other federal agencies, including the Advanced Research Projects Agency (ARPA), the Department of Defense (DOD), and the National Aeronautics and Space Administration (NASA). The FIX-West interconnect is located at the NASA Ames Research Center, near San Francisco, California. FIX-East is located at the University of Maryland, near Washington, D.C., but is expected to move in the near future to the New York Network Access Point (NY-NAP) in Pennsauken, New Jersey.

Major Internet interconnect points

ESnet maintains numerous interconnect points with other networks. The following is a list of the major interconnect points to which ESnet is currently connected:

FIX-East—University of Maryland (College Park, Maryland)

FIX-West—NASA Ames Research Center (Mountain View, California)

MAE-East—Metropolitan Area Exchange—East (Washington, D.C.)

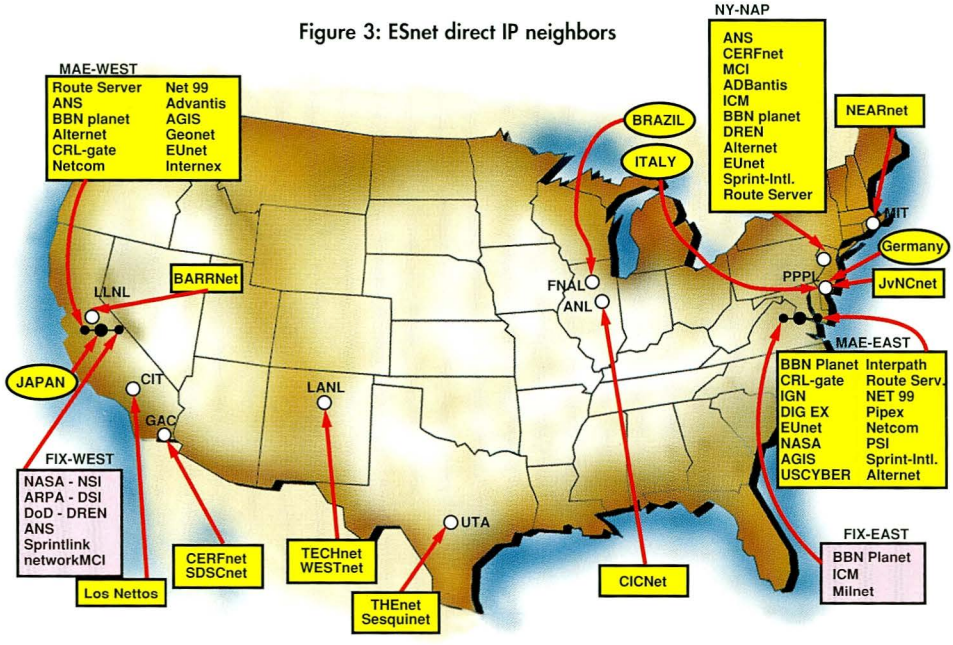
MAE-West—Metropolitan Area Exchange—West (San Jose, California)

NY-NAP—New York Network Access Point (Pennsauken, New Jersey)

Regional networks

ESnet maintains interconnect points with a large number of regional networks; many are provided on a one-to-one basis. A list of such networks is shown in Figure 3.

Figure 3: ESnet direct IP neighbors



Commercial networks

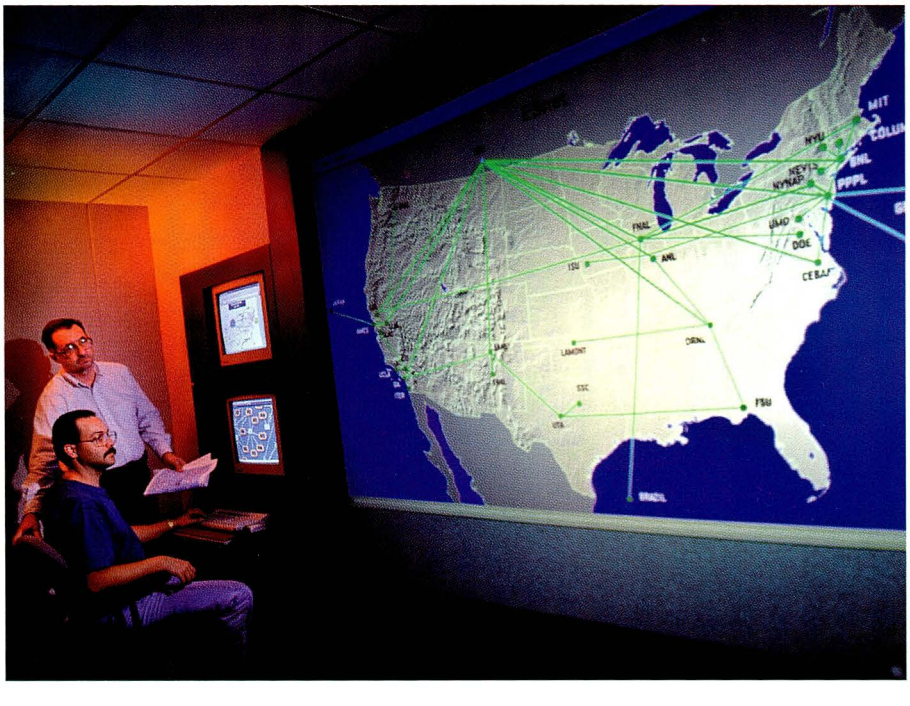
Although commercial IP networks have existed for some time, 1995 marked the beginning of explosive growth in new commercial networks or Internet service providers. ESnet maintains interconnections to all major commercial networks and numerous smaller ones at the major Internet interconnect points. Figure 3 shows many of the commercial networks that interconnect with ESnet.

International connections

A large and growing number of research activities within DOE now involve international collaborations. An example is the International Thermonuclear Experimental Reactor (ITER), which has contributing members from the U.S., Japan, Europe, and Russia. Effective communications and collaboration among these members are essential to the success of the project.

ESnet currently supports direct international communications links to Japan, Germany, Italy, and Brazil. A number of program requirements for access into the former Soviet Union, particularly Russia, have been identified. Access to a number of Russian networks is currently available through indirect connections. Plans for additional access into Russia are currently being formulated.

Meeting room video-conferencing



Current direct international links include:

Bologna, Italy* (via link out of Princeton Plasma Physics Laboratory)
Dusseldorf, Germany* (via link out of Princeton Plasma Physics Laboratory)
Nagoya, Japan (via link out of FIX-West)
Naka, Japan (via link out of FIX-West)
Tsukuba, Japan (via link out of FIX-West)
Sao Paulo, Brazil (via link out of Fermi National Accelerator Laboratory)

*These are links to national research networks in Germany and Italy.

Services

ESnet provides a large number of information and other on-line support services, most of which are provided via replicated servers called Network Information Centers (NICs) with the Internet host names of NIC.ES.NET and NIC2.ES.NET. Generally end-users must have access to the appropriate client software (e.g., Web browser) on their local PC, Mac, or workstation to access these services, although many are available via Telnet or FTP. In most cases client source code is also available on the NIC for users to download and use on their local computing platforms. More information about ESnet services may be found in the ESnet Services Brochure (UCRL-TB-114841) or on-line at the ESnet Web page (www.es.net).

Future plans

A major success for ESnet is its successful incorporation of a new communications technology called Asynchronous Transfer Mode (ATM). ATM is a communications standard that allows data, voice, and video information to travel in a mixed stream through the same network hardware at a very high rate of speed.

Over the next five years, the plan is to upgrade the capability of the network to include access rates of Nx1.5 Mbps, 45 (T3), 155 (OC3c), and 622 (OC12c) Mbps—a 400-fold increase over the current access rates. This upgrade is being done in concert with HPCC goals, and will include a collaborative effort with a national communications vendor. This working relationship with industry will help to enhance U.S. competitiveness in emerging high-speed data communications technology. By mak-

ing new technology available to ESnet for initial "shakedown" and subsequent incorporation into a production network, the selected vendor will be able to accelerate the deployment of new technology into the commercial marketplace. Other U.S. vendors will also be helped by the increased marketplace acceptability of the technology.

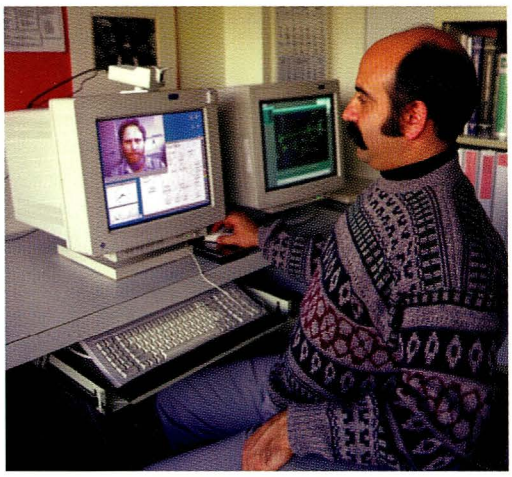
There has been growing interest in using ESnet to support research within DOE but outside of ER. Internal formal agreements are the first steps toward making ESnet capabilities more broadly available. Expansion and enhancement of ESnet is anticipated to respond to the requirements of these DOE program areas.

Video conferencing

ESnet provides support for both "meeting-room" and "desktop" video conferencing.

Meeting-room video conferencing typically uses a small- to medium-sized meeting room specifically equipped to serve as a mini-studio, including cameras, microphones, and monitors. Communication currently takes place over dial-up Integrated Services Digital Network (ISDN) circuits at speeds ranging from 64 Kbps to T1 in 64 Kbps steps, with typical conferences using 128 Kbps to 384 Kbps. ESnet provides a large multi-point control unit (MCU) which serves as a director for conferences with three or more sites participating. The MCU is capable of supporting multiple multi-way conferences simultaneously. ESnet also provides an on-line reservation system that allows users to check availability and reserve video resources needed for future conferences.

Desktop video conferencing is an emerging capability that uses an individual's office, workstation monitor, mini-camera, and microphone as the studio. For many implementations, the compressed video data is transmitted over the network as IP packetized data. Because video generates large and continuous streams of data that may need to be sent simultaneously to several other network sites, duplicate transmissions over ordinary Internet connections might result in delayed reception. To avoid this problem, Esnet has implemented the Multicast Backbone (MBone), a virtual network that minimizes duplicate transmissions by sending traffic to multiple remote locations as one data stream. This experimental service allows users to participate with colleagues around the globe using real-time video images from their office.



Desktop video conferencing

Network Operations Management Center

The ESnet Network Operations Management Center (NOMC) provides 24-hour-a-day monitoring and control capabilities for the various network components that comprise ESnet. The center is operated by personnel from the ESnet and NERSC staffs at Berkeley Lab. The NOMC equipment continuously monitors the ESnet backbone facilities to verify the network's integrity and to routinely gather statistics for troubleshooting and long-term planning. Electronic mail boxes are provided for network information, network operations, and trouble calls. An on-line trouble ticket system ensures that all reported problems are properly tracked. Requests for information on ESnet can be directed to info@es.net. Problems can be reported to trouble@es.net.

The ESnet Network Operations Center

For more information

General contacts

Phone: 1-800-33-ESnet
Outside the U.S.: 1-510-486-7600
Fax: 1-510-486-4300
E-mail:
For information: info@es.net
To report problems: trouble@es.net

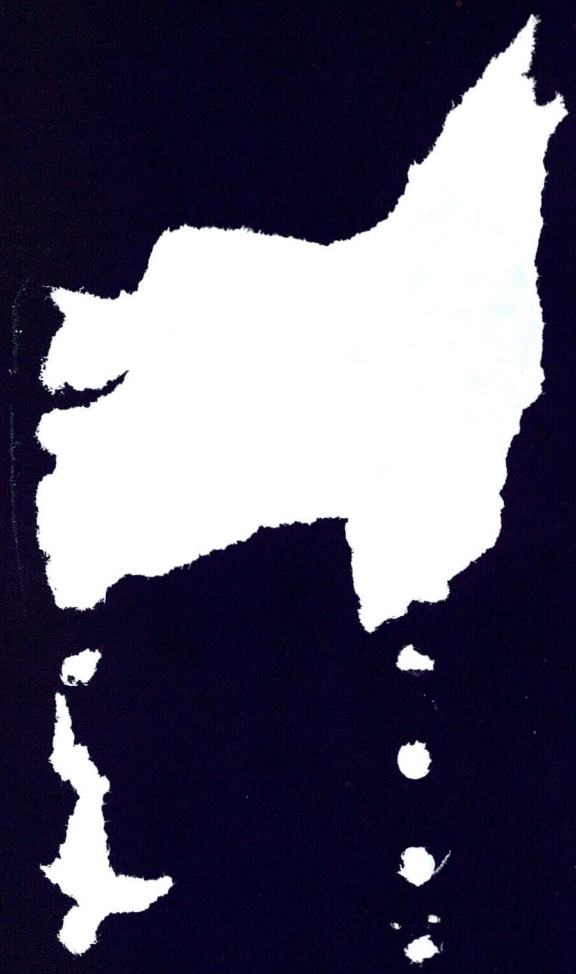
Administrative contacts

Jim Leighton
Network Manager
Phone: 510-486-6440
E-mail: jfl@es.net

Lisa Erspamer
Resource Manager
Phone: 510-486-6121
E-mail: lisa@es.net

On-line information

World Wide Web: http://www.es.net/
Gopher: gopher.es.net
FTP: ftp.es.net (anonymous login)
Telnet: nic.es.net (anonymous login)



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